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QUEUING THEORY AND IT'S IMPACT ON VARIOUS APPLICATIONS - A REVIEW

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ABSTRACT

Waiting is an intimate dimension of our daily lives. Everyone has experienced waiting in line at the traffic control of daily life of human like telecommunications, reservation counter, super market, big bazaar, Picture Cinema hall ticket window and also to determining the sequence of computer operations, computer performance, health services, airport traffic, and airline ticket sales like any number of other places. Queuing theory is the mathematical study of waiting lines and it is very useful to define Modern information technologies require innovations that are based on modelling, analyzing, designing to deals with. Queuing theory is used widely in engineering and industry for analysis and modelling of processes that involve waiting lines. Applications of queuing theory is increased day by day in the fields of banking sector, healthcare, traffic control, computer Parallel System and Distributed system are also have the base of Queue models. This paper is an attempt to analyze the instances of use of queuing theory in various applications and benefits acquired from the same.

Keywords- *queue, queuing theory, queuing system, queuing theory applications.*

I. INTRODUCTION

Queue: queue is a file or line of persons. “Queue” means to form a line while waiting for something or a waiting line, involves arriving items that wait to be served at the facility that provides the service they seek. Queuing theory is the mathematical theory of waiting lines. However, waiting in line is just a part of the overall queuing system. A queuing system (also known as a processing system) can be characterised by four main elements: the arrival, the queue discipline, the service mechanism, and the cost structure. A queuing model of a system is an abstract representation whose purpose is to isolate those factors that relate to the system’s ability to meet service demands whose occurrences and durations are random. Selecting or constructing a queuing model that is rich enough to reflect the complexity of the real system, yet simple enough to permit mathematical analysis is an art. The ultimate objective of the analysis of queuing systems is to understand the behavior of their underlying processes so that informed and intelligent decisions can be made in their management.

A. History

Operation research (O.R) focuses on the application of analytical methods to facilitate better decision-making. Operation Research existed as a scientific discipline since 1930’s.It is a discipline of applying appropriate analytical methods for decision making. OR has been studied in health care settings since 1952. One of the major uses of operational research in healthcare is in the form of Queuing theory. Queues or Queuing theory was first analyzed by A.K Erlang in 1913 in the context of telephone facilities. It is extensively practiced or utilized in industrial setting or retail sector-operations management, and falls under the purview of decision Sciences. The rising cost of health care can be attributed not only to ageing population and new expensive and advanced treatment modalities but also to inefficiencies in health delivery. Queuing theory application is an attempt to minimize the cost through minimization of inefficiencies and delays in the system.

B. Components of a Queuing System

In general, a queuing system comprise with two components, the queue and the service facility. While analyzing a queuing system we can identify some basic elements of it. Namely, **Input process:** if the occurrence of arrivals and the offer of service are strictly according to schedule, a queue can be avoided. But in practice this does not happen. In most cases the arrivals are the product of external factors. **Service mechanism:** the uncertainties involved in the service mechanism are the number of servers, the number of customers getting served at any time, and the duration and mode of service. Networks of queues consist of more than one servers arranged in series and/or parallel.
System capacity: at most how many customers can wait at a time in a queueing system is a significant factor for consideration. If the waiting room is large, one can assume that for all practical purposes, it is infinite. But our

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everyday experience with the telephone systems tells us that the size of the buffer that accommodates our call while waiting to get a free line is important as well.

Service discipline: all other factors regarding the rules of conduct of the queue can be pooled under this heading. One of these is the rule followed by the server in accepting customers for service. In this context, the rules such as First-Come, First-Served (FCFS), Last-Come, First-Served (LCFS), and Random Selection for Service (RS) are self-explanatory

Basic elements of Queue The analysis of queue is based on building a mathematical model representing the process of arrival of Item who joins the queue, the rules by which they are allowed into service, and the time it takes to service.

C. Characteristics of Queuing System

In designing a good queuing system, it is necessary to have good Information about the model. The characteristic are 1. Arrival pattern, 2. Service mechanism, 3. Queue discipline, 4.number of service channels,5. number of service stages.

