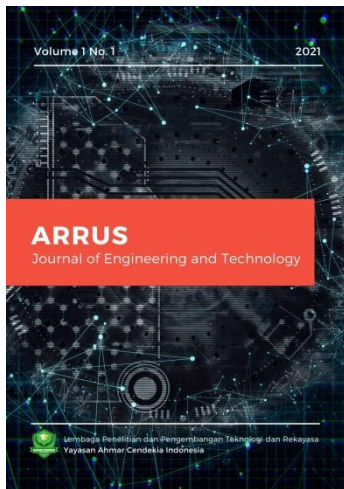




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RESEARCH ARTICLE

Green Technology Transformation Through Integration Of Ergonomic Design And Continuous Improvement In The Total Productive Maintenance Management System

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Abstract: In today's increasingly competitive industrial era, the need for an efficient and sustainable production management system is more critical than ever. This study explores the integration of ergonomic design and continuous improvement within the framework of green technology-based Total Productive Maintenance (TPM). The approach aims not only to enhance operational efficiency but also to improve workplace comfort and promote environmental sustainability. This research adopts a literature review method, analyzing various reputable scientific journals published within the last ten years. The findings reveal that the synergy between ergonomics, continuous improvement, and green technology can significantly improve productivity, reduce musculoskeletal disorder risks, and support global sustainability goals (SDGs). The implementation of Sustainable TPM (STPM) emerges as a strategic approach to address modern industrial challenges through a more holistic and inclusive management system

Keywords: Ergonomi desain, Continuous improvement, Total Productive Maintenance.

1. Introduction

In an increasingly competitive industrial era, companies are required to improve operational performance and efficiency in order to achieve excellence and competitiveness (Schindlerova, V., et al 2020). One critical aspect that is sometimes less realized by industry players in achieving these goals is in terms of technical management. Where there are new projects or improvement projects that must be effective and efficient not only in the context of the project but more than that must be appropriate for the operational users of the project results produced. In the journal (Thawatchai Jitpaiboon et al 2019) "Critical Success Factors Affecting Project Performance: An Analysis of Tools, Practices, and Managerial Support" it is explained that each project management that is implemented has several important factors as follows: the presence of a strong and confident leader accompanied by good communication, the entire project team must be able to adapt the management system methodology used by the user, have data-based insights and be involved in continuous improvement. In line with this, to meet the needs of project challenges, of course, it is necessary to develop technical management in project management, so that the sustainability of the results of the technical project is in accordance with the needs of the operational users who will use it.

With the continuous demands, the development of engineering management about knowledge of management systems in the manufacturing industry is something that cannot



be separated from its work activities. In terms of management systems (Schindlerova, V., et al 2020), the continuous improvement approach of the Total Productive Maintenance (TPM) management system has been proven effective, efficient and has been used in national and international industries in achieving the goals of improvement and sustainability in the industry and there have been many studies related to this. Research (Pardeep Gupta & Sachit Vardhan et al 2016) entitled "Optimizing Overall Equipment Effectiveness, productivity and production cost for improving sales volume in an automobile industry through TPM" shows that continuous improvement in the TPM (Total Productive Maintenance) management system can be one of the best solutions in optimizing performance, increasing productivity and reducing costs. Likewise, in terms of sustainable development, TPM can be the right solution. In the study (Rohan Thorat et al 2018) "Improvement in productivity through TPM Implementation" also provides an illustration that TPM is a management system that is able to improvise to increase production work productivity.

Based on the proponent's experience, in industrial work operations, the role of humans cannot be separated, no matter how sophisticated the machines and systems made by humans still have a central and critical role in their application. The influence of individual performance in this case employees, especially in technical matters, is certainly closely related to work comfort in the field. From research (Rashid Heidarimoghadam et al, 2019), the role of ergonomics, especially ergonomic design, in performance is very significant in the industrial world, the Effect of Ergonomic Design Interventions on musculoskeletal disorders, and productivity is very important. This research (Rashid Heidarimoghadam et al, 2019) also explains that the main causes of lost work days, increased costs, and work-related diseases in all countries, for example in Iran the prevalence of Work Related Musculoskeletal Disorder (WMSD) among workers in small and medium-sized companies was reported at 73%, meaning that it has a very big influence on performance.

