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QUEUING TECHNIQUE AS A SOLUTION FOR LONG LINES ON ELECTION DAY FOR MULTIPLE ELECTION

S.M.A. Shahul Hameed[1], M. Shahul Hameed [2*] and V. Kamal Nasir[3]

[1]*Department of Mathematics, Ramakrishna Mission Vivekananda College, Mylapore, Chennai-35*
[2*]*Department of Mathematics, Government Arts College (Men), Nandanam, Chennai-35*
[3]*Department of Mathematics, The New College, Chennai-14*
[2*]*Corresponding Author Email: smashahul77@gmail.com*

The prospects of a healthy nation depend on the effective governing authorities. There is no other option but to hold elections to elect these members. The Election Commission of India (ECI) intends to hold the Assembly and Parliament elections on the same day to reduce the amount of money that the Indian government must spend. This study aims on reducing the number of polling officers without reducing their assignments and waiting time of electors to conduct the election smoothly with help of (M/M/1) :(GD/E/∞) Queuing Model.
Keywords: Electronic Voting Machine (EVM), Biometric, Polling Officers, (M/M/1): (GD/E /∞) Queuing Model.

1. Introduction:

In a service system with one or more service facilities, customers are referred to as population, person units, or voters depending on the situation. When customers arrive to receive a service and the service provider is not available, they must wait in a queue until the provider becomes available. The arrival of customers is irregular, and often more people arrive at once, causing longer wait times in the queue. The queuing system's performance is determined by various factors such as the pattern of customer arrival, the service pattern, queue discipline, customer behavior, the size of the population, and the maximum length of the queue. As the arrival pattern is random and unpredictable, it follows the Poisson process. On the other hand, the service pattern follows the exponential distribution. The queue system's properties are determined by the waiting time, which depends on the queue discipline. Queue discipline refers to the rule that determines the behavior of customers and how the queue is formed. The system generally follows the FCFS/FIFO model, but sometimes priority customers may be served using the LCFS/LIFO model or served randomly.

Queuing is a process that is commonly used in places like ration shops, cinema theatres, railway ticket counters, barber shops, banks, hospitals, etc. However, in the past, it was also used in an election model for a single election. In this paper presents an extension of a queuing model, considering multiple elections under the assumption that no customer is lost in the system and time is independent. The paper is divided into five sections. In section one, we introduce the problem addressed in our study, while in section two, we present a literature review. Section three presents two different cases of reducing the service provider. In section four, we provide a mathematical analysis of the model, and its performance indices are predicted through diagrammatic representation in the form of graphs. Finally, in section five, we draw a conclusion and observation based on our study.

2. Literature Review:

In recent studies, queuing theory has been found to be useful in solving real-life problems in various fields. Andrea Marin (2020) et al. proposed a queuing model that mainly focuses on handling large jobs. Meanwhile, Nail Akar and Ozancan Dogan (2021) explored the Discrete-Time Queuing Model for the Age of Information, which deals with managing multiple information sources. In another study, Srinivas R. Chakravarthy et al. (2021) discussed a single server queuing model that involves general bulk service. In 2021, Chris Blondia discussed a queuing model for a wireless sensor node that uses energy harvesting in Telecommunication Systems. In 2022, the same author investigated the evaluation of the waiting time in a finite capacity Queue with Bursty Input and a generalized Push-Out strategy. Additionally, Chatak, Bratati, and their colleagues also studied queues in Hospital services in 2022. Mor Harchol-Balter discussed multi-server queuing model systems in the same year. Lastly, in 2022, Binoy Kumar discussed reneging in the transient analysis of the M/M/C queuing model, considering finite capacity and population.

