Annals of Process Engineering and Management

www.apem.reapress.com

Ann. Proc. Eng. Manag. Vol. 2, No. 4 (2025) 253–268.

Paper Type: Original Article

# Machine Interference Problem: A Survey of Queueing Models and Applications

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**Citation:**

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| *Received: 11 May 2025*<br>*Revised: 23 July 2025*<br>*Accepted: 20 October 2025* | Raina, A. A., & Shaheen, F. (2025). Machine interference problem: A survey of queueing models and applications. *Annals of process engineering and management*, 2(4), 253-268. |

**Abstract**

This article presents a comprehensive survey of research related to the Machine Interference Problem (MIP), also known as the Machine Repair Problem (MRP). The problem arises when machines fail randomly in manufacturing or service environments and compete for limited repair facilities, causing queues and production delays. Such failures often result in substantial losses of production, revenue, or reliability. In addition to summarising research articles on MIP/MRP, this paper provides an organised list of books and survey papers to aid researchers in understanding the breadth of work in the queueing domain. The literature is classified according to methodological and modelling approaches. The survey concludes by highlighting recent advances and identifying promising directions for future research in reliability and queueing theory.

**Keywords:** Machine interference problem, Machine repair problem, Queues, Survey.

## 1 | Introduction

The random failures and subsequent repairs of components in the machining system profoundly affect the uninterrupted and efficient operation of the system. It is essential to adopt effective maintenance and repair policies to ensure uninterrupted and efficient operation. The impact of random breakdowns on continuous production must therefore be accounted for when designing machining systems and evaluating their performance. One of the most studied frameworks for analyzing such scenarios is the Machine Interference Problem (MIP), also known as the Machine Repair Problem (MRP), which models a finite-source population. In such systems, congestion may arise due to limited repair facilities or blockages. To mitigate this, industries often establish permanent repair facilities supplemented by additional backup units. Another widely used strategy is the introduction of standby machines that automatically replace failed units, ensuring operational continuity at the cost of additional resources. In practice, failed machines are quickly removed and replaced by spares from standby pools; however, switching itself may be prone to failures. Consequently, repair policies

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https://doi.org/10.48314/apem.vi.48

must be designed to ensure that machines are serviced promptly and production resumes with minimal disruption.

Random failures are not limited to industrial systems-they are prevalent across many facets of modern life. As society becomes increasingly dependent on machines—from household appliances to advanced industrial applications—the need for systematic analysis of machine behavior and reliability grows ever stronger. Modern mathematical techniques, particularly queueing theory, have emerged as powerful tools to study these problems. Queueing models effectively capture the dynamics of congestion, blocking, and delay, and they are widely observed in daily life, including traffic systems, helplines, gas stations, airports, hospitals, communication networks, and computer systems. Within this domain, finite-source queueing models, also known as machine repair or interference models, have found particular relevance in production lines, power supply systems, manufacturing processes, distribution networks, and computing environments.

As machining systems become more sophisticated, they pose increasingly challenging demands on designers and technologists tasked with maintaining efficiency. In industrial practice, the primary objective remains the same: to maximize production quality and quantity while minimizing costs. Breakdowns, however, disrupt this balance by halting operations and leading to production losses. To prevent such disruptions, many systems incorporate dedicated repair facilities capable of restoring failed machines. From an academic perspective, these scenarios inspire the development of new models and analytical approaches within queueing theory, while from an industrial viewpoint, they provide practical insights into resource allocation and efficiency improvement. Thus, research on MIP offers value to both theory and practice: it enriches the scientific understanding of stochastic systems and provides actionable strategies for industries facing machine-related interruptions.

Several factors influence the behavior of machining systems, including the time to failure, the waiting period for repair when multiple machines are down simultaneously, and the availability of repair personnel. In multi-repairman systems, when the number of failed machines exceeds the number of available repairers, the excess machines must wait until repair resources are free, resulting in interference losses and decreased productivity. Understanding such dynamics requires the use of mathematical models rooted in queueing theory, which allow researchers and practitioners to evaluate system effectiveness and optimize performance.

To provide a strong foundation for the study of machining systems, this paper also compiles an extensive list of reference materials, including textbooks [1]-[30] and survey articles [31]-[48]. These works can serve as essential resources for researchers, particularly beginners, by introducing the fundamentals of queueing models and guiding deeper exploration of advanced topics in reliability, maintainability, and performance analysis.

## 1.1 | Applications of the Machine Interference Problem

The MIP has numerous practical applications across industries and service domains:

I. Manufacturing systems: modelling repair and maintenance policies in automated production lines to minimize downtime and optimize throughput.

II. Computer and communication networks: representing server breakdowns, packet losses, and congestion when multiple users compete for limited repair or recovery resources.

III. Healthcare systems: analyzing patient flow in hospitals where finite medical staff serve as "repair facilities" and patients as "machines" requiring service.

IV. Transportation and logistics: managing congestion at service stations, toll booths, and airports, where breakdowns or delays can propagate across the system.

V. Energy and power plants: ensuring reliability of finite sets of generators, turbines, or distribution units, where repair delays may result in blackouts or cascading failures.

VI. Telecommunication systems: Modelling finite-source traffic with switching failures and recovery delays in cellular or satellite networks.

By capturing diverse real-world scenarios, MIP demonstrates its versatility as both a theoretical model and a practical decision-making tool in reliability engineering, operations research, and service system management.

## 1.2 | Machine Repair Model

The MRP is a classic example of a finite-source queueing model, where machines represent the finite customer population, breakdowns correspond to arrivals, and repair crews act as servers. Consider a machining system consisting of $M$ identical operating machines and $R$ repair crews. The repair time for a failed machine is assumed to follow an exponential distribution with a mean $1/\mu$, while the operating time of a machine before failure follows an exponential distribution with a failure rate $\lambda$.

Let $P_n$ denote the steady-state probability that $n$ machines fail at a given instant. The stochastic dynamics of this system can be described by a Continuous-Time Markov Chain (CTMC), as shown in *Fig. 1*.

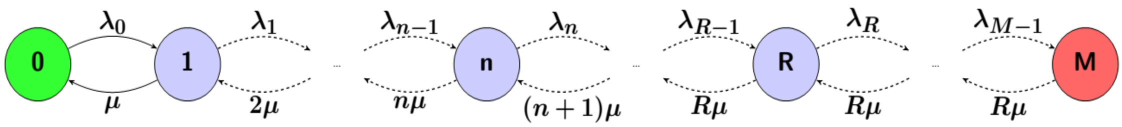


**Fig. 1. Machine repair model [40].**

In this model, the state-dependent failure and repair rates are given as:

$$\lambda_n = (M - n)\lambda. \quad (1)$$

$$\mu_n = \min(n, R)\mu, \quad (2)$$

where $\lambda_n$ is the effective failure rate when $M - n$ machines are operational, and $\mu_n$ is the aggregate repair rate when $n$ machines are down.