One example of the output of engineering management work that has not considered green technology as a basis for synergy with ergonomic design factors and continuous improvement in the TPM management system is also reflected in its production performance:

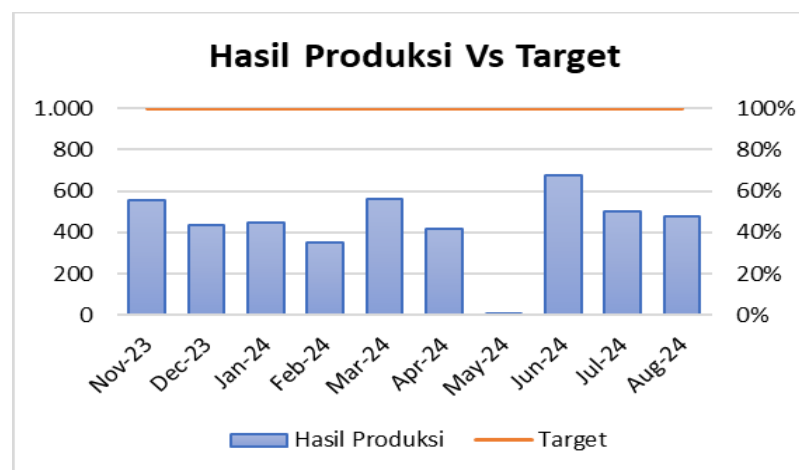


Figure 1: Production Results and Targets

Source. Visual Performance Monitoring (VPM) PT SUL September 2024.

From figure 1 we can see that in each month the output has never reached the target of the installed capacity of the machine, which is 1,000 tons per month. In May there was a complete machine overhaul so that in May the production process almost did not run at all.

In line with the series of backgrounds above, this study is expected to obtain the right strategy for the synergy of green technology in the integration of ergonomic design and continuous improvement in the Total Productive Maintenance management system so that it is appropriate and can create a better work environment, and in turn will increase the comfort of the operator's work while having a positive impact on increasing production performance.

2. Literature Review

In the Journal "Ergonomic program management in Tucurui Hydropower Plant using TPM Methodology" (Santos, et al 2013) presented at the world conference of ergonomics, explains the synergy of approaches used in combining various elements of the Total Productive Maintenance (TPM) management system with a focus on ergonomic management in industry, which involves all employees, its implementation is data-based and directly shows the right green technology improvements.

Ergonomic design focuses on the mental and physical health of workers, with companies becoming increasingly aware of the importance of employee mental and physical health. Ergonomic workspace design not only increases comfort but can also reduce stress and increase productivity. Research shows that a good work environment can increase job satisfaction and reduce absenteeism (Gonzalez et al, 2020). But of course ergonomic design has challenges in implementing ergonomic design, where even though awareness of the importance of ergonomics is increasing, many organizations have not fully implemented these principles. Continuous education and training are essential to improve understanding of ergonomics. In addition, with the increasing trend of remote work, new challenges arise in creating an ergonomic work environment (Kumar et al., 2021).

Continuous improvement, or continuous improvement, is one of the main foundations in TPM known as Focused Improvement which emphasizes systematic and ongoing efforts to identify, analyze, and eliminate sources of loss in the production process. Through this approach, cross-functional teams work together to continuously improve the efficiency and effectiveness of equipment. According to research by (Singh et al. 2022), effective TPM implementation, including a focus on continuous improvement, can significantly improve OEE in industry. The study showed that the continuous improvement approach in TPM contributed to improved equipment performance and reduced downtime.

2.1 Green Technology

Based on the contents of the journal "Sustainable manufacturing: Exploring antecedents and influence of Total Productive Maintenance and lean manufacturing" (Chen et al., 2019), the concept of green in this case green technology is interpreted as part of sustainability that focuses on environmental sustainability, namely reducing waste, emissions, energy use, and hazardous materials in the manufacturing process. From the journal (Chen et al., 2019) it also explains that the right management system in this case TPM as a lean practice that supports green technology can contribute to the environment by: Extending the life of equipment thereby reducing the need for replacement and environmental impacts, Reducing emissions and leaks through better maintenance, Avoiding machine failures that cause production waste and excessive resource consumption, Improving occupational safety and energy efficiency.

