TPM Vol. 32, No. S8, 2025
ISSN: 1972-6325
https://www.tpmap.org/

Open Access

STAFF LEVEL OPTIMIZATION OF AN ELECTRONICS MANUFACTURING ENTERPRISE: A QUANTITATIVE APPROACH USING QUEUING MODEL

[1] CHUM KEJI A. OCAN, [2] CHERADEE ANN M. CABANLIT, [3] ANNA MARIE A. GRANADEROS

[1][2][3] CEBU INSTITUTE OF TECHNOLOGY – UNIVERSITY, INDUSTRIAL ENGINEERING DEPARTMENT
EMAILS: [1] chumkeji.ocan@cit.edu,[2] cheradeeann.cabanlit@cit.edu, [3]annamarie.granaderos@cit.edu

Abstract— The focus of the study is to evaluate the existing set-up of the electronics manufacturing company in terms of staffing levels. The study aims to describe the current staffing level of an electronics manufacturing company in Cebu, Philippines, identify problems and their root causes, and employ staff level optimization techniques to propose recommendation for the company.

The researchers utilized observation and document analysis to determine the existing staff level and observed the arrival of the orders in the line. The arrival of the orders in the assembly line follows a Poisson distribution (the calculated test statistic for the Chi-square Goodness of Fit Test was 0.8092. Comparing this value to the critical value of 7.81 at a significance level of 0.05) thus queuing theory is applied.

The study concluded that the appropriate number of operators should be observed to improve operator efficiency. The recommended number of servers is 48, which would save the company an opportunity loss of Php21,000 per day. In terms of changes in performance, reducing the number of operators to 48 instead of 57 would improve server efficiency by 15%.

Keywords— Manufacturing, Queueing theory, Staff optimization, Workforce utilization.

I. INTRODUCTION

The electronics manufacturing sector in Cebu, Philippines, stands as a critical driver of the region's industrial growth and economic development[1]. Amidst global competition and evolving market demands, the efficient utilization of resources, particularly human capital, is paramount for sustaining competitiveness and fostering growth within the sector[2][3][4]. Staff level optimization emerges as a key strategic imperative for electronics manufacturing companies in Cebu to navigate the complexities of production dynamics while ensuring operational excellence and cost-effectiveness. As the industry evolves, electronics manufacturers face increasingly dynamic production environments characterized by fluctuating demand patterns, diverse product portfolios, and evolving technological requirements[1][4]. In this context, the traditional methods of staff allocation and workforce management may prove inadequate in meeting the demands for agility, flexibility, and efficiency. Recognizing the significance of optimizing staff levels to enhance productivity and competitiveness, this research endeavors to address the specific challenges faced by electronics manufacturing companies in Cebu through a quantitative queueing model approach[5]. By leveraging principles of queueing theory, this study seeks to develop a systematic framework tailored to the unique operational characteristics and constraints of electronics manufacturing enterprises in the region. The rationale behind this research lies in the potential of queueing models to provide insights into the optimal allocation of human resources within manufacturing processes[6]. Through empirical validation and simulation techniques, this study aims to contribute valuable insights and practical guidance to electronics manufacturing companies in Cebu, enabling them to make informed staffing decisions that drive performance improvements and foster sustainable growth in a competitive global landscape. This research aims to optimize staff levels within a manufacturing enterprise through the application of queueing theory. The efficient allocation of human resources is critical for enhancing productivity and minimizing operational costs in manufacturing settings. By employing a queueing model, this study aims to determine optimal staffing levels tailored to the specific requirements and dynamics of an electronic manufacturing environment. The research methodology involves the development and implementation of a queueing model that integrates key parameters such as arrival rates, service times, and staffing levels. The model seeks to identify optimal staffing configurations that balance operational efficiency and workforce utilization while meeting production demands. In this study, the organization was able to improve efficiency level by 15% (from 52% operator efficiency to 61%). By leveraging queueing theory and quantitative analysis, managers can make informed staffing decisions, enhancing operational performance and resource utilization.