In a research paper by Shabana Sharma et al. (2023), queuing systems that consider customers' impatience were discussed. The authors also talked about queuing in the context of the election process. K. Lakshmi et al. (2018) discussed the use of smart e-voting and linking voter identification cards with Aadhar cards. R. Balaji et al. presented an Embedded-based E-voting system that uses Fingerprint and Aadhar verification. Sudharsan B et al. (2019) discussed a secured Electronic Voting System that uses the concepts of Blockchain. Ch. Sai Pratap Varma's paper (2020) presented an Aadhar card verification-based Online Polling system. Colin Mcintyre (2020) discussed the problem of long lines on election day in queuing theory.

3. Proposed Methodology:

Our previous paper (2022) introduced a model using biometrics and a single-server finite model (M/M/1) :(GD/N/) to reduce long queues during an election.

Suppose ECI conducts simultaneous Assembly and Parliament elections in all states. To achieve this, the Election Commission (EC) of India will need a large number of polling officers. The EC will prefer to hire state/central government employees as their polling officers. However, this process will require a significant number of polling officers. This paper focuses on a new model that aims to reduce the number of polling officers required for the smooth conduct of elections in India.

The 17th Lok Sabha election took place in India between April 11th and May 19th in seven phases. The Election Commission of India (ECI) used over a million polling stations for this election, where millions of people cast their vote. A by-election and general election were conducted on the same day in a few states, including Andhra Pradesh, Arunachal Pradesh, Odisha, Sikkim, and 22 seats of the Tamil Nadu Legislative Assembly. Conducting elections across India simultaneously requires a large number of government employees - about 6.2 million. However, it is challenging to get many employees. Currently, the ECI employs five plus one (presiding officer) government employees per polling station. In our research paper, the focus is on reducing the number of polling officials and by developing a mathematical model from five members to four / three members without disturbing their assigned work. Our novelty is to develop a new model in a most effective way to reduce waiting time and queue length in the system.

Table 1: Election Duties-Polling Officers for Existing and Proposed for assembly and parliament election.

Polling Officers	Duties on Election Day	
	Existing	Proposed
PO1	In-charge of Electoral Role, Marked Copy and Identifies the Electors	In-charge of Electoral Role, Marked Copy, Identifies the Electors and BIO-METRIC with voter slip
PO2	Indelible Ink and Voters Register	Voters Register, Indelible Ink
PO3	Incharge of voters slip	
PO4	Controls the Control Unit of Parliament election.	Controls the Control Unit of Legislative election.
PO5	Controls the Control Unit of Legislative election.	Controls the Control Unit of Parliament election
PRO	Head and Overall, In-charge of Polling Station	Head and Overall, In-charge of Polling Station

Construction of Single server Finite Model -(M/M/1): (GD/E /∞) –For Elections.

When voters enter the system, they are directed to cast their votes after receiving service from different polling officers in order. Let E denote the capacity of voters in the system. Our study is based on the following assumptions.

1. Voters are reliable to Bio-Metric System.
2. Operating Characteristic is independent of time.
3. EVM and VVPAT are working in Good Conditions.
4. We assume PO1, PO2, PO3, PO4, PO5 as $\alpha, \beta, \gamma, \delta, \varepsilon$ respectively as unit per time. We divided the service provider time into seven sectors, each consisting of five polling officers with a separate compartment. The two remaining compartments had ballots for the assembly and Parliament elections.

Notations:

1. λ is the arrival rate of voters per unit time
2. μ is the service rate of voters per unit time
3. L_{SE}- Expected number of voters in the existing system (without Bio-metric)
4. W_{SE}- Waiting time of voters in the existing system (without Bio-metric)
5. L_1- Expected number of voters in the proposed system with five PO'S.
6. L_2- Expected number of voters in the proposed system with four PO'S.
7. L_3- Expected number of voters in the proposed system with three PO'S.
8. W_1 −Waiting time of voters in the proposed system with five PO'S.
9. W_2- Waiting time of voters in the proposed system with four PO'S
10. W_3- Waiting time of voters in the proposed system with three PO'S

Mean Arrival Rate When there are 'n' customers in the system

$$\lambda_n = \begin{cases} \lambda \quad , \text{n} = 0,1,2 \dots . E-1 \\ 0, n = E, E+1, \dots \dots . . \end{cases}$$

