Process Optimization Model and Operational Efficiency of Manufacturing Firms in Rivers State, Nigeria

OFOEGBU, Wilson Chukwuemeka
Department of Management, Faculty of Management Sciences, University of Port Harcourt, Rivers State, Nigeria.

OGBONDA, E.H
Lecturer, Department of Business Administration, Faculty of Administration and Management sciences, Rivers State University Nkpolu-Oroworukwo, PMB 5080, Portharcourt, Nigeria.
Email: eyinda.ogbonda@ust.edu.ng

ABSTRACT

This research investigated the correlation between process optimization models and operational efficiency within manufacturing firms located in Rivers State, Nigeria. The study encompassed a population of 246 managers and supervisors from 25 manufacturing firms in the state. From this population, a total of 152 respondents were randomly selected using a simple random sampling technique. Data collection involved administering questionnaires directly to the respondents. The predictor variable, process optimization model, was operationalized through real-time optimization and maintenance optimization, while operational efficiency, the criterion variable, was assessed using cost minimization and capacity utilization metrics. Bivariate analysis, utilizing the Spearman Rank Order Correlation Coefficient, was conducted to determine the relationship between the process optimization model and operational efficiency. The findings indicated a significant and positive correlation between the dimensions of the process optimization model and measures of operational efficiency. Consequently, the study concluded that real-time optimization and maintenance optimization contribute to enhancing the operational efficiency of manufacturing firms. The study recommends that management in manufacturing firms prioritize optimal utilization of production time to improve operational efficiency, particularly in terms of capacity utilization.

Keywords: Process Optimization Model, Operational Efficiency, Real-Time Optimization, Maintenance Optimization, Cost Minimization, Capacity Utilization

Introduction

In today's volatile business environment, maintaining a competitive edge within the manufacturing sector has become paramount for firms. The quest for stability amidst uncertainty has propelled organizations to prioritize operational efficiency. As asserted by Akhigbe and Worlu (2020), Operational Efficiency (OE) not only enhances competitiveness, market share, and productivity but also contributes to the overall fortune of an organization. Efficient operations not only facilitate goal achievement but also enable it to be accomplished with fewer resources. Manufacturing firms in Nigeria face intense competition both domestically and internationally, exacerbating the competitive landscape. This heightened competition underscores the urgent need for improved operational efficiency to navigate the turbulent

industry dynamics. Eletu, Nwuche, and Akhigbe (2021) argue that operational efficiency in manufacturing firms is pivotal for enhancing economic growth, stimulating economic activities, and bolstering employment rates.

Aligned with these perspectives, Chen (2001) emphasizes that operational efficiency hinges on the effective utilization of resources to maximize outcomes at minimal costs. In response to corporate failures, many manufacturing firms are increasingly focusing on optimizing business processes to address operational inefficiencies. Process optimization models entail refining existing procedures to ensure optimal efficiency and cost-effectiveness (Văn, 2020). While scholars have explored avenues to enhance operational efficiency over the years (Larsson, 2004; Eletu, Nwuche & Akhigbe, 2021; Abrantes & Lindberg, 2023), empirical inquiry into the relationship between process optimization models and operational efficiency remains scarce. This study aims to fill this gap by investigating the nexus between process optimization and operational efficiency within manufacturing firms in Rivers State, Nigeria.

Statement of the Problem

The manufacturing landscape in Nigeria is characterized by a hostile business environment, leading to diminishing contributions to the nation's economic growth in recent decades (Eketu, Nwuche & Akhigbe, 2021). One pressing issue is the poor operational efficiency plaguing these firms, exacerbated by their inability to effectively utilize available resources. The ramifications of low operational efficiency extend to profitability, market share, and global competitiveness. Various factors contribute to this operational inefficiency, including inadequate infrastructure, unreliable electricity supply, escalating operational costs, unfavorable policies, and a lack of process optimization. Consequently, many Nigerian manufacturing firms have succumbed to these challenges, becoming defunct due to their inability to withstand the harsh business environment. Omhonria and Needorn (2022) highlight the stark contrast in operational efficiency between Nigerian manufacturing firms and their counterparts in other countries, underscoring the urgent need for improvement. While acknowledging the potential of process optimization models to transform organizational fortunes (Chen, 2001), the extent to which they address operational efficiency remains unclear. Process optimization endeavors to eliminate wastage within organizations, thereby enhancing operational efficiency. Thus, this study seeks to explore how process optimization models, particularly real-time optimization and maintenance optimization, can ameliorate the operational efficiency challenges facing manufacturing firms in Rivers State, Nigeria. By delving into this inquiry, the study aims to shed light on viable strategies to enhance operational efficiency and bolster the resilience of manufacturing firms in the region.