2.2 Related Research

No	Judul	Pengarang	Tahun	Persamaan	Perbedaan
1	An Empirical Study of the Implementation of an Integrated Ergo-Green-Lean Framework	Mohammad Kanan et al	2023	Jurnal ini membahas implementasi kerangka kerja yang mengintegrasikan prinsip ergonomis, hijau (green), dan lean.	Fokus utama penelitian ini adalah untuk memvalidasi model terintegrasi yang telah diajukan serta menganalisis hasil praktis dari penerapan model tersebut melalui studi kasus di unit manufaktur suku cadang otomotif.
2	Green production and green technology for sustainability: The mediating role of waste reduction and energy use	Changlin Li et al	2023	Jurnal ini mengkaji hubungan antara produksi hijau (green production), teknologi hijau (green technology), pengurangan limbah (waste reduction), penggunaan energi (energy use), dan keberlanjutan (sustainability).	Fokus penelitian ini menggunakan pendekatan Partial Least Squares Structural Equation Modeling (PLS-SEM) untuk menganalisis data yang dikumpulkan dari perusahaan di industri tekstil.
3	A Review of Sustainable Total Productive Maintenance (STPM)	Anouar Hallioui et al	2023	Jurnal ini merujuk pada penerapan teknologi dan strategi yang ramah lingkungan untuk mendukung pemeliharaan industri yang berkelanjutan. Green Technology menjadi bagian integral dari transformasi Total Productive Maintenance (TPM) menjadi Sustainable TPM (STPM).	Fokus penelitian ini yaitu STPM sebagai pendekatan alternatif dan pelengkap TPM klasik, dengan memasukkan prinsip keberlanjutan secara menyeluruh melalui kerangka kerja manajemen generasi keempat yang telah direvisi ulang (Re-engineered Fourth Generation Management – R4G4M).
4	The Role Of Green Process Reengineering In Improving The Performance Of Productive Maintenance	Raad Abidmuslim Hraiga et al	2022	Jurnal ini menekankan penerapan Green Process Reengineering (GPRE) sebagai pendekatan strategis untuk meningkatkan efisiensi operasional sekaligus mengurangi dampak lingkungan dari proses industri. Green di sini tidak hanya bermakna pengurangan emisi atau limbah, tetapi mencakup seluruh reka ulang proses bisnis agar: menggunakan energi secara efisien, mengurangi emisi dan polusi, mengelola limbah dengan cara yang lebih ramah lingkungan, menyesuaikan proses dengan regulasi lingkungan nasional dan global.	Jurnal ini mengkaji peran Green Process Reengineering (GPRE) dalam meningkatkan Total Productive Maintenance (TPM), khususnya di sektor industri kimia Irak (pabrik asam sulfat milik Al-Furat Company). Penelitian ini bertujuan untuk menjelaskan konsep TPM dan GPRE, menilai penerapan GPRE dalam meningkatkan efisiensi, efektivitas, dan kepatuhan terhadap regulasi lingkungan, memberikan solusi praktis berbasis studi kasus nyata di Irak.
5	Sustainable manufacturing: Exploring antecedents and influence of Total Productive Maintenance and lean manufacturing	Ping-Kuo Chen et al	2019	Jurnal ini menempatkan green technology dalam kerangka sustainable manufacturing, yakni produksi yang berupaya mengurangi dampak negatif terhadap lingkungan dengan memanfaatkan pendekatan Lean Manufacturing (LM) dan Total Productive Maintenance (TPM). Green technology dalam konteks ini mencakup: Pengurangan limbah dan emisi, Penghematan energi dan air, Pemanfaatan peralatan yang efisien dan berumur panjang.	Fokus Penelitian dari jurnal ini adalah: Mengidentifikasi apakah faktor lingkungan seperti tekanan dari pemangku kepentingan dan keinginan untuk mendapatkan sertifikasi lingkungan menjadi pendorong implementasi LM dan TPM. Dan Menganalisis sejauh mana LM dan TPM memengaruhi kinerja keberlanjutan lingkungan dalam perusahaan manufaktur.