II. METHODS

A. Data Collection

The research will commence with comprehensive data collection from an electronics manufacturing companies in Cebu. This includes gathering information on production processes, historical staffing levels, arrival rates of work orders, and service times.

B. Model Development

Based on the collected data, a queueing model specific to the operational dynamics of electronics manufacturing will be developed. The model will incorporate key parameters such as arrival rates of work orders, service times for different manufacturing tasks, and variability in demand.

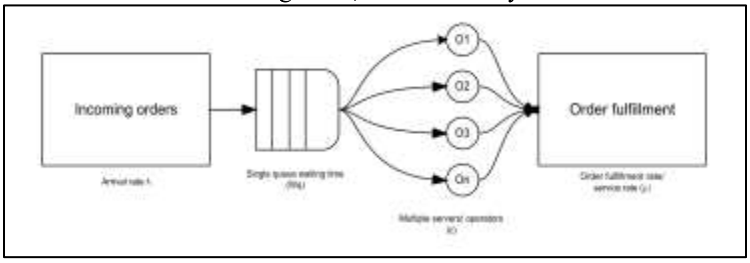

Figure 1. Queuing Model of the Manufacturing Process

C. Model Analysis

Conducting a comprehensive analysis of the queueing model output, including performance metrics like average waiting times, queue lengths, and system utilization rates. This analysis serves to discern patterns, bottlenecks, and inefficiencies within the manufacturing process. The following formulas are utilized:

$$\text{Expected Probability} = \frac{e^{-\lambda}\lambda^{x}}{x!} \quad (1)$$

$$x^2_{\text{computed}} = \sum \frac{(O-E)^2}{E} \quad (2)$$

$$\text{Order fulfillment rate } (\mu) = \frac{\frac{\text{Working time (in minutes)}}{\text{Working days}}}{\text{Average handling time (minute/ customer)}} \quad (3)$$

Queuing Model Notations[7][8][9]

λ: mean rate of arrival
μ: mean order fulfillment rate
c: number of operators in parallel
$\rho = \lambda/(c\mu)$: efficiency of the operator; also, the probability that the operator is busy or the proportion of time the operator is busy
Lq: mean number of orders in the queue
Wq: mean waiting time in the queue

D. Documentation and Reporting

Documenting research findings comprehensively in a detailed report outlining the methodology, results, and recommendations for optimizing staff levels in the selected electronics manufacturing company. Additionally, disseminating research outcomes through academic publications and presentations to enrich the discourse in operations management and industrial engineering.

III. RESULTS

Based on the analysis, it's established that the manufacturing enterprise operates within a mass production framework, where the arrival of orders adheres to a Poisson Distribution. This statistical distribution is particularly pertinent in scenarios where orders arrive independently and at a constant rate over time. The Chi-square Goodness of Fit Test was conducted, yielding a test statistic of 0.8092. Upon comparing this value to the critical value of 7.81 at a significance level of 0.05, it's evident that the distribution of order arrivals conforms to the expected Poisson pattern. Furthermore, the queuing model employed in the study is characterized as a single line, multiple channel configuration. In this queuing setup, orders form a single waiting line but can be processed by multiple operators concurrently. This model configuration is commonly applied in scenarios where incoming orders can be handled by multiple parallel processing channels, enabling efficient utilization of resources and minimizing waiting times for customers.

Based on the existing process data provided, which includes an arrival rate of 324 orders per day, a service rate of 11 arrivals of orders per day per operator, and a workforce comprising 57 operators per day with an efficiency rate of 52%, the mean number of orders in the queue is approximately 0.56, and the mean waiting time in the queue stands at 4.44 minutes.

