Scenario-specific, Statistically sound, Problem-driven Approach to Data Analysis – A Robust Tool for Future Health Managers.

Arvind Vashishta Rinkoo, Tauqeer Nabi, Rahesuddin,
Surendra Pratap Singh, Leela Masih, Hem Chandra
Department of Hospital Administration, SGPGIMS, Lucknow, Uttar Pradesh, India.

***Abstract**: A systematic approach to decision making is necessary in current hectic healthcare delivery scenario. Scenario-specific alternate approaches of data analysis giving clear insight into common maladies are thus imperative for future health managers. This study showcases one such noval approach with an objective of minimizing long waiting time for registration in Out-patient Department of a tertiary care hospital. A pilot study of the Registration Office was done in March 2011 to identify the probable bottlenecks. These bottlenecks were validated scientifically in the main study using standard statistical techniques, and more contributing factors were identified simultaneously. Few patients' waiting time was astronomical in the range of 100-120 minutes. The average service rate of a registration counter was found to be 4.5 minutes per patient. Due to non-steady state of the registration system, application of 'Classical Queuing Model' was not possible. The arrival rate, l in terms of number of patients arriving for new registration per minute, showed an enormous variation. There was no linear association between the arrival rate of the patients and the net service rate provided [r~ 0, p (2 tailed)= 0.357, line of best fit almost parallel to the x axis]. There was a significance difference between service rate per counter when more than 4 counters were operational and the average service rate of a registration counter [p= 0.014], thus showing 'Processes Loss'.*
***Conclusion**: Scenario-specific, problem-driven approach to data analysis was used in the study in lieu of classical queuing theory. Multiple factors such as lack of synchrony between arrival rate and net service rate, 'Processes Loss', inadequate physical facilities, non-deputation of any trained MSW, lack of soft skills in staff, initial pooling of patients etc. were responsible for astronomical waiting time. Necessary recommendations were thus suggested.*

INTRODUCTION

Decision-making is an essential part of Management. Traditionally, decision-making has been considered purely as an art, a talent that is acquired over a period of time through experience. However a systematic approach to decision making is necessary because today's business and the environment in which it functions are far more complex than in the past, and the cost of making errors is becoming graver with time.[1] Management planning is an inevitable prerequisite for the attainment of business objectives by rational use of resources. It helps in the critical appraisal of the relative merits and demerits of alternate policies and actions, thus choosing the best method for achieving the predetermined targets.[2] Operations Research is the application of scientific methods, techniques and tools to problems involving the operations of systems so as to provide those in control of operations with optimum solutions to the problems. [3] Thus, it may be regarded as the scientific method employed for problem solving and decision-making by the management.

Queueing theory is generally considered a branch of operations research because the results are often used when making business decisions about the resources needed to provide service. It is applicable in a wide variety of situations that may be encountered in business, commerce, industry, healthcare, public services and engineering.[4] Queueing theory is the mathematical study of waiting lines or queues. The theory enables mathematical analysis of several related processes, including arriving at the queue, waiting in the queue, and being served at the front of the queue. The theory permits the derivation and calculation of several performance measures including the average waiting time in the queue or the system, the expected number waiting or receiving service, and the probability of encountering the system in certain states, such as empty, full, having an available server or having to wait a certain time to be served. However the assumptions of classical queueing theory like attainment of a steady state position i.e. the system has been running long enough so as to settle down into some kind of equilibrium, may be too restrictive to be able to model real-world situations exactly.[5] Other models suggested, based on computer simulations, are mostly too complicated to be used in general settings.[6] **Alternative means of analysis should thus be devised in order to provide some insight into problems that do not fall under the scope of classical axioms like queueing theory.** These should be scenario-specific consisting of analysis of experimental data with an aim to optimally synchronize arrival and service rates.[7]

Sanjay Gandhi Post Graduate Institute of Medical Sciences (SGPGIMS), Lucknow, India is a 868 bed tertiary care super specialty hospital. SGPGIMS is a premier public medical research institute in India. The institute is dedicated to quality tertiary care at an affordable cost. Over the years, it has strived to become a robust centre of excellence for providing super specialty care, medical education and research facilities of highest order. The institute was established under an Act of State Legislature of Uttar Pradesh in 1983, and functions as an university.

The study was undertaken by the Department of Hospital Administration following patients' grievances regarding long waiting time for new registration in the Out Patient Department (OPD) of the hospital as many patients were reaching the hospital in the wee hours of the morning and forming large queues to get registered early. The aim of the study was to identify the various factors contributing to an increase in waiting time, and to suggest recommendations to decrease waiting time and smoothen the registration process.