Figure 2: Related Research



Based on the relevant previous research above, there are similarities where the research both discuss environmentally friendly green technology in companies, especially emphasizing how this green technology can reduce the environmental impact caused by industrial work activities. The difference between this research and previous research is that the focus of this research is the integration of ergonomic design and continuous improvement in a green technology-based management system as the answer and direction of policy for implementing environmentally friendly technology sustainability.

3. Research Method and Materials

In this study, the literature review approach is used as the main method to understand more about green technology. Researchers review and explore various scientific works that have been published previously, from reputable journals that are relevant to the theme and published in the last ten years. The source selection process is carried out carefully, taking into account the credibility of the publisher. Data sources are collected from leading academic databases such as Google Scholar, Scopus, and Web of Science so that the accuracy of the information can be accounted for, as well as the extent to which the literature is closely related to the topic we are studying. From the various references found, we conduct careful selection and assessment to ensure that each source is indeed relevant, especially in terms of the development, application, and challenges of green technology in various fields of life. After the literature is collected, we conduct a content analysis to find patterns, important themes, and gaps that still need to be studied further. Through this approach, we hope to present a complete and meaningful picture of the direction of green technology development, as well as provide recommendations based on data and scientific considerations to support the use of this technology more widely and sustainably. This process was followed by an in-depth analysis of the selected articles, using a thematic analysis framework to identify patterns, similarities and differences in the research findings (Zolkafli, U.K., Zakaria, N et al 2021).

No	Judul	Penulis	Tahun	Penerbit
1	An Empirical Study of the Implementation of an Integrated Ergo-Green-Lean Framework	Mohammad Kanan et al	2023	Jurnal Sustainability
2	Green production and green technology for sustainability: The mediating role of waste reduction and energy use	Changlin Li et al	2023	Jurnal Heliyon
3	A Review of Sustainable Total Productive Maintenance (STPM)	Anouar Hallioui et al	2023	Jurnal Sustainability
4	The Role Of Green Process Reengineering In Improving The Performance Of Productive Maintenance	Raad Abidmuslim Hraiga et al	2022	Journal of Business and Public Administration
5	Sustainable manufacturing: Exploring antecedents and influence of Total Productive Maintenance and lean manufacturing	Ping-Kuo Chen et al	2019	Journal Advances in Mechanical Engineering
6	Integrating Industry 4.0 and Total Productive Maintenance for global sustainability	Samadhiya, A., Agrawal, R., & Garza-Reyes, J.A.	2024	The TQM Journal
7	A Review of Sustainable Total Productive Maintenance (STPM)	Lahouari, M., et al	2023	Jurnal Sustainability
8	Promoting employee participation in operation and maintenance of green office building by adopting the total productive maintenance (TPM) concept	Au-Yong, C.P., et al	2022	Journal of Cleaner Production
9	Green ergonomics: Definition and scope	Thatcher, A.	2023	Ergonomic Journal
10	Green as the new Lean: How to use Lean practices as a catalyst to greening your supply chain	Dües, C.M., Tan, K.H., & Lim, M.	2023	Journal of Cleaner Production
11	Integrating and implementing Lean and Green practices based on proposition of Carbon-Value Efficiency metric.	Ng, R., Low, J.S.C., & Song, B	2015	Journal of Cleaner Production
12	Lean and green integration into production system models—Experiences from Swedish industry	Kurdve, M., et al.	2014	Journal of Cleaner Production
13	An integrated smart, green, resilient, and lean manufacturing framework: A literature review and future research directions.	Touriki, F.E., et al.	2021	Journal of Cleaner Production
14	Integrating lean and green management. Management Decision,	Hallam, C., & Contreras, C.	2016	Engineering Management Journal
15	Application of a mathematical model for ergonomics in lean manufacturing	Botti, L., Mora, C., & Regattieri, A	2017	Ergonomic Journal
16	Development of an integrated ergo-green-lean model for sustainable manufacturing.	Mehmood, A	2021	International Journal of Production Research
17	Corporate survival in Industry 4.0 era: The enabling role of lean-digitized manufacturing	Ghobakhloo, M., & Fathi, M.	2020	Journal of Manufacturing Technology Management
18	A systematic literature review identifying the current trends and future perspectives. Process Safety and Environmental Protection	Kamble, S.S., Gunasekaran, A., & Gawankar, S.A	2018	Jurnal Sustainability
19	What drives the implementation of Industry 4.0? The role of opportunities and challenges in the context of sustainability	Müller, J.M., Kiel, D., & Voigt, K.I	2018	Jurnal Sustainability
20	Application of Total Green Productive Maintenance in the Soekarno Hatta Airport Water Treatment Unit Using the Overall Equipment Effectiveness Method.	Rachmat, A.R., & Nusraningrum, D.	2024	International Journal of Innovative Science and Research Technology,
21	Green Production and Green Technology for Sustainability: The Mediating Role of Waste Reduction and Energy Use	Chaudhary, S.	2023	Jurnal Heliyon