Mean Service Rate When there are 'n' customers in the system

$$\mu_n = \{ \mu = \frac{1}{\alpha+\beta+\gamma+\delta+\varepsilon}, \quad n = 0,1,2,..\}$$

Utilization factor $\rho = \frac{\lambda}{(\frac{1}{\alpha+\beta+\gamma+\delta+\varepsilon})}$

Probability of 'n' customers in the system

$$P_n = \begin{cases} \left(\frac{\lambda}{(\frac{1}{\alpha+\beta+\gamma+\delta+\varepsilon})} \right)^n P_0 \ , n \leq E \\ 0, n > E \end{cases}$$

Where P_0 is the probability of the system is empty determined by the equation $\sum_{n=0}^{\infty} P_n = 1$ Which gives

$$P_0 = \begin{cases} \dfrac{1-\frac{\lambda}{(\frac{1}{\alpha+\beta+\gamma+\delta+\varepsilon})}}{1-\left(\frac{\lambda}{(\frac{1}{\alpha+\beta+\gamma+\delta+\varepsilon})}\right)^{E+1}}, \rho = \frac{\lambda}{(\frac{1}{\alpha+\beta+\gamma+\delta+\varepsilon})} \neq 1 \\ \frac{1}{E+1}, \quad \rho = 1 \end{cases}$$

$$P_n = \begin{cases} \left(\frac{\lambda}{(\frac{1}{\alpha+\beta+\gamma+\delta+\varepsilon})} \right)^n \dfrac{1-\frac{\lambda}{(\frac{1}{\alpha+\beta+\gamma+\delta+\varepsilon})}}{1-\left(\frac{\lambda}{(\frac{1}{\alpha+\beta+\gamma+\delta+\varepsilon})}\right)^{E+1}}, \rho \neq 1, n = 0,1,2 \dots \dots . E \\ \frac{1}{E+1}, \quad \rho = 1, n > E \end{cases}$$

Note: There is no vote is lost in the system, hence $\lambda_{effective} = \lambda$

Average number of customers in the system

$$L_1 = \begin{cases} \dfrac{\dfrac{\lambda}{\left(\frac{1}{\alpha+\beta+\gamma+\delta+\varepsilon}\right)}}{1-\dfrac{\lambda}{\left(\frac{1}{\alpha+\beta+\gamma+\delta+\varepsilon}\right)}} - \dfrac{(E+1)\left(\dfrac{\lambda}{\left(\frac{1}{\alpha+\beta+\gamma+\delta+\varepsilon}\right)}\right)^{E+1}}{1-\left(\dfrac{\lambda}{\left(\frac{1}{\alpha+\beta+\gamma+\delta+\varepsilon}\right)}\right)^{E+1}}, & \rho \neq 1 \\ \dfrac{E}{2}, & \rho = 1 \end{cases}$$

Waiting time of customer is evaluated by Little's formula

$$W_1 = \frac{L_1}{\lambda}$$

Case 1: When $\gamma = 0$

$$L_2 = \begin{cases} \dfrac{\dfrac{\lambda}{\left(\frac{1}{\alpha+\beta+\delta+\varepsilon}\right)}}{1-\dfrac{\lambda}{\left(\frac{1}{\alpha+\beta+\delta+\varepsilon}\right)}} - \dfrac{(E+1)\left(\dfrac{\lambda}{\left(\frac{1}{\alpha+\beta+\delta+\varepsilon}\right)}\right)^{E+1}}{1-\left(\dfrac{\lambda}{\left(\frac{1}{\alpha+\beta+\delta+\varepsilon}\right)}\right)^{E+1}}, & \rho \neq 1 \\ \dfrac{E}{2}, & \rho = 1 \end{cases}$$

