AN ANALYSIS ON APPLICATION OF QUEUEING THEORY IN HOSPITAL SERVICES

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ABSTRACT:
Queuing theory can be used to analyse wait lines in healthcare settings, because most healthcare systems have sufficient capacity to absorb random changes, queuing analysis can be utilised for short-term interventions as well as facility and resource planning. Most of healthcare systems have excess capacity to accommodate random variations, so queuing analysis can be used as short-term measures, or for facilities and resource planning. This paper reflects an analysis on application of Queueing theory in in Hospital services.
KEYWORDS: queuing, important, hospital, applicable
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INTRODUCTION:
Queueing theory plays an important role in dealing with the problems relating to hospital management. Recently healthcare professionals have discovered the benefits of applying queuing theory techniques. Many have been discouraged by the mathematical mystery shrouding queuing theory. Surprisingly there are some simple queuing functions. The model is descriptive, with an output of expected waiting times for various priorities of patient demand. The waiting times so estimated constitute an index of the quality of nursing care and afford a means of predicting changes in quality with changes in staffing or inpatient load. The model facilitates investigation of the relationships among three factors: patient condition, nurses' activity priorities, and patient load per nurse.

The interpersonal skills of the medical personnel, availability of medicine, hospital infrastructure and medical information plays an important role in managing OPD and create a positive influence on patient satisfaction (Natarajan, 2006). Hence, it is necessary to focus on optimizing waiting time in hospital operations for the benefit and wellbeing of patients The OPD of a hospital acts as a bridge between hospital and community, hence it is very important to plan the OPD with the idea of maximizing the utilisation and quick turnover. (McQuarrie, 1983). It is imperative to have effective co-operation between the medical services and the support line services catering to the OPD requirements.

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The OPD of a hospital acts as a bridge between hospital and community, hence it is very important to plan the OPD with the idea of maximizing the utilization and quick turnover. Planning is the most important aspect of establishing a hospital. If the ready plan is good all may go well as we want. If the plan is not thought out carefully the work may never be completed. Planning a new hospital starts with setting goals for the platform, without which the organization cannot have a definite direction or focus. This is followed by the study of the external environment of the organization, and the internal and external resources with which the goals set are to be achieved. This exercise facilitates selection of the means by which to achieve goals within a reasonable cost.

In a fundamental queueing system, "customers" arrive to a bank of "servers" and ask for a service from one of them. It's crucial to realize that a "client" need not necessarily be a human being; it could be anything that is waiting for assistance. The "customers" in a "back-office" scenario, such as interpreting radiologic images, can be the images that are waiting to be read. The same concept applies to "servers," which might be either an individual or an object. Hence, inpatient beds would be the pertinent servers when looking at delays for patients in the emergency department (ED) awaiting admission to the hospital.

When a customer arrives, they must get in line if all servers are already occupied. Whereas lines of people or objects standing in a queue are common, queues can also be intangible, such as when a phone call is placed on hold. The queue discipline is the policy that governs the sequence in which consumers in a line are served. The well-known first-come, first-served (FCFS) rule is the most widely used discipline, although other practices are frequently employed to boost productivity or shorten wait times for clients who are more time-sensitive. A priority queue discipline would be the triage system used in an emergency department. Depending on whether a service in progress can be halted when a customer with a higher priority arrives, priority disciplines may be preemptive or non-preemptive. In the majority of queueing models, it is assumed that there is an unlimited waiting area and that there is no cap on the number of clients who can be waiting for service. This is a reasonable assumption in situations when clients do not physically join a line, such as in a call center over the phone, or where there is a huge physical waiting area compared to the average number of customers waiting for service. Although though the waiting area has no maximum capacity, occasionally visitors who perceive a long line may decide to "baulk" and not join it. A walk-in clinic might experience this. Reneging, or when consumers get impatient and leave the queue before being served, is a similar characteristic that is included in some queueing systems. In certain EDs, patients who cancel appointments are frequently referred to as "leaving without being seen," which is an example of this conduct.