MATERIAL AND METHODS

At the outset, a pilot study of the Registration Office was planned in March 2011 in order to plan the precise methodology of this study. The activity of the department was observed for one week. Salient points inferred from the pilot study are as follows:

1. The registration system rarely reached a steady state. This was further complicated by the fact that there was a large pool of patients ranging from 75-200 that congregated each morning even before the commencement of the registration. Given the high quality of specialized care rendered at SGPGI, the clientele come from far off destinations and tend to reach the hospital even at odd morning hours. Thus application of 'Classical Queuing Model' in this problem situation was not possible.
2. Few patients' waiting time was astronomical in the range of 100-120 minutes. The average service rate of a registration counter

***Correspondence: Dr. Hem Chandra,** HOD, Hospital Administration Sanjay Gandhi PGIMS, Lucknow-226014. Uttar Pradesh, India*
Fax: +91-0522-2668017, 2668078
***e-mail:** hchandra55@yahoo.com; hchandra@sgpgi.ac.in*

was found to be 4.5 minutes per patient based on data collected over a period of one week.

3. A total of six counters were available for new registration. The number of counters rendering service at a particular point of time was decided by the 'Front Office Manager' vis-à-vis the workload. Manager claimed that the problem of long waiting time was solely due to initial pooling as otherwise relocation of human resources is being planned prudently as per the workload. However, outwardly, even after considering the initial pooling problem, synchrony thereafter between arrival rate and net service rate was not evident. Hence a scientific approach to study the inter-relationship between the arrival rate and net service rendered was deemed imperative.
4. It was further observed that the net service rate failed to increase sizably despite increasing the number of service counters. Thus it was found necessary to establish scientifically whether an increase in number of counters actually lead to a decline in service rate per counter.

With the above background, a prospective study was planned in April 2011, in order to validate the facts identified during the pilot study, as follows:

1. The study was conducted on first four days of the week between 0800 hours to 1200 hours. Days and time were chosen to ensure maximum workload and no idle time for any staffed counter. Initial pool was neglected on all days to minimize the bias.
2. The entire time period of four hours each day was divided into 10 minutes interval, and arrival rate (number of patients arriving for new registration per minute) & net service rate (total number of patients registered by all available service counters per minute) was calculated for each of these 96 time intervals.
3. Coefficient of correlation, r, was calculated for these two independent variables namely, arrival rate and net service rate in order to study the inter-relationship between the two.
4. The service rate per counter was calculated separately for time intervals when more than 4 counters were operational. This was done by dividing the total number of patients registered per minute by the number of counters operational and expressed as time taken in minutes per patient per counter. The data values, so obtained, were tested for normal distribution using 'Kolmogorov-Smirnov Test for Normality'. This test was preferred over 'Shapiro-Wilk Test for Normality' as sample size was more than 50.
5. One sample T-test was then applied to make out whether there is any significant difference between the average service rate per counter (when more than four counters are operating) and the test value. The test value was taken as 4.5 minutes per patient, the value calculated during the pilot study based on one-week data.

Based on the above test results, the facts identified during the pilot study were validated, contributing bottlenecks were identified and relevant recommendations were made to ameliorate the situation.

RESULTS & DISCUSSION

As evident from hospital statistics, the SGPGIMS hospital had catered to approximately 3,00,000 outpatients in the year 2009-10. Out of these nearly 1,00,000 were new patients rest were old OPD patients. At an average, 300 new patients and 650 old patients were registered per day at SGPGIMS. The registration process of new patients, availing facilities of various super specialities like Cardiology, Renal Sciences, Neurosciences, Gastro-enterology, Endocrinology, Immunology, Haematology and Genetic Medicine, is fully centralized whereas old patients are registered in respective outpatient departments. The central registration counter offers services from 8 a.m. to 2 p.m. (up to 12.30 p.m. o Saturdays).

As already mentioned, the pilot study revealed that few patients' waiting time was astronomical in the range of 100-120 minutes. The average service rate of a registration counter was found to be 4.5 minutes per patient based on data collected over a period of one week. It was found that delay in the registration process, at times, occurred due to improper filling of the inquiry slip by the patient at the inquiry counter. Further, as SGPGIMS is strictly a referral centre, new outpatients are accepted only with a proper reference. The references are expected to be verified at the enquiry counter itself. However, many times, these were not checked meticulously at the enquiry counter and the non-referred patients also entered the system leading to further congestion of the already overloaded registration process. Non-deputation of any trained medico-social worker (MSW) at the enquiry counter was identified as the contributing factor in this regard. Frequent slowing down of the central server also contributed to increase in service time. Mass communication to patients with regards to OPD days of various doctors department-wise was found lacking. There was no board delineating the same in the registration hall. As few departments has an upper ceiling limiting the number of new patients to be registered per day, it is imperative to communicate the same to the patients already in the system, once this ceiling is reached for a particular department. This will ensure that the patients waiting to get registered for that particular department leave the system, thus decongesting it a little. However, these patients were actually made to wait in the queue needlessly and the communication was made only when their turn came to receive the service.