$$W_2 = \frac{L_2}{\lambda}$$

Case 2: When $\gamma = 0, \varepsilon = 0$

$$L_3 = \begin{cases} \dfrac{\dfrac{\lambda}{\left(\frac{1}{\alpha+\beta+\delta}\right)}}{1-\dfrac{\lambda}{\left(\frac{1}{\alpha+\beta+\delta}\right)}} - \dfrac{(E+1)\left(\dfrac{\lambda}{\left(\frac{1}{\alpha+\beta+\delta}\right)}\right)^{E+1}}{1-\left(\dfrac{\lambda}{\left(\frac{1}{\alpha+\beta+\delta}\right)}\right)^{E+1}}, & \rho \neq 1 \\ \dfrac{E}{2}, & \rho = 1 \end{cases}$$

$$W_3 = \frac{L_3}{\lambda}$$

4. Illustration:

The data provided by us was collected from the Election Commission of India's website source, published in 2019 after the parliamentary election.

Table 2: Voter's Data for Parliament Election, Tamilnadu Region, 2019

S.No	Parliament	Total elector	X=Total voters	%	Y=Total booth	Z=Voters in single booth=X/Y
1	Ramanathapuram	1559740	1066146	68.35	1916	556

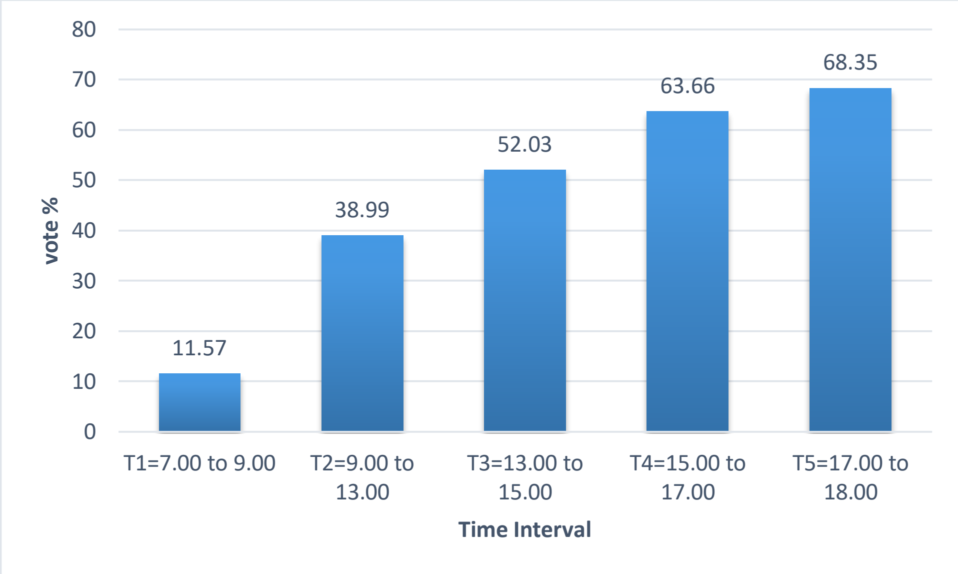

Figure 1: Voter's turnout time, percentage for Parliament Election, Tamilnadu Region (Ramanathapuram),2019

Consider
A = the percentage of voters turn around at the end of the poll.
B = the percentage at different times of polls.
Z = Number of voters in a single booth.

Formula:
Cumulative Arrival Rate $C\lambda = \frac{B}{A} \times Z$
Calculation:
For T_1 (In proposed Model) $\lambda = 47\ per\ hour\ , \mu = \frac{1}{4}$, E=7 $\varrho = \frac{47}{0.25 \times 60} = 3.13$

$$L_{SYS} = L1 = \frac{3.13}{1 - 3.13} - \frac{8(3.13)^8}{1 - 3.13^8} = 6.53$$

$$W_{SYS} = W1 = \frac{6.53}{47 \times 60} = 8.34\ per\ min.$$

Table 3: Calculation for Existing Model for Long Queues on Multiple Election

Timing	Cumulative ($C\lambda$)	No:of arrival (f)	λ per hour	**Existing Model calculation**		
				$If\ \ \mu = \frac{1}{4}$,E=7		
				ϱ	L_{SE}	W_{SE}
T_1	94	94	47	3.92	6.66	8.5
T_2	317	223	55.75	4.65	6.73	7.2
T_3	423	106	53	4.42	6.70	7.6
T_4	518	95	47.5	3.96	6.66	8.42
T_5	556	38	38	1.58	5.49	17.35

