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A short review on queuing theory as a deterministic tool in sustainable telecommunication system

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ABSTRACT

Telecommunication mechanisms have been conceptualized simply as links between two points to send signals. Telecommunication networks are, at present, characterized by clusters of nodes, interconnecting nodes where information is processed and correctly addressed to the output links. The transmission of messages was assisted by the first telecommunication networks for telegraphy. Mobile phone networks were then built to build a physical call circuit set up to connect the source and destination for the entire duration of the conversation. The networks of today are digital and are focused on the dissemination of signals arranged in blocks, called packets, which are either routed independently along the nodes or transmitted from source to destination through a virtual path. On the basis of the network hierarchy, transmission media are usually distinguished. When a customer of a company has any kind of issue, their first contact with the company is the call center. They give feedback of their issues to the call center and the call center's quality service is so important because the service would determine if the customer's issue is resolved and if the customer would continue to do business with the company afterwards. Deciding an optimum number of operators using key performance index is an important factor in optimizing a communication system. Research carried out show that this optimization can be made using queuing theory approach. A practical application of optimizing a call center using stochastic queuing approach is studied in this review. From the research, the optimal number of operators for the call center was determined for various peak periods considering four performance index measures. The information gathered shown the importance of using queuing theory model as a deterministic tool for optimizing a communication system.
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1. Introduction

A situation in which customers wait in line to be serviced by a company is known as a queue [1]. A queue can be applied as inventories in the manufacturing sector or any service that has to do with interactions with humans. Queuing theory can be applied in areas like; telecommunications [2], road traffic studies and computer network traffic studies [3]. Communication system was very suitable for the application of queuing models and theory. Communication systems can be used in areas like banking, telecommunication companies, market research agencies, insurance etc [4]. Resources that allows delivery of services via telephones constitutes a call centre. Call durations are random in a call centre, incoming calls also arrive randomly determined by a stochastic process while waiting calls may end after a random waiting time, some employees may not show up at work too due to some random reasons, all these implies a call centre can be descried as a complex queuing system/model [5]. In some unique cases, emergency calls may arrive randomly, and they must be attended to as soon as possible, for example, in a hospital call centre or the police call centre. Emergency calls in these cases become top priority. It is the duty of a manager to determine the optimal number of operators a call centre must have but it is the duty of the operator

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to manage their stress level thereby leaving an impression to the customer [6]. The optimal number of operators for a period in a communication system depends on the number of calls the call centre receives at a time and the time it takes for an operator to serve a caller. The key performance index in communication systems are the service quality level and operational cost. Mostly used approach in optimizing a call centre is minimization of the operational cost using the service level as a variable [7]. Duration of a waiting call before a customer is attended to determine the quality of service of the company hence, the satisfaction of the customers. There are a lot of mathematical model that can be applied to optimize a telecommunication system. However, the basic assumptions of the mathematical model must align with the operation of a call centre and its properties [8]. The probability density function of inter-arrival times is the basis for properly selecting mathematical model to describe and analyse a communication system/call centre. The PDF can be derived if all the data about the operation of the call centre are accurate and provided for analysis [9]. A major issue concerning this function is the absence of expert knowledge in the company, usually in a company the number of operators used are predicted via rule of thumbs and not necessarily the optimal number of operators [10]. A practical application on how to optimize a call centre using queuing theory is reviewed in this paper. The call centre used is a Slovenian Telecommunication Provider and the data from this provider will be used to analyse pattern of service and call arrival [11]. From this suitable mathematical queuing model would be selected to optimize the call centre under study; then, an optimal would be determined for various peak period using various performance index measures [12].

