



## **Role Green Leadership In Digitalizing Production And Operations Management To Realize Sustainable Development In The Industry 4.0 Era**

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**Abstract.** *The Industrial Revolution 4.0 is driving digitalization in production and operations management (MPO), but it is also giving rise to environmental challenges such as increased energy consumption and e-waste. This situation demands the presence of green leadership as a form of leadership capable of balancing digital efficiency with environmental sustainability. This study aims to analyze the role of green leadership in MPO digitalization to realize sustainable development. The method used is a Systematic Literature Review (SLR) with a content analysis approach of eight national and international journals from the period 2019–2025. The results show that green leadership plays a significant role in strengthening MPO digitalization. Seven of the eight studies support that green leadership encourages efficiency, innovation, and green behavior that support sustainable digital transformation. Meanwhile, one study indicates that digitalization without green leadership values can have negative ecological impacts.*

*This research emphasizes the urgency of green leadership as a moral and strategic guide in MPO digitalization, so that the technological transformation process is not only oriented towards efficiency, but also based on sustainability in accordance with the objectives of the Sustainable Development Goals (SDGs).*

**Keywords:** *Green leadership , Digitization of Production and Operation Management , Sustainable .*

### **INTRODUCTION**

The current development of the global industry is marked by the presence of the fourth industrial revolution or Industry 4.0. This fourth industrial revolution brings production and operations into the era of... increasingly sophisticated. Industry 4.0 is characterized by the use of advanced digital technology such as *Internet of Things (IoT)*, *Big Data Analytics* , *Artificial Intelligence (AI)*, and *Cyber-Physical Systems* (Binus.ac.id, 2020) . This transformation not only changes organizational work patterns but also demands more adaptive, efficient, and highly competitive production and operations management (MPO). Digitalization of MPO has become a strategic necessity for companies to be able to respond to increasingly dynamic market competition. there are demands for high productivity, and to support long-term production sustainability.

Digitalization On the one hand, MPO has indeed contributed significantly to production efficiency, real-time energy usage control, increased production, and improved product quality. However, digital technology also poses environmental risks. The rapid growth of electronic devices has led to an increase in e-waste, which, if inadequate recycling infrastructure is lacking, can exacerbate pollution (Kartiasih et al., 2025). Furthermore, in the use of *cloud management*, and Data servers also contribute significantly to environmental emissions due to their high energy consumption (Kartiasih et al., 2025). Therefore, advances in digital technology applied to production and operations systems not only have positive impacts but also present new challenges, particularly regarding environmental impacts, energy consumption, and resource optimization.

It's true that in today's world, global environmental issues are no longer taboo; their impacts are already being felt in every sector of activity. These issues include climate change, the energy crisis, and ecosystem degradation. According to Armida, a 2002 *WHO report* stated that the quality of urban air pollution in various countries, when accumulated, has caused approximately 800,000 deaths annually (Alisjahbana & Murniningtyas, 2021). This is due to the high levels of fine particles, generally produced by vehicles and industry, which can lead to respiratory infections and cancer.

environmental damage is also actually caused by human behavior and business activities themselves. Therefore, companies also feel the impact of the pressure, namely in the form of demands to take action to carry out green initiatives as part of their CSR programs. The CSR or Corporate Social Responsibility program in Indonesia itself has been regulated in the *Republic of Indonesia Law No. 40 of 2007, concerning Limited Liability Companies*. In Chapter I Article 1 of the Republic of Indonesia Law No. 40 of 2007 concerning Limited Liability Companies point 3, it is explained that " *social and environmental responsibility is a company's commitment to participate in sustainable economic development in order to improve the quality of life and the environment that is beneficial, both for the company itself, the local community, and society in general* " (Law of the Republic of Indonesia, 2007).

This law is a form of commitment between the government and companies to maintain sustainable production and preserve the environment in Indonesia. Thus, companies are no longer solely oriented towards economic performance, but also take an active role in sustainable development, also known as the *Sustainable Development Goals (SDGs)*. To realize this active role, the steps taken by an organization to address this challenge cannot be met simply by making changes to operational improvements. It also requires a transformation of organizational culture and leadership. This will enable the organization to grow and direct its workforce to be more environmentally conscious. This effort is crucial because it will align the organization with the concept of the SDGs as a *Global Agreement* that encourages new development approaches. Namely, development that provides increased community welfare (*People and Profit*), without having a negative impact or being able to minimize damage experienced by the environment (*Planet*) (Alisjahbana & Murniningtyas, 2021).