The steady-state probabilities can be obtained by solving the Chapman–Kolmogorov equations using the transition rates in *Eq. (1)* and *Eq. (2)*. The stationary distribution is expressed as:

$$P_n = P_0 \prod_{i=1}^{n} \frac{(M - i + 1)\lambda}{\min(i, R)\mu}, \quad n = 1,2,3, \dots, M, \quad (3)$$

where $P_0$ is determined using the normalising condition:

$$\sum_{n=0}^{M} P_n = 1. \quad (4)$$

## 1.3 | Performance Measures

For the effective operation of machining systems, failed machines must be repaired in a timely and efficient manner. Excessive congestion can lead to long wait times, service disruptions, and production delays. Increasing the number of repair facilities reduces downtime but raises service costs, while too few repair facilities reduce costs but increase waiting times, leading to production losses. Therefore, the objective is to strike a balance between the cost of service and the cost of waiting.

Queueing theory offers quantitative measures to evaluate this trade-off. Since machining systems are inherently stochastic, these measures are random variables obtained from the distributions of queue size, busy period, and waiting time. Some key performance measures are:

I. Mean number of failed machines in the system:

$$E[X] = \sum_{n=0}^{M} nP_n. \quad (5)$$

II. Expected number of failed machines waiting in the queue:

$$L_q = E[X] - \frac{\lambda}{\mu}. \quad (6)$$

III. Mean waiting time in the system (Little's Law):

$$W = \frac{E[X]}{\lambda(M - E[X])}. \quad (7)$$

IV. Mean waiting time in the queue:

$$W_q = W - \frac{1}{\mu}. \quad (8)$$

V. Expected number of machines under repair:

$$L_S = \sum_{n=0}^{M} \min(n, R)\, P_n. \quad (9)$$

VI. Average server utilisation:

$$U = \frac{L_S}{R}. \quad (10)$$

These performance measures provide valuable insights into the functioning of machining systems by quantifying expected downtime, congestion, and resource utilization. They enable decision-makers to design repair policies that minimize machine interference while balancing service costs against waiting costs.

## 1.4 | Numerical Illustration (Finite-Source Machine Repair Model)

$M = 5$ identical machines, $R = 2$ repair crews, exponential times to failure with a rate $\lambda = 0.1$ per unit time, and an exponential repair time with a rate $\mu = 0.5$ per unit time (per repair crew).

**State-dependent rates**

For $n = 0, \ldots, M$ failed machines,

$$\lambda_n = (M - n)\lambda, \qquad \mu_n = \min(n, R)\, \mu.$$

**Steady-state probabilities**

With $P_n$ the stationary probability of $n$ failed machines,

$$P_n = P_0 \prod_{i=1}^{n} \frac{(M - i + 1)\lambda}{\min(i, R)\mu}, \quad n = 1,2,3, \ldots, M \text{ and } \sum_{n=0}^{M} P_n = 1.$$

Plugging in $M = 5$, $R = 2$, $\lambda = 0.1$, $\mu = 0.5$ gives:

$P_0 = 0.3927112787.$

$P_1 = 0.3927112787.$

$P_2 = 0.1570845115.$

$P_3 = 0.04712535344.$

$P_4 = 0.009425070688.$

$P_5 = 0.000942507069.$

(Round to $10^{-10}$), which sum to ~ 1.

**Key performance measures**

Mean number of failed machines in the system

$$E[X] = \sum_{n=0}^{M} nP_n = 0.89066918.$$

Expected number under repair

$$L_S = \sum_{n=0}^{M} \min(n, R)P_n = 0.82186616.$$

Expected number waiting (in queue)

$$L_q = E[X] - L_S = 0.06880302.$$

Effective arrival/throughput rate (failures that actually join the system = repairs completed in steady state)

$$\lambda_{eff} = \sum_{n=0}^{M} \lambda_n P_n = \lambda \sum_{n=0}^{M} (M - n)P_n = 0.410933082.$$

(Checks with repair side: $\sum_n \mu_n P_n = 0.410933082$).

The mean time a failed machine spends in the system ($\text{Little's Law}, E[X] = \lambda_{eff} W$)

$$W = \frac{E[X]}{\lambda_{eff}} = 2.16743119.$$

$\left(\text{Consistent with } W = W_q + 1/\mu, \text{since } 1/\mu = 2\right).$

**Average repairman utilization**

$$U = \frac{L_S}{R} = 0.410933082 \text{ (about 41.1\% per repair crew)}.$$

**System availability (fraction of machines up)**

$$A = 1 - \frac{E[X]}{M} = 0.82186616 \ (\approx 82.19\%).$$

To demonstrate the applicability of the machine repair model, a numerical illustration with $M = 5$ machines, $R = 2$ repair crews, failure rate $\lambda = 0.1$, and repair rate $\mu = 0.5$ is presented. The corresponding state-dependent rates and steady-state probabilities are summarized in *Table 1*, indicating that the system is most likely to operate with zero or one failed machine at any given time. *Fig. 2* illustrates the steady-state distribution, highlighting that the probability of encountering three or more simultaneous failures is negligible. *Fig. 3* depicts the variation in state-dependent failure and repair rates, showing that the repair rate increases with the number of failed machines until the repair capacity is reached. In contrast, the failure rate decreases as fewer machines remain operational. *Fig. 4* presents the steady-state probabilities of the different failure states as a bar chart, providing a more precise visual comparison of their likelihoods. As summarized in *Table 2*, the mean number of failed machines in the system is less than one $(E[X] \approx 0.89)$, while the system's average availability is approximately 82%. The average waiting time in the queue is relatively low $(\approx 0.17)$, indicating minimal congestion. Together, these results emphasize the system's reliability and stability under the given parameter values.

**Table 1. State-dependent rates and steady-state probabilities.**

| n (Failed Machines) | $\lambda_n = (M - n)\lambda$ | $\mu_n = Min(n, R)\mu$ | $P_n$(Steady – State Probability) |
|---|---|---|---|
| 0 | 0.5 | 0.0 | 0.392711279 |
| 1 | 0.4 | 0.5 | 0.392711279 |
| 2 | 0.3 | 1.0 | 0.157084512 |
| 3 | 0.2 | 1.0 | 0.047125353 |
| 4 | 0.1 | 1.0 | 0.009425071 |
| 5 | 0.0 | 1.0 | 0.000942507 |

