OPTIMAL NO. OF CREW IN A WORKSHOP SUBJECT TO MINIMIZE THE TOTAL COST

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ARTICLE INFO	ABSTRACT
	Purpose: The main objective of this paper is, to determine the optimal no. of technicians' men in a workshop crew of an Industrial System. **Theoretical framework:** The purpose of applying these tools is to explore their ability to reduce costs and improvements that can be obtained in the process of providing services to the end customer. **Design/methodology/approach:** The literature structure review was built from analyzing 12 of scientific papers and books, from web sciences and the Elsevier database. The papers were analyzed from descriptive, methodologic, and citation characteristics. **Finding:** By applying the equation model of the paper, the optimal no. of technician men in the crew of the workshop can be determined when it meets the lowest total costs of operating cost and technicians cost taking into account the arrival rate and the service rate. **Research practical& social implication:** The data that examined in this paper assumed the number of technicians starting with the number that makes the measure of performance logical and acceptable. **Originality/ value:** The paper is academic research, aimed at the application of queuing theory especially the multi-server decision, where it can lead to a better maintenance decision.

Nº IDEAL DA EQUIPE EM UMA OFICINA SUJEITA A MINIMIZAR O CUSTO TOTAL

RESUMO

Objetivo: O principal objetivo deste artigo é determinar o número ideal. de homens técnicos em uma equipe de oficina de um Sistema Industrial.

Referencial teórico: O objetivo da aplicação dessas ferramentas é explorar sua capacidade de redução de custos e melhorias que podem ser obtidas no processo de prestação de serviços ao cliente final.

Desenho/metodologia/abordagem: A revisão da estrutura da literatura foi construída a partir da análise de 12 artigos científicos e livros, de ciências da web e da base de dados Elsevier. Os artigos foram analisados a partir de características descritivas, metodológicas e de citação.

Descoberta: Aplicando o modelo de equação do papel, o não ideal. de homens técnicos na tripulação da oficina pode ser determinado quando atende aos menores custos totais de custo operacional e custo de técnicos levando em consideração a taxa de chegada e a taxa de serviço.

Implicação prática e social da pesquisa: Os dados examinados neste artigo assumem o número de técnicos a partir do número que torna a medida de desempenho lógica e aceitável.

Originalidade/valor: O artigo é uma pesquisa acadêmica, voltada para a aplicação da teoria das filas principalmente a decisão multi-servidor, onde pode levar a uma melhor decisão de manutenção.

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NÚMERO ÓPTIMO DE TRIPULACIÓN EN UN TALLER SUJETO A MINIMIZAR EL COSTO TOTAL

RESUMEN

Propósito: El objetivo principal de este trabajo es, determinar el número óptimo. de técnicos en una cuadrilla de taller de un Sistema Industrial.

Marco teórico: El propósito de aplicar estas herramientas es explorar su capacidad para reducir costos y las mejoras que se pueden obtener en el proceso de prestación de servicios al cliente final.

Diseño/metodología/enfoque: La revisión de la estructura de la literatura se construyó a partir del análisis de 12 artículos y libros científicos, de ciencias web y la base de datos Elsevier. Los artículos fueron analizados a partir de características descriptivas, metodológicas y de citación.

Hallazgo: Aplicando el modelo de ecuaciones del papel, el óptimo no. de hombres técnicos en la cuadrilla del taller se puede determinar cuando cumple con los costos totales más bajos de costo operativo y costo de técnicos teniendo en cuenta la tasa de llegada y la tasa de servicio.

Implicaciones prácticas y sociales de la investigación: Los datos que se examinaron en este artículo supusieron el número de técnicos a partir del número que hace que la medida del desempeño sea lógica y aceptable.

Originalidad/ valor: el artículo es una investigación académica, dirigida a la aplicación de la teoría de colas, especialmente la decisión de múltiples servidores, donde puede conducir a una mejor decisión de mantenimiento.

