J. Mountain Res. P-ISSN: 0974-3030, E-ISSN: 2582-5011 DOI: https://doi.org/10.51220/jmr.v20-i1.9
Vol. 21(1), (2025), 79-87

An Analysis of Queuing Management Process for Effective Congestion Control: A Case Study of Base Hospital Srinagar, Pauri Garhwal

Jagdish C. Purohit[1*] • Ankit Kaparwan[2] • Pushpa Panwar[3]

[1]*Assistant Professor, Department of Agriculture & Horticulture, Dolphin (PG) College of Biomedical & Natural Sciences, Dehradun, Uttarakhand (An Autonomous College)*

[2]*Assistant Professor, Department of Statistics, HNB Garhwal University (A Central University), Srinagar Garhwal, Uttarakhand.*

[3]*Assistant Professor, Department of Statistics, Government PG College, New Tehri, Tehri Garhwal, Uttarakhand*

*Corresponding Author Email ID: dr.jagdish2023@gmail.com

Received: 22.04.2025; Revised: 20.05.2025; Accepted: 31.05.2025

Abstract: The orderly analysis of the queuing system of Base Hospital Srinagar Pauri Garhwal in Garhwal Region shows that the present arrangement and figure of the servers are not adequate for well-timed customer service and congestion control. It is also observed that there is an extensive need for a few more servers in place of the three at present. The findings of the present study highlight the importance of expanding the server capacity from three to five. This enhancement aims to more effectively address customer needs, alleviate congestion, and significantly boost the operational efficiency of Base Hospital Srinagar in Pauri Garhwal. By implementing this change, the hospital can provide a higher quality of service and achieve improved outcomes for patients and staff alike. This study employed a quantitative research approach to explore the intricacies of the queuing system. Over the course of a week, data were diligently collected through a daily log that documented customer flow and wait times.

This research comprised a thorough analysis of queuing systems and techniques of Base Hospital Srinagar in Pauri Garhwal, in addition to the development of a refined queuing model specifically aimed at addressing the challenges posed by customer arrival rates. This model was designed to accurately predict the optimal number of service providers needed and to estimate the time required to minimise customer wait times. By utilising this model, the goal was to ensure that customers are served efficiently and promptly, thereby enhancing their overall experience during their visits to the establishment throughout the week.

Keywords: Queuing Model • Arrival Rate • Service Rate • Waiting Period.

Introduction

A queue occurs when a unit arrives at a service point to receive assistance. If immediate service isn't available, the unit joins a queue and exits after being served. Queues form when resources can't meet demand, leading to waits that are often unpleasant. However, effective queue management can benefit both waiting units and service providers, enhancing efficiency for everyone involved. Nowadays, queuing is a common experience in our daily lives. We find ourselves in queues at post offices, banks, restaurants, train stations, and hospitals to get the services. So, queuing theory is a part of operations research in which we perform a mathematical study of waiting queues with the objective of providing satisfactory service to customers who are waiting in a queue and estimate the queue length and waiting period. The queueing theory originated with Agner Krarup Erlang in 1909, who developed mathematical models to analyse telephone call congestion in Copenhagen. His work laid the foundation for studying waiting lines in various service systems. Later, in 1928, Thornton C. Fry expanded these concepts to address engineering problems, and in 1953, D.G. Kendall formalised the field by introducing standard queue notation and Markovian analysis. (Cooper 1981). These advancements have enabled the widespread application of queueing theory in sectors such as telecommunications, healthcare, traffic engineering, computing, design of factories and operations management. (Sundri et al., 2012). Kusum Singh et al. (2010) examined feedback queues with three service channels, allowing customers to move freely both forward and backward between them. They assumed a constant probability for each return, simplifying their analysis. However, this model may not reflect real-world scenarios. In practice, customers might be limited in the number of movements to previous or next channels, and the probabilities for these movements could vary due to factors like wait times and service quality. This highlights the complexity of customer behavior and suggests a need for more refined models that account for these constraints and variations in movement probabilities.