1. Arrivals can be measured as the arrival rate or the inter arrival time(time between arrivals).Interarrival time =1/ arrival rate
2. As with arrival patterns, service patterns may be deterministic or stochastic. There may also be batched services. The service rate may be state-dependent. (This is the analoge of impatience with arrivals).
3. This is the manner by which customers are selected for service. (i) First in First Out (FIFO)(ii) Last in First Out (LIFO), also called (iii) Service in Random Order (SIRO) (iv) Priority Schemes. Priority schemes are either: Preemptive, Non-Preemptive
4. Number of service channels: Parallel Queue, Single Queue
5. Customers are served by multiple servers in series.

D. Queuing network

A queuing network is Networks of queues are systems which contain an arbitrary, but finite, number of queues. Customers, sometimes of different queue travel through the network and are served at the node. The user sources for some of the queuing systems in the network may be other queuing systems in the same network.

E. Queuing Software's

To solve practical problems the first step is to identify the appropriate queuing system and then to calculate the performance measures [1]. Of course the level of modelling heavily depends on the assumptions. It is recommended to start with a simple system and then if the results do not fit to the problem continue with a more complicated one. Various software packages help the interested readers in different level. The following links worth's a visit

http://web2.uwindsor.ca/math/hlynka/qsoft.html

For practical oriented teaching courses we also have developed a collection of Java-applets calculating the performance measures not only for elementary but for more advanced queueing systems. It is available at

http://irh.inf.unideb.hu/user/jsztrik/education/09/english/index.htmls

For simulation purposes the author [1] recommend

http://www.win.tue.nl/cow/Q2

II. REVIEW BASED ON QUEUING THEORY APPLICATIONS

Queuing theory has been applied to a great variety of business situations. Here we shall discuss a few problem s where the theory may be applied-

1) Waiting line theory can be applied to be determine the number of checkout counters needed to secure smooth and economic operations of its stored at various time during the day of a super market or a departmental store .

2) Waiting line theory can be used to analyze the delays at the toll booths of bridges and tunnels.

ISSN 2348 – 8034
Impact Factor- 3.155

3) Waiting line theory can be used to improve the customers service at restaurants, cafeteria ,gasoline service station , airline counters, hospitals etc.,

4) Waiting line theory can be used to determine the proper determine the proper number docks to be constructed in the building of terminal facilities for trucks &ships.

5) Several manufacturing firms have attacked the problems of machine break down &repairs by utilizing this theory . Waiting line theory can be used to determine the number of personal to be employed so that the cost of the production loss from down time & the cost is minimized.

6) Queuing theory has been extended to study a wage incentive plan.

a. Healthcare

In hospital, queuing theory can be used to assess a multitude of factors such as prescription fill-time, patient waiting time, patient counselling-time, and staffing levels. The application of queuing theory may be of particular benefit in hospitals with high-volume outpatient workloads and/or those that provide multiple points of service.

S. No	Paper Discuss about	Proposed Method/Techniques/ Algorithms/Model	Results Achieved	Merits and Demerits	Future Enhancement
[1]	Paper [2] discusses about, General background into queuing theory, its associated terminology, and its relationship to patient satisfaction. ✓ Past and present applications of queuing technology and what staffs can do to manage patient or customer queues more effectively will be discussed. ✓ automated queuing technology will be described	The only suggestion offered by the authors for managing perceived waiting time is to distract the customer by providing entertainment, refreshments, or comfortable conditions, such as television and coffee in the waiting area.	The goal of this paper was to give the reader a general understanding of concepts, current technology, and applications of queuing theory as it relates to patient satisfaction and waiting time.	Perhaps the most common and useful application of queuing theory in hospital operations is to reduce patient waiting time and maximise staff effectiveness.	Wouldn't it be nice to practice hospital in a setting where the worry and burden of wait time management was eased, even liminated — keeping patients happy and decreasing the anxiety of those behind the counter trying to provide the best hospital service?
[2]	This paper[3] is an attempt to analyze the theory (Queuing) and instances of use of queuing theory in health care organizations around the world and benefits acquired from the same	Why use the queuing theory in first place-the answer is to minimize total cost to the system. These costs can be divided into two broad categories: ✓ costs associated with patients or customers having to wait for the ✓ Service costs of providing the service (capacity costs) health care system can be visualized as a	In health sector it is mainly used in ED wait line and staffing studies, analysis of queues in outpatient and ambulatory care settings and for disaster management.	offset partially if they are used in conjunction with other decision analysis methods such as simulation and regression. With the increasing cost pressure, changing reimbursement mechanisms and affiliations, pressure for quality control, and awareness and demands of the patients,	Sooner or later we will have to tap into the benefits of engineering techniques such as queuing theory top provide smooth, safe and efficient healthcare services to our customers, internal and external customer satisfaction and for optimization of resources.