Palabras clave: Teoría de Colas, Modelo de Colas Multiestado, Unidades Fallidas, Averías, Tiempo de Espera, Tasa de Llegada, Tasa de Servicio.

INTRODUCTION

Visits to and conversations with several reputable companies and organizations with maintenance procedures ranging from the simple to the complex that support the authors' first assessment of industry maintenance methodologies. The utilization of workshop technicians dispatched to a wide range of manufacturing locations within an organization, to the maintenance workshop, is occasionally required for failed units. These units will resume production after some period, with upon on the workload of the workshop.

During the workload of the organization, the fail units rise up and the workshop will be then busy of receiving the fail units, which make them, wait until the service is available in the workshop. Service delay is unavoidable as a system gets blocked. There will be a cost of downtime units and the cost of operations in workshop.

It is clear that the workshop can presented as a queuing system, where the fail units arrive and get maintenance operations immediately if the workshop technician available, otherwise, wait in a queue, and so on. The workshop blocked as the workload a rise, more fail units have to wait for maintenance operation, which leads to more down time and costs. As a result, the Company needs to assess, its workshop service systems while taking into account the queue system's peculiarities. These traits include the likelihood of unoccupied technicians,

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The Average no. of failed units in the queue, the Average no. of failure units in the system, the Average Waiting Time for failure units in the queue, the average waiting time for failure units in the system, and the average number of busy technicians.

As the arriving of fail units gets faster than it can be processed, the queue will be up to infinite queue, (in practice, an infinite queue cannot be formed). A.K. Erlang, a Danish engineer, first began to research queuing theory and waiting in lines at telephone facilities in 1913. Moreover, since, the principles are applied to computing, telecommunication, traffic engineering, and the configuration of offices, stores, factories, and hospitals.

Kandenmir, C; Cavas, I, (2007) (Abuzaid et al., 2022)(A et al., 2022), some queueing theory-based model is used in the current study to account for insulin level and insulin receptor density. The queueing theory used to compute some factors, including the number of insulin receptors, the optimal insulin level, and the least amount of energy needed.   .

Kembe, M.M, Onah,E.S, Iorkegh,S (2012), have studied multi-server queuing model and the waiting and the service costs of a Riverside Specialist Clinic, with the view to determining the optimal service level.**Lakshmi C.; Sivakumar Appa Iyer, (2013),** This paper reviews the contributions and applications of queueing theory in the field of health care management problems. This review proposes a system of classification of health care areas, which examined with the assistance of queueing models. **S.   shanmugasundaram.   S. Punitha, (2014),** Through simulation, the multichannel queuing system is analyzed using the study's goal to identify queueing theory and its analysis using data from a hospital that has assigned a patient to see a doctor**. E. Berhan, (2015),** In order to estimate the service performances of the bank system in Addis Ababa, this study focuses on the multi-channel queue model technique. The results of one of a private bank's branches were as a case study**. Ahmad Muhajir and Nikenasih Binatari (2017)**, presented a study of determine the principles of the queue system which then to optimize the number of servers in regards to the total cost, **A.K. S. Jarden, (2017)**, has introduced concepts of optimization; brought to bear upon that resolution of decision-making problems pertaining to equipment reliability, maintenance, and replacement. Which lead us to other applications for queuing characteristics in maintenance decisions. The practical work shows that the queue model represented by (M/M/k) :(GD/∞/∞). The waiting and service rates utilized to measure the number of servers. **Lawal et al., (2019),** was discovered that for the morning session patient waiting and service costs with the evening session costs were the optimal value for the queuing system after the two conflicting costs were

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balanced. **Muhammad, I ; Adamu,L (2020),** determined the optimal no. of servers in a network queuing system to minimize the patient waiting time at the Tertiary Institution Clinic.

LITERATURE REVIEW

Downtime Analysis

When a unit fails, it enters the workshop for maintenance. The workshop can decomposed in to a number of different subtasks and delay times**.** As shown in fig. (1).

