



Integrated Framework of Green Lean-Agile Management (GLAM) for Ensuring the Long-Term Sustainability of Operational Excellence Initiatives: A Case Study of Crude Palm Oil Industry in Riau Province, Indonesia

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Abstract. This article aims to develop and empirically validate an integrated framework of Green Lean-Agile Management (GLAM) to ensure the long-term sustainability of operational excellence initiatives within the crude palm oil (CPO) industry in Riau Province, Indonesia. Grounded in the Resource-Based View (RBV) and Dynamic Capabilities Theory, the research examines how lean practices, eco-innovation, and organizational agility interact to drive Sustainable Operational Excellence (SOE) in a resource-intensive, environmentally sensitive sector. A mixed-method approach was employed, combining quantitative analysis using *Partial Least Squares–Structural Equation Modeling* (PLS-SEM) with qualitative triangulation through in-depth interviews and NVivo-assisted coding. The quantitative data were obtained from 205 respondents representing palm oil mill management units and cooperative partners (KUD). The model incorporated 39 reflective indicators tested for reliability and validity following Hair et al. (2022), while the qualitative data provided contextual interpretations to strengthen empirical findings. The results reveal that *Lean Management* strongly and significantly influences *Eco-Innovation* ($\beta = 0.768$, $p < 0.001$), supporting the NRBV assumption that operational efficiency serves as a foundation for innovation capability. *Eco-Innovation* significantly enhances both *Organizational Agility* ($\beta = 0.651$, $p < 0.001$) and *Sustainable Operational Excellence* ($\beta = 0.632$, $p < 0.001$), confirming its mediating role in the GLAM model. However, *Organizational Agility* did not significantly affect SOE ($\beta = -0.028$, $p = 0.831$), indicating that flexibility and rapid responsiveness may have limited strategic relevance in industries characterized by long production cycles and relatively stable market structures such as palm oil. The article provides actionable insights for managers and policymakers to prioritize eco-innovation capabilities, particularly in green technology adoption, regulatory compliance, and stakeholder collaboration, to enhance sustainability performance. Strengthening cooperative partnerships (KKPA model), audit mechanisms, and cross-functional coordination is also recommended to institutionalize green lean-agile practices across the supply chain.

Keywords: Green Lean-Agile Management, Eco-Innovation, Organizational Agility, Sustainable Operational Excellence, PLS-SEM, Palm Oil Industry.

1 Introduction

The performance of processing mills does not solely support the sustainability of the palm oil industry but also heavily relies on the pivotal role of smallholders as key actors within the industrial ecosystem. In the face of global market pressures, stringent environmental regulations, and fluctuating commodity prices, smallholders are increasingly required to enhance efficiency, adopt environmentally friendly practices, and demonstrate adaptive capacity in response to change. The Natural Resource-Based View (NRBV) theory posits that competitive advantage can be achieved through sustainable resource management, particularly by fostering environmentally oriented innovation among both palm oil industries and smallholders [2]. However, to date, there remains no integrated framework that holistically connects operational efficiency, environmental innovation, and organizational agility within the Indonesian palm oil industry.

The Indonesian palm oil industry plays a strategic role in the national economy, accounting for more than 50% of global supply [1], with plantation areas expanding from 14.43 million hectares in 2018 to an estimated 16.83 million hectares by 2025 [3]. As one of the leading producers, Riau Province faces multifaceted challenges in maintaining operational excellence while complying with increasingly stringent environmental standards [4,5]. Global pressure for sustainable practices, commodity price volatility, and demands for operational efficiency require an integrated and comprehensive management approach [6,7,8,9,10].

According to data from the Badan Pusat Statistik (BPS) of Riau Province [4], there are 285 palm oil mills (POMs) operating under various partnership models, including Kredit Koperasi Primer Anggota (KKPA) schemes and independent smallholders. However, operational excellence initiatives often lack sustainability due to limited integration of environmental, social, and economic dimensions [21]. Preliminary studies have identified several critical issues, including inefficiencies in production processes, slow adoption of green technologies, and limited organizational responsiveness to market volatility [11,12,13,14,15].

This article proposes an integrative framework that combines the principles of Lean Management, Eco-Innovation, and Organizational Agility to ensure the long-term sustainability of operational excellence initiatives. The framework is grounded in the NRBV, emphasizing that sustainable competitive advantage can be attained through efficient and innovative resource management [16]. The integration of these three elements is expected to provide a holistic solution to the operational and environmental challenges currently faced by the palm oil industry in Riau.

