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Line Balancing Analysis Using the Rank Positional Weight Method to Improve OEE Value on the Machining Line in an Indonesian Automotive Company

Suhendra[1] ✉, Tri Ngudi Wiyatno[2], Fibi Eko Putra[3], Nida An Khofiyah[4], Supriyati[5]

[1,2,3,4,5]*Industrial Engineering Study Program, Faculty of Engineering, Universitas Pelita Bangsa, Indonesia (suhendra@pelitabangsa.ac.id[1])*

Abstract

This study investigates the application of the Rank Positional Weight (RPW) method and line balancing techniques to improve Overall Equipment Effectiveness (OEE) and productivity on the machining line of an Indonesian automotive manufacturer. The automotive industry in Indonesia, particularly in the wake of the 2024 economic uncertainty, faces significant challenges such as reduced consumer purchasing power, rising vehicle prices, and disruptions in the global supply chain. PT XYZ, an automotive company, has faced inefficiencies in its production process, notably in its machining line, leading to high cycle times and low productivity. By implementing RPW and line balancing, the company aimed to optimize task distribution among operators and reduce production delays. This qualitative study employs a literature review methodology to examine existing research on RPW, line balancing, and OEE improvement in manufacturing systems. The findings demonstrate that RPW and line balancing significantly enhanced PT XYZ's OEE from 75% to 89%, thereby increasing productivity and reducing operational inefficiencies. These results align with previous studies showing the effectiveness of these methods in improving manufacturing performance. The study concludes that RPW and line balancing are highly effective techniques for optimizing automotive manufacturing processes, offering practical solutions to address current challenges in the industry.

Keywords: Rank Positional Weight, Line Balancing, Overall Equipment Effectiveness, Machining Line, Productivity, Manufacturing Optimization

INTRODUCTION

The automotive industry in Indonesia, like many others globally, has been significantly impacted by economic uncertainties, particularly following the 2024 general election. According to the Association of Indonesian Automotive Industries (GAIKINDO), retail sales from January to May 2024 saw a 14.4% decline, compared to the same period in 2023, highlighting a substantial drop in consumer purchasing power (Schmidt, 2025). This situation is further compounded by the inevitable rise in vehicle prices due to inflation, increased taxes, and the global semiconductor shortage. The combination of these factors has created a challenging environment for automotive manufacturers, making it imperative to improve operational efficiency and reduce production costs.

PT XYZ, a leading automotive manufacturer in Indonesia, has recognized the importance of enhancing production efficiency. Despite significant investments in building a facility to supply air conditioning compressors for motor vehicles, the company faces challenges in its machining line. These challenges include waste generation, imbalanced workload distribution among operators, and long cycle times, which significantly reduce productivity. As such, optimizing production processes is crucial for the company to remain competitive in this difficult economic climate.

While existing studies have explored various techniques to optimize manufacturing processes, few have specifically addressed the application of Rank Positional Weight (RPW) and line balancing techniques in improving productivity and Overall Equipment Effectiveness (OEE) in the context of automotive manufacturing in Indonesia. Previous research has largely focused on general line balancing techniques and their effects on efficiency (Manaye, 2019), but little attention has been given to how these methods can be combined with RPW to specifically address inefficiencies in machining lines in automotive production. This presents a research gap in applying these methods to the specific context of air conditioning compressor production in Indonesia's automotive industry.

The urgency of this research is underscored by the growing need for Indonesian automotive manufacturers to adapt to economic challenges by improving productivity and reducing operational inefficiencies. As the automotive industry faces significant external challenges, improving internal processes such as production line balancing and task allocation is critical. The application of RPW and line balancing techniques could lead to improvements in OEE, reducing waste and downtime, and ultimately enhancing production capacity. Therefore, it is imperative to explore how these methods can help optimize machining lines to boost productivity and support the sustainability of the automotive industry in Indonesia during uncertain economic times.

Previous studies have explored line balancing techniques in manufacturing environments and their impact on productivity. For instance, Rasib et al. applied line balancing in automotive manufacturing, demonstrating its potential to reduce cycle time and increase throughput (Rasib et al., 2025). However, while many studies discuss line balancing techniques, few focus on the Rank Positional Weight (RPW) method, which specifically ranks tasks based on their duration and dependencies. This method has been shown to be effective in optimizing task distribution and minimizing idle time, thereby improving overall system performance (Ghafari et al., 2022). However, research on the combined application of RPW and line balancing in automotive production remains scarce, particularly in the context of Indonesia's automotive industry.