Aim and Objectives of the Study

The aim of this study is to explore the relationship between process optimization models and operational efficiency among manufacturing firms in Rivers State, Nigeria. The specific objectives are to investigate the relationship between:

i. Real-time optimization and cost minimization.
ii. Real-time optimization and capacity utilization.
iii. Maintenance optimization and cost minimization.
iv. Maintenance optimization and capacity utilization.

Research Hypotheses

The study tested the following hypotheses:

Ho1: There is no significant relationship between real-time optimization and cost minimization.
Ho2: Real-time optimization does not significantly correlate with capacity utilization.
Ho3: Maintenance optimization is not significantly related to cost minimization.
Ho4: Maintenance optimization does not significantly relate to capacity utilization.

Review of Related Literature

Conceptual Framework

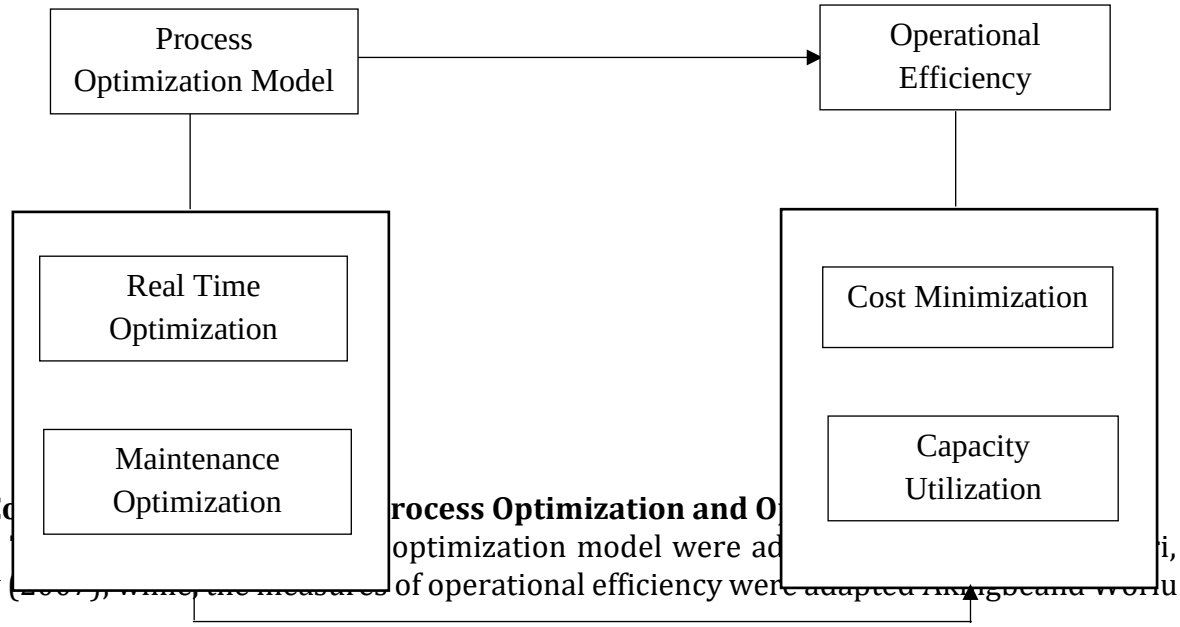

Fig. 1: Co rocess Optimization and O
Source: optimization model were ad i, Mejeed and Roy (2007), while the measures of operational efficiency were adapted Akagbe and Worlu (2020).