Figure (1), Total Downtime, (Lawal Adamu , A. Isaac, A. Abubakar, (2019)
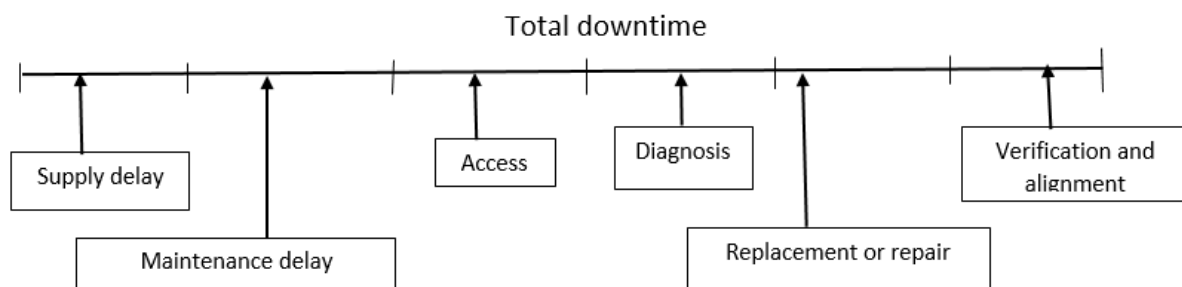
1- **Supply delay** represents the total delay time in searching necessary spare parts or component, in which to complete the repair process. The supply delay time will be zero if the needed replacement part is immediately available.

2- **Maintenance delay time** is the time needed in waiting for maintenance resources or crew. Maintenance delay time in influenced by the number of assigned technician men. If the technicians are available on failure of the unit, the maintenance delay time is zero, (**Charles E. Ebbeling, (1997)**.

3- **Access time:** Is the amount of time required to get access, to the failed component. For example, it may require a removable of panels or covers.

4- **Diagnosis time:** Is the amount of time required to determine the cause of the failure.

5- **The repair time**: Once the problem has identified, the replacement time only includes the time spent working directly on the failed unit to finish the restoration procedure. **Hamdy A. Taha, (2017).** With all the downtime parts that the fail units pass through in the maintenance workshop, will be costly for the organization.

The Cost Optimization

The cost optimization mode that attempt to minimization, the Sum of the Cost of offering the Service and the Cost of Waiting, by fail units. Figure (2), depicts a typical of Cost

Model, where the Cost of Service increases with, the increase of Service Level. At the same time, the Cost of Waiting in the system decreases with the increase in the Level Service, (**Viliam Makis &Andrew K. S. Jardine.(02 December 2017)).**

Figure (2), cost optimization, (Viliam Makis &Andrew K. S. Jardine.(02 December 2017)).
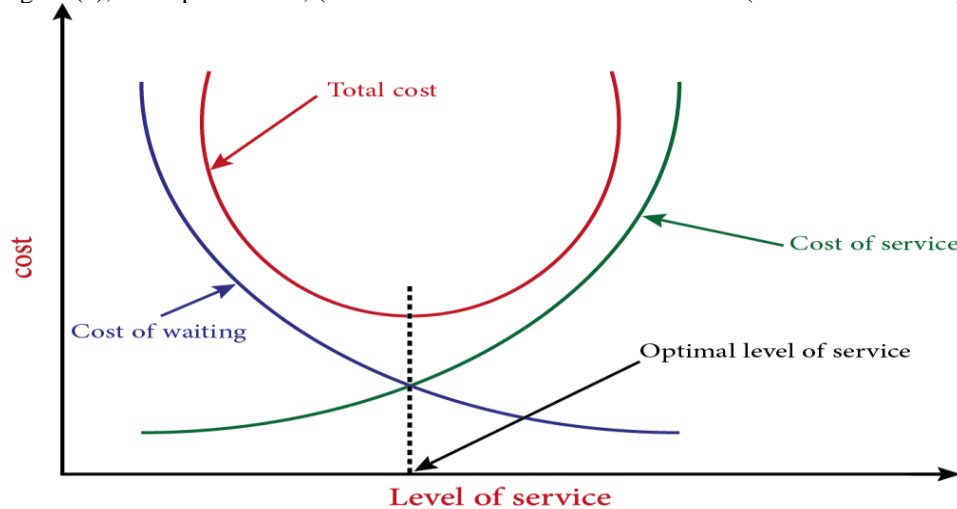
(The highest level of service means deciding the maintenance actions properly and less downtimes.)