This article aims to address this research gap by proposing an integrative model that places both palm oil industries and smallholders at the center of analysis, grounded in three key elements: Lean Management, Eco-Innovation, and Organizational Agility. By analyzing data from two distinct partnership models in Riau Province, this article not only elucidates the theoretical relationships among these variables but also provides a

practical framework for understanding how smallholders can directly contribute to achieving Sustainable Operational Excellence.

2 Literature Review

Sustainable Operational Excellence (SOE) is defined as the organization's ability to achieve and sustain superior operational performance by integrating economic, environmental, and social dimensions in a balanced and continuous manner [17,18]. This concept evolves from the traditional understanding of operational excellence by embedding sustainability as a core component of long-term value creation. In the palm oil industry, SOE involves optimizing production efficiency, minimizing environmental impacts, and empowering local communities [19]. Attaining SOE requires not only process efficiency but also a transformation in organizational mindset, in which environmental stewardship and social responsibility are considered strategic imperatives rather than compliance obligations. Through this perspective, SOE represents both a performance philosophy and a dynamic capability that enables palm oil organizations to maintain competitiveness while aligning with global sustainability standards.

Lean Management serves as a foundational approach to achieving SOE, emphasizing the systematic elimination of waste and the enhancement of value across all operational processes [32]. Originating from the Toyota Production System, lean management seeks to maximize customer value while minimizing resource utilization and inefficiencies. Within the palm oil sector, lean principles translate into efforts to optimize production flow, improve machinery efficiency, and reduce processing losses [33]. Empirical evidence indicates that implementing lean practices can increase productivity by up to 30% while simultaneously reducing environmental footprints through improved resource management [26]. Moreover, lean implementation cultivates a culture of continuous improvement, employee involvement, and problem-solving, which are vital to sustaining operational excellence in a competitive, resource-dependent industry [34,35,36,37,38,39].

Complementing lean practices, Eco-Innovation focuses on developing and implementing new products, processes, and business practices that promote environmental sustainability while driving economic benefits [27,28]. In the palm oil industry, eco-innovation manifests through waste-to-energy initiatives, biogas capture systems, renewable energy adoption, and sustainable agricultural practices [29]. These initiatives contribute not only to pollution reduction and energy efficiency but also to cost savings and enhanced market reputation. Previous studies highlight that eco-innovation strengthens environmental performance while simultaneously reinforcing competitive advantage [30]. Aligned with the Natural Resource-Based View (NRBV), eco-innovation is conceptualized as a strategic capability through which firms transform environmental challenges into opportunities for sustainable growth [40,41,42,43].

Another key determinant of SOE is Organizational Agility, which refers to an organization's ability to sense and respond swiftly and effectively to environmental changes [23,24]. In the highly volatile palm oil industry, characterized by fluctuating prices,

evolving regulations, and climate-related uncertainties, agility becomes an essential capability for maintaining performance stability and competitiveness [25]. Agile organizations exhibit flexible structures, rapid decision-making, and adaptive learning mechanisms that allow them to respond proactively to emerging challenges. However, applying agility in industries with long production cycles, such as palm oil, remains complex, as it requires balancing operational consistency with strategic responsiveness. Developing such agility demands not only internal flexibility but also collaboration with smallholders and supply-chain actors to strengthen collective responsiveness across the production ecosystem [44,45,46,47,48].

Drawing upon the integration of Resource-Based View (RBV) [16], Dynamic Capabilities Theory [22], and the Natural Resource-Based View (NRBV), this article constructs a comprehensive framework linking Lean Management, Eco-Innovation, Organizational Agility, and Sustainable Operational Excellence. The RBV emphasizes that valuable, rare, inimitable, and non-substitutable resources underpin sustained competitive advantage. Dynamic Capabilities Theory extends this view by highlighting the firm's ability to integrate, build, and reconfigure competencies to adapt to environmental dynamics. Meanwhile, the NRBV enriches this perspective by positioning sustainability-oriented resources and capabilities as critical drivers of long-term competitiveness [49,50,51,52].