Process Optimization Model:
At the core of manufacturing excellence lies the concept of optimization. Optimization entails the quest for the best possible outcomes in diverse scenarios. It permeates the entire lifecycle of engineering systems, driving decisions aimed at either minimizing effort or maximizing gains. By discerning conditions that yield optimal values of a function, organizations can chart pathways to efficiency and effectiveness in real-world scenarios. Business Process Optimization (BPO) epitomizes this ethos, emphasizing the streamlining of operations to harness existing resources more effectively. In today's data-driven corporate milieu, BPO emerges as a pivotal strategy, leveraging advanced analytics such as machine learning and predictive modeling to enhance productivity and competitiveness.

Real-Time Optimization (RTO):
Real-Time Optimization (RTO) stands as a beacon of efficiency in manufacturing processes. By deploying automated systems that adjust plant operations based on production control and scheduling, RTO maximizes profitability while minimizing emissions. It embodies a model-based adaptive optimization technique, striving to identify the best operating conditions for plants by considering economic indices and various constraints. These constraints encompass physical limitations, environmental regulations, safety requirements, and product quality standards. RTO systems, characterized by closed-loop, model-based control mechanisms, strive to maintain processes as close to the ideal operating point as possible. By utilizing precise process models and real-time economic data, RTO mitigates disruptions and performance losses, thereby enhancing economic performance and environmental sustainability.

Maintenance Optimization:
Maintenance optimization emerges as a cornerstone of operational resilience in manufacturing ecosystems. It involves quantifying expenses and striking the ideal balance between maintenance costs and related benefits. As system failures during real-world operations can be costly and risky, optimizing maintenance activities becomes imperative. A malfunctioning machine can disrupt scheduled processes, leading to penalties and reputational damage for organizations. Maintenance optimization models, informed by statistical and stochastic methodologies, offer frameworks to navigate these challenges. By accounting for production schedules, working conditions, safety protocols, and variability in activities, these models enhance operational reliability and resource allocation efficiency.

The characterization of inherent variability and uncertainty distinguishes maintenance optimization strategies, underscoring their adaptability and resilience in dynamic manufacturing environments.

Operational Efficiency:

Operational efficiency epitomizes the prudent utilization of material, human, and financial resources to enhance output and service delivery while minimizing costs. It embodies a strategic imperative for organizations, necessitating efficient resource procurement and deployment strategies to achieve overarching objectives. Operational efficiency hinges on tactical organizational planning, aimed at preserving a secure cost-productivity ratio. By identifying and eliminating inefficient procedures that lead to resource loss, organizations bolster revenues and profitability. The operating income to operating expense ratio serves as a key metric to gauge efficiency, signaling effective cost control and revenue maximization. As operational efficiency improves, organizations witness enhanced profitability and competitiveness, reflecting the efficacy of their asset and liability management strategies.

Cost Minimization:

Cost minimization serves as a linchpin in the pursuit of financial prudence and sustainability within manufacturing enterprises. It encompasses strategies aimed at reducing expenses while maintaining product quality and meeting consumer expectations. By adopting cost-effective solutions and leveraging technological advancements, organizations optimize production costs and maximize profitability. Cost minimization approaches offer roadmaps for systemic adoption of waste management systems, emphasizing legislative support for social and environmental sustainability. The pursuit of cost reduction underscores a fundamental tenet of business and economics, advocating for prudent resource allocation and operational excellence. By continuously striving to satisfy consumer expectations without compromising product quality, organizations navigate cost challenges while enhancing operational resilience and profitability.

Capacity Utilization:

Capacity utilization plays a pivotal role in determining manufacturing costs and profit margins. It refers to the extent to which an organization's productive capacity is being utilized to generate output. In essence, it represents the efficiency with which resources are deployed to achieve production objectives. Loto (2012) defines capacity utilization as the ratio of actual output to the maximum output level achievable within a specified time frame. It reflects the organization's ability to leverage its resources, including workforce, machinery, and infrastructure, to achieve optimal productivity levels.