1.1. Telecommunication invention

From the development of the telegraph and of the telephone networks (internet) the significance of media transmission innovations has been unmistakably apparent. Individuals need to connect consistently [13]. The trading of data of various kinds is today a flat out need. Broadcast communications favour the improvement of nations and the dispersion of information, and they are playing and will assume a vital job in the public. Initially, media transmission frameworks were essentially considered as connections to transmit data between two focuses [14]. At present, media transmission frameworks are described by systems with hubs, where data is prepared and accurately routed to yield joins, interconnecting hubs. The first media transmission systems for telecommunication bolstered the transmission of messages. At that point, phone systems were imagined setting up a physical circuit at call set up to interface source and goal for the entire term of the discussion [15]. The present systems are computerized and dependent on the transmission of data sorted out in squares, called bundles, which are either freely directed along the hubs or sent through a virtual way from source to goal [16]. Transmission media are normally separated based on the system progression; specifically, contorted sets (copper) or remote transmissions are utilized for the client get to, though, optical fibres are received in the centre system [17]. Media transmission frameworks have arrived at an overall dissemination based on the endeavours of global and territorial normalization bodies, which have accomplished a significant work, permitting various bits of equipment to interoperate based on well-defined conventions and organizations. Rather than having a specific system for each traffic type, the advanced portrayal of data has made it conceivable to efficiently incorporate diverse traffic types and afterward benefits (from voice, to video to information traffic, and so forth.) in a similar system [18]. At present, the system of the systems, that is the Internet, has an enormous around the world expanding dispersion. The result of this amazing procedure is that the Internet convention has become the paste, binding together unique system advancements, from portable to fixed and from earthly to satellite [19]. The focal issue for current media transmission systems is the arrangement of sight and sound administrations with worldwide scale network (additionally including portable clients), ensuring a few Quality of Service (QoS) prerequisites, and separated relying upon the use of the client [20]. System assets are valuable and expensive and must be efficiently used. Then again, computerized data and information traffic overall are encountering an exponential development that speaks to a test to be tended to by the framework fashioner and the system organizers. In this situation, remote access will assume a significant job since from 2011 remote associations have outperformed broadband wired ones [21]. The plan of present-day systems requires a profound information on organize attributes, transmission media types, traffic request measurements, etc. Based on these qualities, logical strategies can be embraced to decide the suitable transmission limit of connections, the quantity of connections, the administration methodology for sharing assets among traffic classes, etc. [22].

2. Determining the optimal service level of a queuing system

Queues are formed when a server cannot service all the customers at once. Usually a queuing system is made up of more than one service unit, customer's arrival, and service process. A queue may lead to increase in the operational costs (waiting cost) [23]. In order to reduce the waiting cost, an optimum service level that ensures better performance of the system should be implemented. It should be noted that the operational cost of the call center when improvements are implemented [24]. Different key performance indicators can be used to indicate the optimal service level of a queuing system in a cell center. These measures can be converted to variables by using a suitable queuing model. The following elements would determine the mathematical model that would be chosen [25].

Pattern of Arrival: a lot of queuing model assumes customers arrive independently and the inter-arrival time is independent and identically distributed. The population of arrivals in a queuing system however depends on whether the call center is a limited/-closed system or open system.

Method of Service: mechanism of service is dependent on the probability density function of service duration, availability of the operator and capability of the system. A lot of the queuing models presumes that customers arrive independently, and the inter-arrival time is independent and identically distributed [26].

The arrangement of the queue is known as queuing discipline. These arrangements include Last In First Out (LIFO) and First In First Out (FIFO), customer selection based on assigned priorities, random customer selection. In a scenario where there is only one server/service unit or a parallel and equivalent number of servers the system is called a simple queuing system [27]. The notations used to describe PDF of service and inter-arrival duration by a simple queuing system are : G – a general distribution of time, D – a deterministic situation, M – a poisson process of the events [28].

Notation M/M/r (infinity/infinity/FIFO): these notations describe a simple queuing system that has ; r parallel servers, unlimited queue, unlimited population, FIFO queuing discipline; while, the inter-arrival duration and service duration are distributed using Exponential Distribution Function (EDF) [29]. The system performance index are closed forms in most simple queuing system. In this type of system all the four measures of performance are available to determine optimal service level. The equation below can be used to calculate the waiting time expected [29].