A queueing model is a mathematical representation of a queuing system that includes certain presumptions on the discipline and organisation of the queue, the number and type of servers, the arrival and service procedures, and their probabilistic character. There are infinite variations imaginable, however several queueing models are more generally used and we will focus on these in this chapter. There are formulae available for these models as well as many others that enable the quick computation of several performance measurements that may be used to aid in the design of a new service system or improve an existing one.

Several performance indicators, including mean delay and chance of waiting longer than a certain length of time before being served, can be predicted using queueing models, which only need a small amount of data and produce comparatively straightforward equations. This indicates that they can be used to find "optimal" solutions more easily and affordably than just evaluating the system performance in a particular scenario.

MANPOWER PLANNING FOR REGISTRATION AND ADMISSION DEPARTMENT OF HOSPITAL :

Manpower planning call for the integration of information, formulation of policies and forecasting of future requirements of human resources so that the right personnel are available for the right job at the right time. Manpower planning starts with the analysis of the future needs of the hospital and its objectives.

Manpower Planning is the primary function of the hospital human resource manager but before the stats filling individual jobs, he should consider the overall management problem of making the best use of available human resources. Just as the controller of finance budget for the best use of financial resources, the human resources manager is basically concerned with budget for the best use of human resources. Manpower planning call for the integration of information, formulation of policies and forecasting of future requirements of human resources so that the right personnel are available for the right job at the right time.

Manpower planning starts with the analysis of the future needs of the hospital and its objectives. It determines organization structure, decides what jobs have to be filled and what their requirements are. Short-term manpower planning –two year or so ahead is promoting planning. But the really important planning is the long-term planning –five or ten years ahead. In manpower planning the basic question of objectives organization structure and age structure of personnel have to be considered.

When a patient enters into the hospital the function of hospital starts from outpatient registration then the patient moves to the outpatient department/casualty/ICU. If the patient only takes the medicinal advice after the laboratory investigation and exit then the patient is treated as outpatient. If the doctor advises the patient for admission in inpatient department, then the patient has to move for inpatient admission. In many times the patients come in serious condition. In that case the patient is admitted to casualty or the patient may be admitted in ICU. In this context the function of Registration and Admission department provides the following services:

- Outpatient registration
- Inpatient registration
- ICU admission
- Allied services like shorting of discharged case sheets and preparation of statistical reports as per the requirements from time to time.

The time spend by the patient in the queue is of interest to the decision maker. One of the objectives of study of queueing is to find out the optimum service rate and number of server (Counters) so that, average waiting time in queueing system and the costs of service are minimized.

Methodology of application :

Data on arrival rate and service time have to be collected for a sustained period to fit a suitable statistical distribution. Simulation models are used for this purpose. Having fitted satisfactory statistical distributions, the next task is to evaluate p, W_q and L_q. If these indices are within specified performance measures, present queueing system is a satisfactory one. If not, studies are terms of increasing the number of counters of service and the economics there of should be carried out.

Out Patient Registration :

Suppose the registration service mechanism of the outpatient registration has one counter for registration. Let us assume that the service time distribution is exponential with mean μ = 40 patient/hr. The arrival rate of patient at the registration counter be approximated by Poisson distribution which is a satisfactory model in most cases with arrival rate of one in 1.8 minute which means average number of patients arriving 33/hr.

Let us calculate the various performance measures:

$$p = \frac{\lambda}{\mu} = \frac{33}{40} < 1$$

Which means the traffic is in control.

$$W_q = \frac{\lambda}{\mu(\mu-\lambda)} = \frac{33}{40(40-33)} = \frac{33}{280} hr \approx 7 \text{ minutes}$$

$$L_q = \frac{\lambda^2}{\mu(\mu-\lambda)} = \frac{33^2}{40(40-33)} \approx 3\ persons$$

Now suppose that the patients demand for another service counter: Is it justifiable? When should be the management go for it? What should be the increase in the arrival data warranting such action? Are the kinds of analysis possible for arriving at optimum queueing system? These are the basic questions.