ISSN 2348 – 8034
Impact Factor- 3.155

		complex queuing network in which delays can be reduced			
[3]	This paper[4] presents the results of a study that evaluates the effectiveness of a queuing model in identifying the ante-natal queuing system efficiency parameters	This paper presents the results of a study that evaluates the effectiveness of a queuing model in identifying the ante-natal queuing system efficiency parameters	The study showed that pregnant mothers spent less time in the queue and system in the first week than during the other succeeding two weeks. This implies that there are less average pregnant women in the queue and system in the first week than in the other weeks except on the third week when less expectant mother waited in the system.	✓ a further study is recommended to cover some selected hospitals for a longer period of time. ✓ this study takes into consideration the actual waiting time but ignores the effect of perception of waiting time on patient satisfaction.	The queuing modeling approach and adopted software (Tora) can be used to model different health care units such as general outpatient clinic, intensive care unit, blood banks etc. In addition, the model can also be applied to manufacturing facilities and other service organizations such as banks, restaurants, and telecommunication.
[4]	In this study[5], the queuing characteristics at the Riverside Specialist Clinic of the Federal Medical Centre , Makurdi was analysed using a Multi-server queuing Model and the Waiting and service Costs determined with a view to determining the optimal service level. Data for this study was collected at the Riverside specialist clinic for four weeks through observations, interviews and by administering questionnaire	The data was analysed using TORA optimization Software as well as using descriptive analysis.	The results of the analysis showed that average queue length, waiting time of patients as well as overutilization of doctors at the Clinic could be reduced at an optimal server level of 12 doctors and at a minimum total cost as against the present server level of 10 doctors with high Total Cost which include waiting and service costs.	The operation managers can recognize the trade-off that must take place between the cost of providing good service and the cost of customers waiting time. Service cost increases as a firm attempts to raise its level of service. As service improves, the cost of time spent waiting on the line decreases.	This model can also be used by decision and other policy makers to solve other Multi-server queuing problems.
[5]	This paper[6] considers the waiting of patients in university health centers as a single-channel queuing system with Poisson arrivals and exponential service rate where arrivals are handled on a first come first serve basis.	m/m/1 queuing system, Poisson arrivals, exponential service rates. Data on arrival times, time service begins, time service ends, and departure time of 100 patients was collected over 14 days. This data will enable us to obtain the arrival rate, the service rate, and the	The traffic intensity $\rho=0.8444$ is the probability of patients queuing on arrival which clearly indicates a higher possibility of patients waiting for treatment since the doctor is busy rendering service to a patient that has earlier arrived. This also shows that the service in the health centre is not 100% efficient.	This will offer service on arrival. It is also recommended that more health care centers should be created to take care of all categories of patients (students or members of staff) in the university community	

ISSN 2348 – 8034
Impact Factor- 3.155

		traffic intensity of the patients using results from the birth and death model (which is synonymous to arrival and departure).	✓ The average time in the queue system (both on queue receiving service) is greater than the average time in queue before service is rendered.		
[6]	In the present study[7], a queueing theory originated model is applied to insulin level and number of insulin receptors. Based on real data, some parameters such as optimum insulin level, number of insulin receptor and minimum required energy spent were calculated by using queueing theory.	M/M/c queue, uses FCFS (First-come, First-served) service discipline.	Our results show an indirect correlation between insulin level and receptor. The total energy spent is also decreased up to optimum number of insulin receptors and then it is increased. From the results, it could be said that queuing theory predicts the optimal number of insulin receptors.	the data reveals that queueing theory can be applied to insulin level and number of insulin receptors. Estimation of insulin levels in insulin-insulin receptor complex and number of insulin receptors obtained through queueing analysis may identify etiological origins of some insulin-based metabolic disorders.	