3 Methodology

This article employs a quantitative approach through survey analysis to examine the relationships among variables, followed by a qualitative phase using in-depth interviews to explore the underlying mechanisms and contextual dynamics of these relationships. The research population consists of 285 palm oil mills (POMs) operating in Riau Province. A total of 74 respondents were selected using purposive sampling based on the following criteria: (1) a minimum of five years of experience in the palm oil industry, (2) involvement in operational decision-making processes, and (3) representation across different partnership models. The sample composition comprises 44 respondents (59.5%) from the Kredit Koperasi Primer Anggota (KKPA) partnership model and 30 respondents (40.5%) representing independent smallholders.

Primary data were collected using a structured questionnaire adapted from previously validated instruments [32,53]. The questionnaire used a five-point Likert scale and comprised 39 indicators distributed across four latent constructs. In addition, qualitative data were collected through in-depth interviews with 15 key informants selected by expert judgment to complement and contextualize the quantitative findings. Quantitative data analysis was conducted using Partial Least Squares–Structural Equation Modeling (PLS-SEM) with SmartPLS version 4.0 [53,54]. The model evaluation followed a two-step procedure: an outer model assessment (validity and reliability testing) and an inner model assessment (hypothesis testing and structural path analysis). To triangulate and enrich the results, the qualitative data were analyzed using thematic analysis, which identified patterns and themes that supported the quantitative outcomes.

The validity and reliability of the research instrument were tested using the PLS-SEM approach in accordance with the guidelines established by Hair et al. (2022) for evaluating reflective measurement models [53,54]. The measurement model comprised 39 indicators across four latent constructs: Lean Management (12 indicators), Eco-Innovation (15 indicators), Organizational Agility (6 indicators), and Sustainable Operational Excellence (6 indicators). Each construct was assessed for convergent validity, discriminant validity, and composite reliability to ensure robustness and consistency of the measurement framework.

4 Results

4.1 Results

The validity and reliability of the research instrument were examined using the Partial Least Squares-Structural Equation Modeling (PLS-SEM) approach with SmartPLS software, following the guidelines established by Hair et al. (2022) for reflective measurement model evaluation [53][54]. The measurement model comprised 39 indicators distributed across four latent constructs: Lean Management (12 indicators), Eco-Innovation (15 indicators), Organizational Agility (6 indicators), and Sustainable Operational Excellence (6 indicators). All indicators were designed in a reflective format, grounded in the Resource-Based View (RBV) theory, which emphasizes that organizational capabilities are reflected through a combination of tangible and intangible resources that are valuable, rare, inimitable, and organized [16][19].

The results of the convergent validity analysis indicated that the Average Variance Extracted (AVE) values for all constructs exceeded the recommended threshold of 0.50, with Lean Management at 0.587, Eco-Innovation at 0.612, Organizational Agility at 0.569, and Sustainable Operational Excellence at 0.634. Composite reliability values ranged from 0.821 to 0.894, demonstrating strong internal consistency and meeting the criteria established by Fornell and Larcker (1981) for a robust measurement model. Discriminant validity was confirmed using both the Fornell-Larcker criterion and cross-loadings, which indicated that each construct possessed distinct conceptual characteristics that could be statistically differentiated.

Table 1. Path Coefficients and Significance of Direct Relationships

Path Relationship	Path Coefficient (β)	Standard Deviation	T-Statistics	P-Value
LM \rightarrow EI	0.768	0.038	20.233	0.000
LM \rightarrow OA	0.212	0.104	2.031	0.042
LM \rightarrow SOE	0.258	0.114	2.255	0.024
EI \rightarrow OA	0.651	0.102	6.362	0.000
EI \rightarrow SOE	0.632	0.132	4.790	0.000

Notes: LM: Lean Management; EI: Eco-Innovation; OA: Organizational Agility; SOE: Sustainable Operational Excellence

The outer loading evaluation revealed that most indicators achieved loading values above 0.70. However, several indicators within the Green Technology dimension of the Eco-Innovation construct exhibited slightly lower loadings (ranging from 0.65 to 0.69). This finding aligns with the qualitative interview data, which indicated that the implementation of environmentally friendly technologies remains in the developmental phase for most palm oil mills (PKS) in Riau Province, particularly in relation to ongoing research and development (R&D) initiatives concerning the use of organic fertilizers, which are still under experimentation and improvement.