$$E(W_q) = \frac{1}{S}\frac{(r\rho)^r}{r!(1-\rho)^2 r\sigma} \tag{1}$$

The expected customer waiting customers is given by the expression:

$$E(N_q) = \frac{1}{S}\frac{(r\rho)^r \rho}{r!(1-\rho)^2} \tag{2}$$

The probability that customer would have to wait a random time due to a server being busy is

$$P_{wait} = \frac{1}{S}\frac{(r\rho)^r}{r!}\frac{1}{1-\rho} \tag{3}$$

The condition above is otherwise called the Erlang C recipe [27] and assumes a significant job in the presentation of phone frameworks. The administration level is the most widely recognized proportion of nature of the call community administration. It is characterized by a given percentile of the holding up time appropriation, and can be determined by the accompanying articulation:

$$SL(t_0) = P[W_q \le t_0] = 1 - \frac{1}{S}\frac{(r\rho)^r}{r!(1-\rho)}\exp(-(1-\rho)r\sigma t_0) \tag{4}$$

The condition (4) gives the drawn-out part of clients whose holding up time q -W and line is no bigger than a limit t0 [6], The images utilized in conditions (1) to (4) mean

r: quantity of the servers

α: appearance rate- $1/\alpha$ is the normal time between the two progressive appearances

σ: administration rate- $1/\sigma$ is the normal help time

ρ: traffic power determined as $\rho = \alpha/r\sigma$

S: entirety to be determined as follows:

$$S = 1 + r\rho + \frac{(r\rho)^2}{2!} + \cdots + \frac{(r\rho)^{r-1}}{(r-1)!} + \frac{(r\rho)^r}{r!}\frac{1}{1-\rho} \tag{5}$$

Eqs. (1) to (4) bode well when the value $S < \infty$. The condition can be met when $\rho < 1$. Condition $\rho < 1$ensures that consistent state circulation exists. In this case the interminable lines are not framed and the lining framework despite everything works after a since quite a while ago run. The base number of servers are expected to fulfill the consistent state condition is the most minimal whole number that satisfy the condition

$$r > \frac{\alpha}{\sigma} \tag{6}$$

2.1. Exploiting simulation for call center optimization

The duty of a communication system manager is to run the system at a low operational cost with a high service level. In order to achieve these contradicting goals, the manager has to optimize the number of operators/agents, by matching the right skills to the right peak period so as to deliver service for uncertain demands that vary with time [24]. Nevertheless, with the high number of queuing model that can be applied to optimize a call center, the gap in the performance measure of an ideal call center to a real time call center is wide. These approaches have one limitation, they cannot predict randomness. This shows that DES is the most viable model to optimize a queuing system for accurate real time performance index modeling as well as being a good decision support model. As call traffic management increases in complexities, the need for a good decision support model increases as well as usage of various channel in communication system operations [25].

Albeit numerous scientists have just investigated the utilization of DES in call focus condition, they have not legitimately tended to the issues of compelling directing arrangements that frequently join need rules for the calls and specialists [26]. In particular, the number and sorts of operators, who handle the calls and the working timetables of these specialists under limitations on the nature of administration and on acceptable calendars is one of the primary improvement issues experienced in dealing with these multi-aptitude call focuses. Without appropriate DES models, it is exceptionally hard for the supervisors to manage such issues and to investigate 'imagine a scenario where' situations consistently. Without such models, administrators cannot imagine the results of various procedure changes before they are executed [27]. Recently, communication systems have become more pivotal in business transactions, and has been a medium of employment for millions of employees and operators around the world and as well ass been the major medium of interaction with the customers in many business industries [28]. Communication system has become a growing area of interest for researchers of operations management on topics like personal scheduling, queuing, forecasting etc. the challenges that are being tackled by the call centers managers are becoming more complex as telecommunications and information technology advances [29]. Domains like marketing and sales and human resources management have become more pivotal in the operations of communication systems and research in the field. The mode of operations management in call centers is being reviewed in this paper [30]. This paper main theme includes new management issues caused by advancement of technologies, interrelationship between marketing and sales and call center/communication systems operations, as well as paying attention to basic areas of research. Most companies are investing in improving the assistance and information offered to customers. With the advancement of technologies [31], decrease in the cost of telecommunications and information technology usage has made it easier for companies to combine information and data delivery function, communication with customers are also now less costly thereby improving operations. There are companies that deal with the management of the inter arrival calls for companies [33]. They however only handle incoming calls known as inbound calls. Inbound calls of a communication system are labor intensive and the cost of agents who operates the telephones makes up 80% of the total cost of operations. Call centers operations can take place in physical locations in different time zones or states or different regions. Communication systems operations constitute a large part of the global economy now. It is difficult to get accurate statistics on inbound calls, however, the Incoming Call Management Institute (ICMI), keeps a record of published statistics in the industry by from various sources of origin. [34]. On the basis of the efforts of international and regional standardization bodies, which have done an important job, telecommunication systems have entered a worldwide diffusion, enabling various pieces of technology to communicate and collaborate on the premise of very well-defined protocols and formats. The network of communications, that is, the Internet, has a massive network. Globally increasing transmission. The consequence of this amazing phase is that, from mobile to fixed and from terrestrial to satellite, the network layer has become the cornerstone, binding together numerous network technologies.