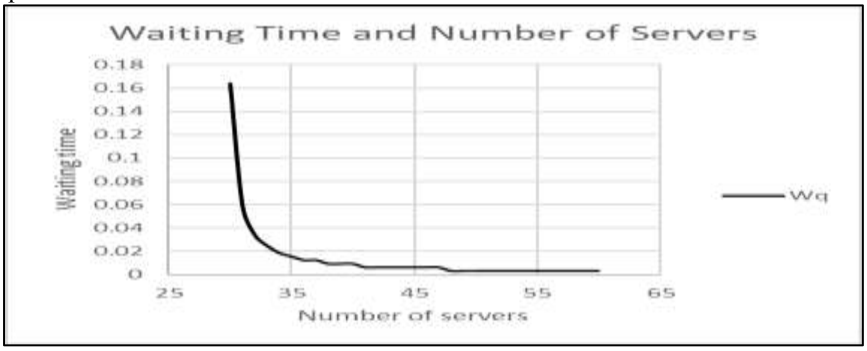

Figure 2. Waiting Time and Number of Servers

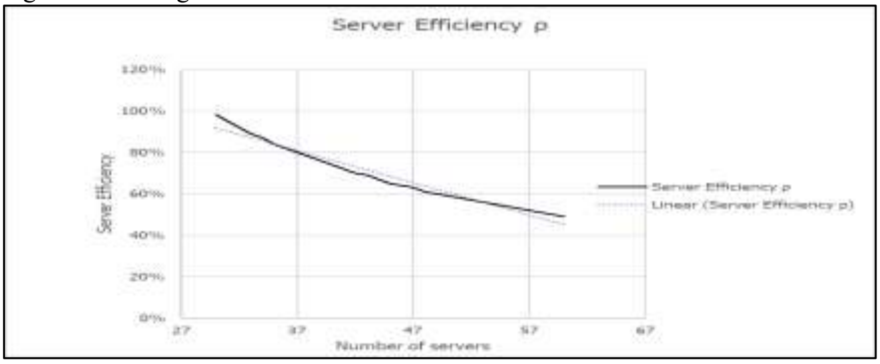

Figure 3. Operator Efficiency vs Number of Operators

The linear relationship between the operator efficiency and the number of operators is inversely proportional. As the number of servers increases, the server efficiency decreases on constant arrivals.

IV. DISCUSSION

In contrast, a proposed adjustment entails reducing the number of operators to 48 while simultaneously improving the efficiency rate to 61%. This adjustment aims to enhance productivity and streamline operations within the manufacturing environment. With this modification, it is anticipated that the efficiency of the workforce will improve, potentially leading to reduced idle time and enhanced throughput. While the proposed adjustment may result in a decrease in the mean waiting time in the queue and potentially lead to increased productivity, further analysis is required to ascertain the precise impacts on system performance. Adjusting staffing levels and optimizing workforce efficiency can significantly influence operational dynamics, affecting factors such as order processing speed and overall customer satisfaction. Overall, the proposed adjustment represents a strategic approach to optimizing resource utilization and improving operational efficiency within the manufacturing enterprise. Through careful analysis and simulation, the potential benefits and trade-offs associated with the proposed changes can be thoroughly evaluated, enabling informed decision-making aimed at enhancing productivity and driving sustainable growth.

A benefit–cost ratio (BCR) is an indicator, used in cost–benefit analysis, that attempts to summarize the overall value for money of a project or proposal. This is computed by the formula:

$$\text{BCR} = \frac{\text{Benefit (in Php)}}{\text{Cost (in Php)}}$$

The opportunity loss of Php21,000 is computed per day, which is equivalent to Php462,000 per month. The computation for the BCR is:

$$\text{BCR} = \frac{462{,}000}{46{,}500}$$

$$\text{BCR} = 9.94$$

A benefit-cost ratio greater than 1 indicates that the alternative is expected to deliver a positive net present value