The aim of this study is to provide a comprehensive analysis of how customer waiting times fluctuate within the queueing system. This analysis will be presented through both numerical data and graphical representations, allowing for a clear understanding of the relationship between waiting times and various queueing parameters such as arrival rates, service rates, and system capacity. By illustrating these connections, we hope to offer valuable insights into the dynamics of the queueing system and identify potential areas for improvement in customer service efficiency.

Statement of the Problem

In Base Hospital Srinagar Pauri Garhwal Uttarakhand, one of the fundamental challenges facing the hospital is that attendance has increased due to an increase in population and awareness, and hospital/clinic capacity has remained constant; as a result, patients must wait for a lengthy period of time before receiving treatment. Furthermore, multiple studies have been found in the literature that demonstrate a high level of patient dissatisfaction with extended waiting times, indicating that there is a widespread problem in hospital practice resulting in a high level of patient anxiety and unhappiness. Furthermore, additional hands are required to raise the service rate. In addition, waiting for patients might have negative effects, such as man-hours lost during idle waiting in a queue or a loss of goodwill when patients are not happy with the system. The purpose of this study is to estimate how long a patient at Base Hospital Srinagar, Pauri Garhwal, Uttarakhand, is likely to spend in the system.

Objectives

The Queuing Model serves as an analytical tool for assessing the performance of waiting lines in service systems. It evaluates essential metrics, including the average arrival and service rate of customers and the system utilizationion, which indicates the efficiency of service capacity utilisation. Furthermore, the model estimates the probability number of customers waiting in the system.

Research Methodology

The daily records of the queue management system at Base Hospital Srinagar, located in Pauri Garhwal, Uttarakhand, served as the primary source of data for this research. Extensive primary data were gathered through a combination of structured questionnaires and careful observation of patient interactions and flow within the hospital. This approach allowed for a comprehensive analysis of the efficiency and effectiveness of the queue system over the course of the week.

 DOI: https://doi.org/10.51220/jmr.v20-i1.9

Formulas used for service analysis:

1. The average number in line $Lq = \frac{\lambda\mu\left(\frac{\lambda}{\mu}\right)^M}{(M-1)!(M\mu-\lambda)^2} P_0$.

2. Probability of zero units in the system $P_0 = \left[\sum_{n=0}^{M-1}\frac{\left(\frac{\lambda}{\mu}\right)^n}{n!} + \frac{\left(\frac{\lambda}{\mu}\right)^M}{M!\left(1-\frac{\lambda}{M\mu}\right)}\right]^{-1}$

3. Average waiting time for n arrivals not immediately served $W_a = \frac{1}{M\mu-\lambda}$

4. Waiting time of customers wait in queue $W_q = \frac{Lq}{\lambda}$

5. Probability of waiting service time for arrival $P_W = \frac{W_q}{W_a}$

6. Within system average waiting time $W_s = W_q + \frac{1}{\lambda} = \frac{L_s}{\lambda}$

7. System Utilization $\rho = \frac{\lambda}{M\mu}$

Result and Discussion

The focus of the study is on interpreting tables, graphs, and data, assessing statistical estimates, and examining patterns. The model will calculate how long it really takes to fulfil a customer by the deadline and project how many real working hours are required within the company.

During a one-week observation period, this model was used to forecast the number of servers needed and the time required to address the issue of clients waiting in line for services at the institution. By simulating various scenarios, the model assessed how effectively the queuing system operated based on the number of available servers and the rate of customer arrivals. This approach aimed to gain insights that could lead to improved service delivery and reduced wait times for clients. The analysis of the queuing system in Table 1 indicates that all three servers are consistently overloaded, with arrival rates surpassing service rates throughout the week. Server 1 is the most burdened, particularly on Monday and Tuesday, which raises concerns about potential delays and congestion. Saturday is the only day that shows balanced performance. Overall, the system experiences high utilization rates (all exceeding 1), highlighting the need for load balancing, increased server capacity, and improved task distribution in order to enhance efficiency and reduce wait times.