MATERIAL AND METHODOLOGY

Relatively high proportion of Industrial and Engineering Systems consists of several components, that are repairable or replaceable, (**Muhammad, I; Adamu, L. (19 October 2020)).** This signifies that following a failure, the system, and component repaired, or some of its components replaced in order to restore operation or operational readiness. According to this assumption, there is no major distinction between a repair and replacement, except in the number and types of spears used. Therefore, in this paper, for simplicity, we assume that all repairs and replacements as repairs.

Queuing theory deals with problems of congestion where items arrive at the service channel perhaps wait in a queue, served in service channels, and then leave the service facility. In maintenance problems customers may take the form of failing units arriving at a workshop from various production facilities, breakdowns occurring in a group of machines, and servers in this case could be the technician men crew in the workshop, (**Kembe et al. (2012)).**

By determining the workshop size and the no. of Technician men in maintenance crew, the Average Time that the fail unit has to wait in a queue, the Average no. of fail units in the system and the Average of Idle Time for maintenance. Crew will be then determined. Moreover,

it may be possible to identify the Optimal size of the maintenance crew in which to minimize the total cost of service and downtime incurred due to failing units waiting in the queue for service.

The arrival of the breakdowns is independent; there is only one line queue (single waiting line), with arrival rate (λ). The idle technician man will serve the fail unit at the head of queue. The system is the first-come-first-served discipline,(**Lawal Adamu , A. Isaac, A. Abubakar. (2019)).** after the fail units get the maintenance operations at the workshop, with the service rate (µ), it may leave the workshop and back to work.

Model Assumption

- The Arrival Rate of breakdowns to the workshop requiring maintenance operations is "Poisson distribution" with Arrival Rate **λ**.

- The Service Time a crew requires, to maintain the breakdowns is "Negative Exponential" distributed; with mean (**1/µ**).

- The Downtime Cost per time, for a breakdown units waiting in the system (either served or in the queue) is **Cd.**

- The Cost of operation per time for each technician man in the crew of maintenance (operating or idle) is **Ct**.

- The objective is determine the optimal number of technicians in the crew of maintenance (**n),** in which to minimize the total cost per time **C (n)** of the system.

The M/M/S Model

The Multi-Channel Queuing model is used mostly in analyzing service stations with more than one server. Assuming that all servers are independent the service time is following an identical distribution by mean service time **µ, (Hamdy A. Taha, (2017)).**

Multi-Channel model (M/M/S): (GD/ ∞ / ∞) where the number of arrivals is "Poisson" distributed, the service time is an "Exponential distribution", there are S servers(S>1), the queuing discipline is general discipline. The system capacity and the population are both infinity, (**Kembe et al. (2012)).**

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The Formulas for Multi-channel Model

The probability of idle technician, (service channel), (G. Donald, F.S. John, M. T. James, and M. H. Carl, (2008)),

$$Po = \frac{1}{\left[\sum_{n=0}^{n=k-1} \frac{1}{n!}\left(\frac{\lambda}{\mu}\right)^n\right] + \frac{1}{k!}\left(\frac{\lambda}{\mu}\right)^k \frac{k\mu}{k\mu-\lambda}}$$

…. ……(1)

The probability that (k) or more units in the system.