Outpatient Registration during Busy Period :

During busy period (i.e., 9AM to 2PM) suppose the service mechanism of outpatient registration has two counters for registration. In general, during the busy period about 500 patients comes for registration. Let us assume that the service time distribution is exponential with mean μ = 80 patients /hr. The arrival rate of patients at counter be approximated by Poisson distribution with arrival rate is 36 second which means average number of patients arriving is 100/hr.

Let us calculate the various performance measures:

$$p = \frac{\lambda}{\mu} = \frac{100}{80} > 1$$

Which means that the traffic is not in control? Since the traffic is not in control, we have to increase one counter. Let us assume the service time distribution is exponential with mean μ = 120 customer/hr. in three counters. The arrival rate of patients at counter be approximated by Poisson distribution with arrival rate is 36 second which means average number of patients arriving is 100/hr.

Let us calculate the various performance measures:

$$p = \frac{\lambda}{\mu} = \frac{100}{120} < 1$$

Which means the traffic is in control.

$$W_q = \frac{\lambda}{\mu(\mu-\lambda)} = \frac{100}{120(120-100)} = \frac{33}{120 \times 20} hr = 2.5 \text{ minutes}$$

$$L_q = \frac{\lambda^2}{\mu(\mu-\lambda)} = \frac{100^2}{120(120-100)} \approx 4\ persons$$

Now supposing the patients demand for another service counter: Is it justifiable? When should be the management go for it? What should be the increase in the arrival data warranting such action? Are the kind of above analyses possible for arriving at optimum solution? These are the basic questions.

Inpatient Registration :

Suppose the service mechanism of the inpatient registration counter has one counter for inpatient registration and bed allotment to the patient. Let us suppose the service time is exponentially distributed with mean μ = 20 patients/hr. The arrival rate of patients at the counter be approximated by Poisson distribution with arrival rate of one in 32 minutes which means average number of patients arriving is 1.8/hr.

Let us calculate the various performance measures;

$$p = \frac{\lambda}{\mu} = \frac{1.8}{20} < 1$$

Which means the traffic is in control.

$$W_q = \frac{\lambda}{\mu(\mu - \lambda)} = \frac{1.8}{20(20 - 1.8)} = \frac{27}{91} \text{minutes}$$

$$L_q = \frac{\lambda X \lambda}{\mu(\mu - \lambda)} = 1.8X\frac{27}{91} < 1$$

Registration of ICU Admission :

In this case the patient behavior is vastly different from another situation. If on arrival the patient does not find the bed, he may give up totally and does not try again. Assuming R is the occupancy rate per month and 1/μ is the mean occupancy time, the bed will not be available for a fraction R/μ of the month.

Assume that alternate bed is not available. During this time X(R/μ) patients come for admission and having found it is occupied, give up and leave. X the arrival rate is the number of persons per month who would like to be admitted. It can be seen that the number of patients who have found the bed and have been able to admit is **λ-λ** (R/μ). But by definition it is equal to R, the number of times the bed is occupied per month. 2756

$$\lambda\left(1 - \frac{R}{\mu}\right) = R$$

$$R = \frac{\lambda\mu}{\lambda + \mu}$$

Giving the expected occupation rate in terms of demand rate and 'vacant ratio'. It can also be shown that the probability that a patient will find the bed (P_i), the probability that the bed is occupied by patient when he comes (P_o), expected occupied rate (R) and the mean unsatisfied demand (U) are given by

$$P_0 = \frac{\lambda\mu}{\lambda+\mu} \qquad P_1 = \frac{\mu}{\lambda+\mu} \qquad R = \frac{\lambda\mu}{\lambda+\mu} \qquad U = \frac{\lambda\lambda}{\lambda+\mu}$$

The management can fix the limitations on the value of U, say 2 or 3 or 4 beyond which multiple beds have to be bought or arranged. Criterion for multiple bed can be derived in terms of the demand rate **λ** also.