Table 1: Daily Queuing System Analysis for three Servers in the hospital.

Days		Servers					
		Server (1)		Server (2)		Server (3)	
		A. R	S. R	A. R	S. R	A. R	S. R
Day 1 (Monday)	Total	90	81	108	92	104	93
	Average	15	13	18	15.33	17.33	15.5
Day 2 (Tuesday)	Total	117	95	95	89	115	98
	Average	19.5	15.83	15.83	14.83	19.16	16.33

Day 3 (Wednesday)	Total	86	75	97	91	89	84
	Average	14.33	12.5	16.16	15.16	14.83	14
Day 4 (Thursday)	Total	53	46	84	76	106	91
	Average	8.83	7.66	14	12.66	17.66	15.16
Day 5 (Friday)	Total	66	55	83	73	97	84
	Average	11	9.16	13.83	12.16	16.16	14
Day6 (Saturday)	Total	36	36	44	42	57	55
	Average	9	9	11	10.5	14.25	13.75
Total of the Week	Total Average	448	388	511	463	568	505
Average System Utilization		1.4779		1.10134		1.1216	

Source: Analysis by Researcher (NOTE: A.R = Arrival Rate, S.R =Service Rate)

Table 2: Customer arrival rate for each server

S.No.	Server	Average Customer arrival rate
1.	Server 1 (λ_1)	12.9443
2.	server 2 (λ_2)	14.8053
3.	server 3 (λ_3)	16.569
	Average Customer arrival rate for all servers (λ)	14.7728

Source: Analysis by Researcher

Table 3: Customer service rate for each server:

S.No.	Server	Average Customer Service Rate
1.	Server 1 (μ_1)	11.2775
2.	Server 2 (μ_2)	13.443
3.	Server 3 (μ_3)	14.7915
	Average Customer service rate for all servers (μ)	13.17067

Source: Analysis by Researcher

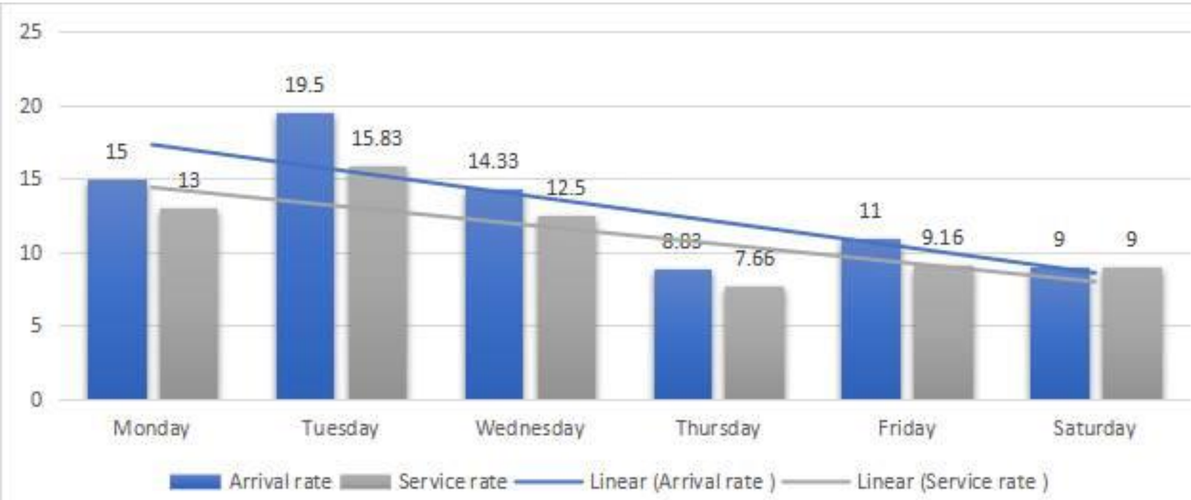

Fig. 1: Average arrival and service rate for server 1 in the hospital.