= The probability that the arrivals has to wait.:

$$Pk = \frac{1}{k!}\left(\frac{\lambda}{\mu}\right)^k \frac{k\mu}{k\mu-\lambda} \cdot po$$

……….. (2)

The average number of units in the queue:

$$Lq = \frac{\lambda\mu \left(\frac{\lambda}{\mu}\right)^k}{(k-1)!(k\mu-\lambda)^2} \cdot po$$

…………(3)

The Average No. of units in the system:

$$Ls = \frac{\lambda\mu \left(\frac{\lambda}{\mu}\right)^k}{k! \ (k\mu-\lambda)^2} \cdot po + \frac{\lambda}{\mu}$$

………(4)

The Average Time a unit spend in the queue:

$$Wq = \frac{\mu \left(\frac{\lambda}{\mu}\right)^k}{(k-1)!(k\mu-\lambda)^2} \cdot po$$

…………..(5)

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The average Time a unit spend in the system:

$$\text{Ws} = \frac{\mu \left(\frac{\lambda}{\mu}\right)^k}{(k-1)!(k\mu-\lambda)^2} \cdot po + \frac{1}{\mu}$$

………(6)

By simplifying:

$$\text{Ls} = \text{Lq} + \frac{\lambda}{\mu} \qquad\qquad ………… (7)$$

$$\text{W s} = \text{Wq} + \frac{1}{\mu} \qquad\qquad ……….(8)$$

Average busy Time per week for technician man=

Average No. of fail units per week X Average time of service

$$= \frac{\lambda}{n} \text{ X } \frac{1}{\mu} \qquad\qquad ………(9)$$

Therefore

Average Idle Time per week = 1- $\frac{\lambda}{n\mu}$ ………. (10)

Model Formulation

The main formula for our objective is *C (n)*, where:

C (n) = **Cost per time for the technicians in maintenance crew + Downtime Cost**

per time due to breakdown units being in the system.

Cost per time for technicians in maintenance crew = Number of technicians in the

maintenance crew

X cost per time per one technician.

= *n .Ct* ……….(11)

Ct, represent the cost of each technician man.

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Downtime Cost per unit time due to breakdown units being in the System =

Average Waite in the System per breakdown unit X Arrival rate of breakdown units in the system per time

X   Downtime cost per unit time /breakdown unit.

$$= \quad Ws\,.\lambda\,.Cd \qquad ………..(12)$$

Cd, represent the downtime cost of the fail units.

Where, *Ws* = mean Waite of a breakdown unit in the system.

Hence, adding (1), (2)   we have,

$$C\,(n) = n.Ct + Ws.\lambda.Cd \qquad ……….(13)$$

In this model, we relate the number of technicians in the maintenance crew to the total cost.

RESULTS AND DISCUSSION

We assume that the arrival rate of the fail units to the workshop $\lambda=30$ unit /week, and the service rate for one technician $\mu= 6$ unit/week.

The downtime cost=$500 /week, the cost of each technician=$200/week.

As the No. of technicians is growing in Table (1), the prob. Of idle technicians is rising, and the average No. of failed units in the system (Ls), and in the workshop (Lq) is getting less. The average time of waiting for the fail units in the workshop (Ws) is getting less as well.

Table (1). Performance Measures of Multi-server Queuing Model and the Total cost per week

n	P0	Lq	Ls	WS	C(n)
6	0.0039	2.5461	7.5461	0.2515	4973
7	0.0046	1.1529	6.1529	0.2051	4476.4
8	**0.0046**	**0.3991**	**5.3991**	**0.18**	**4299.6**
9	0.0042	0.1401	5.1401	0.1713	4370
10	0.0044	0.0566	5.0566	0.1686	4528.3
11	0.0043	0.0211	5.0211	0.1674	4710.6
12	0.0043	0.0076	5.0076	0.1669	4903.8

Source: Prepared by the authors (2022).

