Application of Queueing Theory with Multi Objective Linear Programming in Temples

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Abstract: In temples, how resource allocation and visitor flow are to be managed is crucial in ensuring smooth and rich experiences for the devotees. This paper explores the implementation of the Queueing Theory and Multi Objective Linear Programming framework to optimize temple operation so that waiting times are minimized, staffing is optimized, and visitor satisfaction is guaranteed. Queueing theory can be used for modeling different service areas in a temple, e.g., entrance, darshan queues, prasad counters and rest areas, to determine rates of arrivals and service times for the visitors and points of congestion. From the perspective of the available data a multi-objective optimization model is developed, which includes several performance measures, such as minimization of operational costs; maximization of visitor satisfaction; and betterment of the spiritual ambiance of the temple. In this way, the temple management can ensure an optimal balance in competing demands with respect to resource allocation like staff and space. This method will result in improving the visitor experience by reducing congestion and waiting time and will also make the utilization of resources more efficient on the operations side. The outcomes suggest that using Queueing Theory along with MOLP would give a comprehensive solution to the general complex problem of temple operations, particularly during peak times or in certain festivals. The paper ends by drawing attention to the proposed use of these mathematical models in significantly modifying management practices of temples to be more sustainable but with a positive spiritual experience felt by devotees.

Keywords: Queueing Theory, Multi-Objective Linear Programming (MOLP), Temple Management Service; FIFO; M/M/s; Poisson distribution; Queue; Service time; Utilization factor; Waiting time, optimization.

Introduction: Temples, as significant cultural and spiritual centers, often experience large influxes of visitors, especially during festivals, special events, or religious ceremonies. Managing these crowds efficiently is essential to ensure a positive visitor experience while maintaining the sanctity and smooth operation of temple activities. With a growing number of visitors, the challenge lies in minimizing congestion, reducing waiting times, optimizing resource allocation, and ensuring a peaceful, spiritual environment. Traditional methods of managing visitor flow may fall short of addressing the complexity and dynamic nature of crowd behavior in temple settings.

Queueing theory, a mathematical approach to studying waiting lines, offers valuable insights into the dynamics of visitor arrivals, service times, and queue formation. By modeling different service areas in a temple, such as darshan queues, prasad counters, and entry points, queueing theory can predict crowd

behavior, identify bottlenecks, and suggest improvements in the flow of visitors. On the other hand, Multi-Objective Linear Programming (MOLP) allows for the simultaneous optimization of multiple, often competing, objectives. In the context of temple management, MOLP can balance goals such as minimizing waiting times, maximizing resource efficiency, maintaining a peaceful atmosphere, and enhancing visitor satisfaction.

The integration of Queueing Theory with MOLP offers a robust framework for optimizing temple operations. By incorporating both the dynamics of visitor flow and the strategic allocation of resources, temples can effectively manage crowd congestion, enhance visitor experiences, and improve operational efficiency. This paper explores the application of these mathematical models in the context of temples, providing a systematic approach to managing visitor flow, optimizing staffing, and ensuring that temple resources are utilized efficiently. Through this approach, temple management can strike a balance between operational needs and spiritual objectives, ultimately fostering an environment that supports both the physical and spiritual well-being of visitors.

In almost every field in daily life, Queues are observed. If queues can be managed with a proper technique,then time can be saved. The technique to be used is scheduling their visit to the temple.Now a days different applications are developed.A particular application will be developed for visiting Lord Jagganath temple.The ultimate goal is to achieve a time balance between the sources of service and the time associated with the waiting for that service. Queuing theory is the study of waiting in all these various guises. Forming a Queue being a social phenomenon, it is essential to the society if it can be managed so that both the unit that waits and the one which serves get the most benefit.

Review of literature: The application of mathematical modeling, specifically Queueing Theory and Multi-Objective Linear Programming (MOLP), in managing complex systems has been widely studied across various domains, including healthcare, telecommunications, and manufacturing. However, its application in religious and spiritual contexts, particularly in temples, remains relatively unexplored. This literature review highlights the existing research in the fields of queueing theory, optimization techniques, and their integration in managing visitor flow and resources, with a focus on religious and cultural sites.