Amidst the urgency of sustainable development, the concept of a leadership approach that focuses not only on profit but also on environmental sustainability is gaining popularity and familiarity. This approach is known as *Green Leadership*. (Widiartanto et al., 2023). The concept of the *Green Leadership approach* is considered to align with the objectives of the SDGs, particularly in the production and operations sector, namely goals 9 (*industry, innovation, and infrastructure*), 12 (*responsible consumption and production*), and 13 (*climate action*). Therefore, the concept of *Green Leadership* plays a crucial role in the sustainability of a company's business today.



Gambar 1. SDGs Goals

Furthermore, organizations must be sensitive to the two major challenges currently facing economic sustainability and current global issues. With the demands of the Industrial Revolution 4.0 and environmental issues, combining the concepts of *Green Leadership* and Digital MPO (Management and Public Opinion) can be a relevant strategy to address current challenges. Both concepts have the potential to provide competitive advantage to companies and integrate sustainability principles into their operations. production and operations management or in facing future environmental regulations.

Against this backdrop , it is clear that previous research has provided a significant foundation for understanding the role of *green leadership* and the contribution of MPO digitalization to sustainability. However, the focus of this study differs from previous research . While much of this research focused on the relationship between *green leadership* and company performance or corporate culture, research on MPO digitalization focuses on the impact of digitalization on efficiency, increased production, and product quality. While previous research explicitly discusses the relationship between MPO digitalization and sustainable development, none has yet specifically emphasized the role of green leadership in this regard. Therefore, this research is important to be conducted with the aim of gaining a comprehensive understanding of the role of *green leadership* in the digitalization of production and operations management in realizing development sustainable in this industrial era 4.0 .

## LITERATURE STUDY

### Green leadership

*Green leadership* is etymologically composed of two syllables, namely *green* and *leadership* , which means green leadership. In Indonesian, "*green*" can be contextually interpreted as "environment. " *Leadership* , in terminology, is the ability of an individual to direct group activities to achieve common goals (Constantinus et al., 2022) .

*Green leadership*, in terminology, is a leadership approach that emphasizes the values of sustainability, environmental awareness, and social responsibility in strategic organizational decision-making (Tri Siwi Agustina et al., 2025) . The concept of *green leadership* has evolved along with the increasing need for organizations to adapt to global environmental challenges and the demands of sustainable development or SDGs (Ullah Khan et al., 2023) . In the context of modern management, a green leadership style acts as an agent of change that directs organizations towards environmentally friendly behavior through strategic decision-making, employee education, and the implementation of green values in the work culture.

In practice, a green leadership approach focuses not only on an organization's profits but also ensures that organizational decisions and actions align with environmental

sustainability goals. The characteristics of someone who implements this green leadership approach include: first, visionary, where someone with green leadership has a long-term vision that combines a balance between economic, social, and environmental interests (Sun et al., 2022) . Second, inspirational, where someone with a green leadership style is able to inspire their followers to care for the environment (Sopiawadi et al., 2021) . Third, they are oriented towards green innovation, meaning they encourage creative ideas that produce environmentally friendly products, processes, or technologies and are not easily influenced to deviate from principles that support environmental sustainability ( Sopiawadi et al., 2021) . Fourth, open to change, meaning someone with green leadership must be open to current changes, whether from technological developments, digitalization, global conditions, and other elements of change (Widiartanto et al., 2023) .

With these characteristics, individuals with green leadership skills have become very important figures in helping companies accelerate and broaden their understanding of current business issues, particularly those related to sustainable development.

## Digitalization of Production and Operations Management

The digitalization of Production and Operations Management (MPO) is a fundamental transformation in the modern industrial world, where previously manual and fragmented production and operational processes are now being replaced by integrated digital systems. This transformation utilizes technologies such as *the Internet of Things* (IoT), *Big Data Analytics* , *Artificial Intelligence* (AI), and cyber-physical systems with the aim of increasing the efficiency, flexibility, and adaptability of industries to market changes. According to research by Angelopoulos et al. (2023), digital transformation in production and operations management not only changes tools and work processes but also redefines human roles through the phenomenon of agency reversal, where digital systems take over part of the decision-making process, while humans shift to strategic monitoring and control functions (Angelopoulos et al., 2023) .