From the result Table (1) and (2), it's clear that the minimum cost appears when the number of the technicians equal (8),also the figure (3), illustrates the underlying pattern of downtime and technician costs which when added together give the Total Costs in Table(2).
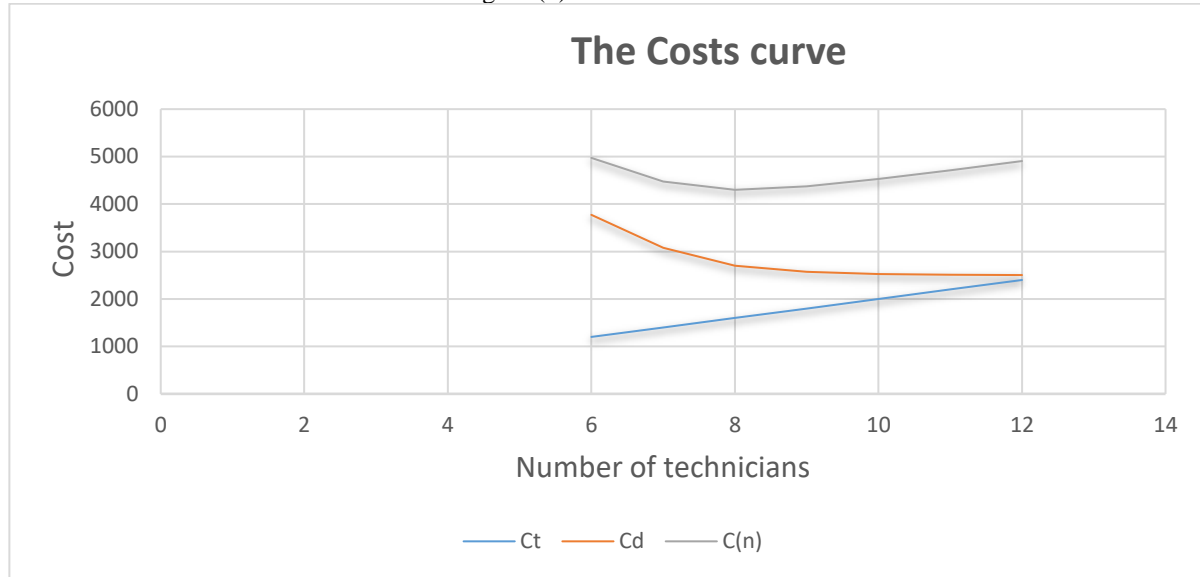
The optimal number of technicians in the maintenance crew equal (eight).When the number of technician equal (one), then $\rho=\lambda/n\mu$. The Arrival traffic intensity is greater than (one). Thus, an infinite queue will eventually build up since failed units arrive faster than it processed and so we consider arrivals cases of (n) at least equal to (six).

Table (2).The Costs table

n	Ct	Cd	C(n)
6	1200	3773.034	4973.034
7	1400	3076.428	4476.428
8	**1600**	**2699.552**	**4299.552**
9	1800	2570.029	4370.029
10	2000	2528.279	4528.279
11	2200	2510.559	4710.559
12	2400	2503.817	4903.817