Queueing Theory in Religious and Public Spaces: Queueing theory has been effectively applied to manage visitor flow and reduce waiting times in various public spaces. In the context of temples, where large crowds gather for religious rituals, queueing models help predict the number of visitors, service rates (such as darshan duration or prasad distribution), and waiting times.

Queueing Models in Religious Environments: A study by Tavakkolizadeh et al. (2011) examined the use of queueing models to optimize crowd management during large religious events in Iran. The research showed that applying queueing theory allowed for better prediction of crowd behavior, reducing bottlenecks and waiting times in temples during peak periods. Similarly, Chien et al. (2013) explored the use of queueing models in theme parks, highlighting the potential for application in temples to handle visitor queues during festivals or special ceremonies.

Modeling Visitor Flow in Temples: In a similar vein, research by **Zhou et al. (2016)** used queueing theory to model the movement of people in large venues, focusing on minimizing delays and optimizing

service systems. Such studies demonstrate the utility of queueing theory in understanding and managing visitor behavior in religious institutions.

Multi-Objective Linear Programming (MOLP) in Complex Systems: MOLP is a powerful optimization technique employed when multiple objectives need to be optimized simultaneously. MOLP has been applied in a variety of sectors, from supply chain management to urban planning, but its use in temple operations remains an emerging field.

Multi-Objective Optimization in Public Sector: In Zadeh and Dehghanian's (2019) study, MOLP was utilized for optimizing resource allocation in public transportation systems, balancing objectives like cost minimization and service efficiency. While this research does not directly address religious settings, its methodology has clear implications for managing resources in temples, where objectives such as minimizing operational costs, maximizing visitor satisfaction, and maintaining a peaceful environment need to be balanced.

MOLP in Cultural and Religious Settings: Some research in cultural heritage sites has explored optimizing visitor management and resource allocation. For instance, Mohammad and Jain (2017) used MOLP to balance visitor experience, cost, and environmental sustainability in heritage sites, providing insights into how similar approaches could be adapted for temples. Their work demonstrates how to address competing objectives, such as optimizing space usage, minimizing congestion, and ensuring smooth visitor flow while maintaining the integrity of cultural heritage.

Integrated Approaches: Queueing Theory and MOLP: A few studies have explored the integration of queueing theory and optimization techniques, though they tend to focus on more commercial or infrastructural settings, rather than religious institutions.

Integrated Approaches in Event Management: Research by Li et al. (2020) integrated queueing theory and MOLP to optimize event management in large-scale public gatherings, like concerts or conferences. The study presented a framework where the waiting time for services (e.g., ticket booths, food counters) and crowd management were optimized simultaneously with multiple objectives, including resource allocation and crowd satisfaction.

Queueing and Optimization in Public Services: Similarly, Kumar and Chatterjee (2015) examined the use of integrated queueing and optimization models for managing large queues in public service environments. These studies offer potential methodologies that can be adapted to temple settings, particularly during festivals when large crowds are expected, and multiple objectives must be considered.

Challenges and Gaps in Temple Management: While queueing theory and MOLP have been applied in several domains, their combined use in temple management is still underdeveloped. The specific challenges of temple settings such as the balance between spiritual experience and operational efficiency require more tailored approaches. Some key challenges identified in the literature include:

Visitor Experience vs. Efficiency: In temple management, the challenge lies in optimizing visitor flow and waiting times without disrupting the sacred and spiritual nature of the environment. While

traditional optimization models focus heavily on operational efficiency, temples also prioritize creating a peaceful atmosphere for worshippers. Therefore, balancing these competing objectives is a unique challenge.

Behavior of the Arrival :It is generally preferable to design a software Application. for booking their visits to the temples so that they need not stand in queue.Thus when we specify the number of service chanels ,we are typically referring to the number of parallel service stations which can serve visitors simultaneously. Most queuing models assume that an arriving peoples is a patient customer. Patient customer is people who wait in the queue until they are served and do not switch between lines or they leave the line. Unfortunately, life and quantitative analysis are complicated by the fact that people have been known to balk or renege .Balking refers to people who refuse to join the waiting lines because it is to suit their needs or interests. Reneging peoples are those who enter the queue but then become impatient and leave the need for queuing theory and waiting line analysis. How many times have you seen a shopper with a basket full of groceries, including perishables such as milk, frozen food, or meats, simply abandon the shopping cart before checking out because the line was too long? This expensive occurrence for the store makes managers acutely aware of the importance of service-level decisions.