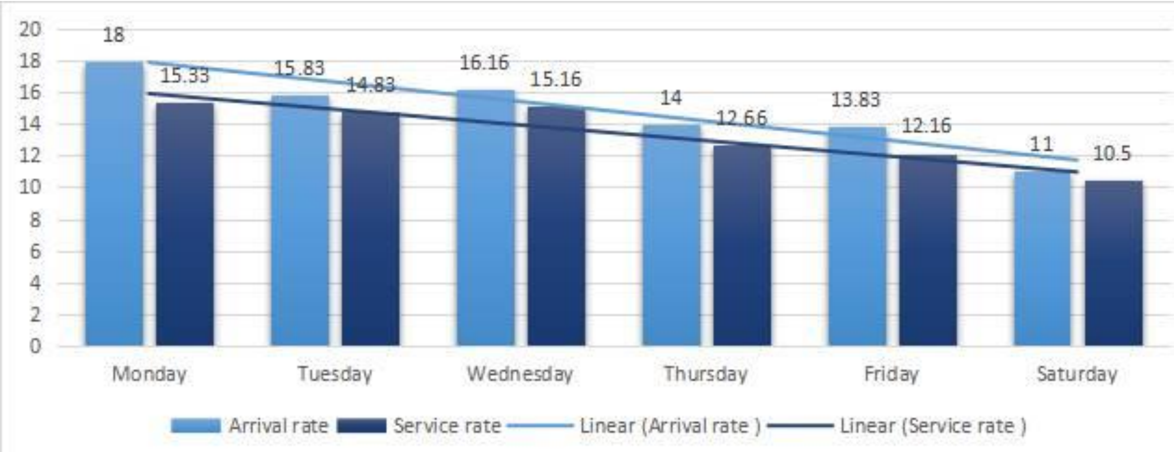

Fig. 2: Average arrival and service rate for server 2 in the hospital.

Table 4: The typical quantity of customers being attended to by each server.

S.No.	Servers	Average number of customers
1.	Server 1 (R_1)	1.4779
2.	Server 2 (R_2)	1.10134
3.	server 3 (R_3)	1.12017
	Average(R)	1.1216

Source: Analysis by Researcher (NOTE: The average (R) is calculated by the formula [$R=\lambda/\mu$].)

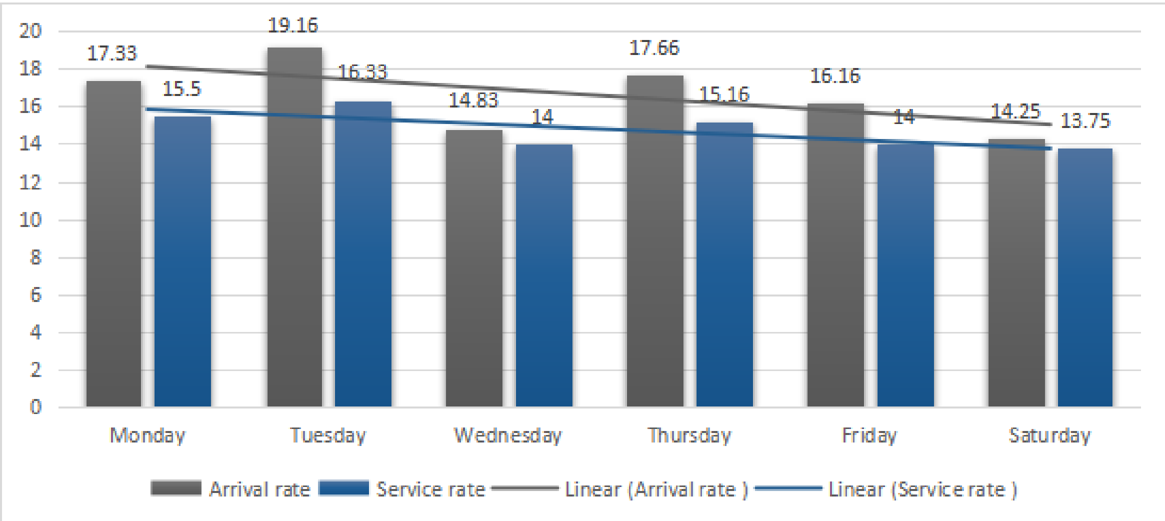

Fig. 3: Average arrival and service rate for server 3 in the hospital.