The path coefficient results revealed an intriguing pattern of relationships, with varying strengths across the structural paths. The relationship between Lean Management and Eco-Innovation exhibited the strongest path coefficient of 0.768 with a t -statistic of 20.233 ($p < 0.001$), indicating a significant influence (see Table 1). This finding aligns with the in-depth interviews, which emphasized that lean management practices, particularly those related to top management leadership and operational cost efficiency, serve as the foundation for developing environmentally friendly innovations. Respondents from the KKPA model reported that a well-understood corporate vision, mission, and goals among employees and cooperatives (KUD) have encouraged the implementation of standardized production processes that are not only efficient but also environmentally sustainable. This supports the propositions of Lean Management Theory as articulated by Hernandez-Matias et al. (2020) [32].

The influence of Eco-Innovation on Sustainable Operational Excellence demonstrated a path coefficient of 0.632 and a t -statistic of 4.790 ($p < 0.001$), confirming the hypothesis that eco-innovation acts as a primary driver of sustainable operational excellence (see Table 1). This result is consistent with the findings of Fernando et al. (2021) in the automotive industry [28]. Field data corroborated this outcome, showing that palm oil mills (PKS) implementing RSPO (Roundtable on Sustainable Palm Oil) and ISPO (Indonesian Sustainable Palm Oil) audits consistently exhibit stronger performance in economic and social sustainability dimensions. However, challenges remain in achieving full environmental sustainability. The interview data further confirmed that cross-functional coordination, facilitated through regular forums with smallholder farmers and open dialogues with NGOs and local stakeholder organizations, has enhanced the organizations' eco-innovation capabilities.

The relationship between Eco-Innovation and Organizational Agility yielded a path coefficient of 0.651 with a t -statistic of 6.362 ($p < 0.001$), indicating that the development of eco-friendly innovation simultaneously strengthens an organization's ability to adapt to external changes (see Table 1). This finding is consistent with Dynamic Capabilities Theory as developed by Carvalho et al. (2019), which posits that innovation capabilities serve as antecedents of organizational agility [20][22]. However, a surprising finding emerged: Organizational Agility did not have a significant effect on Sustainable Operational Excellence, with a path coefficient of -0.028 and a t -statistic of 0.213 ($p = 0.831$) (see Table 1). This result contradicts the initial hypothesis and offers new insights into the mechanisms underlying SOE in Indonesia's traditional palm oil industry, characterized by long production cycles and relatively stable market structures.

