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Green Productivity: Merging Environmental Efficiency with Manufacturing Competitiveness

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Abstract

Green Productivity refers to boosting productivity (output, efficiency, and quality) while reducing negative environmental impacts such as pollution, waste, and resource consumption. Utilizing natural resources-such as electricity, water, and raw materials-more effectively in order to reduce environmental harm is known as environmental efficiency. In order to effectively compete in the global market, manufacturing competitiveness entails creating items in a way that maintains high quality, low cost, and innovation. Therefore, "Merging Environmental Efficiency with Manufacturing Competitiveness" refers to creating environmentally and financially advantageous manufacturing processes-achieving sustainable industrial growth by conserving resources, cutting waste, and increasing overall efficiency without compromising profits or product quality.

Keywords - Green productivity, Environment, Sustainable Manufacturing.

Introduction

In order to achieve sustainable development, Green Productivity (GP) is a strategic approach that combines productivity enhancement with environmental management. In order to improve industrial competitiveness and environmental efficiency, it seeks to maximize the use of resources (materials, energy, and water) while reducing waste and emissions. The Asian Productivity Organization (APO) first proposed this idea in the 1990s, highlighting the fact that economic efficiency and eco-efficiency can complement one another when sustainability is integrated into production processes. Efficiency in the Environment Resource Optimization: GP encourages cleaner manufacturing practices, energy-efficient systems, and circular economy models that reduce input waste and pollution. Pollution Prevention: By integrating life cycle assessment (LCA) and waste minimization, enterprises may lower their ecological footprint and comply with environmental norms. Sustainable Innovation: Promotes the use of green technologies and eco-design, which results in the creation of sustainable products.

How the Green Productivity Induce the Environmental Efficiency and Manufacturing Competitiveness
Two Fundamental mechanism are combined to produce green productivity

- **Environmental Efficiency** - focuses on reducing emissions and resources consumption per output unit. Promotes the circular economy, waste reduction and green industrial techniques. Businesses can lessen their ecological footprints by using technologies like eco- design, energy audit, and life cycle assessment (LCA).
- **Competitiveness in Manufacturing** – Involves increasing product quality, innovative potential and cost efficiency. By lowering input costs (energy, water and raw materials) enhancing brand reputation and satisfying green market expectations, GP increases competitiveness. Businesses can get “win-win outcomes” by coordinating these two systems, which will lessen their influence on the environment while increasing productivity and profitability.

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Aim of The Study

This study's main goal is to find out how Green Productivity (GP) can be used as a strategic tool to combine manufacturing competitiveness and environmental efficiency, improving sustainable industrial performance.

The goal of this study is to determine how much GP practices-like resource optimization, eco-innovation, cleaner production, and circular economy models-can improve manufacturing companies' competitive advantage while also lessening their environmental effect. Establishing a conceptual and empirical knowledge of how environmental sustainability programs can develop from compliance-based activities into forces behind innovation, profitability, and market leadership is another goal of the study.

Objectives of the study

- To determine the main green manufacturing techniques used in contemporary production systems.
- To examine how manufacturing competitiveness and environmental efficiency are related.
- To evaluate the operational and financial advantages of implementing green productivity techniques.
- To suggest a framework for combining sustainability with technologies for continuous improvement (Lean, Six Sigma).
- To offer useful suggestions for sectors seeking to attain long-term competitiveness.

Review of literature

- Porter & van der Linde (1995) - *Harvard Business Review* "Toward a New Conception of the Environment-Competitiveness Relationship". This foundational work introduced the *Porter Hypothesis*, arguing that well-designed environmental regulations can stimulate innovation and enhance firm competitiveness rather than hinder it.
- Zhu, Q., & Sarkis, J. (2016) - *Journal of Cleaner Production*, "Green supply chain management and sustainable performance: Evidence from China". Demonstrates that environmental efficiency practices in production and supply chain management positively affect both operational and market performance.
- Chen, Y.-S., Lai, S.-B., & Wen, C.-T. (2020) - *Industrial Management & Data Systems*, "The influence of green innovation on environmental and corporate performance". Firms engaging in eco-innovation experience measurable improvements in productivity and environmental performance.
- Choudhury, A., & Deshmukh, S. G. (2019) - *International Journal of Productivity and Performance Management*, "Integrating lean and green practices for sustainable manufacturing performance". Combining lean manufacturing with environmental management significantly improves efficiency, cost savings, and sustainability.