By analyzing the Daily Queuing System Analysis of the server's data in Table 1 and uses of formulas. We calculated the result variables shown in Tables 2,3, 4, 5 and 6.

Table 5: Average system utilization across all servers.

	Servers		
Weekly	**Server (1)**	**Server (2)**	**Server (3)**
First Day	1.153	1.174	1.118
Second Day	1.231	1.067	1.173
Third Day	1.146	1.065	1.057
Fourth Day	1.152	1.105	1.164
Fifth Day	1.200	1.137	1.154
Sixth Day	1.000	1.047	1.036

Source: Analysis by Researcher
Note: Utilization=Service Rate/Arrival Rate

Table 6: System Utilization for each server.

S.No.	Server	Average Utilization
1.	Server 1 [$\rho_1 = \lambda_1/M_1\ (\mu_1)$]	1.4779
2.	Server 2 [$\rho_2 = \lambda_2/M_2\ (\mu_2)$]	1.10134
3.	Server 3 [$\rho_3 = \lambda_3/M_3\ (\mu_3)$]	1.1216
	Average system utilization for all server(ρ)	1.1216

Source: Analysis by Researcher (NOTE: System Utilization for each Channel is calculated by the formula [$\rho = \lambda/M(\mu)$], where ρ is the average system utilization of each channel.)

The finding of the queuing system in Table 2 result that all three servers consistently operate under high load conditions, with daily system utilization values exceeding 1.0. This indicates that customer arrivals surpass the servers' capacity to serve them. The calculated system utilization rates in Table 6 further support this, with Server (1) has the highest utilization rate at 1.4779, followed by Server (3) at 1.1216 and Server 2 at 1.1013. These rates are based on the customer arrival and service rates presented in Tables 3 and 4, respectively. Although Server 3 experiences the highest customer arrival rate (16.569, Table 3), its greater service rate (14.7915, Table 4) helps maintain a relatively lower utilization compared to Server 1. Server 1 struggles with both a lower service rate (11.2775) and a higher arrival rate (12.9443). Additionally, the average number of customers being served at each server (Table 5) reinforces these observations, with Server 1 showing the highest load (R = 1.4779). A day-wise breakdown (Table 2) indicates that Tuesday and Friday are peak workload days for all servers, while Saturday demonstrates a more balanced server performance. Overall, the high system utilization and queuing stress highlight the need for corrective actions. Using the above formulas, we draw the conclusion, which is shown in Tables 7 and 8.

Table 7: Result for M, L_q and P_o.

M	L_q	P_o
1	0.000	0.1804
2	0.836	0.351
3	0.138	0.4845
4	0.05	0.5406
5	0.025	0.568
6	0.015	0.5813
7	0.015	0.5862
8	0.007	0.5857
9	0.005	0.5812

Source: Analysis by Researcher

From Table 7, we find that "M" is 5 ", *Lq*" is 0.025871 □ 0.026 and P_0 is 0.569136 □ 0.569,
So, by using these values and formulas, we calculate-

	Results	Calculated Value
1.	Expected inter-arrival time per hour ($1/\lambda$)	4.0615min
2.	Service Time per hour (μ)	13.17067
3.	The average number of customers waiting for service (L_q)	0.0258 □ 0.026
4.	Average waiting time for an arrival not immediately served (W_a)	1.1742 min
5.	The average time customers wait in line (W_q)	0.10559 *min*
6.	Probability that an arrival will have to wait for service (P_w)	0.0899
7.	The Average Number of Customers in the System (L_s)	1.226
8.	The average time spent in the system (W_s)	0.08299
9.	System Utilization	0.22433
10.	The system capacity (Mμ)	65.85

The aforementioned outcome, with the aid of Table 8, demonstrated that five (5) servers were required to service the consumers in the case study establishment. This designated number of servers is essential to guarantee that clients receive prompt service, minimizing their waiting time. The likelihood that an arrival waiting period is decreased by this increase in servers to 0.08299. However, for an hour, 0.22433 system utilization was noted. Additionally, it was found that the five servers' combined system capacity was 65.85 for one hour.