The development of MPO digitalization aligns with the Industrial Revolution 4.0, which emphasizes the integration of the physical and digital worlds. In this context, *the smart factory concept* symbolizes the comprehensive implementation of digital technology, from real-time data collection and the use of smart sensors for quality control to the implementation of predictive maintenance to minimize machine downtime. According to Lasi, Industry 4.0 reflects a paradigm shift toward interconnected production systems capable of making autonomous decisions based on data collected simultaneously from all lines of operation (Angelopoulos et al., 2023) .

The development of MPO digitalization is driven by the industry's need to respond to rapid market dynamics and demanding customer needs for high quality. According to Frank et al. (2019), cited in Estin et al. (2024), the application of digital technology in the manufacturing sector can encourage production process optimization, the implementation of predictive maintenance systems, and increased integration within the supply chain (Pristiwaningsih et al., 2024) . The combination of these three aspects results in reduced operational downtime, reduced maintenance costs, and an impact on increasing the effectiveness of resource use, which ultimately also impacts higher operational efficiency.

Examples of digital transformation implementations in MPO include *IoT integration* . This integration enables real-time monitoring of production processes. IoT's role in *this area* helps manufacturers identify and prepare resolution options for problems. This allows for faster and more measurable decisions, before downtime occurs. Furthermore, automation and AI play a crucial role in digital transformation in manufacturing. These technologies help automate repetitive tasks, improve accuracy, and reduce human error. Despite the numerous benefits of digital transformation in MPO, MPO digital



transformation also presents several challenges. Issues such as high implementation costs, resistance to change, cybersecurity risks, and the ongoing impact on the environment can hinder the successful adoption of digital technology.

### ***Sustainable Development Goals (SDGs)***

*Development Goals* (SDGs) are a global agenda adopted by the United Nations (UN) in 2015. The SDGs consist of 17 main goals and 169 targets to be achieved by 2030. The focus of the SDGs covers three main dimensions: social, economic, and environmental. The background to the emergence of *the Sustainable Development Goals* (SDGs) began with global awareness of the need for development that is not only oriented towards economic growth, but must also pay attention to social balance and environmental sustainability. *SDGs* In the context of industrial and economic development, the SDGs provide a major impetus for the adoption of technology, innovation, and resource efficiency. Through a sustainable approach, the production and operations sectors are encouraged to be more environmentally friendly, energy efficient, and adaptive to the development of digitalization. This shows that the SDGs are not only about social development, but also become an important foundation for the transformation of the industrial system towards a sustainable green and digital economic model.

**Tabel 1.** Ringkasan penelitian terdahulu yang relevan

Research Title	Research methods	Research Focus	Correlation of Research Results with the Role of Green Leadership in MPO Digitalization
Integration of Green Leadership and Green Human Resources Management: Strategies for Achieving Sustainability Organizations in the Modern Business Era	<i>Systematic Literature Review</i> (SLR) with PRISMA Approach	<i>Green leadership</i> and GHRM	Identifying the main dimensions of <i>green leadership</i> that are visionary, transformational, and participatory is a crucial aspect in building and supporting MPO digital transformation and sustainability.
The Impact of Digital Technologies on Environmental Quality: Empirical Evidence from Indonesia	Quantitative – System Generalized Method of Moments (GMM), panel data of 34 Indonesian provinces (2013–2023).	The impact of digital technology on environmental quality	The results show that digitalization without green leadership has the potential to increase emissions and waste, so green leadership is needed to make digitalization more sustainable.
Green Transformational	Quantitative - analyzed using	<i>Green transformational</i>	<i>Green leadership</i> provide a positive impact