This study presents a novel approach by integrating the RPW method with line balancing techniques to improve the OEE of a machining line at PT XYZ. While previous studies have explored each technique independently, few have examined their combined impact on improving production efficiency in the automotive sector, particularly in the Indonesian context. This study's contribution lies in demonstrating how the combination of these methods can reduce cycle times, balance workloads, and enhance the OEE, leading to increased productivity. Additionally, it highlights the potential benefits for other automotive manufacturers facing similar challenges in optimizing production processes.

The primary objective of this study is to evaluate the impact of applying the RPW method and line balancing techniques on the machining line at PT XYZ. Specifically, the study aims to:

- Assess the improvement in Overall Equipment Effectiveness (OEE) following the implementation of RPW and line balancing.
- Analyze how task distribution and workload balancing affect production efficiency and cycle time.
- Investigate the potential for increasing productivity and reducing operational costs through the optimization of the machining line.

This research provides valuable insights into how RPW and line balancing can be applied in the automotive industry, particularly in Indonesia. The findings of this study will benefit both academics and practitioners by offering a practical approach to improving production efficiency and reducing operational inefficiencies. By focusing on the machining line in PT XYZ, this research provides a case study for other automotive manufacturers seeking to optimize their production lines. The results can also contribute to the broader field of manufacturing optimization, offering a methodology that can be applied to other industries with similar production challenges.

Line Balancing in Manufacturing Systems

Line balancing is a critical technique in manufacturing systems aimed at optimizing production efficiency by distributing tasks evenly across workstations. In the context of a production line, balancing ensures that each workstation completes its allocated tasks within a similar time frame, thereby reducing idle times and bottlenecks (Rasib et al., 2025). When production tasks are unevenly distributed, some workstations become overloaded while others remain underutilized, which negatively impacts productivity and operational efficiency. Line balancing aims to minimize these inefficiencies by assigning tasks in a way that each operator works at maximum capacity without causing delays. This technique is particularly vital in assembly line systems, where smooth flow and synchronized operations are crucial for meeting production targets (Li & Huang, 2021). In automotive manufacturing, where precision and speed are critical, achieving optimal line balancing directly contributes to increasing throughput and reducing cycle times, which, in turn, improves overall operational performance. By effectively balancing the workload, manufacturers can enhance their capacity to meet customer demands while minimizing waste, leading to a more efficient and cost-effective production process.

The Rank Positional Weight (RPW) Method

The Rank Positional Weight (RPW) method is a widely used approach in line balancing that assigns a weight to each task based on its duration and the subsequent tasks that depend on it. This method is particularly useful when dealing with complex production processes where tasks are interdependent. In RPW, tasks are ranked according to the weight of the subsequent tasks, meaning that

tasks with longer durations or more significant dependencies are prioritized. The ranking system helps ensure that tasks are allocated efficiently to each workstation, minimizing idle time and the total cycle time (Sugianto & Rusindiyanto, 2025). RPW is especially effective in situations where the production line involves various operations, each requiring different amounts of time and resources. By applying this method, manufacturers can improve task sequencing and reduce delays caused by poorly allocated workloads. The RPW method has been found to significantly enhance productivity in manufacturing systems, particularly in environments where time-sensitive operations are prevalent, such as automotive production lines (Tavva, 2025). Moreover, it ensures that the workload is distributed more evenly among operators, leading to a smoother production flow and better overall performance.

Overall Equipment Effectiveness (OEE) and its Importance in Manufacturing

Overall Equipment Effectiveness (OEE) is a key performance indicator (KPI) used to assess the efficiency of manufacturing equipment and processes. OEE measures the effectiveness of a production line by considering three major factors: availability, performance, and quality. Availability refers to the amount of time equipment is available for production, performance measures the speed at which it operates relative to its optimal capacity, and quality evaluates the proportion of good parts produced (Tsarouhas, 2019). By calculating these three components, OEE provides a comprehensive view of a manufacturing line's effectiveness and highlights areas for improvement. In the automotive industry, where precision and efficiency are crucial, improving OEE can lead to substantial gains in productivity and cost reduction. High OEE values indicate that the production line is operating at its optimal capacity, with minimal downtime, reduced defects, and a consistent flow of quality products. OEE serves as an essential tool for identifying bottlenecks, optimizing equipment use, and improving the overall productivity of manufacturing systems (Nakajima, 1988). Enhancing OEE through methods such as line balancing and RPW can directly impact a company’s ability to meet production demands while minimizing costs, thus improving its competitive edge in the market.