Empirical Review:

Scholars have extensively studied capacity utilization and its implications for manufacturing performance. Erni and Ratnawati (2019) conducted a qualitative interpretative research study on optimizing information technology infrastructure for enhancing firm performance. Their findings underscored the critical role of IT infrastructure in driving innovation and service excellence within organizations. Through innovations such as e-dapem, authentication systems, and web-based applications, organizations can streamline operations and enhance service delivery to stakeholders.

Islam, Hassan, and Rashid (2020) conducted a comprehensive literature review on optimization processes and their impact on productivity. Their study examined various optimization categories, including inventory management, production processes, and layout optimization. By analyzing tools and procedures such as discrete event simulation and root cause analysis, the study highlighted the significance of optimization strategies in driving organizational growth and success across industries.

Rahman, Sugiono, Sonief, and Novareza (2022) investigated the optimization of maintenance performance levels through the collaboration of overall equipment effectiveness and machine reliability. Their study demonstrated the importance of machine reliability and maintenance intervals

in enhancing overall equipment effectiveness. By leveraging data-driven insights and maintenance optimization techniques, organizations can minimize downtime and maximize production efficiency.

Implications for Manufacturing Efficiency and Productivity:

The empirical insights underscore the critical role of capacity utilization in driving manufacturing efficiency and productivity. By optimizing capacity utilization through strategic investments and operational excellence, organizations can enhance their competitiveness and profitability. Leveraging IT infrastructure, embracing optimization strategies, and fostering a culture of innovation and efficiency emerge as key imperatives for organizations seeking to thrive in dynamic market environments.

Moreover, the findings highlight the interplay between operational efficiency, business strategy, and ownership structure in shaping manufacturing performance. Proactive business strategies, coupled with efficient resource allocation and operational practices, drive enhanced manufacturing performance and competitiveness. The moderating role of market uncertainty and competition intensity underscores the importance of adaptability and strategic foresight in navigating competitive market dynamics.

Methodology

The research utilized a cross-sectional survey design to investigate the relationship between process optimization models and operational efficiency in manufacturing firms in Rivers State, Nigeria. The study population comprised 246 managers and supervisors from 25 manufacturing firms in the region. From this population, a sample of 152 respondents was selected using the Yamane (1968) formula for sample size determination.

The sampling technique employed was simple random sampling, a probabilistic method ensuring equal chances of selection for each member of the population. Structured questionnaires served as the primary data collection instrument for the study.

The predictor variable, process optimization model, was operationalized using two components: real-time optimization and maintenance optimization. Each component was measured using five items to capture different aspects of the optimization process.

On the other hand, the criterion variable, operational efficiency, was assessed through two dimensions: cost minimization and capacity utilization. Five items were utilized to measure cost minimization, while four items were employed to gauge capacity utilization. The Likert scale, ranging from strongly agree to strongly disagree, was utilized for respondents to express their agreement with the statements provided.

Data analysis relied on the Spearman's Rank Order Correlation to examine the bivariate hypotheses and establish the relationship between the process optimization model and operational efficiency of manufacturing firms in Rivers State, Nigeria.

Results

The distribution, retrieval, and validity of the questionnaires are outlined in this subsection. A total of 152 questionnaires were distributed to the selected respondents. Impressively, 150 questionnaires were retrieved, representing a retrieval rate of 98.7% of the distributed copies.

Upon examination of the retrieved questionnaires, 15 copies (9.9%) were deemed invalid due to various issues such as duplicated responses and omissions of key questions. Consequently, 135 questionnaires (88.8%) were deemed properly completed and valid for subsequent analysis in the study.

The high retrieval rate and the majority of valid responses indicate a strong level of engagement and cooperation from the respondents, enhancing the reliability and validity of the data collected for the research.

Table 1: Real Time Optimization and Cost Minimization Correlations

			Real Time Optimization	Cost Minimization
Spearman's rho	Real Time Optimization	Correlation Coefficient	1.000	.841**
		Sig. (2-tailed)	.	.000
		N	135	135
	Cost Minimization	Correlation Coefficient	.841**	1.000
		Sig. (2-tailed)	.000	.
		N	135	135

**. Correlation is significant at the 0.01 level (2-tailed).

Ho_1: There is no significant relationship between real time optimization and cost minimization

The results from the correlation analysis presented in Table 1 indicate a strong and statistically significant relationship between real-time optimization and cost minimization among the manufacturing firms in Rivers State, Nigeria.