Alternative situation is when everyone who desires the bed, either in a reservation card or otherwise pesters the registration until eventually the bed is vacant. This is a simple case of general queueing system. All arrivals are eventually served on the average L_q of them are waiting to get the bed. For this model, the actual rate of occupancy R per month is equal to the arrival rate, because all arrivals are eventually able to get the bed. The various measure of queueing system in the case are:

Average number of persons at any time waiting to get a bed

$$L_Q = \frac{R^2/\mu}{(\mu - R)}$$

Average length of time would be patient has to wait until he can get bed

$$L_{Q/R} = \frac{R/\mu}{(\mu - R)}$$

Average number of unsatisfied patients per month.

$$U = \mu L_q$$

In general, the limiting value of U will be between 2 to 4. It can be shown that whenever the monthly occupancy rate R is greater than about 1/3U, too many patients would get waiting too long to get a bed or giving up entirely. In either case management is not serving them adequately.

CONCLUSION:

Queueing model, becomes quite complex when the practices of individual ICU deviate from the standard, say the patient will be let out more than a stipulated period or information's are sent to transfer the patient to ward if the patient's condition is better only when it is known that someone else wants the bed.

The theory of queueing is sufficiently developed so that any of these complications could be included in the model, but the resulting formulae would be complicated and would depend on additional parameters that would be hard to evaluate. In such situations, it is advisable to start off with simple models and introduce complications one by one, until sufficient accuracy is obtained.

REFERENCES :

[1] Afolalu, Adeniran & Ikumapayi, Omolayo & Abdulkareem, Ademola & Emetere, Moses & Adejumo, Olaoluwa. (2021). A short review on queuing theory as a deterministic tool in sustainable telecommunication system. Materials Today: Proceedings. 44. 10.1016/j.matpr.2021.01.092.

[2] Afolalu, Adeniran & Oluwasegun, Adelakun & Ongbali, Samson & Abioye, Abiodun & Ajayi, Oluseyi. (2019). Queueing Theory -A Tool for Production Planning in Health Care.

[3] Afrane, Samuel & Appah, Alex. (2014). Queuing theory and the management of Waiting-time in Hospitals: The case of Anglo Gold Ashanti Hospital in Ghana. International Journal of Academic Research in Business and Social Sciences. Vol. 4. 34-44. 10.6007/IJARBSS/v4-i2/590.

[4] Agrawal, Sachin & Singh, B.K.. (2018). Development and Analysis of Generalized Queuing Model. International Journal of Computer Sciences and Engineering. 6. 15-32. 10.26438/ijcse/v6i11.1532.

[5] Ahdika, Atina. (2019). Mathematical model and numerical simulation of dual-channel multiphase bulk arrival queuing system with heterogeneous service time. Journal of Physics: Conference Series. 1127. 012070. 10.1088/1742-6596/1127/1/012070.

[6] Ailobhio, Titilayo & Owolabi, T & Ayoo, Peter. (2020). Application of Queuing Theory in Antenatal Clinics. IOSR Journal of Mathematics. 16. 42-47. 10.9790/5728-1606034247.

[7] Ariff, Hajar & Kamardan, M & Sufahani, Suliadi & Ali, Maselan. (2018). Review on Queueing Problem in Healthcare. International Journal of Engineering & Technology. 7. 304. 10.14419/ijet.v7i4.30.22291.

[8] Aziati, A. & Hamdan, Nur Salsabilah. (2018). Application Of Queuing Theory Model And Simulation To Patient Flow At The Outpatient Department.

[9] Borthakur, Partha & Borthakur, Barbie. (2021). An Introduction to Queuing Theory. 10.13140/RG.4.24284.72322.

[10] Broyles JR& Cochran JK. (2007), 'Estimating business loss to a hospital emergency department from patient reneging by queuing-based

regression', Proceedings of the 2007 Industrial Engineering Research Conference; May 19- 23; Nashville, TN. pp. 613-618.