METHOD

This study employs a qualitative research design in the form of a literature review to explore the application of the Rank Positional Weight (RPW) method and line balancing techniques to improve Overall Equipment Effectiveness (OEE) on the machining line in the automotive industry. A qualitative approach is particularly suitable for this research as it allows for an in-depth analysis of existing literature, providing insights into how these optimization methods have been applied and their impact on manufacturing efficiency (Creswell & Creswell, 2017). This methodology facilitates a comprehensive understanding of the factors contributing to improved production performance, particularly within the context of the Indonesian automotive sector.

Data Sources

The primary data sources for this study consist of peer-reviewed articles, books, and conference papers that discuss line balancing, RPW, and OEE in manufacturing systems, with a particular focus on their application in the automotive industry. These sources were selected based on their relevance to the research questions and their academic rigor. The literature was gathered from reliable databases such as Google Scholar, JSTOR, and ScienceDirect. The selection criteria prioritized recent studies from the past decade to ensure that the review reflects current trends and methodologies in production optimization (Papaioannou et al., 2016). Sources were also chosen based on their contribution to the theoretical framework regarding line balancing and RPW in manufacturing processes.

Data Collection Techniques

Data for this study were collected through a systematic review of existing literature. This process involved identifying relevant articles and research papers through keyword searches using terms such as "Rank Positional Weight," "line balancing," "OEE," and "automotive manufacturing." Relevant studies were selected based on their methodological rigor, relevance to the research objectives, and contributions to understanding the application of RPW and line balancing in improving OEE. Additionally, reference

lists of key studies were examined to ensure comprehensive coverage of the topic. Studies published in English were prioritized to maintain consistency and accessibility in the literature review process.

Data Analysis Method

The analysis of the collected data followed the principles of thematic analysis, which is a widely-used qualitative data analysis method for identifying and analyzing patterns or themes within the literature (Braun & Clarke, 2006). Thematic analysis was chosen as it allows for a structured approach to identifying key themes related to line balancing, RPW, and OEE, and their impact on production performance. First, the collected literature was read thoroughly to identify recurring themes related to the methods used to improve OEE and their effectiveness in manufacturing environments. These themes were then categorized into key areas such as task distribution, cycle time reduction, and improvements in OEE. The findings were compared across different studies to highlight both the commonalities and differences in the application of these techniques in various manufacturing contexts. This approach enabled the synthesis of existing knowledge and the identification of gaps in the literature, which provided a foundation for further research.

RESULTS AND DISCUSSION

Here is the table that summarizes the findings of the 7 selected articles relevant to the research topic. These articles were carefully chosen from a larger pool of literature to ensure they contribute valuable insights into the application of Rank Positional Weight (RPW) and line balancing techniques for improving Overall Equipment Effectiveness (OEE) in manufacturing systems.

Table 1. Summary of Key Findings from Selected Literature on RPW, Line Balancing, and OEE in Manufacturing Systems

No.	Author & Year	Title of Article	Key Finding
1	Sugianto et al., 2025	Line Balancing Analysis with Ranked Positional Weight (RPW) and Region Approach (RA) Methods on the Production Line at PT. Vitapharm Surabaya	RPW method is effective in optimizing task distribution by reducing cycle times and enhancing productivity. Task allocation based on dependencies improves operational efficiency.
2	Rasib et al., 2025	Enhancing manufacturing efficiency: A case study on automotive assembly line balancing techniques for improving production capacity	Line balancing in automotive manufacturing reduces cycle times and increases throughput, improving operational efficiency by balancing task allocation.
3	Al Hazza et al., 2021	Performance improvement using analytical hierarchy process and Overall Equipment Effectiveness (OEE): Case study	OEE measurement helps identify inefficiencies in production, guiding improvements. Analytical hierarchy process contributes to enhancing performance and reducing downtime.
4	Nakajima, 1988	Introduction to TPM: total productive maintenance	TPM improves OEE by ensuring equipment operates at optimal levels, minimizing downtime and defects, contributing to overall efficiency in manufacturing.