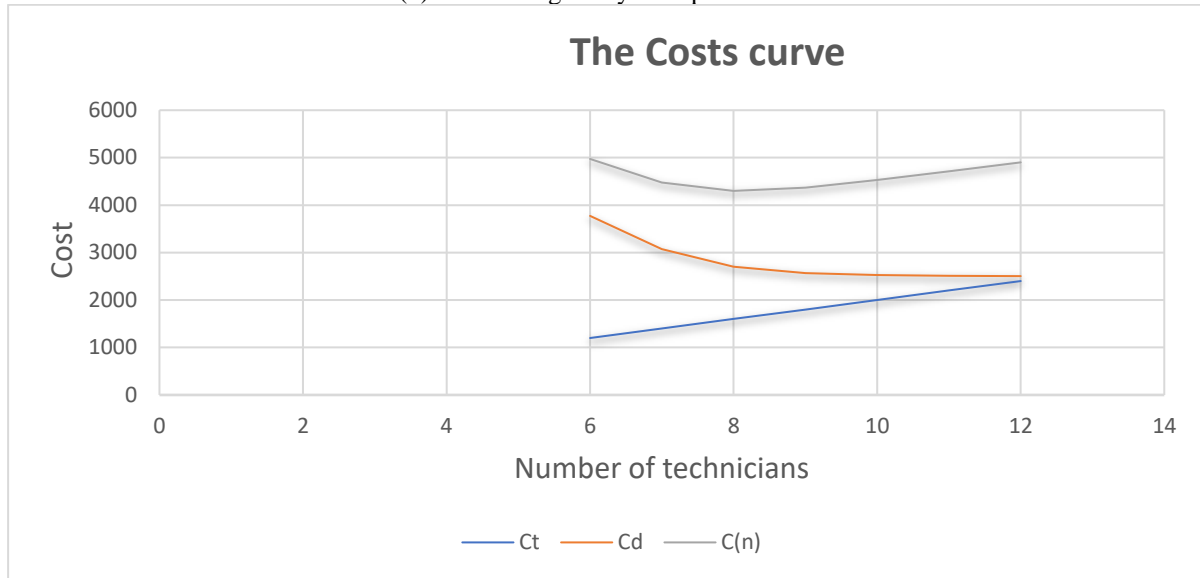(Source: prepared by the authors,(2022))

Figure (3). Total Cost curve

(Source: prepared by the authors,(2022))

The average of the Idle Time and busy time per week for different number of technicians are in Table (3).

Note that when (**n=8**), is the Optimal number of the total cost, **The Average Idle Time= 37% and The Utilization =62%.** So often, the comment made that, a high-level utilization for technician man is they do their duty efficiently. In some cases this will be so but, if the utilization of the technician man were increase (say from62% to 83%) which would occurs when (n=6), the Total Cost per week would be increased from **$4299.552** to **$4973.034**, at this point we should remember or objective to achieve the minimum total costs in our maintenance decision.

Table (3). The average busy time per technician man

The Costs curve

(Source: prepared by the authors,(2022))

CONCLUSION

In Industry systems, as the workload appears, this load effects to the machines duty. Which may cause breaking downs. the costs are then rise up including the repairing cost and the down time costs. In the problem of this study, we assumed that all technician do the same works. This may not be the case, for example within the experience of each technician man in the crew, there may do mechanic works, electric works or simply cleaning and lubrication. All these works processed in the workshop and assumed to be as on job. Depending on the measurement of performance for the Queuing system of the workshop as a Multi-Channel queuing model, we made a mathematical model in which to determine the optimal number of technicians in the maintenance crew, taking into account minimum total costs, which include the costs of Downtime and technician's men. The results of the analysis tables showed the average queue length, waiting time of fail units in the workshop as well as the average of the utilization of the technician men in the maintenance crew. Which is reduce as the number of the technician increased. This may be not satisfied from the organization, unless compared with the minimum total costs that we get when the optimal no. of technicians in the crew equal (eight). This study may give a point view, for taking into accounts the costs of downtimes and technicians. Sometimes we may need a support from technicians outside the system to control the downtime of breaking down units, also adding the preventive maintenance programs so we avoid the breakdowns unit. In the future, we seek to try to apply these models using simulation in both the industrial and service sectors, and in different environments.