The Spearman's rho correlation coefficient between real-time optimization and cost minimization is 0.841, with a p-value of .000, indicating that the correlation is significant at the 0.01 level (2-tailed). This suggests a highly positive and significant association between real-time optimization and cost minimization practices within the manufacturing firms under study.

In simpler terms, the findings imply that as real-time optimization efforts increase within these manufacturing firms, there is a concurrent increase in the level of cost minimization achieved. This suggests that the adoption and implementation of real-time optimization strategies contribute positively to reducing costs associated with the manufacturing processes.

Therefore, based on the statistical analysis and the significant correlation coefficient, we reject the null hypothesis (Ho1) that posited no significant relationship between real-time optimization and cost minimization. Instead, the results provide evidence to support the alternative hypothesis, indicating a clear and meaningful association between real-time optimization efforts and the reduction of costs in manufacturing operations.

The findings suggest that embracing real-time optimization methodologies can effectively lead to cost minimization in manufacturing firms, thereby enhancing operational efficiency and potentially improving overall financial performance.

Table 2: Real time optimization and Capacity utilization

Correlations

			Real Time Optimization	Capacity Utilization
Spearman's rho	Real Time Optimization	Correlation Coefficient	1.000	.796**
		Sig. (2-tailed)	.	.000
		N	135	135
	Capacity Utilization	Correlation Coefficient	.796**	1.000
		Sig. (2-tailed)	.000	.

	N	135	135

**. Correlation is significant at the 0.01 level (2-tailed).

Ho_2: There is no significant relationship between real time optimization and capacity utilization.

The correlation analysis presented in Table 2 demonstrates a strong and statistically significant relationship between real-time optimization and capacity utilization among the manufacturing firms in Rivers State, Nigeria.

The Spearman's rho correlation coefficient between real-time optimization and capacity utilization is 0.796, with a p-value of .000, indicating that the correlation is significant at the 0.01 level (2-tailed). This implies a robust and positive association between real-time optimization efforts and capacity utilization within the manufacturing firms under examination.

In practical terms, the results suggest that as manufacturing firms implement real-time optimization strategies, there is a corresponding improvement in their capacity utilization rates. This indicates that the adoption of real-time optimization methodologies positively influences the efficient utilization of production capacities within these firms.

Consequently, based on the statistical analysis and the significant correlation coefficient, we reject the null hypothesis (Ho2) which stated that there is no significant relationship between real-time optimization and capacity utilization. Instead, the findings provide support for the alternative hypothesis, indicating a meaningful and substantial association between real-time optimization practices and enhanced capacity utilization in manufacturing operations.

The results imply that the implementation of real-time optimization techniques can lead to increased capacity utilization levels within manufacturing firms, thereby potentially enhancing overall operational efficiency and productivity.

Table 3: Maintenance Optimization and Cost Minimization Correlations

			Maintenance Optimization	Cost Minimization
Spearman's rho	Maintenance Optimization	Correlation Coefficient	1.000	.656**
		Sig. (2-tailed)	.	.000
		N	135	135
	Cost Minimization	Correlation Coefficient	.656**	1.000
		Sig. (2-tailed)	.000	.
		N	135	135

**. Correlation is significant at the 0.01 level (2-tailed).

Ho_3: There is no significant relationship between maintenance optimization and cost minimization.

The correlation analysis presented in Table 3 indicates a statistically significant relationship between maintenance optimization and cost minimization among the manufacturing firms in Rivers State, Nigeria.

The Spearman's rho correlation coefficient between maintenance optimization and cost minimization is 0.656, with a p-value of .000, suggesting that the correlation is significant at the 0.01 level (2-tailed).

This signifies a moderate to strong positive association between maintenance optimization efforts and cost minimization within the manufacturing firms under investigation.

In practical terms, the findings imply that as manufacturing firms focus on optimizing their maintenance processes, there is a corresponding reduction in costs associated with their operations. This suggests that the implementation of maintenance optimization strategies contributes to lowering overall operational expenses and promoting cost-efficient practices within these firms.