***Table 1**: Showing the arrival rate (AR; number of patients arriving for new registration per minute), λ calculated for each of the 96 time intervals of 10 minutes.*

S.No.	Parametres	Value
1.	Valid Cases	96
2.	Mean	0.67
3.	Standard Deviation	0.36
4.	95% Confidence Interval for Mean	[0.60, 0.74]

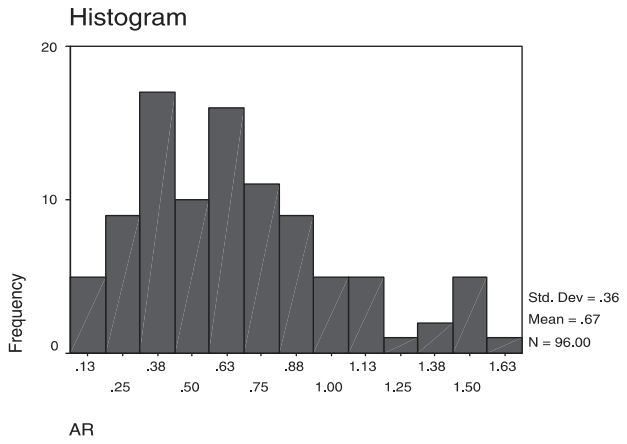

***Figure1:** Histogram showing the distribution of the arrival rate across the range of values*

As clearly depicted in Table 1 & Figure 1, the arrival rate, λ in terms of number of patients arriving for new registration per minute, shows an enormous variation. Maximum λ was observed on first two weekdays and about 1 hour after the start of registration process i.e. between 9 a.m. to 10 a.m. if initial pool of patients ranging from 75-200, which congregates each morning even before the commencement of the registration, is neglected. However λ further showed variation vis-à-vis OPD days and availability hours of different consultants.

Table 2: *Showing the net service rate (SR; total number of patients registered by all available service counters per minute), μ calculated for each of the 96 time intervals of 10 minutes each*

S.No.	Parametres	Value
1.	Valid Cases	96
2.	Mean	1.10
3.	Standard Deviation	0.38
4.	95% Confidence Interval for Mean	[1.03, 1.18]

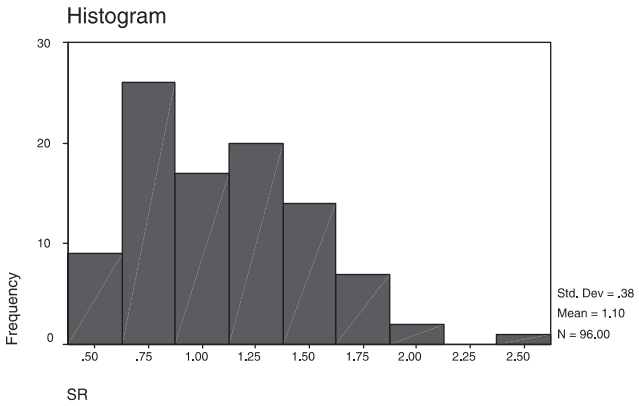

Figure2: *Histogram showing the distribution of the net service rate across the range of values*

Table 2 & Figure 2 delineate the pattern of net service rate, m, calculated in terms of total number of patients registered by all available service counters per minute. The value of m in a particular time interval will be a function of the total number of registration counters operational and the rate at which the registration is being done at each of these counters. It should be well synchronized with l to minimize the number of patients waiting in the system and maximize the efficient use of available resources.