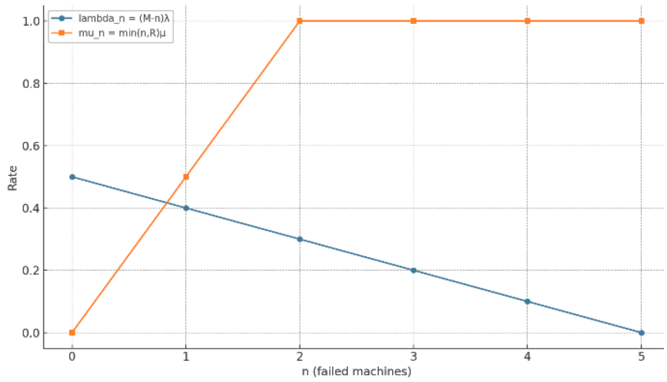


**Fig. 2. Steady-state distribution of failed machines.**

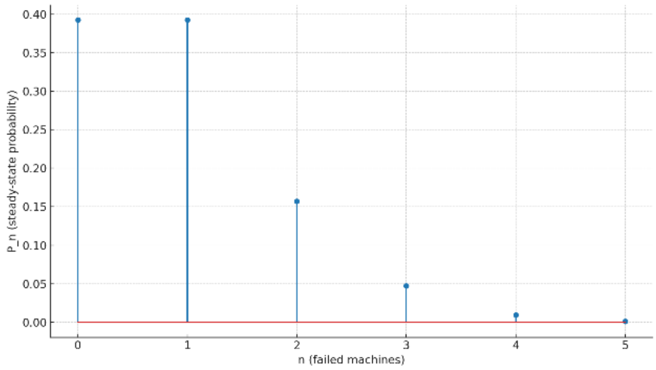


**Fig. 3. State-dependent failure and repair rates.**

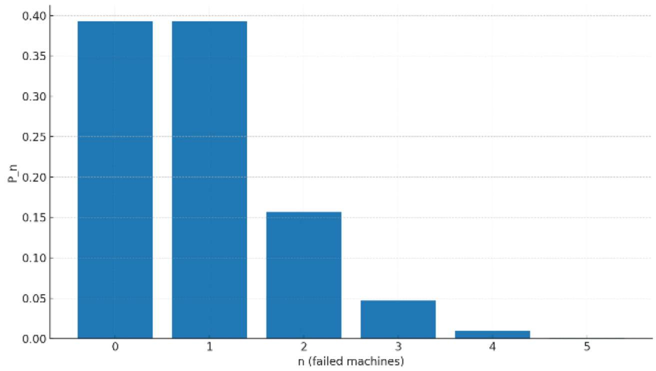


**Fig. 4. Steady-state probabilities.**

**Table 2. Key performance measures of the machine repair model.**

| Performance Measure | Expression | Value (approx.) | Interpretation |
|---|---|---|---|
| Mean number of failed machines $(E[X])$ | $\sum_{n=0}^{M} nP_n$ | 0.891 | On average, fewer than one machine is down. |
| Expected number under repair $L_S$ | $\sum_{n=0}^{M} \min(n, R)P_n$ | 0.822 | About 0.82 machines are being repaired at any time. |
| Expected number waiting $L_q$ | $E[X] - L_S$ | 0.069 | Very few machines wait for repair. |
| Effective arrival/throughput rate $(\lambda_{eff})$ | $\sum_{n=0}^{M} \lambda_n P_n$ | 0.411 | The average rate at which breakdowns occur and are repaired. |
| Mean time in system $(W)$ | $\frac{E[X]}{\lambda_{eff}}$ | 2.167 | A failed machine spends ~2.17 time units in the system. |
| Mean waiting time $(W_q)$ | $\frac{L_q}{\lambda_{eff}}$ | 0.167 | Average wait before repair is minimal. |
| Average server utilization $(U)$ | $\frac{L_S}{R}$ | 0.411 | Each repairer is ~41% busy. |
| System availability $(A)$ | $\frac{1-E[X]}{M}$ | 0.822 | The system operates with ~82% availability. |

# 2 | Literature Review

Failures significantly affect the performance of machining systems within their subsystems. Failures may be mitigated either by providing spare subsystems or by improving repair facilities so that overall performance is not compromised. The reliability and maintainability of redundant systems are central to engineering design and critical to life-cycle costing, cost-benefit analysis, operational capability studies, facility resourcing, spare parts inventory, replacement decisions, and preventive maintenance planning. Early studies on machine maintenance and interference can be traced back to Khintchine [49], Lotka [50], and Palm [51]. A comprehensive review of the MIP was later provided by Stecke and Aronson [47], which laid the foundation for subsequent studies. In the domain of scheduling and setup times, Allahverdi et al. [44] conducted the first extensive survey on scheduling problems with separate setup times or costs, followed by Govil and Fu [42], who surveyed the applications of queueing theory in discrete part manufacturing and classified contributions into descriptive and generative categories. Later, Haque and Armstrong [33] reviewed research on the MIP, organising findings along several dimensions, while Allahverdi et al. [45] further extended the scheduling literature by classifying models with setup times and costs into multiple categories. More recently, Ma et al. [46] provided a brief survey of complexity results, exact algorithms, and approximation algorithms across diverse scheduling environments, including single-machine, parallel-machine, flow-shop, open-shop, and job-shop settings.

In parallel, high reliability and availability requirements in technological systems led to extensive studies of redundancy, particularly the well-known k-out-of-n: G systems. These systems have been widely adopted in industrial design, motivating research into their reliability under different assumptions [52]-[54]. Analytical approaches to redundancy have been proposed by Gupta and Sharma [55], Shooman [30], Birolini [27], and Azaron et al. [56], with methods ranging from recursive techniques to numerical approximations. Yuan [57] applied discrete transforms and Runge–Kutta methods for theoretical and numerical analysis of MRPs with identical machines and multiple repairers, while Ke et al. [58] modelled the multi-repairman problem as a finite-state Markov chain.

A substantial body of literature has also investigated MRPs with spare provisioning and reliability analysis [59]-[62]. For queueing and reliability modelling of repairable redundant systems, diverse analytical and numerical methods have been employed, including recursive techniques, product-type solutions, supplementary variable approaches, Newton–Quasi methods, diffusion approximations, and fuzzy or evolutionary algorithms. Beyond redundancy, researchers have explored failures in more realistic contexts, such as switching failures, reboot delays, multi-mode failures, and common-cause failures. Wang and Chen

[63] examined switching and reboot delays, while Jyh-Bin et al. [64] developed reliability measures for repairable systems with standby switching failures. Jain et al. [65] investigated steady-state availability and queueing indices under common-cause and switching failures, whereas Jain et al. [66] evaluated steady-state queue distributions for an $(m, M)$ machine repair model with warm spares and heterogeneous repairers, incorporating both switching failures and server vacations. Shekhar et al. [67] extended these models further by including fuzzified exponential distributions for time-to-failure and repair, thereby enriching the machine repair literature with stochastic and fuzzy perspectives.

Another important dimension of research involves optimal repair and control policies. Threshold-based and state-dependent policies have been studied to balance repair costs and waiting costs. Jain et al. [68] analysed an unreliable $M / M / K$ system under an $(N, F)$ policy with multi-phase repair facilities. Kumar and Jain [69] determined the optimal number of standby units using the successive over-relaxation method, minimising cost under an $N$-policy for multi-component machining systems. Jain et al. [70] further studied MRPs with unreliable servers, where failed machines arrived according to an $F$-policy.

In recent years, Shekhar, Jain, Raina, and collaborators have made significant contributions by extending classical machine interference models with more realistic operational constraints and performance policies. Shekhar et al. [71] introduced a threshold-based control policy for unreliable workstations, demonstrating how these rules mitigate congestion and improve maintainability. Shekhar et al. [72] studied fault-tolerant machining systems with reboot and recovery delays, demonstrating how even minor delays significantly affect reliability and availability. In related work, Shekhar et al. [73] conducted a transient analysis of systems with spare provisioning and geometric reneging, capturing the short-term effects of spares and abandonment. Shekhar et al. [74] proposed an optimal $(N, F)$ policy for queue-dependent, time-sharing redundant systems, demonstrating that dual-trigger mechanisms outperform single-threshold strategies in reducing interference. Finally, Shekhar et al. [75] performed sensitivity analysis of redundant systems with switching failures and reneging, showing that switch reliability and reneging behavior are critical performance determinants, often outweighing gains from additional redundancy. Collectively, these works bridge theoretical modelling with the practical complexities of modern manufacturing environments.