Therefore, based on the statistical analysis and the significant correlation coefficient, we reject the null hypothesis (Ho3), which posited that there is no significant relationship between maintenance optimization and cost minimization. Instead, the results support the alternative hypothesis, indicating a meaningful and substantial association between maintenance optimization initiatives and the minimization of costs in manufacturing operations.

The findings suggest that the adoption of maintenance optimization practices can lead to cost minimization within manufacturing firms, thereby potentially enhancing their overall financial performance and competitiveness in the market.

Table 4: Maintenance Optimization and Capacity Utilization Correlations

			Maintenance Optimization	Capacity Utilization
Spearman's rho	Maintenance Optimization	Correlation Coefficient	1.000	.677**
		Sig. (2-tailed)	.	.000
		N	135	135
	Capacity Utilization	Correlation Coefficient	.677**	1.000
		Sig. (2-tailed)	.000	.
		N	135	135

**. Correlation is significant at the 0.01 level (2-tailed).

Ho_4: There is no significant relationship between maintenance optimization and capacity utilization.

The correlation analysis presented in Table 4 indicates a statistically significant relationship between maintenance optimization and capacity utilization among the manufacturing firms in Rivers State, Nigeria.

The Spearman's rho correlation coefficient between maintenance optimization and capacity utilization is 0.677, with a p-value of .000, suggesting that the correlation is significant at the 0.01 level (2-tailed). This indicates a moderate to strong positive association between maintenance optimization efforts and capacity utilization within the manufacturing firms under investigation.

Practically, these findings imply that as manufacturing firms focus on optimizing their maintenance processes, there is a corresponding increase in their capacity utilization. This suggests that the implementation of maintenance optimization strategies contributes to maximizing the effective use of available resources and facilities within these firms, resulting in higher levels of capacity utilization.

Therefore, based on the statistical analysis and the significant correlation coefficient, we reject the null hypothesis (Ho4), which posited that there is no significant relationship between maintenance optimization and capacity utilization. Instead, the results support the alternative hypothesis, indicating a meaningful and substantial association between maintenance optimization initiatives and the enhancement of capacity utilization in manufacturing operations.

The findings suggest that the adoption of maintenance optimization practices can lead to improved capacity utilization within manufacturing firms, thereby potentially enhancing their operational efficiency, productivity, and overall performance in the market.

Summary of Findings

The findings from the correlation analysis of the relationships between process optimization models and operational efficiency indicators offer valuable insights into the dynamics of manufacturing firms in Rivers State, Nigeria. These insights can help guide strategies for enhancing operational performance and competitiveness within the industry.

Firstly, the strong positive correlation between real-time optimization and both cost minimization and capacity utilization underscores the importance of implementing efficient, adaptive strategies in manufacturing processes. Real-time optimization systems, as highlighted in the study, enable firms to dynamically adjust production operations based on demand fluctuations, resource availability, and other relevant factors. This adaptability not only minimizes costs by optimizing resource allocation but also enhances capacity utilization by ensuring that production levels align with actual demand in real-time. Therefore, firms that prioritize real-time optimization are likely to achieve higher levels of operational efficiency and cost-effectiveness.

Similarly, the significant correlation observed between maintenance optimization and both cost minimization and capacity utilization reaffirms the critical role of proactive maintenance practices in maximizing operational efficiency. By optimizing maintenance schedules, preventive measures, and equipment reliability, manufacturing firms can mitigate downtime, reduce repair costs, and optimize resource utilization. The positive association between maintenance optimization and capacity utilization suggests that well-maintained equipment and facilities contribute to higher production outputs and improved asset utilization rates. Consequently, investing in robust maintenance optimization strategies can yield tangible benefits in terms of cost savings, productivity gains, and overall operational performance.

Furthermore, the findings highlight the interconnectedness of various operational factors and their collective impact on organizational efficiency. The correlations observed between different components of process optimization models (real-time optimization and maintenance optimization) and operational efficiency indicators (cost minimization and capacity utilization) underscore the complex, multifaceted nature of manufacturing operations. Effective process optimization requires a holistic approach that considers the interplay between technological, managerial, and operational factors to achieve optimal outcomes. By integrating real-time optimization and maintenance optimization initiatives into their operations, manufacturing firms can create synergies that drive continuous improvement and sustainable competitive advantage.