Table 8: Analyses of Multiple Servers result.

$\frac{\lambda}{\mu}$	M	Lq	P_o	$\frac{\lambda}{\mu}$	M	Lq	P_o
1.0	2	0.5	0.5	2.1	3	0.8677	0.0807
	3	.08333	.667		4	0.2057	0.0811
	4	.02778	.75		5	0.15753	0.0616
	5	.0125	.8		6	0.09830	0.0415
	6	.0066	.833		7	0.0566	0.0257
1.1	2	.06722	.4090	2.2	3	1.166	0.0644
	3	.1126	.5538		4	0.3484	0.06572
	4	.03977	.6231		5	0.1745	0.04753
	5	.01924	.6609		6	0.1065	0.0212
	6	.01106	.6842		7	0.06328	0.01836
1.2	2	000.9	.33	2.3	3	1.45087	0.05080
	3	.148148	.462963		4	0.395693	0.06533
	4	.04518	.515312		5	0.19422	0.02826
	5	.02587	.569136		6	0.117566	0.02365
	6	.01701	.548823		7	0.069051	0.0133
	7	.011719	.550118	2.4	3	1.81132	0.03992
1.3	2	1.207143	.26923		4	0.448122	0.04322
	3	.190613	.38575		5	0.213889	0.03028
	4	.072004	.42411		6	0.127566	0.01802
	5	.038266	.43412		7	0.084912	0.00976
	6	.024414	.4297	2.5	3	2.3148	0.0296

1.4	2	1.633	.214286		4	0.406894	0.03506
	3	.24087	.321027		5	0.2349	0.02406
	4	.092162	.347518		6	0.1267	0.01384
	5	.050189	.34554		7	0.09070	0.00723
	6	.032800	.3282	2.6	3	3.06896	0.02114
1.5	2	2.25	.1667		4	0.5733	0.02837
	3	.3	.2667		5	0.2563	0.01913
	4	.114894	.2836		6	1.528019	0.0107
	5	.063347	.2725		7	0.07506	0.0054
	6	.04186	.2480	2.7	3	4.322134	0.01463
1.6	2	3.2	.125		4	0.649412	0.002
	3	.369404	.22076		5	0.281304	0.01533
	4	.14012	.23081		6	0.1588	0.00832
	5	.077461	.21348		7	0.103502	0.00406
	6	.05123	.18474	2.8	3	6.8257	0.0088
1.7	2	4.81667	.088235		4	0.737464	0.01561
	3	.450982	.182506		5	.306187	.01234
	4	.167815	.18757		6	.171804	.0065
	5	.092314	.166595		7	.11015	.00308
	6	.0069	.136737	2.9	3	14.32961	.00404
1.8	2	8.1	.0556		4	.840862	.01488
	3	.547200	.1505		5	.335282	.00994
	4	.18802	.152169		6	.184211	.0051
	5	.1066	.129788		7	.117079	.0023
	6	.06012	.101028	3.0	4	.964286	.011905
1.9	2	18.05	.02621		5	.36599	.0080
	3	.661938	.12291		6	.196751	.0040
	4	.23089	.12336		7	.124318	.0018
	5	.12366	.10119		8	.05196	.0076
	6	.07951	.04769	3.1	4	.1148	.00946
2.0	3	.8	.1		5	.03996	.00652
	4	.26667	.1		6	.0211	.00323
	5	.140351	.07864		7	.0121	.0014
	6	.0889	.0556		8	.0090	.0043
	7	.061836	.03623		9	.006563	.0023