Beyond journal articles, several textbooks provide foundational insights into the reliability and maintainability of machining systems. Classic works by Tillman et al. [25], Kothandapani and Chandrasekar [76], Sethi et al. [19], O'Connor [26], and Telang and Telang [77] cover fundamental principles, mathematical modelling, and applications across domains such as manufacturing, telecommunications, and computer networks. These texts complement research papers by offering structured introductions to modelling methodologies, data-driven approaches, and inference techniques, thereby serving as essential references for both academicians and practitioners.

# 3 | Classical Queueing Models in a Machining System

Queueing models provide a powerful tool for designing and evaluating the performance of machining systems. In *Table 3*, we have summarised some critical and classical queueing models used to investigate queues in machining systems, using standard Kendall notation, including Markovian, non-Markovian, Erlangian, bulk, and general queues.

**Table 3. Literature on machining systems using different models.**

| Models | Authors |
|---|---|
| $M / M / 1$ | Ayyappan et al. [78], Jain et al. [79], Ammar et al. [80], Sharma and Kumar [81] , Kim and Kim [82], Vijayashree and Pavithra [83] |
| $M / G / 1$ | Dimitriou and Langaris [84], Ramanath and Kalidass [85], Thangaraj and Vanitha [86], [87], Wang et al. [88], Gao and Liu [89], Gao et al. [90], Lee and Kim [91], Chaudhry et al. [92] |
| $M^{[X]} / G / 1$ | Wang and Li [93], Choudhury and Deka [94], Gao and Yao [95], Rajadurai et al. [96], Singh et al. [97] |

**Table 3. Continued.**

| Models | Authors |
|---|---|
| $M / M / c$ | Gomez-Corral and Garcia [98] |
| $M / E_K / 1$ | Yu et al. [99] |
| $M / PH / 1$ | Kim and Kim [100] |
| $M / G / 1 / K$ | Kuo et al. [101] |
| $M^X / H_2 / 1$ | Sharma [102] |
| $MAP / PH / 1$ | Goswami and Selvaraju [103] |
| $M^X / (G_1, G_2) / 1$ | Mary et al. [104], Arivudainambi and Godhandaraman [105] |
| $M(t) / M / c / c$ | Tirdad et al. [106] |
| $PH / PH / 1 / K$ | Hanbali [107] |
| $G / M / 1$ | Mohit et al. [108] |
| $Geo / Geo / 1$ | Lin et al. [109], Gao and Wang [110] |
| $Geo_1, Geo_2^X / G_1, G_2 / 1$ | Liu and Gao [111] |
| $Geo^X / G / 1 / N$ | Luo et al. [112] |
| $Geo^X / G / 1$ | Gao and Wang [113], Gao and Yin [114] |
| $GI / D - MSP / 1$ | Samanta and Zhang [115] |
| $GI / Geo / 1$ | Tao et al. [116] |
| $GI^X / Geo / 1 / N$ | Gao et al. [90], [117] |
| $GI^X / Geo / 1 / N - G$ | Gao and Wang [118] |
| K-out-of-N : G | Ruiz-Castro and Li [119], Jain and Gupta [120], Yuan [57], Kumar and Bajaj [121], [122], Grover [123] |
| $D - BMAP / PH / 1 / N$ | Lenin et al., [124] |

# 4 | Comparative Summary of Models

**Table 4. Summary of variants of the machine interference problem.**

| Model Type | Queueing Notation | Key Assumptions | Applications |
|---|---|---|---|
| Classical MRP | M/M/1//N | Exponential failure & repair | Manufacturing shops |
| Multi-repairman | M/M/c//N | c identical repairmen | Service centers |
| General service | M/G/1//N | General repair distribution | Reliability analysis |
| Heterogeneous machines | GI/M/1//N | Different failure rates | IT systems |
| Priority repair | M/M/1//N with priorities | Repair priority rules | Healthcare & defense |
| Preventive maintenance | Semi-Markov models | Scheduled interventions | Smart factories |

# 5 | Key Research Themes

I. Finite-source queueing theory – rigorous stochastic analysis

II. Reliability and availability – preventive maintenance, redundancy

III. Optimization and control – repair policies, priority queues

IV. Computational approaches – simulation, matrix-analytic methods, RL

V. Applications – cross-domain implementations

# 6 | Future Research Directions

I. AI/ML-driven predictive maintenance

II. Non-stationary demand environments

III. Multi-objective optimization (cost vs. availability)

IV. Integration with IoT & cyber-physical systems

# 7 | Conclusion

In this survey article, we have reviewed the literature on the MIP, drawing on both classical foundations and contemporary research. The MIP, also known as the machine repair model, has wide-ranging applications in the analysis and modelling of manufacturing and industrial systems where machines are subject to random failures and repairs. The main objective of this work has been to present a unified perspective for analysing MIPs through a queue-theoretic framework, while highlighting how different extensions-such as redundancy, spare provisioning, switching failures, reboot delays, and optimal control policies-enrich the classical model and make it more suitable for modern industrial applications.

It is expected that this survey will serve as a valuable reference for learners and researchers pursuing further studies in queueing models, with a specialised focus on MIPs. Looking ahead, this survey can be extended by exploring more complex configurations, such as heterogeneous repair facilities, advanced maintenance and threshold policies, stochastic optimisation techniques, and computational approaches including simulation, fuzzy modelling, and artificial intelligence. Such advancements will not only strengthen the theoretical depth of machine interference models but also broaden their applicability to emerging domains such as smart manufacturing, cyber-physical systems, and industrial automation.

# References

[1] Bhat, U. N. (2008). *An introduction to queueing theory: Modeling and analysis in applications*. Springer Nature. https://doi.org/10.1007/978-0-8176-4725-4

[2] Cooper, R. B. (1972). Introduction to queueing theory. *Elsevier north holland*. https://www.abebooks.com/9780023246807

[3] Gross, D., Shortle, J. F., Thompson, J. M., & Harris, C. M. (2011). *Fundamentals of queueing theory* (Vol. 627). John wiley & sons. https://books.google.com/books/about/Fundamentals_of_Queueing_Theory.html?id=K3lQGeCtAJgC

[4] Thomas, M. U. (1976). *Queueing systems*. volume 1: Theory (leonard kleinrock). SIAM Review. https://doi.org/10.1137/1018095

[5] Newell, C. (1971). *Applications of queueing theory* (Vol. 4). Springer Science & Business Media. https://doi.org/10.1007/978-94-009-5970-5

[6] Saaty, T. L. (1961). *Elements of queueing theory: With applications* (Vol. 34203). New York: McGraw-Hill. https://books.google.com/books/about/Elements_of_Queueing_Theory.html?id=MN5QAAAAMAAJ

[7] Raina, A. A. (2017). *Reliability and maintainability analysis of redundant repairable systems* [Thesis]. https://www.researchgate.net/publication/355443718

[8] Takács, L. (1962). *Introduction to the theory of queues.* Greenwood Press. https://lccn.loc.gov/82000973