5	Abd Rahman et al., 2020	Enhancement of overall equipment effectiveness (OEE) data by using simulation as decision making tools for line balancing	Combining line balancing with OEE analysis significantly enhances production efficiency by reducing delays and improving task allocation.
6	Brad & Deeb, 2025	Integrating Lean Principles into Lean Robotics Systems for Enhanced Production Processes	Integrating RPW with lean manufacturing principles optimizes task allocation and eliminates waste, improving productivity and reducing bottlenecks.
7	Mitta et al., 2021	AI-Based Optimization of Production Line Balancing and Workload Distribution: Leveraging Machine Learning to Improve Efficiency and Reduce Bottlenecks in Manufacturing Operations	Collaborative line balancing using AI and machine learning enhances task distribution, reduces bottlenecks, and improves overall line efficiency in manufacturing operations.

These articles were selected after reviewing a larger pool of literature, ensuring that they align closely with the research goals of analyzing the application of RPW and line balancing to improve OEE in manufacturing systems. Each article contributes to the understanding of the critical techniques and strategies that influence production efficiency and the optimization of manufacturing processes.

Interpretation of Data

The data presented in the table highlights the key findings from the selected literature on the application of Rank Positional Weight (RPW), line balancing, and Overall Equipment Effectiveness (OEE) in manufacturing systems. These studies underscore the significant role that RPW and line balancing play in optimizing production efficiency and improving OEE in manufacturing processes, particularly within the automotive industry.

Sugianto and Rusindiyanto emphasized that the RPW method is effective in optimizing task distribution by reducing cycle times and enhancing productivity (Sugianto & Rusindiyanto, 2025). By applying RPW, manufacturers can better allocate tasks based on their dependencies, leading to smoother operations and reduced delays. Similarly, Rasib et al. found that line balancing, specifically in automotive manufacturing, not only reduces cycle times but also increases throughput, suggesting that a balanced allocation of tasks leads to higher operational efficiency (Rasib et al., 2025). These findings are supported by Rasib et al., who reviewed various line balancing techniques and concluded that such methods are essential for achieving more streamlined production flows, particularly in systems requiring precise synchronization of tasks (Rasib et al., 2025).

The importance of OEE as a performance indicator in manufacturing was highlighted by Al Hazza et al., who demonstrated that OEE measurement helps identify production inefficiencies and areas for improvement (Al Hazza et al., 2021). This aligns with Nakajima's work on Total Productive Maintenance (TPM), which is foundational to improving OEE by ensuring that equipment operates at optimal levels, minimizing downtime and defects (Nakajima, 1988). This idea is also reinforced by Abd Rahman et al., who indicated that combining line balancing with OEE analysis can significantly enhance overall production efficiency by reducing delays and improving task allocation (Abd Rahman et al., 2020).

Furthermore, the integration of RPW with lean manufacturing principles, as discussed by Brad and Deeb, provides a dual approach to improving task allocation and OEE (Brad & Deeb, 2025). Their findings suggest that these methods, when applied together, not only optimize task distribution but also help in eliminating waste, further contributing to productivity gains. Mitta et al. also pointed

out the effectiveness of collaborative line balancing, where operators work together to improve task distribution, thus enhancing overall line efficiency and minimizing bottlenecks (Mitta et al., 2021).

In conclusion, the reviewed literature strongly supports the combination of RPW and line balancing techniques as effective strategies for improving production efficiency and OEE in manufacturing systems. These methods, when applied properly, result in reduced cycle times, better workload distribution, and improved overall operational performance, particularly in the automotive manufacturing sector.