REFERENCES

Abuzaid, A. N., Al Haraisa, Y. E., & Alateeq, M. M. (2022). the Mediating Effect of Dynamic Capabilities on the Relationship Between Strategic Foresight and Strategic Renewal: Evidence From Islamic Banks in Jordan. International Journal of Professional Business Review, 7(2), 1–18. https://doi.org/10.26668/businessreview/2022.v7i2.369

Ahmad Muhajir and Nikenasih Binatari, (04 August 2017). Queuing System of Multi-Server Model at XYZ Insurance Company in Tasikmalaya City. AIP Conference Proceedings 1868, 040004 (2017); https://doi.org/10.1063/1.4995119

A, Y. S., Gunadi, B., C, A. W., & D, R. M. (2022). *COVID-19 PANDEMIC Article history : Received 04 October 2022 Keywords : Workload ; Work environment ; Work motivation ; Employee Performance Analysis Along Work from Home During the Covid-19 Pandemic*. 1–24. https://doi.org/https://doi.org/10.26668/businessreview/2022.v7i6.e459

Charles E. Ebbeling, (1997), An Introduction to Reliability and Maintainability Engineering, The Mc Graw-Hill companies, Inc. https://onlinelibrary.wiley.com/doi/epdf/10.1002/%28SICI%291099-1638%28199807/08%2914%3A4%3C295%3A%3AAID-QRE197%3E3.0.CO%3B2-Y

E. Berhan, (2015), Bank Service Performance Improvements using Multi-Server Queue System. IOSR- Journal of Business and Management, Vol3 Issue 6. Pp 65-69. https://www.iosrjournals.org/iosr-jbm/papers/Vol17-issue6/Version-1/I017616569.pdf

G. Donald, F.S. John, M. T. James, and M. H. Carl,(2008),Fundamental of Queuing Theory Forth Edition, John Willy &Sons, Canada. https://www.wiley.com/en-us/Fundamentals+of+Queueing+Theory,+4th+Edition-p-9781118625651

Hamdy A. Taha, (2017). Operation Research, An introduction, 10th Ed. © Pearson Education Limited. https://www.pearson.com/uk/educators/higher-education-educators/program/Taha-Operations-Research-An-Introduction-Global-Edition-10th-Edition/PGM1104072.html

Kandenmir, C; Cavas, L. (2007), An application of queuing theory to the relationship between insulin level and number of insulin receptors. Turk .J. Biochem, 2007. https://www.iitg.ac.in/nselvaraju/ma402_2007/Assignments/04010245-qt_insulin.pdf

Kembe et al. (2012). A Study of Waiting And Service Costs of A Multi-Server Queuing Model In A Specialist Hospital. *International Journal of Scientific & Technology Research* 1: 19-23. https://api.semanticscholar.org/CorpusID:111077550

Lakshmi C.; Sivakumar Appa Iyer, (2013), Operations Research for Health Care. ELSEVIER, Volume 2, Issues 1–2, March–June 2013, Pages 25-39. https://doi.org/10.1016/j.orhc.2013.03.002

Lawal Adamu , A. Isaac, A. Abubakar. (2019). A Study of Waiting and Service Costs of a Multi-Server Queuing System at National Health Insurance Scheme (NHIS) Unit of General Hospital Minna. Transaction of the Nigerian of Mathematical Physics. http://repository.futminna.edu.ng:8080/jspui/handle/123456789/9001#:~:text=to%20this%20i

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tem%3A-,http%3A//repository.futminna.edu.ng%3A8080/jspui/handle/123456789/9001,-Title%3A%C2%A0

Muhammad, I; Adamu, L. (19 October 2020). Determination of Optimal Number of Servers at Network Queuing Nods to Reduce waiting Time in a Teriary Institution Clinic in Bida,Nigeria. J. Appl. Sci. Environ. Manage Vol.24 (9). https://doi.org/10.4314/jasem.v24i9.22

S. shanmugasundaram. S. Punitha, (2014), A study on Multi Server Queuing Simulation. Journal of Science and Research, Vol 3 Issue7 pp 1519-1521. https://www.ijsr.net/archive/v3i7/MDIwMTQxMjQ0.pdf

Viliam Makis &Andrew K. S. Jardine.(02 December 2017). Optimal Replacement Policy for a General Model with Imperfect Repair. Journal of the Operational Research Society,volume43, Issue2. https://doi.org/10.1057/jors.1992.17