Figure 3: Literature Review

Through this literature review approach, this study aims to provide an in-depth and informed view on how the manufacturing industry can have policy directions and face the challenges and exploit the opportunities that exist in the application of environmentally friendly green

technologies to improve efficiency, productivity, and business processes or economic performance.

4. Results and Discussion

The results of the study (Changlin Li et al 2023) show that green production and green technology have a positive and significant effect on waste reduction and energy use. This indicates that companies that implement green production and technology practices can effectively reduce waste and energy use. Waste reduction and energy use serve as mediators connecting green production and green technology with sustainability. This means that to achieve better sustainability, companies should focus on waste reduction and energy use. And the practical implications of this paper provide guidance for managers and policy makers in all manufacturing industries to adopt more sustainable practices. By optimizing resource use and reducing waste, companies can not only improve operational efficiency but also support long-term sustainability goals. This study highlights the importance of integrating green production and green technology into modern manufacturing practices. With the increasing awareness of environmental and sustainability issues, the adoption of sustainable practices is becoming increasingly urgent. The use of environmentally friendly technologies not only reduces negative impacts on the environment but can also improve company profitability through better efficiency.

In the Journal (Kanan M et al 2023) is very relevant in the current context when many organizations are trying to integrate sustainable practices in their production processes. Its main contribution is the validation of the integrated model and its positive impact on organizational performance. The results presented show that the integrated approach not only successfully reduces work stress but also has a positive impact on operational efficiency and environmental sustainability. These findings strengthen the argument for the importance of integrating ergonomic and green aspects in lean practices. And although this study provides encouraging results, further analysis of the limitations of the model and its application in other industrial contexts could be an interesting area of research. In addition, developing further regression models to predict long-term outcomes could be a suggestion for future research. Thus, this paper offers a valuable insight into how the integration of ergonomic, green and lean principles can have a positive impact on the work environment and production efficiency, and emphasizes the importance of a holistic approach in operational management.

The importance of sustainability in company operations, in line with the 2030 Agenda for Sustainable Development by the UN has become a research topic by (Halloui et al. 2023), and in this study, STPM is introduced as a strategy that is aligned with the principles of lean manufacturing and sustainability. This study shows that STPM is proposed as an innovative methodology that complements TPM practices by integrating lean and sustainability principles, and there is still a misunderstanding among researchers about STPM, which is often considered only as a complement to traditional TPM. This journal also noted that the majority of articles related to sustainability and TPM were published in the period 2018–2023, with Sustainability (Switzerland) as the most relevant journal. So STPM not only aims to improve sustainability in maintenance practices, but also supports companies in achieving broader sustainability goals, including the sustainable development goals (SDGs). And STPM can be a useful solution for companies that want to integrate more sustainable maintenance practices. The authors recommend expanding research on the understanding of STPM and its impact on maintenance practices in the context of sustainable business.