The findings from the correlation analysis underscore the significance of process optimization models in enhancing the operational efficiency of manufacturing firms in Rivers State, Nigeria. By embracing real-time optimization and maintenance optimization strategies, firms can streamline their operations, minimize costs, maximize resource utilization, and ultimately improve their competitive positioning in the market. Moving forward, policymakers, industry stakeholders, and business leaders should prioritize investments in technology, infrastructure, and human capital to support the adoption and implementation of effective process optimization practices across the manufacturing sector. By doing so, they can foster innovation, resilience, and long-term growth within the industry while contributing to the broader economic development goals of the region.

Conclusion

In conclusion, the study findings underscore the significant potential of integrating a Process Optimization Model (POM) comprising Real Time Optimization (RTO) and Maintenance Optimization to enhance operational efficiency within manufacturing firms in Rivers State, Nigeria. By leveraging

these dimensions of process optimization, companies can streamline production processes, mitigate downtime, and optimize resource allocation effectively.

Real Time Optimization (RTO) emerges as a critical component enabling companies to dynamically adjust production processes in response to evolving market conditions. This adaptability ensures operational efficiency and responsiveness to market demands, ultimately driving enhanced productivity and competitiveness. Similarly, Maintenance Optimization plays a pivotal role in ensuring equipment reliability and longevity. Proactive maintenance strategies help minimize the risk of unexpected breakdowns and associated downtime, contributing to overall operational efficiency.

The assessment of operational efficiency through metrics such as cost minimization and capacity utilization provides valuable insights into the effectiveness of optimization efforts. By minimizing production costs and maximizing resource utilization, firms can improve profitability and sustainability significantly. Consequently, the integration of a Process Optimization Model focusing on real-time optimization and maintenance optimization proves to be a viable approach for enhancing operational efficiency in manufacturing firms within Rivers State.

Recommendations

1. Management of manufacturing firms should ensure optimal utilization of production time to enhance operational efficiency in terms of capacity utilization.
2. Investment in state-of-the-art production scheduling software integrating real-time optimization algorithms can dynamically adjust production schedules, catering to demand fluctuations and resource constraints, thereby enhancing operational efficiency.
3. Regular maintenance of machines and equipment should be ensured to enhance operational efficiency in terms of capacity utilization.
4. Developing a comprehensive asset management plan encompassing regular equipment inspections, preventive maintenance schedules, and predictive maintenance strategies is vital to ensure optimal performance and operational efficiency.

Implementing these recommendations will enable manufacturing firms in Rivers State to realize the full potential of process optimization models, thereby enhancing operational efficiency and competitiveness in the market landscape.

References

1. Afroz, G. & Roy, D. K. (1976). Capacity utilisation in selected manufacturing industries of Bangladesh. *The Bangladesh Development Studies, 4*(2), 275-288
2. Akhigbe, E. A. & Worlu, G. O. (2020). Production Planning and Operational Efficiency in the Food and Beverage Industry in Nigeria. *Anusandhan - NDIM's Journal of Business and Management Research, 2*(2), 16-26.
3. Allen B, (2000). "*Capacity Pre-commitment as a barrier to entry: a Bertrand*- Egdeworth approach economic theory 15: 501-530.
4. Baik, B., Chae, J., Choi, S., & Farber, D. (2011). Changes in operational efficiency and firm performance: A frontier analysis approach. *Contemporary Accounting Research, 20*(10), 1-32.
5. Buchory, H.A. (2014). Analysis of the effect of capital, operational efficiency, credit risk and profitability to the implementation of banking intermediation functions (study on regional development banks all over Indonesia in 2012). *Academic Research International, 5*(4), 440-457.
6. Chen, T.Y. (2001). An estimation of x-inefficiency in Taiwan's banks. *Applied Financial Economics, 11*(3), 237-242
7. Chung, S.H., Lau, H.C.W., Ho, G.T.S., and Ip, W.H. (2009). "Optimization of system reliability in multi-factory production networks by maintenance approach", *Expert Systems with Applications, 36*(6):10188–10196.
8. Coelli, T. J., & Rao, D. S. (2005). Total factor productivity growth in agriculture: A Malmquist index analysis of 93 countries, 1980–2000. *Agricultural Economics, 32*,115–134.