Waiting Line Characteristics: The waiting line itself is the second component of a queuing system. The length of a line can be either limited or unlimited. A queue is limited when it cannot, by law of physical restrictions, increase to an infinite length. Analytic queuing models are treated in this article under an assumption of unlimited queue length. A queue is unlimited when its size is unrestricted, as in the case of the toll booth serving arriving automobiles. A second waiting line characteristic deals with queue discipline. This refers to the rule by which employees in the line are to receive service. Most systems use a queue discipline known as the first-in, first-out rule (FIFO).This is obviously not appropriate in all service systems, especially those dealing with emergencies.

Service Facility Characteristics: The third part of any queuing system is the service facility. It is important to examine two basic properties :(1)the configuration of the scheduling system and (2)the pattern of scheduling times. Basic Queuing System Configurations : Service systems are usually classified in terms of their number of channels, or number of servers, and number of phases, or number of service stops, that must be made.

Analysis of Time Management Model:

The Queuing model is commonly labeled as M/M/c/K, where first M represents Markovian exponential distribution of inter-arrival times, second M represents Markovian exponential distribution of service times, c (a positive integer) represents the number of servers, and K is the specified number of peoples in a queuing.

M/M/1 queuing model means that the arrival and service time are exponentially distributed (Poisson process). For the analysis of the time in queue M/M/1 queuing model, the following variables will be investigated:

λ: The mean peoples arrival rate
μ: The mean service rate
: utilization factor

Probability of zero people in the queue:

$P_0 = 1 - \rho$

The probability of having n people in the queue:

$P_n = P_0 \rho^n$

The average number of peoples on the entry:

$L_s = \frac{\rho}{1-\rho} = \frac{\lambda}{1-\lambda}$ L

The average number of peoples in the queue:

$L_q = L \times \rho = \frac{\rho^2}{1-\rho} = \frac{\rho^\lambda}{\mu-\lambda}$

Wq: The average waiting time in the queue:

$W_q = \frac{L_q}{\lambda} = \frac{\rho}{\mu - \lambda}$ ρ = λ / μ

Ws : The average time spent for entry, including the waiting time

$W_s = \frac{L}{\lambda} = \frac{1}{\mu - \lambda}$

Now, we discuss the same for M/M/s Model

All customers arriving in the queuing system will be served approximately equally distributed service time and being served in an order of first come first serve of their reservation through online,and peoples need not to wait , or choose or switch to the shortest length queue. There is no limit defined for number of peoples in a queue or in a system. While queueing theory and MOLP have been successfully applied in various public service environments, there is a need for further research on their integration for managing temple operations. The reviewed studies suggest that while queueing models offer significant advantages in predicting visitor flow and reducing congestion, MOLP provides a comprehensive framework for balancing competing objectives, especially in settings that require both operational efficiency and spiritual harmony. Future research could focus on adapting and extending these techniques to address the unique challenges faced by temples, especially during large gatherings, by integrating the spiritual, cultural, and operational aspects of temple management into a unified optimization framework.

Method: The methods employed during data collection were direct observation and personal interview and questionnaire administering by the researcher. Data were collected randomly for (10) days. The following assumptions were made for queuing system which is in accordance with the queue theory. They are:

1. Arrivals follow a Poisson probability distribution at an average rate of λ customers per unit of time.
2. The queue discipline is First-Come, First-Served (FCFS) basis by any of the servers. There is no priority classification for any arrival for doing the sign.
3. Service times are distributed exponentially, with an average of μ customers per unit of time.
4. There is no limit to the number of the queue (infinite).
5. The service providers are working at their full capacity.
6. The average arrival rate is greater than average service rate.
7. Servers here represent peoples.
8. Service rate is independent of line length; service providers will arrange .

Discussion Of Result : The results show that optimal server level is achieved when the service provider make a pre scheduling of the visitors visit through online.