Source: Analysis by Researcher

Conclusion

The assessment of the queuing system at Base Hospital Srinagar Pauri Garhwal, located in the Garhwal Region, reveals a critical need to expand the number of service channels or servers from the current capacity to five (5). This strategic increase is projected to significantly decrease the average waiting time for patients, ensuring they receive timely medical attention, which is essential for effective healthcare delivery. Incorporating additional servers will not only streamline the patient flow but also enhance the overall operational efficiency of the hospital. With improved service speed, staff can attend to more patients within a given timeframe, which is vital in a healthcare setting where timely interventions are often crucial for patient outcomes. Moreover, as patients experience reduced wait times and more efficient service, their satisfaction levels are likely to rise, fostering a greater appreciation for the hospital's commitment to quality care. Ultimately, this enhancement in the queuing system at Base Hospital Srinagar Pauri Garhwal is aimed at fostering a more responsive and patient-centred healthcare environment, which is essential for building trust and reliability within the community it serves.

References

Atencia I .and Moreno P (2004). Discrete-time Geo[X]/GH/1 retrial queue with Bernoulli feedback. *Computers & Mathematics with Applications, 47*(8–9), 1273–1294.

Cooper R B (1981). *Introduction to queueing theory* (2nd ed.). North Holland.

Dowdy L W, Almeida V A F and Menasce D A (2004). *Performance by design: Computer capacity planning by example* (p. 480).

Ho Y C & Cao X R (1983). Optimization and perturbation analysis of queueing networks. *Journal of Optimization Theory and Applications, 40*, 559–582.

Ke J C & Chang, F M (2009). Modified vacation policy for M/G/1 retrial queue with balking and feedback. *Computers & Industrial Engineering, 57*(1), 433–443.

Kelly F P (1975). Networks of queues with customers of different types. *Journal of Applied Probability, 12*(3), 542–554.

Krivulin N K (1994). A recursive equation-based representation for the G/G/m queue. *Applied Mathematics Letters, 7*(3), 73–78.

Kumar B K, Arivudainambi D & Krishanmoorthy A (2006). Some results on a generalized M/G/1 feedback queue with negative customers. *Annals of Operations Research, 143*(1), 277–296.

Kumar B K, Madheshwari S P & Kumar A V (2002). The M/G/1 retrial queue with feedback and starting failures. *Applied Mathematical Modeling, 26*(11), 1057–1075.

Kumar B K, Madheshwari S P & Lakshmi S R A (2013). An M/G/1 Bernoulli feedback retrial queuing system with negative customers. *Operations Research, 13*(2), 187–210.

Kumar B K & Raja J (2006). On multi-server feedback retrial queues with balking and control retrial rate. *Annals of Operations Research, 141*(1), 211–232.

Law A M & Kelton W D (1991). *Simulation modeling and analysis* (2nd ed.). McGraw-Hill.

Lee A M (1958). *Applied queueing theory*. Macmillan and Company.

Mayhew L & Smith D (2006). *Using queuing theory to analyse completion times in accident and emergency departments in light of the Government's 4-hour target*. Cass Business School.

Penttinen A (n.d.). Chapter 8 – Queuing systems. In *Lecture notes: S-38.145 - Introduction to teletraffic theory*.

Rubinstein R Y (1986). *Monte Carlo optimization, simulation, and sensitivity of queueing networks*. Wiley.

Sathy T L (1961). *Elements of queueing theory with applications*. McGraw-Hill.

Schlechter K (2009, May 10). Hershey Medical Center to open redesigned emergency room. *The Patriot- News*.

Sundarapandian V (2009). Queuing theory. In *Probability, statistics, and queuing theory* (pp. xx–xx). PHI Learning.

Sundri S M & Srinivasan S (2012). Multi-phase M/G/1 queue with Bernoulli feedback and multiple server vacation, *52*(1), 18–23.

Singh T P, Kusum and Gupta Deepak "On Network Queue Model Centrally Linked with Common Feedback Channel," Journal of Mathematics and System Sciences, vol. 6, no. 2, pp. 18-31, 2010.

Van Dijk N M (1993). On the arrival theorem for communication networks. *Computer Networks and ISDN Systems, 25*(10), 1135–2013.