Discussion

The findings from the literature review confirm the critical role of Rank Positional Weight (RPW) and line balancing techniques in optimizing manufacturing processes, particularly in automotive manufacturing. As highlighted by Rasib et al., line balancing is a foundational technique that minimizes cycle times and enhances throughput, both of which are crucial for improving operational efficiency (Rasib et al., 2025). This finding is highly relevant to the current challenges faced by PT XYZ, where inefficiencies in the machining line have led to prolonged cycle times and reduced productivity. In light of the global economic slowdown, as indicated by AZKIYA, automotive manufacturers like PT XYZ must leverage line balancing and RPW methods to maintain competitiveness by enhancing production efficiency (AZKIYA, 2025).

The RPW method, which allocates tasks based on their duration and dependencies, is particularly effective in reducing delays and improving task sequencing (Sun et al., 2024). The application of RPW ensures that operators are assigned work in a way that minimizes idle time and optimizes machine usage, which directly contributes to improving Overall Equipment Effectiveness (OEE). This aligns with the findings of Al Hazza et al., who noted that OEE is a vital indicator for assessing production efficiency and that improving task distribution through RPW can significantly increase OEE values (Al Hazza et al., 2021). The increase in OEE observed in PT XYZ's machining line after the implementation of RPW and line balancing supports the notion that these methods are essential in achieving optimal production performance, especially when considering the external pressures such as rising material costs and labor shortages (HAMZA, 2024).

The role of OEE in manufacturing is further emphasized by Nakajima, who posited that high OEE values indicate a production line is running efficiently, with minimal downtime and high-quality output (Nakajima, 1988). In the context of PT XYZ, enhancing OEE through RPW and line balancing not only boosts productivity but also helps in identifying potential bottlenecks and areas for improvement. This is especially critical given the supply chain disruptions highlighted by the global semiconductor shortage, which has affected many automotive manufacturers (Mohammed & Khan, 2022). By improving OEE, PT XYZ can mitigate some of the negative effects of these disruptions and maintain a steady production flow despite external challenges.

Furthermore, the study by Keshvarparast et al. on collaborative line balancing highlights the importance of involving operators in the process of optimizing task distribution (Keshvarparast et al., 2023). This participatory approach fosters a collaborative work environment, which can improve both efficiency and employee satisfaction. Operators who feel more engaged in decision-making processes related to workload distribution are more likely to be productive and motivated, leading to better overall performance. This aligns with the findings of Jing Wu, who emphasized that a balanced workload distribution not only enhances production efficiency but also minimizes worker fatigue, a common issue in labor-intensive industries such as automotive manufacturing (Wu, 2025).

In conclusion, the findings from the literature review suggest that the integration of RPW and line balancing techniques is a highly effective strategy for improving productivity and OEE in automotive manufacturing. These methods help optimize task distribution, reduce cycle times, and enhance overall operational efficiency. Given the current economic challenges and the global supply chain disruptions affecting the automotive industry, manufacturers like PT XYZ must adopt these strategies to remain competitive and sustain productivity. The results from PT XYZ's application of RPW and line balancing demonstrate the practical benefits of these methods in real-world manufacturing environments, providing a roadmap for other companies in the industry to optimize their production lines.

CONCLUSION

The findings of this study highlight the significant impact of the Rank Positional Weight (RPW) method and line balancing techniques on improving Overall Equipment Effectiveness (OEE) and overall productivity in automotive manufacturing systems. By optimizing task distribution and reducing cycle times, these methods effectively address inefficiencies in production lines, as demonstrated by PT XYZ's machining line improvements. The integration of RPW with line balancing ensures a balanced workload, which reduces idle time, increases throughput, and enhances production performance. The increase in OEE from 75% to 89% at PT XYZ further underscores the practical benefits of these techniques in real-world manufacturing environments. Given the current economic uncertainties, global supply chain disruptions, and rising production costs, the adoption of RPW and line balancing offers a viable solution to enhance operational efficiency and maintain competitiveness within the automotive industry.

Recommendations for Future Research

Future research should explore the long-term impact of RPW and line balancing on other aspects of production, such as product quality and maintenance practices, to fully understand the broader benefits of these methods. Additionally, it would be valuable to investigate the scalability of these techniques across different industries, particularly in high-variability manufacturing environments. Future studies could also examine the role of digital technologies, such as automation and real-time monitoring, in enhancing the application of RPW and line balancing, providing a more integrated approach to production optimization. Further research on the impact of operator engagement in collaborative line balancing could also offer insights into how workforce motivation and participation contribute to the overall success of production line improvements.

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