[9] Wolff, R. W. (1989). *Stochastic modeling and the theory of queues.* Prentice-hall. https://cir.nii.ac.jp/crid/1371413280526420226

[10] Cox, D. R., & Miller, H. D. (1965). *The theory of stochastic process*. Chapman & Hall, London. https://doi.org/10.1201/9780203719152

[11] Dobrow, R. P. (2016). *Introduction to stochastic processes with R*. John Wiley & Sons. https://dl.nemoudar.com/Introduction-to-Stochastic-Processes-with-R.pdf

[12] Heyman, D. P., & Sobel, M. J. (1984). *Stochastic models in operations research*. McGraw-Hill. https://2024.sci-hub.box/3322/365e97fe3d4aa434604973c7ed3fb867/arthur1983.pdf

[13] Jones, P. W., & Smith, P. (2017). *Stochastic processes: An introduction*. Chapman and Hall CRC. https://doi.org/10.1201/9781315156576

[14] Karlin, S. (2014). *A first course in stochastic processes*. Academic Press. https://webdelprofesor.ula.ve

[15] Medhi, J. (1994). *Stochastic processes*. New Age International. https://books.google.com/books/about/Stochastic_Processes.html?id=DnCWgeoalKQC

[16] Medhi, J. (2002). *Stochastic models in queueing theory*. Elsevier. https://shop.elsevier.com/books/stochastic-models-in-queueing-theory/medhi/978-0-12-487462-6

[17] Nelson, R. (2013). *Probability, stochastic processes, and queueing theory:The mathematics of computer performance modeling*. Springer Science & Business Media. https://B2n.ir/td9887

[18] Ross, S. M. (2013). *Applied probability models with optimization applications*. Courier Corporation. https://books.google.com/books/about/Applied_Probability_Models_with_Optimiza.html?id=HftunnI-1zwC

[19] Sethi, S. P., Zhang, H., & Zhang, Q. (2005). *Average—cost control of stochastic manufacturing systems*. New York, NY: Springer New York. https://doi.org/10.1007/0-387-27615-7_3

[20] Ash, R. B. (2008). *Basic probability theory*. Courier Corporation. https://www.amazon.com/Basic-Probability-Theory-Dover-Mathematics/dp/0486466280

[21] Clarke, A. B., & Disney, R. L. (1970). *Probability and random processes for engineers and scientists.* Wiley. https://lccn.loc.gov/76104008

[22] Drake, A. W. (1967). *Fundamentals of applied probability theory*. Mcgraw-Hill College. https://www.noisebridge.net/images/a/ae/Fundamentals_of_Applied_Probability_by_Drake.pdf

[23] Feller, W. (1991). *An introduction to probability theory and its applications* (Vol. 2). John Wiley & Sons. https://B2n.ir/uq1675

[24] Parzen, E. (1960). *Modern probability theory and its applications* (Vol. 10). Wiley. https://www.wiley.com/en-us/Modern+Probability+Theory+and+Its+Applications+-p-9780471572787

[25] Tillman, F. A., Hwang, C. L., & Kuo, W. (1980). *Optimization of systems reliability*. Marcel Dekker Inc. https://doi.org/10.1016/0143-8174(82)90024-5

[26] O'Connor, P. D. T. (2005). *Practical reliability engineering, 4th Ed*. Wiley India Pvt. Limited, 2008. https://books.google.com/books/about/Practical_Reliability_Engineering_4th_Ed

[27] Birolini, A. (1997). *Quality and reliability of technical systems*. Springer Berlin, Heidelberg. https://doi.org/10.1007/978-3-642-97983-5

[28] Ebeling, C. (1996). *An introduction to reliability and maintainability engineering*. McGraw-Hill Education. https://books.google.com/books/about/An_Introduction_to_Reliability_and_Maint

[29] Bhat, U. N., & Miller, G. K. (1972). *Elements of applied stochastic processes third edition*. A John Wiley & Sons, Inc., Publication. https://doi.org/10.2307/30045359

[30] Shooman, M. L. (1968). *Probabilistic reliability: an engineering approach*. McGraw-Hill. https://books.google.com/books/about/Probabilistic_Reliability.html?id=D29RAAAAMAAJ

[31] Aissani, A. (1994). A retrial queue with redundancy and unreliable server. *Queueing systems*, *17*(3), 431–449. https://doi.org/10.1007/BF01158703

[32] Gani, A. N., & Sabarinathan, G. (2013). Fuzzy approach on optimal ordering strategy in inventory and pricing model with deteriorating items. *International journal of pure and applied mathematics*, *87*(1), 165–180. http://dx.doi.org/10.12732/ijpam.v87i1.10

[33] Haque, L., & Armstrong, M. J. (2007). A survey of the machine interference problem. *European journal of operational research*, *179*(2), 469–482. https://doi.org/10.1016/j.ejor.2006.02.036

[34] Jain, M., & Gupta, R. (2011). Redundancy issues in software and hardware systems: An overview. *International journal of reliability, quality and safety engineering*, *18*(1), 61–98. https://doi.org/10.1142/S0218539311004093

[35] Jain, M., Sharma, G. C., & Pundhir, R. S. (2010). Some perspectives of machine repair problems. *International journal of engineering*, *23*(3–4), 253–268. https://www.sid.ir/paper/570644/en

[36] Krishnamoorthy, A., Pramod, P. K., & Chakravarthy, S. R. (2014). Queues with interruptions: A survey. *Top*, *22*(1), 290–320. https://doi.org/10.1007/s11750-012-0256-6

[37] Shekhar, C., Raina, A.A., Kumar, A. & Iqbal, J. (2016). A brief review on retrial queue: Progress in 2010-2015. *International journal of applied sciences and engineering research*, *5*(4), 324-336. https://doi.org/10.2298/Y.TOR161117006R

[38] Sztrik, J., & Bunday, B. D. (1993). Machine interference problem with a random environment. *European journal of operational research*, *65*(2), 259–269. https://doi.org/10.1016/0377-2217(93)90338-N

[39] Teghem, J. (1986). Control of the service process in a queueing system. *European journal of operational research*, *23*(2), 141–158. https://doi.org/10.1016/0377-2217(86)90234-1

[40] Shekhar, C., Raina, A. A., Kumar, A., & Iqbal, J. (2017). A survey on queues in machining system: Progress from 2010 to 2017. *Yugoslav journal of operations research*, *27*(4), 391–413. https://doi.org/10.2298/YJOR161117006R

[41] Sharma, R. (2014). Mathematical analysis of queue with phase service: An overview. *Advances in operations research*, *2014*(1), 240926. https://doi.org/10.1155/2014/240926

[42] Govil, M. K., & Fu, M. C. (1999). Queueing theory in manufacturing: A survey. *Journal of manufacturing systems*, *18*(3), 214–240. https://doi.org/10.1016/S0278-6125(99)80033-8

[43] Sharma, A. K., & Sharma, G. K. (2013). Queueing theory appr oach with queueing model: A study. *International journal of engineering science invention*, *2*(2), 1–11. https://www.idc-online.com/technical_references/pdfs/data_communications/QUEUEING THEORY.pdf