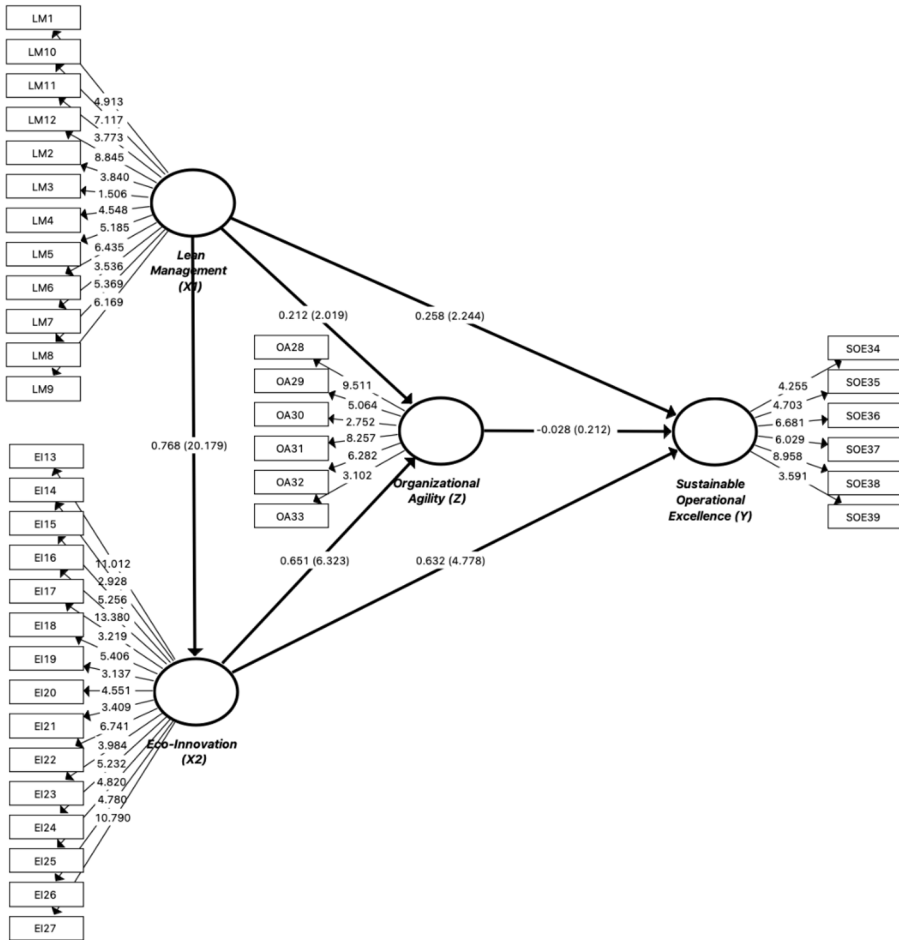


Fig. 1. Output SEM-PLS

The mediation analysis employed a serial mediation approach to explore the indirect pathways through which Lean Management influences Sustainable Operational Excellence (SOE) via Eco-Innovation and Organizational Agility, adopting the multiple mediator methodology proposed by Hayes (2017). The results revealed a complex mediation pattern that only partially aligned with the initial theoretical assumptions (see Figure 1). The single mediation path of Lean Management → Eco-Innovation → Sustainable Operational Excellence demonstrated a significant indirect effect of 0.485 ($t = 4.658, p < 0.001$), indicating a robust mediating role for Eco-Innovation. This finding suggests that approximately 65.3% of the total effect of Lean Management on SOE is transmitted through Eco-Innovation. In comparison, the remaining 34.7% represents a direct effect, consistent with the concept of partial mediation established in the SEM

literature [53][54]. Insights from the in-depth interviews provided a contextual explanation for this result. The implementation of lean principles, such as cost efficiency through cooperative-based management systems (KUD) and the 5% management fee mechanism, has stimulated cross-functional coordination and compliance with environmental regulations. Field observations further revealed that palm oil mills (PKS) applying standardized fruit sorting, direct labor allocation in plantation areas under HGU ownership, and R&D collaboration with agricultural laboratories, while requiring at least 60% compliance with laboratory recommendations, successfully integrated operational efficiency with sustainability practices.

The mediation path Lean Management → Eco-Innovation → Organizational Agility also demonstrated a significant indirect effect of 0.499 ($t = 6.421, p < 0.001$), confirming that Lean Management enhances organizational agility by developing eco-innovation capabilities. This finding supports the theoretical propositions of the Dynamic Capabilities framework advanced by Motwani and Katatria (2024) [23]. However, the full serial mediation pathway, Lean Management → Eco-Innovation → Organizational Agility → Sustainable Operational Excellence, was found to be statistically insignificant (indirect effect = $-0.014, t = 0.201, p = 0.840$), indicating that Organizational Agility does not mediate the pathway to SOE. This provides an important theoretical contribution to understanding the mechanisms underpinning sustainable operational excellence in traditional industries. Qualitative evidence from interviews suggests that the concept of organizational agility, which emphasizes rapid responsiveness and flexibility in dynamic markets, may be less applicable in the palm oil sector, characterized by long production cycles (25–30 years) and relatively stable market structures. Respondents indicated that decision-making flexibility and problem-solving in production processes tend to be reactive rather than proactive, thus offering limited contribution to long-term operational sustainability.

4.2 Discussion

The structural model revealed varying levels of significance across the hypothesized relationships, offering substantive contributions to the body of knowledge on sustainable operations management. Hypothesis H1, which posited a positive relationship between Lean Management and Eco-Innovation, was strongly supported ($\beta = 0.768, p < 0.001$) (see Table 2). This finding aligns with the Resource-Based View (RBV), which asserts that operational efficiency serves as the foundation for the development of innovative capabilities [16][19]. The implementation of lean management principles, particularly those related to top management leadership and cross-functional teamwork, has been instrumental in establishing a solid foundation for regular farmer discussion forums and ensuring compliance with RSPO and ISPO sustainability standards. These findings corroborate the results of Almeida and Wasim (2023), who identified lean practices as key enablers of eco-innovation within SMEs [30].

Hypotheses H2 and H3, concerning the direct influence of Lean Management on Organizational Agility ($\beta = 0.212, p = 0.042$) and Sustainable Operational Excellence ($\beta = 0.258, p = 0.024$), were also supported, although with moderate effect sizes (see Table 2). These results confirm that lean principles not only exert indirect effects through

mediating variables but also have a direct influence on organizational outcomes, reinforcing the propositions of Hernandez-Matias et al. (2020) regarding the multidimensional impacts of lean manufacturing practices [32]. Field evidence indicates that initiatives such as standardized fruit sorting, direct labor deployment on HGU-owned plantation lands, and R&D collaborations with agricultural laboratories have directly enhanced organizational responsiveness and operational sustainability. Furthermore, integrating internal audits with KUD cooperatives and external audits coordinated with the Plantation Office strengthened the direct pathway from lean practices to operational excellence.