<b>Leadership and Environmental Performance in Small and Medium Enterprises</b>	SmartPLS-based <i>Structural Equation Modeling</i> (SEM).	<i>leadership and environmental performance</i>	on environmental performance through GHRM and <i>Green Innovation</i> .
<b>The Influence of Green Transformational Leadership and Environmental Satisfaction on Employee Environmental Performance at Jakarta Harbor Hospital Employees</b>	Quantitative - correlational with AMOS analysis; samples were taken through convenience sampling.	<i>Green Transformational Leadership Satisfaction</i> , and <i>Green Work Engagement</i> in the employee environment.	<i>Green leadership</i> skills are effective in growing employee engagement and participation in being environmentally friendly.
<b>Green leadership and Corporate Social Responsibility: Study of Community Responses to CSR Activities of PT Pertamina Fuel Terminal Boyolali</b>	Quantitative descriptive, with a sample of 146 respondents who were beneficiaries of 12 CSR programs in four assisted villages (2017–2020)	Green leadership and CSR	The implementation of green leadership encourages CSR sustainability and transparency, which can be enhanced through the digitalization of corporate social reporting and monitoring systems.
<b>Green Leadership, Extroversion Personality, and Emotional Intelligence on Employee Performance at the Sidoarjo Regency Environmental Service</b>	Quantitative with multiple linear regression analysis; data obtained through questionnaires to employees of the Sidoarjo Regency Environmental Service.	Analyzing the influence of green leadership, extroversion personality, and emotional intelligence on employee performance at the Sidoarjo Environmental Service	Green leadership enhances positive and adaptive behaviors that serve as the foundation for implementing efficiency and sustainability-based MPO digitalization.
<b>Digital Transformation in the Manufacturing Industry: Impact on Operational Efficiency</b>	Quantitative, survey of 150 small manufacturing firms, multiple linear regression analysis.	Digital transformation and operational efficiency	The research results show that innovation and efficiency-oriented leadership (core values in green leadership) plays an important role in accelerating the adoption of sustainable digital technologies.

<b>Digital Transformation in Operations Management: Fundamental Change through Process Innovation</b>	Systematic Literature Review (SLR)	Analyze how digital transformation is changing operations management through process and business model innovation.	The research results show that green-oriented visionary leadership is needed so that digital transformation is not only efficient but also environmentally sustainable, in line with the principles of green leadership in MPO digitalization.
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## RESEARCH METHODS

This research uses a *Systematic Literature Review* (SLR) approach. to comprehensively examine the role *Green leadership* in supporting the digitalization of production and operations management to realize sustainable development in the era of industry 4.0 . The SLR research method was chosen because this method is able to collect, evaluate, and synthesize the results of previous research systematically, so as to produce a comprehensive understanding of a topic (Supriadi et al., 2025). The literature search process was carried out through databases in the form of scientific articles, national and international journals relevant to the topic. The literature search process was carried out with the search string: ( *Green Leadership* ) , (MPO Digitalization), and ( *Sustainable Development Goals / SDGs*). From the initial search, 22 articles were found. After being filtered based on inclusion criteria such as the year of publication (2020-2025), type of article, and scientific journal, 8 articles remained *that* were considered relevant and in accordance with the research objectives. From all the article data that has been collected, it will then be researched or analyzed with the aim of obtaining comprehensive conclusions. In this study, the analysis technique that will be used is the content analysis technique. Content analysis techniques can be interpreted as a data analysis method by identifying and describing all data that is relevant to the research.

## DISCUSSION

As part of the literature analysis , **Table 1** presents a summary of relevant previous research, along with research findings related to *green leadership* , sustainable development, and MPO digitalization.

Based on the analysis of eight journals reviewed using the *Systematic Literature Review* (SLR) approach, various findings were obtained that demonstrate a close relationship between the role of green leadership and the digitalization process in production and operations management (MPO). To gain a deeper understanding, the data was processed descriptively and grouped into several discussion subthemes that reflect the patterns of interrelationships between the studies to achieve a comprehensive understanding.

### The Relationship Between Green Leadership and MPO Digitalization

Based on the analysis of eight relevant journals, it was found that the concept of green leadership has a strong and significant relationship with the success of digitalization in

production and operations management (MPO). Of the total studies, seven journals (87.5%) showed that green leadership plays a role in supporting the sustainable digitalization process, while one journal (Kartiasih et al., 2025) indicated that digitalization without green leadership can actually have a negative impact on the environment. This shows that the successful implementation of MPO digitalization depends not only on technological readiness but also on a leadership style that can guide organizational change ethically and sustainably. In this context, green leadership plays a role as a link between digital innovation and sustainability values, so that digitalization not only emphasizes process efficiency but also considers the ecological and social impacts of a company's operational activities.