[44] Allahverdi, A., Gupta, J. N. D., & Aldowaisan, T. (1999). A review of scheduling research involving setup considerations. *Omega*, *27*(2), 219–239. https://doi.org/10.1016/S0305-0483(98)00042-5

[45] Allahverdi, A., Ng, C. T., Cheng, T. C. E., & Kovalyov, M. Y. (2008). A survey of scheduling problems with setup times or costs. *European journal of operational research*, *187*(3), 985–1032. https://doi.org/10.1016/j.ejor.2006.06.060

[46] Ma, Y., Chu, C., & Zuo, C. (2010). A survey of scheduling with deterministic machine availability constraints. *Computers & industrial engineering*, *58*(2), 199–211. https://doi.org/10.1016/j.cie.2009.04.014

[47] Stecke, K. E., & Aronson, J. E. (1985). Review of operator machine interference models. *International journal of production research*, *23*(1), 129–151. https://doi.org/10.1080/00207548508904696

[48] Chandrasekaran, V. M., Indhira, K., Saravanarajan, M. C., & Rajadurai, P. (2016). A survey on working vacation queueing models. *International journal of pure and applied mathematics*, *106*(6), 33–41. https://doi.org/10.12732/ijpam.v106i6.5

[49] Khintchine, A. Y. (1932). Mathematical theory of stationary queues. *Matem. sbornik*, *39*, 73–84. https://www.mathnet.ru/rus/sm/v39/i3/p27

[50] Lotka, A. J. (1939). A contribution to the theory of self-renewing aggregates, with special reference to industrial replacement. *The annals of mathematical statistics*, *10*(1), 1–25. https://www.jstor.org/stable/2235984

[51] Palm, C. (1947). The distribution of repairmen in servicing automatic machines. *Industritidningen Norden*, *75*, 75-80.

[52] Linton, D. G., & Saw, J. G. (2009). Reliability analysis of the k-out-of-n: F system. *IEEE transactions on reliability*, *23*(2), 97–103. https://doi.org/10.1109/TR.1974.5215215

[53] Nakagawa, T. (2009). Optimization problems in k-out-of-n systems. *IEEE transactions on reliability*, *34*(3), 248–250. https://doi.org/10.1109/TR.1985.5222134

[54] Moustafa, M. S. (1996). Transient analysis of reliability with and without repair for K-out-of-N: G systems with two failure modes. *Reliability engineering & system safety*, *53*(1), 31–35. https://doi.org/10.1016/0951-8320(96)00014-2

[55] Gupta, H., & Sharma, J. (2009). State transition matrix and transition diagram of k-out-of-n-: G system with spares. *IEEE transactions on reliability*, *30*(4), 395–397. https://doi.org/10.1109/TR.1981.5221136

[56] Azaron, A., Katagiri, H., Kato, K., & Sakawa, M. (2006). Reliability evaluation of multi-component cold-standby redundant systems. *Applied mathematics and computation*, *173*(1), 137–149. https://doi.org/10.1016/j.amc.2005.02.051

[57] Yuan, L. (2012). Reliability analysis for a k-out-of-n: G system with redundant dependency and repairmen having multiple vacations. *Applied mathematics and computation*, *218*(24), 11959–11969. https://doi.org/10.1016/j.amc.2012.06.006

[58] Ke, J. C., Hsu, Y. L., Liu, T. H., & Zhang, Z. G. (2013). Computational analysis of machine repair problem with unreliable multi-repairmen. *Computers & operations research*, *40*(3), 848–855. https://doi.org/10.1016/j.cor.2012.10.004

[59] Sivazlian, B. D., & Wang, K. H. (1989). Economic analysis of the M/M/R machine repair problem with warm standbys. *Microelectronics reliability*, *29*(1), 25–35. https://doi.org/10.1016/0026-2714(89)90007-3

[60] Hsieh, Y. C., & Wang, K. H. (1995). Reliability of a repairable system with spares and a removable repairman. *Microelectronics reliability*, *35*(2), 197–208. https://doi.org/10.1016/0026-2714(95)90086-6

[61] Wang, K. H., & Chiu, L. W. (2006). Cost benefit analysis of availability systems with warm standby units and imperfect coverage. *Applied mathematics and computation*, *172*(2), 1239–1256. https://doi.org/10.1016/j.amc.2005.02.052

[62] Ke, J. B., Lee, W. C., & Wang, K. H. (2007). Reliability and sensitivity analysis of a system with multiple unreliable service stations and standby switching failures. *Physica a: Statistical mechanics and its applications*, *380*, 455–469. https://doi.org/10.1016/j.physa.2007.02.095

[63] Wang, K. H., & Chen, Y. J. (2009). Comparative analysis of availability between three systems with general repair times, reboot delay and switching failures. *Applied mathematics and computation*, *215*(1), 384–394. https://doi.org/10.1016/j.amc.2009.05.023

[64] Jyh-Bin, K., Jyh-Wei, C., & Kuo-Hsiung, W. (2011). Reliability measures of a repairable system with standby switching failures and reboot delay. *Quality technology & quantitative management*, *8*(1), 15–26. https://doi.org/10.1080/16843703.2011.11673243

[65] Jain, M., Shekhar, C., & Shukla, S. (2013). Queueing analysis of two unreliable servers machining system with switching and common cause failure. *International journal of mathematics in operational research*, *5*(4), 508–536. https://doi.org/10.1504/IJMOR.2013.054732

[66] Jain, M., Shekhar, C., & Shukla, S. (2014). Markov model for switching failure of warm spares in machine repair system. *Journal of reliability and statistical studies*, *7*, 57–68. https://journals.riverpublishers.com/index.php/JRSS/article/view/21629

[67] Shekhar, C., Jain, M., & Bhatia, S. (2014). Fuzzy analysis of machine repair problem with switching failure and reboot. *Journal of reliability and statistical studies*, *7*(Special Issue), 41–55. https://journals.riverpublishers.com/index.php/JRSS/article/view/21627

[68] Jain, M., Sharma, G. C., & Sharma, R. (2012). Optimal control of (N, F) policy for unreliable server queue with multi-optional phase repair and start-up. *International journal of mathematics in operational research*, *4*(2), 152–174. https://doi.org/10.1504/IJMOR.2012.046375

[69] Kumar, K., & Jain, M. (2013). Threshold N-policy for (M, m) degraded machining system with K-heterogeneous servers, standby switching failure and multiple vacations. *International journal of mathematics in operational research*, *5*(4), 423–445. https://doi.org/10.1504/IJMOR.2013.054719

[70] Jain, M., Shekhar, C., & Shukla, S. (2014). Machine repair problem with an unreliable server and controlled arrival of failed machines. *Opsearch*, *51*(3), 416–433. https://doi.org/10.1007/s12597-013-0152-3

[71] Shekhar, C., Jain, M., Iqbal, J., & Raina, A. A. (2017). Threshold control policy for maintainability of manufacturing system with unreliable workstations. *Arabian journal for science and engineering*, *42*(11), 4833–4851. https://doi.org/10.1007/s13369-017-2636-6

[72] Shekhar, C., Jain, M., Raina, A. A., & Iqbal, J. (2018). Reliability prediction of fault tolerant machining system with reboot and recovery delay. *International journal of system assurance engineering and management*, *9*(2), 377–400. https://doi.org/10.1007/s13198-017-0680-y%0A%0A