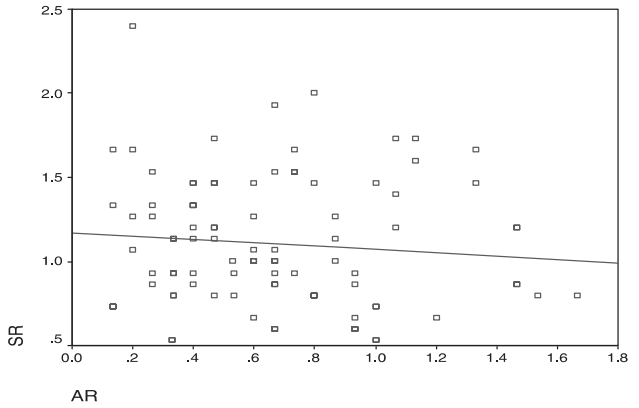

Figure3: *Scatter Diagram showing correlation between the arrival rate (AR; number of patients arriving for new registration per minute), λ & the net service rate (SR; total number of patients registered by all available service counters per minute), μ for each of the 96 time intervals of 10 minutes each*

Table3: *Showing the results of correlation analysis between the arrival rate (AR; number of patients arriving for new registration per minute), λ & the net service rate (SR; total number of patients registered by all available service counters per minute), μ for each of the 96 time intervals of 10 minutes each*

S.No.	Parametres	Value
1.	Valid Cases	96
2.	Pearson Correlation Coefficient	-0.095
3.	p value (2 tailed)	0.357

As value of Pearson Correlation Coefficient, r, in Table 3 is very close to 0, there is no linear association between the arrival rate of the patients and the net service rate provided by all available registration counters. The value of p is also less than 0.05, hence it further validates that the null hypothesis stands and there is no significant linear association between the two variables. In a scatter diagram, if the pattern of dots slopes from lower left to upper right, it suggests a positive correlation between the variables being studied. If the pattern of dots slopes from upper left to lower right, it suggests a negative correlation. A line of best fit can be drawn in order to study the correlation between the variables.[8] In case of strong linear association between any two independent variables, this line will make an angle of 45 degree with x axis. It will be almost parallel to the x axis when no linear association exists between the two variables, as is the case in Figure 3. The scatter diagram shown in Figure 3 thus makes it very conspicuous that the net service rate is not being synchronized according to the arrival rate of the patients. Actually it was quite evident that there was no strict schedule for opening various registration counters.

Kolmogorov-Smirnov Test for Normality, when applied on the service rate per counter calculated separately for time intervals when more than 4 counters were operational (SRPC; expressed as time taken in minutes per patient per counter), gave a p value of 0.2. As the p value is more than 0.05, the null hypothesis stands and we can take the distribution of SRPC as normal. Hence a parametric test like one sample T test can be applied on it.

Table4*: Showing the result of one-sample T test when applied on the service rate per counter calculated separately for time intervals when more than 4 counters were operational (SRPC; expressed as time taken in minutes per patient per counter)*

S.No.	Parametres	Value
1.	Mean	4.96
2.	Test Value	4.50
3.	p value (2 tailed)	0.014

Table 4 gives the p value of the one sample T test to be 0.014 i.e. less than 0.05. **Hence there is a significant difference between service rate per counter when more than 4 counters were operational and the average service rate of a registration counter of 4.5 minutes per patient. Hence staff at different registration counters tends to perform less when more counters are working simultaneously and an increase in number of counters actually leads to a decline in service rate per counter.** It was observed that staff at different registration counters tends to ease up when more counters are working simultaneously. This is in conformance to the fact opined by Karau & Williams that people work less hard in teams.[9] Steiner coined the term 'Processes Loss' to describe the decline in performance, from some theoretical maxim, which groups or teams working towards common output typically show.[10] More frequent unofficial breaks by the staff, when all five or six counters were operational, made the situation worse. Queue discipline was especially questionable when five to six counters were working concurrently. Lack of separate registration counter for staff added to queue indiscipline. Further, lamination machine & token display machine at few counters were not working leading to increased service time. Many staff, specially those relocated from other front office areas to staff the additional registration counters made operational to hasten the whole process during peak hours, lacked proper communication skills. Some of these lacked information and expertise as to which department a particular patient should be referred in case of ambiguity. They were dependent on regular staff for this matter, thus further decelerating the service delivery process.

The number of registration counters operational at a particular point of time seemed to be more guided by the availability of staff from

other front office areas rather than the pattern of the arrival process. This resulted in complete lack of synchrony between the arrival rate and the net service rate. This problem was further exaggerated by the fact that an increase in number of counters actually leads to a decline in service rate per counter. The value of Pearson Correlation Coefficient, r being very close to 0, validates that both these factors are working in synergy to disrupt any positive linear association between the arrival rate of the patients and the net service rate provided by all available registration counters. Besides, the failure of the net service rate to increase sizably despite increasing the number of service counters will independently jeopardize the synchrony between the arrival rate and the net service rate, even if any bona fide attempts are made in this direction. The large pool of patients that congregated each morning even before the commencement of the registration also warrants special attention.