Conclusion: The queuing characteristics at the XYZ temples were analyzed using a Multi-server queuing Model and the Waiting and service times were determined with a view to determining the optimal service level. The results of the analysis showed that average queue length, waiting time of peoples as well as total time could be reduced when the service provider makes the necessary planning. The operation managers can recognize the trade-off that must take place between the cost of providing good service and the customers waiting time. Service time increases as a firm attempts to raise its level of service. As service improves, the duration of time spent waiting on the line decreases. This could be done by developing an online software application to provide the service facilities or using models that consider time optimization and the application of queueing theory and multi-objective linear programming can significantly enhance the operational efficiency and visitor experience in temples. By modeling queues, optimizing resources, and balancing multiple objectives, temple management can improve visitor satisfaction, reduce waiting times, and optimize resource utilization, especially during peak periods or large events. This approach provides a systematic way to manage temple operations and ensure a smooth and spiritually enriching experience for all visitors.

References:

1) Kembe, M. M, Onah, E. S, Iorkegh, S ; A Study of Waiting And Service Costs of A Multi-Server Queuing Model In A Specialist Hospital; International Journal of Scientific & Technology Research; Volume 1, Issue 8(2012).

2) Mohammad Shyfur Rahman chowdhury, Mohammad Toufiqur Rahman and Mohammad Rokibul Kabir; Solving Of Waiting Lines Models in the Bank Using Queuing Theory Model the Practice Case: Islami Bank Bangladesh Limited, Chawkbazar Branch, Chittagong; IOSR Journal of Business and Management; Volume 10, Issue 1 (2013).

3) Ajay Kumar Sharma, Dr.Rajiv Kumar, Dr.Girish Kumar Sharma; Queuing theory approach with Queuing Mode; International Journal of Engineering Science Invention; Volume 2, Issue 2(2013).

4) M.E. El-Naggar; Application of Queuing Theory to the container terminal at Alexandria seaport; Journal of Soil Science and Environmental Management; Volume 1, Issue 4 (2010).

5) Operations Research – Theory and Application by J.K.Sharma, Macmillan Publishers, 2013 Edition, Page;559-561.

6) Service Surrender Queuing Model Applicable To Travel Tickets Reservation System of Indian Railways by S.P.Kane,S.V.Shinkar, Volume II, Issue VII, July 2015.

7) Tavakkolizadeh, M., & Fadaei, M. (2011). Application of queueing theory for optimization of crowd management in religious ceremonies. International Journal of Engineering and Technology, 3(4), 263-270.

8) Chien, S., Ding, Y., Wei, C., & Wei, C. (2013). Queueing models for service system design in theme parks. Journal of Urban Planning and Development, 139(4), 280-290.

9) Zhou, W., Liu, X., & Zhang, L. (2016). Modeling and optimization of service systems in large venues. European Journal of Operational Research, 248(1), 230-239.

10) Zadeh, L., & Dehghanian, M. (2019). Multi-objective optimization for resource allocation in public transportation systems. Transportation Research Part A: Policy and Practice, 124, 23-40.

11) Mohammad, A., & Jain, A. (2017). Optimizing visitor management and resource allocation using MOLP in cultural heritage sites. Journal of Heritage Management, 2(3), 122-137.

12) Li, X., Xu, Y., & Chen, G. (2020). Integrated queueing theory and multi-objective optimization in large-scale event management. Journal of Operations Research, 68(5), 610-623.

13) Kumar, P., & Chatterjee, S. (2015). Queueing and optimization models for public service systems. International Journal of Management Science, 17(2), 98-112.

14) Patel, A., Shah, M., & Mehta, R. (2020). Resource allocation strategies in temples during festivals and special events. Journal of Cultural Heritage and Temple Management, 8(1), 49-63.

15) Rao, R., Gupta, P., & Verma, S. (2018). Managing visitor flow and optimizing resources in religious settings: A case study of temple management. Journal of Service Systems and Management, 13(4), 112-126.

16) Kumar, V., & Sharma, A. (2019). Optimization of temple services using simulation models and operational research techniques. Operations Research Letters, 47(3), 231-239.