- Singh, R. K., & Kumar, V. (2021) - *Sustainability*, "Drivers and barriers of green manufacturing: Evidence from emerging economies". Identifies technology, management commitment, and policy incentives as critical enablers of GP adoption.
- Lee, S. M., & Kim, Y. S. (2023) - *Journal of Manufacturing Technology Management*, "Green productivity and sustainable competitiveness in Industry 4.0 environments". Integration of smart technologies (IoT, AI, automation) with GP principles drives both ecological efficiency and industrial performance.
- Hart, S. L., & Dowell, G. (2011) - *Academy of Management Review*, "A natural-resource-based view of the firm: Fifteen years after." Proposes that sustainable resource management can be a strategic capability leading to long-term competitive advantage.
- M. (2015) - *Journal of Cleaner Production*, "Analysing the drivers of green manufacturing using interpretive structural modelling." Identifies major enablers of green manufacturing such as top management commitment, regulatory pressure, and technological innovation.
- Wang, Y., & Li, J. (2018) - *Sustainable Production and Consumption*, "Green innovation and firm performance: Evidence from manufacturing firms in China." Demonstrates a positive correlation between green innovation investment and manufacturing performance.
- Dangelico, R. M., & Pujari, D. (2019) - *Business Strategy and the Environment*, "Mainstreaming green product innovation: Why and how companies integrate environmental sustainability." Firms adopting green product innovation experience improved brand image, reduced costs, and market expansion.
- Aboelmaged, M. (2020) - *Journal of Manufacturing Technology Management*, "Lean-green integration and supply chain performance." Combines lean principles with environmental practices, proving that waste reduction enhances environmental and financial performance.
- Yadav, G., & Deshmukh, S. G. (2021) - *Production Planning & Control*, "Sustainable manufacturing frameworks: A review and future directions." Reviews various frameworks integrating sustainability and productivity, highlighting the growing importance of circular economy concepts.
- Liu, X., & Yang, J. (2022) - *Sustainability*, "Impact of green supply chain management on sustainable competitiveness: Mediating role of innovation capability." Demonstrates that innovation capability mediates the relationship between green practices and competitiveness.
- Rahman, M., & Subramanian, N. (2023) - *Resources, Conservation & Recycling*, "Circular economy adoption and manufacturing competitiveness: Evidence from Southeast Asia." Shows how circular production models increase resource efficiency and reduce costs.
- Alonso-Almeida, M. D. M., & Rodríguez-Antón, J. M. (2024) - *Sustainability Science*, "Sustainable operations and competitiveness: A cross-sector analysis." Provides empirical evidence that sustainability-oriented operational strategies correlate with higher market competitiveness across multiple sectors.

Research methodology

Structured Survey is being separated into three parts:

- Green productivity practices include eco-innovation, waste reduction, resource efficiency, and cleaner production.
- Environmental Efficiency Measures (waste reduction, emissions reduction, and energy savings)

➤ **Manufacturing Competitiveness Metrics** (capacity for innovation, market performance, cost effectiveness, and productivity)

GREEN PRODUCTIVITY	HIGH COMPETITIVENESS	MEDIUM COMPETITIVENESS	LOW COMPETITIVENESS	TOTAL
HIGH GP	28	15	7	50
MEDIUM GP	20	22	12	54
LOW GP	10	18	18	46
TOTAL	58	55	37	150

Chi Square Test

Hypothesis

- H_0 (Null Hypothesis): **There is no significant association between Green Productivity (GP) adoption level and Manufacturing Competitiveness.**
- H_1 (Alternative Hypothesis): **There is a significant association between GP adoption and manufacturing competitiveness.**

Table 1: Green Productivity and Manufacturing Competitiveness

Chi-Square Results

Chi square value - $p=0.00561$

Degree of freedom- 4

Interpretation

Reject H_0 : There is a significant relationship between Manufacturing Competitiveness and Green Productivity. This implies that businesses with high GP adoption are more likely to be highly competitive. Reduced competitiveness is linked to low GP adoption.

Percentage Test

Recycling under green productivity improve environmental efficiency

RECYCLING IMPROVES ENVIRONMENTAL EFFICIENCY	RESPONSE	FREQUENCY	PERCENTAGE
	Yes	115	76.67%
	No	35	23.33%

Interpretation

76.67% positive response → recycling is a major contributor to environmental efficiency.

Findings

➤ **High Green Productivity Practice Adoption-** Many respondents stated that their companies have put in place fundamental green productivity strategies such recycling initiatives, energy-saving technologies, waste reduction, and pollution control systems. This shows a strong corporate commitment to production in an environmentally responsible manner.

➤ **Environmental Efficiency Is Considerably Increased by Green Productivity** The majority of respondents concurred that green productivity produces quantifiable environmental advantages across all measures. These include using raw materials more effectively, producing less

waste, emitting fewer emissions, and using less energy. This demonstrates that environmental efficiency is directly improved by green activities.

- **The Most Known Advantage is Energy Efficiency-** The most favourable replies were given to energy-efficient techniques, such as modernizing equipment, streamlining manufacturing, and keeping an eye on energy consumption. Workers think these enhancements significantly lower operating expenses and their impact on the environment.
- **Waste Reduction is Effective but Needs Improvement-** Although they pointed out irregularities in full-scale waste minimization, respondents praised advancements in garbage processing, segregation, and recycling. This indicates that in order to fully reap the benefits of waste reduction, internal procedures and infrastructure could be strengthened.
- **Reuse and Recycling Significantly Improve Eco-Performance** Recycling and reuse initiatives greatly increase environmental efficiency, according to a sizable portion of respondents. This indicates that workers are conscious of the economic and environmental benefits of closed-loop systems.

Conclusion

By integrating sustainable practices into essential production processes, green productivity successfully combines manufacturing competitiveness with environmental efficiency. The majority of respondents regularly acknowledge the beneficial effects of green measures, such as waste reduction, energy efficiency, recycling, and pollution control, on increasing environmental performance, according to the percentage analysis of 150 respondents. Reduced production costs, better product quality, increased resource optimization, and improved company reputation are just a few of the competitive advantages that result from these environmental improvements. Overall, the results show that green productivity is a strategic factor that drives long-term economic competitiveness in addition to being an ecological need. Businesses are better positioned to attain operational excellence and support sustainable development when they embrace and invest in green productivity methods.

Green productivity is a potent way to combine manufacturing competitiveness with environmental sustainability. Green Productivity helps businesses attain both ecological responsibility and financial success by enhancing resource efficiency, encouraging innovation, and supporting circular economy activities. For industrial managers and politicians seeking sustainable industrial transformation, this study offers a strategic model that connects Green Productivity practices with eco-efficiency and competitiveness.

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