Table 4: Calculation for Proposed Model for Long Queues on Multiple Election

Timing	Cumulative ($C\lambda$)	No:of arrival (f)	λ per hour	**Proposed Model**		
				PO'S=5	**PO'S=4**	**PO'S =3**
				$If\ \alpha = \beta = \gamma = 1/min$ $\delta = \varepsilon = 0.5$ / min	$If\ \alpha = \beta = 1/min$	$If\ \alpha = \beta = 1$ / min $\delta = 0.5\ /\ min$

				$\mu = \frac{1}{4}$,E=7			$\delta = \varepsilon = 0.5$ / min $\mu = \frac{1}{3}$, E=6			$\mu = 0.4$, E=5		
				ϱ	L_1	W_1	ϱ	L_2	W_2	ϱ	L_3	W_3
T_1	94	94	47	3.13	6.53	8.34	2.37	5.29	6.75	1.95	5.02	5.19
T_2	317	223	55.75	3.72	6.63	7.14	2.82	5.45	5.87	2.32	5.26	4.61
T_3	423	106	53	3.5	6.61	7.48	2.68	5.41	6.13	2.21	5.2	4.78
T_4	518	95	47.5	3.12	6.54	8.26	2.40	5.30	6.7	1.98	5.04	5.15
T_5	556	38	38	1.27	4.67	14.75	0.96	2.84	8.95	0.79	2.11	5.81

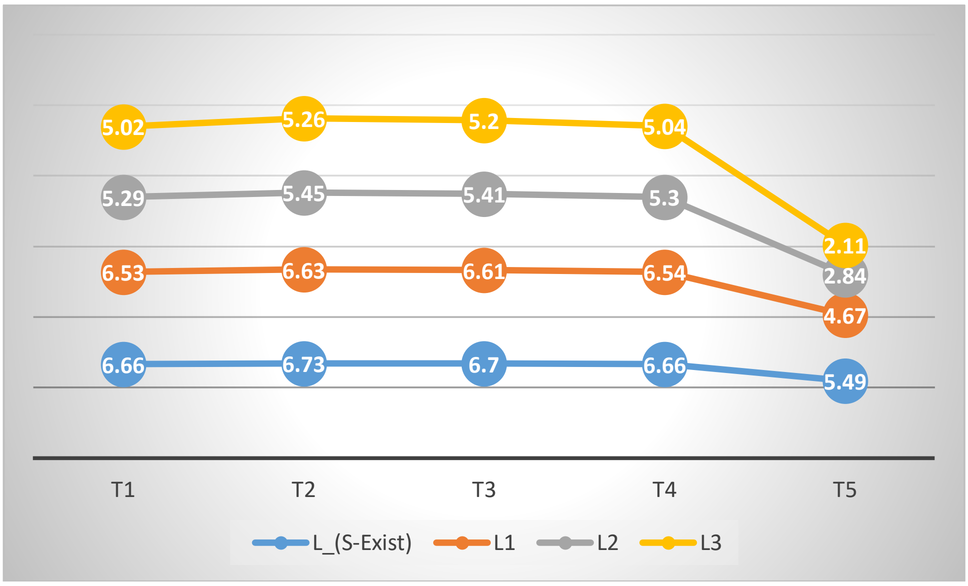

Figure **2:** Expected number of voters in the system existing and proposed method