In the article (Ping-Kuo Chen et al 2019) highlighted that environmental pressure from stakeholders and efforts to obtain environmental certification significantly influence the implementation of lean manufacturing and TPM practices. This finding emphasizes the increasing importance of sustainability in the manufacturing industry. The study shows that although there is a positive correlation between the implementation of certain lean practices (including TPM) and various environmental indicators, the impact is not uniform across

practices. Different lean practices affect different operations, so a tailored approach needs to be taken in sustainability initiatives. The findings provide practical insights for manufacturing companies, allowing them to selectively implement the most effective lean practices based on their sustainability goals. The authors suggest that not all lean practices provide the same benefits for environmental outcomes, and companies should prioritize practices that are appropriate to their specific sustainability challenges. This article makes significant contributions to the knowledge of sustainable manufacturing by: filling the research gap on the relationship between TPM and environmental sustainability, proposing a framework for manufacturers to assess which lean practices are most effective in improving their environmental performance, highlighting the importance of stakeholder pressure and environmental certification as drivers in adopting green practices. Overall, this article emphasizes the important role of TPM and lean manufacturing in advancing sustainable manufacturing practices. By outlining the relationships between these variables, this article provides useful guidance for practitioners in optimizing their operational strategies to align with environmental sustainability goals. This study is significant in demonstrating that achieving sustainability is not just about implementing lean practices, but also understanding the environmental implications of these practices and choosing the right combination that delivers tangible benefits.

As another perspective in terms of green technology from the study (Raad Abidmuslim Hraiga et al 2023) emphasized that amidst the global demand for environmentally friendly production and cost efficiency, many industrial units, including in Iraq, still rely on conventional production processes. This paper underlines the importance of a green approach in process re-engineering as an answer to performance and environmental challenges. With the main reference in the implementation of the management system to support green technology where: TPM is recognized as a strategic approach that involves all employees in maintaining machines and increasing production efficiency, GPRE has proven effective in reducing maintenance costs, increasing process efficiency, and reducing environmental pollution, Process units such as chemical contact units, filtration units, and sediment treatment units are considered not to meet the green process criteria and are recommended to be re-engineered, Implementation of the double absorption tower method is an innovative solution to reduce SO₂ emissions and increase annual production capacity from 13,200 tons to 24,750 tons, and it was found that the implementation of TPM in the factory is still informal and not comprehensive. This study confirms that the integration between TPM and GPRE is a strategic approach to achieving operational efficiency and environmental responsibility. Green Process Reengineering is not only able to improve productive maintenance performance, but also becomes the foundation for more sustainable production practices. So it needs to be agreed by the industry to: ensure that there is a formal TPM unit within the factory organizational structure, comprehensive implementation of GPRE with investment support in technology such as double absorption towers, and the need for stricter supervision and use of modern measuring instruments by the Directorate of Environment to ensure compliance with environmental regulations.

5. Conclusion

As a result of an in-depth literature review and mapping of trends and challenges in the modern manufacturing industry, this study highlights the importance of an integrative approach in production management systems. The main focus lies on how the synergy between ergonomic design, continuous improvement, and green technology within the Total Productive Maintenance (TPM) framework can provide strategic solutions that not only improve operational efficiency, but also support environmental sustainability and employee well-being. The findings from various relevant studies indicate that the simultaneous application of these principles can answer the needs of the industry to remain competitive while being environmentally and socially responsible. Based on the previous discussion, the following are the conclusions that are the core of this study:



- (1). The synergy between ergonomic design, continuous improvement, and green technology in the Total Productive Maintenance (TPM) management system is crucial in creating a sustainable and efficient production system.
- (2). The application of ergonomic design has been proven to improve work comfort, reduce musculoskeletal disorders, and have a positive impact on employee productivity and well-being.
- (3). Continuous improvement as the core of TPM is able to identify and eliminate sources of loss in the production process systematically and sustainably, which leads to increased equipment efficiency and operational performance.
- (4). Green technology plays a major role in realizing an environmentally friendly production process by reducing waste, energy consumption, and hazardous emissions, as well as extending the life of production equipment.
- (5). Literature studies show that the integration of these three components (ergonomics, continuous improvement, and green technology) in an integrated manner can improve production performance, create a healthier work environment, and support the achievement of global sustainability targets (SDGs).
- (6). The implementation of green technology-based TPM (Sustainable TPM/STPM) offers a strategic approach in responding to the challenges of modern industry, by involving all elements of the organization, and supported by digital technology such as Industry 4.0.

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