3. Justification

Queuing theory can be applied in various sectors like a) computer network traffic studies b) telecommunications c) road traffic. Queuing theory is one of the applications of stochastic model theory [24,35,36]. Most literature in the area of queuing theory shows that Stochastic Model can be used to optimize and analyse how efficiently the call centres are being used by various companies

for providing information and assistance to customers and also for marketing and sales purposes. The mathematical model selected would determine how relevant and useful the results gotten would be. The selection for mathematical model could base on the analyses if the probability distribution functions of these variables; service duration (call time length) and inter-arrival times (time between successive calls), and these variables are random in nature [37]. These parameters can be derived if the data about the operations of the communication system gathered is accurate and complete. Modern technologies allow entering of data, events, and information in the communication system, thereby making available for the mathematical model analysis the needful data. Nevertheless, lack of expertise in the application of the data, makes the optimization of the call centre operations difficult. As stated earlier the number of operators in a communication system is still based on rule of thumbs and is usually not the optimum number of operators per peak period [38,39].

4. Conclusions

Most recent literatures show that waiting time may not only be the performance index for the level of service quality. Customers seems to place priority on other measure of performance like; perceived agent behavioral pattern, perceived agent competency, perceived agent friendliness, perceived agent politeness and resolution on the first call. Therefore, if there is need to consolidate service quality and customer values, the pdf for optimal service quality level must be reflected upon. Subsequently, research on scheduling and adjustment of schedules and schedule flexibility should be done to effectively allocate personal schedules to call centers operators for the entirety of the time duration. Another viable and effective approach for performance modeling is discrete event simulation and it could be considered too, when optimizing call center operations.

CRediT authorship contribution statement

S.A. Afolalu: Investigation, Writing - original draft. **O.M. Ikumapayi:** Writing - review & editing, Resources. **A. Abdulkareem:** Writing - review & editing. **M.E. Emetere:** Writing - review & editing, Funding acquisition. **O. Adejumo:** Writing - review & editing, Funding acquisition.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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References