b. Bank

S.No	Paper Discuss about	Proposed Method/Techniques/Algorithms/ Model	Results Achieved	Merits and Demerits	Future Enhancement
[1]	This paper[8] done the Comparative Study between M/M/Z/∞ with M/M/1/∞.	✓ Establish the optimization model of queuing and calculate the optimal model of queuing. ✓ Calculate the optimal number of service stations to improve operational efficiency ✓ Calculate the optimal service rate and the	Studied the condition of one service station that is consider the model M/M/1/∞. To determine the particular level of service, which minimizes the total cost of providing service and waiting for that service	Merits: ✓ The time of customer queuing is reduced. ✓ The customer satisfaction is increased.	✓ In banking service, in terms "if first come , first serve" the principle of fairness or technically, a line is better that more lines, so bank managers should have the attention on this problem.

ISSN 2348 – 8034
Impact Factor- 3.155

		service efficiency y the operating costs			
[2]	The paper [9] discusses a finite waiting spacfe Markovian single server queuing model with discouraged arrivals, reneging and retention of reneged customers is studied.	✓ Markovian queuing model investigated based on some assumptions.	✓ Differential difference equations of the model are derived and solved ✓ Steay- state solution and Measures of effectiveness are derived	Merits: ✓ Keeping the negative impact of customer impatience, the novel concept of the retention of reneged customers with discouraged arrivals is studied. Demerit ✓ Limited to finite capacity	✓ Infinite capacity case of the model can also be studied. ✓ The cost profit can analysis can be extended to some non-markovian queuing models.
[3]	In this study[10], Bank ATMs would avoid losing their customers due to a long wait on the line. The bank initially provides one ATM. However, one ATM would not serve a purpose when customers withdraw to use ATM and try to use other bank ATM. Thus, to maintain the customers, the service time needs to be improved. This paper shows that the queuing theory may be used to solve this problem. We obtained the data from a bank ATM in a city.	We used Little's Theorem and M/M/1 queuing model.	The arrival rate at a bank ATM on Monday during banking time is customer per minute (cpm) while the service rate is . cpm. The average number of customers in the ATM is . and the utilization period is . .	This research can help bank ATM to increase its QoS (Quality of Service), by anticipating, if there are many customers in the queue. The result of this paper is helpful to analyse the current system and improve the next system. Because the bank can now estimate the number of customers waiting in the queue and the number of customers going away each day.	This theory is also applicable for the bank, if they want to calculate all the data daily and this can be applied to other branch ATM also.
[4]	Analysis of a queuing system in an organization (a case	The research method used in	The analysis of the queuing system	The increase in the	

ISSN 2348 – 8034
Impact Factor- 3.155

	study of First Bank PLC, Nigeria [11])	this work is a quantitative research approach	shows that the number of their servers was not adequate for the customer's service. It observed that they need 5 servers instead of the 3 at present. This increase in servers reduces the waiting time, and the probability that an arrival will have to wait for service is 0.056. However, the system utilization was observed to be 0.235 for an hour. Furthermore, the system capacity of the five servers was observed to be 92.7 for an hour	number of servers will reduce the time customers have to wait in line before been served. This will also increase the efficiency of the establishment due to the appreciation in their serve to the customers as and at when due.	
[5]	In this article[12], we describe several common queuing situations and present mathematical models for analyzing waiting lines following certain assumptions. Those assumptions are that (1) arrivals come from an infinite or very large population, (2) arrivals are Poisson distributed, (3) arrivals are treated on a FIFO basis and do not balk or renege, (4) service times follow the negative exponential distribution or are constant, and (5) the average service rate is faster than the average arrival rate	multiple-channel queuing model with Poisson Arrival and Exponential Service Times (M/M/S).	After a series of operating characteristics are computed, total expected costs are studied, total costs is the sum of the cost of providing service plus the cost of waiting time. Finally we find the total minimum expected cost.	Queuing theory provides models that are capable of determining arrival pattern of customers or most appropriate number of service stations. 2. Queuing models are helpful in creating balance between the two opportunity costs for optimization of waiting costs and service costs. 3. Queuing theory provides better understanding of waiting lines so as to develop adequate service with tolerable waiting.	discrete and continuous probability distribution used in the analysis of queuing models

c. Computer Science

S. No	Paper Discuss about	Proposed Method/Techniques/ Algorithms/Model	Results Achieved	Merits and Demerits	Futu-re work
[1]	[13] Studied about the concept and work culture in call centers and summarize the results	✓ Poisson Process ✓ Homogeneous, Non Homogeneous, Space time poisson	✓ The criticism of call centers from callers and staffs view discussed ✓ Characteristics and properties of various poisson process studied.	-	-