CONCLUSION

In conclusion, this research has delved into the intricate dynamics of staffing optimization within a mass production manufacturing enterprise operating in Cebu. Through rigorous analysis and modeling, several key findings and insights have been unearthed, shedding light on opportunities for enhancing operational efficiency and resource utilization. The utilization of a Poisson Distribution for modeling the arrival of orders, validated through the Chi-square Goodness of Fit Test, underscores the significance of statistical rigor in understanding the underlying patterns of order arrivals. This statistical foundation forms the basis for accurate modeling and forecasting of operational dynamics, facilitating informed decision-making and resource allocation strategies. Moreover, the adoption of a single line, multiple channel queuing model offers a structured framework for analyzing the flow of orders through the manufacturing process. This model configuration enables the identification of bottlenecks, streamlining of workflows, and optimization of staffing levels to mitigate waiting times and improve overall customer satisfaction. The proposed adjustment in staffing levels, reducing the number of operators to 48 while concurrently enhancing the efficiency rate to 61%, presents a promising avenue for enhancing productivity and operational performance within the manufacturing enterprise. However, it is imperative to conduct further analysis and simulation to comprehensively evaluate the impacts of these adjustments on system performance and customer service metrics. In essence, this research underscores the importance of data-driven decision-making and quantitative modeling techniques in addressing the complexities of staffing optimization and operational management in mass production environments. By leveraging statistical insights and queuing theory principles, manufacturing enterprises can unlock new avenues for efficiency improvements, cost reductions, and competitive advantage in today's dynamic business landscape. Moving forward, ongoing research and continuous improvement efforts will be vital in driving sustainable growth and innovation within the manufacturing sector.

REFERENCES

[1] "The 2016 Economic and Product Market Databook for Cebu City , Philippines," 2016. Accessed: Mar. 06, 2024. [Online]. Available: https://www.semanticscholar.org/paper/The-2016-Economic-and-Product-Market-Databook-for-%2C/d5cae29e62b6f7068f6d3dfa4aadc09b4e4d543b
[2] A. Ibitz, "Assessing Taiwan's endeavors towards a circular economy: the electronics sector," Asia Eur J, vol. 18, no. 4, pp. 493–510, Dec. 2020, doi: 10.1007/s10308-019-00568-w.
[3] R. E. Ofreneo, "Auto and car parts production: can the Philippines catch up with Asia?," Asia Pacific Business Review, vol. 22, no. 1, pp. 48–64, Jan. 2016, doi: 10.1080/13602381.2014.990212.
[4] P. Low, G. O. Pasadilla, A. Wirjo, and G. O. Pasadilla, "MANUFACTURING OF AIRCRAFT CONTROL SYSTEMS IN THE PHILIPPINES," WORLD SCIENTIFIC, Jul. 2016, pp. 59–100. doi: 10.1142/9789813141469_0002.
[5] W. Thorbecke, "The East Asian Electronics Sector: The Roles of Exchange Rates, Technology Transfer, and Global Value Chains," Cambridge University Press, Mar. 2023. doi: 10.1017/9781009216838.
[6] rbareno045@gmail.com, judygimena@gmail.com, jesszon.cano@bisu.edu.phl, Arcelo Memorial National High School – Cebu, Philippines, University of Cebu – Banilad, Philippines, Bohol Island State University – Candijay, Bohol, Philippines, R. A. Bareño, J. A. F. Gimena, and J. B. Cano, "Business Classification of the Small and Medium-Sized Enterprises (SMEs) Industry in Mandaue City, Cebu, Philippines," IMRJ, vol. 4, no. 4, Jan. 2023, doi: 10.54476/ioer-imrj/224231.
[7] T. Hoeiland-Joergensen, P. McKenney, D. Taht, J. Gettys, and E. Dumazet, "The Flow Queue CoDel Packet Scheduler and Active Queue Management Algorithm," p. RFC8290, Jan. 2018, doi: 10.17487/RFC8290.
[8] O. Pryshchepa et al., "Optimization of multi-channel queuing systems with a single retail attempt: Economic approach," 10.5267/j.dsl, pp. 559–564, 2020, doi: 10.5267/j.dsl.2020.8.002.
[9] P. S. Murdapa, "Modeling the Multi-channel Section in the Supply Chain System using the Multiserver Queue Analogy," in Jurnal Teknik Industri, May 2021, pp. 47–54. doi: 10.9744/jti.23.1.47-54.