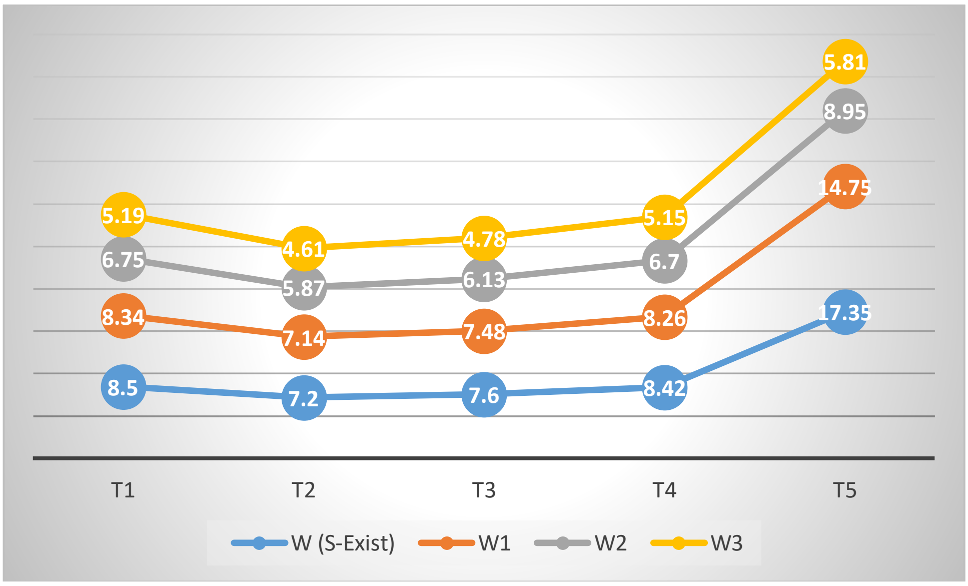

Figure 3: Waiting time of voters in the system existing and proposed method

5. Observation And Conclusion:

The following conclusion are made

1. Trending line L3 indicates a smaller number of voters in the system when we compare it with the existing model.
2. Trending line W3 indicates reduced waiting time for voters so that they don't have to wait in long queues to cast their votes.
3. Our model of reducing polling officers will increase the rate of voter arrivals during peak hours in the morning and evening, without causing any loss of voters, thereby increasing the overall turnout percentage.
4. After reducing the number of polling officers from five to three (excluding PRO), our model yielded the best results.
5. The novelty of our approach to reducing the minimum number of polling booths with reduced polling officer without reducing their duties will give monetary benefits to ECI.
6. The primary feature of our model is to reduce queue length and enable smooth conduction of multiple elections.

References:

1. Ajay Kumar Sharma, Dr. Rajiv Kumar, Research Scholar, Department. Of Mathematics, DCRUST, Murthal, Sonepat, India Dr. Girish Kumar Sharma,
2. Associate Professor, Department of Computer Application, BPIBS, Delhi, India. A study on Queueing Theory Approach with Queueing Model.
3. Andrea Marin (2020), Sabina Rossi "A queuing model that works only on the biggest jobs" – Computer Performance Engineering: 16th European Workshop, EPEW 2019, Milan, Italy 118-132,
4. Aduri Kishore Reddy Assistant Professor, Department of ECM, KL University, A. P, India, krish.aduri@gmail.comA Case Study on Indian E.V.M.S Using Biometrics
5. Balaji.R et.al "Embedded based E voting system through Finger print and Aadhar verification"
6. Binoy Kumar (2022) Transient analysis of M/M/C queuing model with reneging, finite capacity and population, IJMOR, Vol 21, No.1
7. Ch, Sai Pratap Varma et.al (2020) Aadhar card verification base Online Polling" -4th international conference on Trends in Electronics and informatics
8. Chatak,Bratati(2022); et.al "An Analysis on application of Queueing theory in Hospital services" doi:10.48047/NQ.2022.20.22.NQ10267
9. Chris Blondia (2021)- "A queuing model for a wireless sensor node using energy harvesting" Telecommunication Systems 77(2), 335-349
10. Chris Blondia (2022) "Evaluation of the waiting time in a finite capacity Queue with Bursty Input and a generalized Push-Out strategy by.//doi.org/10.3390/math10244771/15 Dec 2022
11. Colin Mcintyre (2020)" Solving the problem of long lines on election day" Elena Stankevich, Igor Tananko, Michele Pagano (2022) "Chapter 4 Analysis of Open Queueing Networks withBatch Services"
12. Fan-Qi Ma and Rui-Na Fan (2022) "Queueing theory of improved practical Byzantine Fault Toleren Consensus". doi.org/10.3390/math10020182/2022,
13. Joyce, D. "Configurations in abelian categories. III. Stability conditions and identities", Advances in Mathematics, 20071020
14. Lakshmi et.al (2018) Aadhar card based smart e-voting system-IJEAT ISSN:2249-8958, Volume-8 Issue-2S, December 2018
15. Mustafa Demircioglu, Herwig Bruneel et.al (2021)" Analysis of a Discrete –Time Queuing Models with disasters// doi.org/10.3390/math9243283
16. Mor Harchol-Balter (2022)," The multi-server Queuing model" Queueing systems"100(3-4),201-203,
17. Nail Akar, Ozancan, Dogan (2021)" Discrete-time queuing model of age of information with multiple information sources" IEEE Internet of things Journal 8 (19),14531-14542,
18. Prasanna Lakshmi, K. Jeganathan*, V. Kamal Nasir, et.al (2019) "A Queueing Inventory System with Server Working Breakdown", International Journal of Innovative Technology and Exploring Engineering, 2019.
19. Sapana Sharma et.al (2023)" Queuing models with customers Impatience:a Survey,

doi:10.1504/IJMOR.2023.135546

20. Sanban-cho, Chiyoda-ku, Queuing Analysis of Polling Models HIDEAKI TAKAGI IBM Research, Tokyo Research Laboratory, 5-19 Tokyo 102, Japan
21. S.M.A. Shahul Hameed, M. Shahul Hameed, V. Kamal Nasir (2022). A Solution to Long lines on Election Day using Queuing Technique NEUROQUANTOLOGY | OCTOBER 2022 | VOLUME 20 | ISSUE 11 |PAGE 7170-7177| DOI: 10.14704/NQ.2022.20.11. NQ66711
22. Srinivas R.Chakravarthy(2021)-'Analysis of a queueing model with batch Markovian arrival process and general distribution for qroup clearance" Methodology and computing in Applied probability 23,1551-1579,
23. S. D Sharma Operation research, Taha H. A. Operation Research an introduction (2003), Macmillan Publication Company, New York
24. Takero Yoshida, Kazuo Ouchi (2021) "Improved Accuracy of Velocity Estimation for Cruising Ships by Temporal Differences Between Two Extreme Sublook Images of ALOS-2 Spotlight SAR Images with Long Integration Times", IEEE Journal of Selected Topics in Applied Earth Observations and Remote Sensing,
25. Sudharsan B, Rishi Tharun V, Nidhish Krishna M P, Boopathi Raj J, Surya, Arvindh M, Dr. M. Alagappan. (2019) "Secured Electronic Voting System Using the Concepts of Blockchain", 2019 IEEE 10th Annual Information Technology, Electronics and Mobile Communication Conference (IEMCON),
26. Vishal, Risab Garg (2016) Online voting system linked with Aadhar, Third International conference computing for Sustainable Global development (INDIACom), New Delhi,2016 pp 3239-3240
27. William A. Edelstein Johns Hopkins University School of Medicine, w.edelstein@gmail.com Arthur D. Edelstein University of California,
28. San Francisco.Queuing and Elections: Long Lines, DREs and Paper Ballots www.wikipedia.com
29. www.eci.gov.in
30. www.newsindianexpress.com,www.thehindu.com/elections