ISSN 2348 – 8034
Impact Factor- 3.155

		process, continuous time markov process			
[2]	In the present work[14], two queuing models (M/M/1): ((C+1)/FCFS) and (M/M/2): ((C+1)/FCFS) have been applied to determine the forecast way for the stable congestion rate of the network traffic.	M/M/1): ((C+1)/FCFS) and (M/M/2): ((C+1)/FCFS) have been applied to determine the forecast way for the stable congestion rate of the network traffic	✓ Using the Queuing Theory models, it is convenient and simple way for calculating and monitoring the network traffic properly in the network communication system. We can monitor the network efficiently, in the view of the normal, optimal and or even for the high overhead network management, by monitoring and analyzing the network traffic rate.	we can say that network traffic rate can have an important role in the network communication system.	-
[3]	This paper[15] shown how the queuing model, M/M/S model is used for multiple servers to reduce the mean queue length and waiting time in cloud computing	It is the work of cloud computing service provider(CCSP) to provide service to users with less waiting time otherwise there is a chance that the user might be leaving from queue.	✓ M/M/S model for two servers which increases the performance over sing one server by reducing the queue length and waiting time. ✓ M/M/2 reduces queue length and waiting time when compared to M/M/1	Merits: ✓ Guarantee the QoS requirements of the CCU's jobs ✓ Maximum profits for the CCSP	
[4]	In this paper[16] we extend the analysis to cover the batch arrivals. i.e. we consider a batch alTiva! single-server queue with renewal input and multiple exponentIal vacations.	Imbedded Markov chain and supplementary variable techniques we obtain steady-state distribution of number of customers in the system at prearrival and arbitrary epochs. The Laplace-Stieltjes transforms of the actual waiting-time distribution of the first-. arbitrary-and last-customer of a batch under First-Come-First-Serve discipline have been derived	we have derived a few important system characteristics. which includes the blocking probabilities. the average waiting limes of the f1rst-. un arbitrary-and the last-customer of a batch	used to analy se other complex models such as the finite-buffer bulk arrival bulk service queue with renewal input and exponential multiple vacations. i .c. Cl1\ 'N.	

d. Traffic Control

S.No	Paper Discuss about	Proposed Method/Techniques/Algorithms/Model	Results Achieved	Merits and Demerits	Future Enhancement
[1]	This paper[17] seeks to model the vehicular traffic flow and explore	✓ M/M/1/∞ ✓ Poisson arrivals	It was observed that in the evening Motor traffic transport unit (MTTU) do not work and the drivers of	Government of Ghana could introduce a	Stakeholders can promote the use of bikes,

ISSN 2348 – 8034
Impact Factor- 3.155

	how vehicular traffic could be minimized using queuing theory in order to reduce the delays on roads in the Kumasi metropolis of Ghana.		commercial cars take advantage of the situation, park and offload/on load passengers at unauthorized places very close to the traffic signals, impeding the flow of traffic when servers resumed work.	public transport system so that people do not travel with private cars to their places of work to reduce congestion on the roads, which in turn boosts productivity.	which apart from serving as a form of exercise, helps to reduce fuel consumption thereby saving money for the government to tackle problem of other sectors of the economy.
[2]	Paper [18] Discusses the various problems faced because of traffic	✓ Erlang Unit ✓ Poisson Proces	Call arrivals can be modelled by a poisson process and that call holding times are described by a negative exponential distribution.	-	-