### **Green leadership as a driver of sustainable digital transformation**

Analytical results from several studies (Perwira et al., 2025; Sun et al., 2022; Lituhayu et al., 2024; Yanti & Nawangsari, 2019) show that green leadership plays a crucial role in shaping the direction and culture of an organization that supports sustainable digital transformation. Green leaders generally possess visionary, inspirational, and innovation-oriented characteristics, which encourage employee engagement and greater adaptability to technology-based changes. For example, research by Perwira et al. (2025) shows that the integration of green leadership and green human resource management strengthens innovation and production efficiency, while research by Sun et al. (2022) confirms that green transformational leadership can improve environmental performance through the mediation of green HRM and green innovation. Both findings emphasize that green leaders not only guide organizations to adopt technology but also ensure that digital transformation is carried out with attention to energy efficiency, human well-being, and ecological impact. Thus, green leadership can be understood as a strategic factor that ensures digitalization is aligned with the principles of sustainability-oriented transformation.

### **Synergy of Green Leadership with Innovation and Operational Efficiency**

Digitalization in MPOs primarily aims to improve operational efficiency and effectiveness, but this is only optimal if accompanied by green-oriented leadership. Research by Angelopoulos et al. (2023) confirms that digital transformation through process innovation and real-time data integration can fundamentally transform operations management toward efficiency and sustainability. Similarly, Pristiwaningsih et al. (2024) found that the adoption of digital technologies such as automation and big data analytics significantly improves operational efficiency in the manufacturing sector. Both findings demonstrate that green-oriented leaders play a crucial role in guiding digital innovation, ensuring that it not only pursues efficiency but also ensures that environmental responsibility principles are implemented in every process. In the context of MPOs, green leadership plays a role in ensuring that digital innovation does not create new pollution but instead helps control waste and optimize production resources.

### **Human Resource Empowerment as a Strengthening Element of MPO Digitalization**

Human resources are a key variable in linking green leadership to successful digitalization. Research by Yanti & Nawangsari (2019) shows that green training *and* employee green behavior are foundational to sustainable corporate performance. A similar finding was found by Lituhayu et al. (2024), who found that green transformational leadership increased green work engagement, which indirectly strengthened employee environmental performance.

Furthermore, Astuti et al. (2023) added a psychological dimension to green leadership, namely through the role of personality and emotional intelligence, which enhance adaptive capacity to digital innovation. From a social perspective, research by



Widiartanto et al. (2023) also highlighted the importance of green leadership in strengthening corporate social responsibility (CSR), where digital-based activities can expand transparency and community participation. Therefore, it can be concluded that human resource empowerment led by green leadership focuses not only on technical skills but also on building ecological awareness and collaboration, which are the foundation for successful MPO digitalization

## Challenges and Implications for the Implementation of MPO Digitalization

Although the majority of research supports the role of green leadership in MPO digitalization, research by Kartiasih et al. (2025) reveals another side of digital transformation. The study found that the use of digital devices without sustainable management actually increases energy consumption and generates electronic waste (e-waste). This indicates the risk that digitalization without green leadership values can lead to new environmental degradation. Therefore, the role of green leaders is crucial in directing digital policies to be more environmentally friendly through energy efficiency, sustainable product design, and green digital education for employees. Practically, organizations need to implement a green digital strategy policy led by a visionary leader to ensure that digital transformation not only accelerates business processes but also strengthens the company's commitment to sustainable development.

## CONCLUSION

Based on the analysis of eight journals examining the relationship between green leadership and the digitalization of production and operations management (MPO), it can be concluded that green leadership plays a strategic and fundamental role in ensuring the success of sustainable digital transformation. Of the eight studies, seven showed that *green leadership* consistently supports the MPO digitalization process, both directly through increased efficiency, innovation, and environmental performance, and indirectly through strengthening green behaviors, training, and employee engagement. The role of *green leadership* is reflected in its ability to build a visionary, adaptive, and environmentally conscious organizational culture.

Green leaders serve not only as decision-makers but also as change agents who instill sustainability values in every aspect of digital transformation. The integration of green leadership and digital technology results in efficient production processes, resource optimization, and reduced ecological impacts through environmentally friendly technology-based innovations. Conversely, without green leadership, digitalization has the potential to negatively impact the environment, such as increased energy consumption and e-waste, as demonstrated by research by Kartiasih et al. (2025). Thus, *green leadership* can be positioned as a guiding factor and moral driver in the MPO digitalization process, bridging the goals of economic efficiency with the principles of environmental sustainability. The synergy between the two not only increases organizational competitiveness in the Industry 4.0 era but also supports the achievement of the Sustainable Development Goals (SDGs), particularly goals 9 (Industry, Innovation, and Infrastructure), 12 (Responsible Consumption and Production), and 13 (Action on Climate Change).

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