9. Eletu, I, T., Nwuche, C. A. & Akhigbe, J. O. (2021). Learning capability and operational efficiency of manufacturing firms in Nigeria. *Journal of Emerging Trends in Economics and Management Sciences, 12*(4), 150-161.
10. Erni , T.,& Ratnawati, W. (2019) Information technology infrastructure optimization for achieving innovation-based company performance. *International Journal Of Business And Economic And Law. 23* (3), 171-185
11. Ibidunni, A. S., Ufua, D. E., Okorie, U. E., & Kehinde, B. E. (2019). Labour productivity in agricultural sector of Sub-Sahara Africa (2010–2017): A data envelopment and panel regression approach. *African Journal of Economic and Management Studies, 11*(2), 207-232.
12. Islam, S. Hassan, A & Rashid, A.R.M.H. (2020). Optimization Processes & Analysis of Impact on Productivity: A Literature Review. *Proceedings of the International Conference on Industrial & Mechanical Engineering and Operations Management* Dhaka, Bangladesh, 26-27.
13. Kustina, K.T., Dewi, G.A.A.O., Prena, G.D., & Suryasa, W. (2019). Branchless banking, third-party funds, and profitability evidence reference to banking sector in Indonesia. *Journal of Advanced Research in Dynamical and Control Systems, 11*(2), 290-299.
14. Larsson, M. (2004). Strategy and operational efficiency. *The Limits of Business Development and Economic Growth, 8,* 57-65.
15. Loto, M.A, (2012): The Determinants of Output Expansion in the Nigerian Manufacturing Industries. *Journal of Emerging Trends in Economics and Management Sciences (JETEMS) 3*(6): 991-996
16. Mohajan, H. K., Deb, S. K., & Rozario, S. O. (2012). Environmental Accounting and Roles of Economics. *International Journal of Economics and Research, 3*(1), 133-140.
17. Omhonria, D., & Needorn, R. S. (2022). Production improvement function and organizational performance of manufacturing firms in Rivers State. *International Journal of Advanced Academic Research, 8*(1), 13-29.
18. Paul K, Chattopadhyay S, Dutta A, Krishna AP, & Ray S (2019). A Comprehensive Optimization Model for Integrated Solid Waste Management System: A Case Study. Korean Society of Environmental Engineers, *Environmental Engineering Research, 24*(2):220-237.
19. Rahman F., Sugiono, S., Sonief, A. A. & Novareza, O. (2022). Optimization maintenance performance level through collaboration of overall equipment effectiveness and machine reliability. *Journal of Applied Engineering Science, 20*(3), 917-936. DOI:10.5937/jaes0-35189
20. Samuelson, P. A. (1947). *Foundations of Economic Analysis.* Harvard University Press, Cambridge, MA.
21. Sandve, K. & Aven, T., (1999). Cost optimal replacement of monotone, repairable systems, *European Journal of Operational Research, 116*(2):235–248.
22. Suryasa, W., Sudipa, I. N., & Puspani, I. A. M., & Netra, I. (2019). Towards a Change of Emotion in Translation of Kṛṣṇa Text. *Journal of Advanced Research in Dynamical and Control Systems, 11*(2), 1221-1231.
23. Trierweiler, J.O. (2014). Real-Time Optimization of Industrial Processes. In *Encyclopedia of Systems and Control;* Springer: Berlin, Germany, p. 1–12.
24. Vergidis, K., Tiwari, A., Majeed, B., & Roy, R, (2007). Optimization of business process design: An algorithmic approach with multiple objectives. *International Journal of Production Economics, 109(1-2), 105-121.*
25. Wiese, H. (2021). *Cost Minimization and Profit Maximization.* In Advanced Microeconomics. Springer Gabler, Wiesbaden. https://doi.org/10.1007/978-3- 658-34959-2_9