[1] A. Attahirusule, Queuing Theory for Telecommunications: Discrete Time Modelling of a Single Node System, Springer, New York, 2010.
[2] Afolalu, S. A., Babaremu, K. O., Ongbali, S. O., Abioye, A. A., Abdulkareem, A., & Adejuyigbe, S. B. (2019, December). Overview Impact of Application of Queuing Theory Model on Productivity Performance In A Banking Sector. In Journal of Physics: Conference Series (Vol. 1378, No. 3, p. 032033). IOP Publishing.
[3] T.G. Robertazzi, Computer Networks and Systems: Queuing Theory and Performance Evaluation, 3rd ed., Springer, New York, 2000.
[4] L. Brown, N. Gans, A. Mandelbaum, A. Sakov, H. Shen, S. Zeltyn, L. Zhao, Statistical analysis of a telephone call center: A queuing-science perspective, J. Am. Stat. Assoc. 100 (469) (2005) 36–50.
[5] O.M. Ikumapayi, E.T. Akinlabi, P. Onu, S.A. Akinlabi, M.C. Agarana, A Generalized model for automation cost estimating systems (ACES) for sustainable manufacturing, J. Phys. Conf. Ser. 1378 (2019) 032043, https://doi.org/10.1088/1742-6596/1378/3/032043.
[6] A.N. Avramidis, W. Chan, M. Gendreau, P. L'Ecuyer, O. Piscane, Optimizing daily agent scheduling in a multiskill call center, Europ. J. Operat. Res. 200 (3) (2010) 822–832.
[7] Aksin, Z., Armony, M. and Mehrotra, V. (2007), The Modern Call Center: A Multi-Disciplinary Perspective on Operations Management Research, Production and Operations management, Vol. 16 No. 6, pp. 665-688.
[8] Dombacher, C. (2010), Queuing Models for Call Centers, available at http://www.telecomm.at/documents/Queuing_Models_CC.pdf / (12 June 2013)
[9] E. Chassioti, Queuing Models for Call Centers (PhD thesis), Lancaster, Lancaster University Management School, 2005.
[10] A. Brezavšček, A. Saje, J. Šumi, Call center efficiency analysis using stohastic queuing models] 19th Conference Dnevi slovenske informatike, Slovenia, Slovenian Society Informatika, Ljubljana, Portorož, 2012.
[11] Brezavšček, A. and Baggia, A. (2013), Stochastic queuing models: a useful tool for a call center performance optimization, The 12th International Symposium on Operational Research in Slovenia, - Section for Operational Research, Ljubljana, pp. 259-264.
[12] M. Žugaj, K. Dumičić, V. Dušak, Temelji znanstvenoistraživačkog rada, Metodologija i metodika, Varaždin, Sveučilište u Zagrebu, Fakultet organizacije i informatike, 2006.
[13] M. Kembe, E. Onah, S. Iorkegh, A study of waiting and service costs of a multi-server queuing model in a specialist hospital, Int. J. Sci. Technol. Res. 1 (8) (2012) 19–23.
[14] F. Gorunescu, S.I. McClean, P.H. Millard, A queueing model for bed-occupancy management and planning of hospitals, J. Operat. Res. Soc. 53 (1) (2002) 19–24.
[15] S.O. Ongbali, S.A. Afolalu, P.O. Babalola, Supply chain management and the accompanying problems in production environment: A review, Int. J. Mech. Eng. Technol. 10 (5) (2019) 613–619.
[16] O. Ongbali Samson, A. Afolalu Sunday, Y. Salawu Enesi, Bottleneck problems arising in inter-industry production setting and vertical integration: a review, Technol. 10 (5) (2019) 606–612.
[17] N. Ameh, B. Sabo, M.O. Oyefabi, Application of queuing theory to patient satisfaction at a tertiary hospital in Nigeria, Nigerian Med. J. J. Nigeria Medi Assoc. 54 (1) (2013) 64.
[18] J.K. Cochran, K.T. Roche, A multi-class queuing network analysis methodology for improving hospital emergency department performance, Comput. Oper. Res. 36 (5) (2009) 1497–1512.
[19] O. Ongbali Samson, S.A. Afolalu, U. Mfon, Model identification technique in production system with stochastic output, Int. J. Mech. Eng. Technol. 9 (11) (2018) 2396–2404.
[20] O. Ongbali Samson, S.A. Afolalu, A.C. Igboanugo, Bottleneck problem detection in production system using fouriertransform analytics, Int. J. Mech. Eng. Technol. 9 (12) (2018) 113–122.
[21] E.Y. Salawu, I.P. Okokpujie, S.A. Afolalu, O.O. Ajayi, J. Azeta, Investigation of production output for improvement, Int. J. Mech. Product. Eng. Res. Develop. 8 (1) (2018) 915–922.
[22] T. Raheja, Modelling traffic congestion using queuing networks, Sādhāna 35 (4) (2010) 427–431.
[23] I.A. Ismail, G.S. Mokaddis, S.A. Metwally, M.K. Metry, Optimal treatment of queuing model for highway, J. Computat. Model. 1 (1) (2011) 61–71.
[24] Sunday A. Afolalu, Oluwasegun J. Adelakun, Samson O. Ongbali, Abiodun A. Abioye, Oluseyi O. Ajayi, Oloyede Olamilekan R (2019). Scheduling -An Index Factor in Production Planning Control made on-time for delivery. Proceedings of the World Congress on Engineering 2019 WCE 2019, July 3-5, 2019, London, U.K
[25] N.M. Van Dijk, R.J. Bouchiere, Queuing Networks: A Fundamental Approach, Springer, New York, 2011.
[26] Akhtar, S. and Latif, M. (2010), "Exploiting Simulation for Call Center Optimization", in Proceedings of the World Congress on Engineering Vol. III, Newswood Limited, London, pp. 2963-2970.
[27] Ongbali S. O., Afolalu S. A. and Udo M. O. (2018). Model Selection Process in Time Series Analysis of Production System with Random Output in IOP Conference Series Materials Science and Engineering (Vol. 413, No. 2, p. 012057). IOP Publishing.
[28] Elewa, R. E., Afolalu, S. A., & Fayomi, O. S. I. (2019, December). Overview Production Process and Properties Of Galvanized Roofing Sheets. In Journal of Physics: Conference Series (Vol. 1378, No. 2, p. 022069). IOP Publishing.
[29] Samson, O. O., Afolalu, S. A., Ojo, S. F., & Oladipupo, S. (2019, December). Inventory replenishment in multi-stage production setting under stochastic demand: a review. In Journal of Physics: Conference Series (Vol. 1378, No. 3, p. 032072). IOP Publishing.
[30] O. Garnett, A. Mandelbaum, M. Reiman, Designing a call center with impatient customers, Manufact. Serv. Operat. Manage. 4 (3) (2002) 208–227.
[31] V. Mehrotra, O. Ozlük, R. Saltzman, Intelligent procedures for intra day updating of call center agent schedules, Product. Operat. Manage. 19 (3) (2010) 353–367.
[32] A.S. Afolalu, O.J. Adelakun, S.O. Ongbali, A.A. Abioye, O.O. Ajayi, Queueing theory – A tool for production planning, Health Care. 0958 (2019).
[33] Armony, M., Israelit, S., Mandelbaum, A., Marmor, Y. N., Tseytlin, Y., & Yom-tov, G. B. (2015). On Patient Flow in Hospitals: A Data-Based Queueing-Science Perspective.