[73] Shekhar, C., Jain, M., & Raina, A. A. (2017). Transient analysis of machining system with spare provisioning and geometric reneging. *International journal of mathematics in operational research*, *11*(3), 396–421. https://doi.org/10.1504/IJMOR.2017.087215

[74] Shekhar, C., Jain, M., Raina, A. A., & Iqbal, J. (2017). Optimal (N, F) policy for queue-dependent and time-sharing machining redundant system. *International journal of quality & reliability management*, *34*(6), 798–816. https://doi.org/10.1108/IJQRM-07-2016-0105

[75] Shekhar, C., Jain, M., Raina, A. A., & Mishra, R. P. (2017). Sensitivity analysis of repairable redundant system with switching failure and geometric reneging. *Decision science letters*, *6*(4), 337–350. https://doi.org/10.5267/j.dsl.2017.2.004

[76] Kothandapani, M., & Chandrasekar, N. (2024). Intuitionistic fuzzy threshold hypergraphs. *Italian journal of pure and applied mathematics*, (52), 67–85. https://ijpam.uniud.it/online_issue/202452/08 Kothandapani-Chandrasekar.pdf

[77] Telang, A. D., & Telang, A. (2010). *Comprehensive maintenance management: Policies, strategies and options*. PHI Learning Pvt. Ltd. https://B2n.ir/gp3612

[78] Ayyappan, G., Sekar, G., & Subramanian, A. M. G. (2010). M/M/1 retrial queueing system with two types of vacation policies under Erlang-K type service. *International journal of computer applications*, *2*(8), 9–18. https://doi.org/10.5120/688-967

[79] Jain, M., Sharma, G. C., & Sharma, R. (2012). Maximum entropy approach for un-reliable server vacation queueing model with optional bulk service. *Journal of king abdulaziz university, marine science* *23*(2), 89–113. www.researchgate.net/publication/267537383

[80] Ammar, S. I., Helan, M. M., & Al Amri, F. T. (2013). The busy period of an M/M/1 queue with balking and reneging. *Applied mathematical modelling*, *37*(22), 9223–9229. https://doi.org/10.1016/j.apm.2013.04.023

[81] Sharma, R., & Kumar, G. (2014). Unreliable server $M/M/1$ queue with priority queueing system. *International journal of engineering and technical research*, (Special Issue), 368–371. chrome-extension://efaidnbmnnnibpcajpcglclefindmkaj/https://www.erpublication.org/published_paper/IJETR_APRIL_2014_STET_101.pdf

[82] Kim, B., & Kim, J. (2015). A single server queue with Markov modulated service rates and impatient customers. *Performance evaluation*, *83*, 1–15. https://doi.org/10.1016/j.peva.2014.11.002

[83] Vijayashree, K. V, & Pavithra, P. (2025). Performance analysis and cost optimization of an M/M/1 queue with N-policy and working breakdown. *Methodology and computing in applied probability*, *27*(3), 1–26. https://doi.org/10.1007/s11009-025-10196-0%0A%0A

[84] Dimitriou, I., & Langaris, C. (2010). A repairable queueing model with two-phase service, start-up times and retrial customers. *Computers & operations research*, *37*(7), 1181–1190. https://doi.org/10.1016/j.cor.2009.03.003

[85] Ramanath, K., & Kalidass, K. (2010). A two phase service M/G/1 vacation queue with general retrial times and non-persistent customers. *International journal of open problems in computer science and mathematics*, *3*(2), 175–185. https://www.ijopcm.org/Vol/10/IJOPCM(vol.3.2.6.J.10).pdf

[86] Thangaraj, V., & Vanitha, S. (2010). A single server M/G/1 feedback queue with two types of service having general distribution. *International mathematical forum*, *5*(1), 15-33. https://www.researchgate.net/publication/228464381

[87] Thangaraj, V., & Vanitha, S. (2010). M/G/1 queue with two-stage heterogeneous service compulsory server vacation and random breakdowns. *International journal of contemporary mathematical sciences. 5*(7), 307–322. https://m-hikari.com/ijcms-2010/5-8-2010/vanithaIJCMS5-8-2010.pdf

[88] Wang, K. H., Yang, D. Y., & Pearn, W. L. (2010). Comparison of two randomized policy $M/G/1$ queues with second optional service, server breakdown and startup. *Journal of computational and applied mathematics*, *234*(3), 812–824. https://doi.org/10.1016/j.cam.2010.01.045

[89] Gao, S., & Liu, Z. (2013). An M/G/1 queue with single working vacation and vacation interruption under Bernoulli schedule. *Applied mathematical modelling*, *37*(3), 1564–1579. https://doi.org/10.1016/j.apm.2012.04.045

[90] Gao, S., Wang, J., & Li, W. W. (2014). An M/G/1 retrial queue with general retrial times, working vacations and vacation interruption. *Asia-pacific journal of operational research*, *31*(02), 1440006. https://doi.org/10.1142/S0217595914400065

[91] Lee, D. H., & Kim, B. K. (2015). A note on the sojourn time distribution of an M/G/1 queue with a single working vacation and vacation interruption. *Operations research perspectives*, *2*, 57–61. https://doi.org/10.1016/j.orp.2015.01.002

[92] Chaudhry, M., Banik, A. D., Dev, S., & Barik, S. (2025). A simple derivation of the waiting-time distribution (in the queue) for the bulk-service $M/G^{(a,b)}/1$ queueing system. *Annals of operations research*, *352*(1), 1–2 https://doi.org/10.1007/s10479-025-06765-84.

[93] Wang, J., & Li, J. (2010). Analysis of the $M^{[X]}/G/1$ queue with second multi-optional service and unreliable server. *Acta mathematicae applicatae sinica*, 26(3), 353–368. https://doi.org/10.1007/s10255-010-0001-6/metrics

[94] Choudhury, G., & Deka, M. (2012). A single server queueing system with two phases of service subject to server breakdown and Bernoulli vacation. *Applied mathematical modelling*, *36*(12), 6050–6060. https://doi.org/10.1016/j.apm.2012.01.047

[95] Gao, S., & Yao, Y. (2014). An MX/G/1 queue with randomized working vacations and at most J vacations. *International journal of computer mathematics*, *91*(3), 368–383. https://doi.org/10.1080/00207160.2013.790964

[96] Rajadurai, P., Chandrasekaran, V. M., & Saravanarajan, M. C. (2016). Analysis of an M [X]/G/1 unreliable retrial G-queue with orbital search and feedback under Bernoulli vacation schedule. *Opsearch*, *53*(1), 197–223. https://doi.org/10.1007/s12597-015-0226-5

[97] Singh, C. J., Jain, M., & Kumar, B. (2016). MX/G/1 unreliable retrial queue with option of additional service and Bernoulli vacation. *Ain shams engineering journal*, *7*(1), 415–429. https://doi.org/10.1016/j.asej.2015.05.006

[98] Gómez Corral, A., & Garcia, M. L. (2014). Maximum queue lengths during a fixed time interval in the M/M/c retrial queue. *Applied mathematics and computation*, *235*, 124–136. https://doi.org/10.1016/j.amc.2014.02.074