CONCLUSION

The study was undertaken following patients' grievances regarding long waiting time for new registration in the OPD. At the outset, a pilot study was done for one week to identify the main bottlenecks in the system. Due to non-steady state of the registration system and pooling of patients in early morning hours, application of 'Classical Queuing Model' in this problem situation was not possible. Scenario-specific, problem-driven alternative approach to data analysis was thus used. The bottlenecks identified during the pilot study were validated scientifically in the main study using standard statistical techniques, and contributing factors were identified simultaneously. Multiple factors such as lack of synchrony between arrival rate and net service rate, 'Processes Loss', inadequate physical facilities, non-deputation of any trained MSW, lack of soft skills in staff, initial pooling of patients etc. were responsible for astronomical waiting time for new registration in OPD at SGPGIMS leading to patient dissatisfaction.

Following ***recommendations*** are deemed necessary to ameliorate the registration process holistically and significantly assuage the patients' grievances:

1. Instead of 8 a.m., the registration should commence from 7 a.m. onwards. This will partially take care of the initial pool of patients, thus preventing the system from over-congestion even before the start of the registration process.
2. A full time MSW should be present at the enquiry counter. This will ensure the following:
   a. Proper filling of the enquiry slip by the patients.
   b. The references of all patients are meticulously verified at the enquiry counter itself.
3. Computer department should ensure optimal working of the server, especially during peak hours.
4. A notice board detailing the patients on OPD days/availability of various doctors department-wise should be provisioned in the registration hall itself.
5. As soon as the upper ceiling, limiting the number of new patients to be registered per day, of a particular department is reached, it should be communicated conspicuously to all the waiting patients in the system via an electronic sign board.
6. Front office manager should ensure relocation of staff from other front office areas to run additional registration counters vis-à-vis the workload. All six registration counters should be operational between 7 a.m. to 8 a.m. daily to nullify the effect of initial pool. Again all registration counters should be operational between 9a.m. to 10.30 a.m. Additionally, on Mondays and Tuesdays, five counters should be operational between 10.30 a.m. to Noon. In fact, a flexible approach based on perspicacious observations and meticulous follow-ups holds the key.
7. Proper monitoring on the part of front office manager will ensure that staff at different registration counters doesn't ease up when more counters are working concurrently.
8. Hospital Management should ensure that technical and soft skills of the staff manning the registration counters should be regularly evaluated and upgraded, if necessary. In these workshops, special focus should be on staff relocated from other areas to the registration counters during peak hours. Communication and Teamwork should form the crux of soft skill curriculum.
9. Hospital Management should ensure that a separate counter for SGPGI staff with strictly scheduled working hours should be in place. This will ensure queue discipline in the registration system.
10. Maintenance cell should be proactive vis-à-vis lamination machine & token display machine, available at all the six registration counters. This will ensure minimum breakdown of the same.

REFERENCES

1. *Vohra ND; Quantitative Techniques in Management: New Delhi, Tata McGraw-Hill, 2009: 1.*
2. *Chandra, H. & Jamaluddin, K.; Hospital Administration at a glance: Lucknow, Bharat Book Centre, 2010: 8-9.*
3. *Churchman CW, Ackoff RL; Introduction to Operations Research: New York, John Wiley & Sons, 1977: 9.*
4. *Yue W, Takahashi Y, Takagi H; Advances in Queuing Theory & Network Applications: New York, Springer Publications, 2009: 14.*
5. *Bose SJ; An Introduction to Queuing Systems: New York, Kluwer Academic- Plenum Publishers, 2002: 23.*
6. *Kelly FP; Networks of Queues with Customers of Different Types: Journal of Applied Probability, September 1975, 12 (3): 542-554.*
7. *Green L; Queuing analysis in healthcare, in Patient Flow- Reducing Delay in Healthcare Delivery: New York, Springer Publications, 2006: 281-308.*
8. *Utts J; Seeing through Statistics: 3rd Edition, Minnesota, Brooks/Cole Publishing Company, 2005: 166-167.*
9. *Karau SJ, Williams KD; Social loafing- A Meta-analytic Review and Theoretical Integration: Journal of Personality & Social Psychology, 1993, 65(4): 681-706.*
10. *Chapanis A, Ochsman R, Parrish R, Weeks G; Studies in interactive communication- the effects of four communication modes on the behavior of teams during cooperative problem solving: Human Factors, 1972, 14(6): 487-509.*