e. Production

S. No	Paper Discuss about	Proposed Method/Techniques/Algorithms/Model	Results Achieved	Merits and Demerits	Future Enhancement
[1]	This paper[19] estimating and analyzing production systems by measures such as utilization, percentage of idle workstations, number of batches in system, number of batches in queue, expected time spent in queue and expected time spent in system.	Analytical model of queuing theory used Chi squared goodness test	✓ Accuracy between data using queuing theory and standard data in the company is 93.80% ✓ Queuing time reduced and efficiency increased	Merit: To help managers in improving the efficiency, effectiveness and selecting the most suitable policy for assembly systems.	Improve the performance of multi product multi stage production lines.
[2]	The aim of this study[20] is to achieve an appropriate queuing analytical model and determine its performance measures by analyzing the capacity requirements and estimating manufacturing cycle times.	state model method where the related data such as data for product and workstation as well as data for setup and processing time are collected. The mechanism can be categorized as follow:record data (check list), past collected data, self timing	The study has shown that queuing theory is able to be applied to analyze production system comprehensively. The capability of the theory to provide system design guidelines, capacity analysis and estimating throughput times make it more effective for process planner in planning their production schedule and future improvement.	**Merit:** queuing theory is very useful and practical in evaluating the capacity requirement of the production system facilities. **Demerit:** The result of this study has established based only on steady state data, while the actual production environment was mixture of both transient stage and steady	Actual transient production system is far too complex and difficult to determine. Future works or studies are needed by adding simulation or computational effort so that the system is able to be modeled perfectly.

ISSN 2348 – 8034
Impact Factor- 3.155

				state	

III. ISSUES IN QUEUING THEORY

There are many problems in health care system which can be solved using queuing theory in operational research. Few of them are discussed below: Long waiting time at outpatient clinics before consultation Patients need to make an appointment for a specialist. An appointment system reduces patient waiting time. A Good appointment Schedule is one that trade-offs patients waiting time for clinics overtime, constrained by patient load and staffing. Using O.R we can use techniques such as queuing theory and discrete event simulation to propose various appointment strategies under different clinics settings. So why use the queuing theory in first place-the answer is to minimize total cost to the system. These costs can be divided into two broad categories [3]:

a) COSTS ASSOCIATED WITH PATIENTS OR CUSTOMERS HAVING TO WAIT FOR THE SERVICE

- ✓ Loss of business to HCO, as some patients might not be willing to wait for the service and may decide to go to the competing organizations.
- ✓ Costs incurred by society for example increased interventions and cost due to delay in care or the value of patients time.
- ✓ Decreased patient satisfaction and quality of care.

b) COSTS OF PROVIDING THE SERVICE (CAPACITY COSTS)

- ✓ Salaries paid to employees.
- ✓ Salaries paid to employees or servers while they wait for service from other server, for example waiting for the pathology report, radiology report, labs, etc.
- ✓ Fixed costs – cost of waiting space, facilities, equipments, and supplies.

If the organization decides to increase the level of service provided, cost of providing services would increase, if it decides to limit the same, costs associated with waiting for the services would increase. So the manager has to balance the two costs and make a decision about the provision of optimum level of service.

The bulk of results in queuing theory is based on research on behavioral problems. Mathematical models for the probability relationships among the various elements of the underlying process are used in the analysis. To make the ideas concrete let us define a few terms which is defined formally later.

A collection or a sequence of random variables that are indexed by a parameter such as time is known as a stochastic process. e.g., an hourly record of the number of accidents occurring in a city. In the context of a queuing system the number of customers with time as the parameter is a stochastic process.

c) Limitations of Queuing Theory

- ✓ Most of the queuing models are quite complex & cannot be easily understood.
- ✓ Many times form of theoretical distribution applicable to given queuing situations is not known.
- ✓ If the queuing discipline is not in" first in, first out", the study of queuing problems become more difficult.

ISSN 2348 – 8034
Impact Factor- 3.155

IV. CONCLUSION

This research paper discussed about detailed information about the queuing system and its application on various areas. The capability of Queuing systems can have an important result on the quality of human life and productivity of the process. The application of queuing theory in the Industries are well known in the world and very wide and well described in the technical literature. Developing appropriate models of the links (or interfaces) between the distinct queuing systems is an important direction for future research. The further studies are as follows: Because of time constraints and work extension only a small part of the applications are investigated in this study. The limitation of this study provide opportunities for future research, so for presenting a complete and comprehensive research we can do Similar researches in other units for providing more complete analysis and first process of our work is to concentrate on Patient satisfaction in healthcare industry. Because as long as increasing the productivity of healthcare organizations remains important, analysts will seek to apply relevant models to improve the performance of healthcare processes.

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