[99] Yu, M., Tang, Y., Fu, Y., & Pan, L. (2011). An $M/E_k/1$ queueing system with no damage service interruptions. *Mathematical and computer modelling*, *54*(5–6), 1262–1272. https://doi.org/10.1016/j.mcm.2011.03.037

[100] Kim, J., & Kim, B. (2013). Waiting time distribution in an M/PH/1 retrial queue. *Performance evaluation*, *70*(4), 286–299. https://doi.org/10.1016/j.peva.2012.12.003

[101] Kuo, C. C., Wang, K. H., & Pearn, W. L. (2011). The interrelationship between N-policy M/G/1/K and F-policy G/M/1/K queues with startup time. *Quality technology & quantitative management*, *8*(3), 237–251. https://doi.org/10.1080/16843703.2011.11673257

[102] Sharma, R. (2010). Threshold N-policy for $M^X/H_2/1$ queueing system with un-reliable server and vacations. *Journal of international academy of physical sciences*, *14*, 1–11. https://www.iaps.org.in/journal/index.php/journaliaps/article/view/289

[103] Goswami, C., & Selvaraju, N. (2010). The discrete-time MAP/PH/1 queue with multiple working vacations. *Applied mathematical modelling*, *34*(4), 931–946. https://doi.org/10.1016/j.apm.2009.07.021

[104] Mary, K. J. R., Begum, M. I. A., & Parveen, M. J. (2011). Bi-level threshold policy of $M^X/(G_1, G_2)/1$ queue with early setup and single vacation. *International journal of operational research*, *10*(4), 469–493. https://doi.org/10.1504/IJOR.2011.039714

[105] Arivudainambi, D., & Godhandaraman, P. (2012). A batch arrival retrial queue with two phases of service, feedback and K optional vacations. *Applied mathematical sciences*, *6*(22), 1071–1087. https://m-hikari.com/ams/ams-2012/ams-21-24-2012/arivudainambiAMS21-24-2012.pdf

[106] Tirdad, A., Grassmann, W. K., & Tavakoli, J. (2016). Optimal policies of M (t)/M/c/c queues with two different levels of servers. *European journal of operational research*, *249*(3), 1124–1130. https://doi.org/10.1016/j.ejor.2015.10.040

[107] Al Hanbali, A. (2011). Busy period analysis of the level dependent PH/PH/1/K queue. *Queueing systems*, *67*(3), 221–249. https://doi.org/10.1007/s11134-011-9213-6

[108] Mohit, S. P., & Raina, A. A. (2016). Numerical solution of G/M/1 queueing model with removable server. *International transactions in mathematical sciences and computers*, *9*(1–2), 51–66. https://www.researchgate.net/profile/Ather-Raina/publication/316134837

[109] Lin, C. H., Ke, J. C., Huang, H. I., & Chang, F. M. (2010). The approximation analysis of the discrete-time Geo/Geo/1 system with additional optional service. *International journal of computer mathematics*, *87*(11), 2574–2587. https://doi.org/10.1080/00207160802691629

[110] Gao, S., & Wang, J. (2016). Equilibrium balking strategies in the observable Geo/Geo/1 queue with delayed multiple vacations. *RAIRO-operations research*, *50*(1), 119–129. https://doi.org/10.1051/ro/2015019

[111] Liu, Z., & Gao, S. (2011). Discrete-time $Geo_1$, $Geo_2^X/G_1$, $G_2/1$ retrial queue with two classes of customers and feedback. *Mathematical and computer modelling*, *53*(5–6), 1208–1220. https://doi.org/10.1016/j.mcm.2010.11.090

[112] Luo, C., Li, W., Yu, K., & Ding, C. (2016). The matrix-form solution for $Geo^X/G/1/N$ working vacation queue and its application to state-dependent cost control. *Computers & operations research*, *67*, 63–74. https://doi.org/10.1016/j.cor.2015.07.015

[113] Gao, S., & Wang, J. (2013). Discrete-time $GI^X/GEO/1/N-G$ retrial queue with general retrial times, working vacations and vacation interruption. *Quality technology & quantitative management*, *10*(4), 495–512. https://doi.org/10.1080/16843703.2013.11673427

[114] Gao, S., & Yin, C. (2013). Discrete-time $Geo^X/G/1$ queue with geometrically working vacations and vacation interruption. *Quality technology & quantitative management*, *10*(4), 423–442. https://doi.org/10.1080/16843703.2013.11673423

[115] Samanta, S. K., & Zhang, Z. G. (2012). Stationary analysis of a discrete-time GI/D-MSP/1 queue with multiple vacations. *Applied mathematical modelling*, *36*(12), 5964–5975. https://doi.org/10.1016/j.apm.2012.01.049

[116] Tao, L., Zhang, L., Xu, X., & Gao, S. (2013). The GI/Geo/1 queue with Bernoulli-schedule-controlled vacation and vacation interruption. *Computers & operations research*, *40*(7), 1680–1692. https://doi.org/10.1016/j.cor.2012.12.019

[117] Gao, S., Wang, J., & Zhang, D. (2013). Discrete-time $GI^X/Geo/1/N$ queue with negative customers and multiple working vacations. *Journal of the Korean statistical society*, *42*(4), 515–528. https://doi.org/10.1016/j.jkss.2013.03.002

[118] Gao, S., & Wang, J. (2015). On a discrete-time $GI^X/GEO/1/NG$ queue with randomized working vacations and at most J vacations. *Journal of industrial and management optimization*, *11*(3), 779–806. http://dx.doi.org/10.3934/jimo.2015.11.779

[119] Ruiz-Castro, J. E., & Li, Q. L. (2011). Algorithm for a general discrete k-out-of-n: G system subject to several types of failure with an indefinite number of repairpersons. *European journal of operational research*, *211*(1), 97–111. https://doi.org/10.1016/j.ejor.2010.10.024

[120] Jain, M., & Gupta, R. (2012). Load sharing M-out of-N: G system with non-identical components subject to common cause failure. *International journal of mathematics in operational research*, *4*(5), 586–605. https://doi.org/10.1504/IJMOR.2012.048932

[121] Kumar, G., & Bajaj, R. K. (2014). Intuitionistic fuzzy reliability of K-out-of-N: G system using statistical confidence interval. *International journal of applied information systems*, *7*(7), 1–7. https://doi.org/10.5120/ijais14-451212

[122] Kumar, T., & Bajaj, R. K. (2014). Reliability analysis of K-out-of-N: G system using triangular intuitionistic fuzzy numbers. http://www.ir.juit.ac.in:8080/jspui/handle/123456789/9099

[123] Grover, R. (2016). Transient analysis of reliability with and without repair for K-out-of-n: G systems with three failure modes. *International research journal of engineering and technology*, *3*(3), 604–608. https://www.irjet.net/archives/V3/i3/IRJET-V3I3132.pdf

[124] Lenin, R. B., Cuyt, A., Yoshigoe, K., & Ramaswamy, S. (2010). Computing packet loss probabilities of D-BMAP/PH/1/N queues with group services. *Performance evaluation*, *67*(3), 160–173. https://doi.org/10.1016/j.peva.2009.10.001