[34] D. Gross, J.F. Shorttle, J.M. Thompson, C.M. Harris, Fundamentals of queuing theory, Wiley Series in Probability and Statistics, New Jersey, 2008.
[35] Akhtar and Latif (2010) Arha, G. (2017). Reducing Wait Time Prediction In Hospital Emergency Room : Lean Analysis Using a Random Forest Model.
[36] E. Onah, S. Iorkegh, A study of waiting and service costs of a multi-server queuing model in a specialist hospital, Int. J. Sci. Technol. Res. 1 (5) (2017) 10–24.
[37] O.M. Ikumapayi, S.T. Oyinbo, E.T. Akinlabi, N. Madushele, Overview of recent advancement in globalization and outsourcing initiatives in manufacturing systems, Mater. Today Proc. 26 (2) (2020) 1532–1539, https://doi.org/10.1016/j.matpr.2020.02.315.
[38] Afolalu, S. A., Ikumapayi, O. M., Ongbali, S. O., Afolabi, S. O. (2020). Analysis of Production Scheduling Initiatives in the Manufacturing Systems. International Journal of Mechanical and Production Engineering Research and Development (IJMPERD). Vol. 10, Issue 3, Jun 2020, 1301-1318. 10.24247/ijmperdjun2020113. Indexed in Scopus
[39] O.M. Ikumapayi, E.T. Akinlabi, F.M. Mwema, O.S. Ogbonna, Six sigma versus lean manufacturing – An overview, Mater. Today Proc. 26 (2) (2020) 3275–3281, https://doi.org/10.1016/j.matpr.2020.02.986.