Table 2. Path Coefficients and Significance of Direct Relationships

Mediation Path	Original Sample	Sample Mean (M)	Standard Deviation	T-Statistics	P-Value	Status
LM → EI → OA	0.499	0.516	0.078	6.421	0.000	Significant
LM → EI → SOE	0.485	0.510	0.104	4.658	0.000	Significant
EI → OA → SOE	-0.018	-0.024	0.089	0.205	0.837	Not Significant
LM → EI → OA → SOE	-0.014	-0.018	0.069	0.201	0.840	Not Significant
LM → OA → SOE	-0.006	-0.008	0.031	0.194	0.846	Not Significant

Notes: LM: Lean Management; EI: Eco-Innovation; OA: Organizational Agility; SOE: Sustainable Operational Excellence

Hypothesis H4, which examined the relationship between Eco-Innovation and Organizational Agility, was strongly supported ($\beta = 0.651$, $p < 0.001$) (see Table 2). This finding indicates that the development of environmentally oriented innovation capabilities simultaneously enhances an organization's adaptability to external dynamics. In-depth interviews revealed that palm oil mills (PKS) that implemented internal and external audits and cross-functional coordination demonstrated superior decision-making agility in addressing production challenges and responding to regulatory changes. This supports the Dynamic Capabilities framework articulated by Carvalho et al. (2021), which emphasizes innovation capabilities as critical building blocks for organizational agility [22]. Hypothesis H5, testing the influence of Eco-Innovation on Sustainable Operational Excellence, was also significantly supported ($\beta = 0.632$, $p < 0.001$), consistent with the theoretical view that green innovation acts as a primary driver of sustainability performance, as suggested by Pinzón-Castro et al. (2024) and Fernando et al. (2021) [27][28] (see Table 2).

Conversely, Hypothesis H6, which proposed a positive relationship between Organizational Agility and Sustainable Operational Excellence, was rejected ($\beta = -0.028$, $p = 0.831$). This result offers new theoretical insights into the limitations of agility concepts in industries characterized by long production cycles, such as palm oil. The finding challenges the assumptions of Organizational Agility Theory advanced by Zighan and Dwaikat (2023), which posit the universal applicability of agility across industries [25].

In the palm oil sector in Riau Province, responsiveness may be less relevant than consistency and long-term stability, given production cycles lasting 25–30 years and a relatively predictable market structure.

The article offers several actionable managerial implications for palm oil mills (PKS) in Riau Province, focusing on developing capabilities that yield the greatest returns in achieving Sustainable Operational Excellence. First, prioritizing investment in Eco-Innovation capabilities, particularly in Green Technology and Market Focus, can provide optimal returns in enhancing SOE. Field data indicated that mills engaged in R&D on organic fertilizers, though still in early stages, are progressing toward stronger environmental sustainability. Regular environmental and waste audits conducted every three months should be complemented by the adoption of more advanced technologies, following the best practices in lean eco-efficient innovation highlighted by Ball and Lunt (2020) [26][31].

Second, the KKPA partnership model should be promoted as a best-practice framework for replication across other regions of Riau, given its superior performance across all SOE dimensions. The balanced core–plasma partnership structure, effective communication forums, and comprehensive audit systems have proven more effective than independent farmer models. However, implementing such models requires strong institutional support and capacity-building initiatives, particularly in cooperative management and financial literacy. The Provincial Government of Riau could facilitate this transformation by developing policy frameworks that promote the transition from independent to KKPA models, leveraging technical assistance and financial incentives, and aligning with the recommendations of Henríquez-Machado et al. (2021) on achieving sustainability through operational excellence in emerging economies [15].

Third, strengthening cross-functional coordination and regulatory compliance can provide significant leverage in achieving multiple performance outcomes, given Eco-Innovation's central mediating role in the model. Empirical evidence revealed that routine discussion forums with farmers and open consultations with NGOs or social organizations not only enhance eco-innovation but also simultaneously reinforce organizational agility. Investments in communication infrastructure and stakeholder engagement mechanisms can therefore generate substantial multiplier effects. PKS managers should adopt a systematic approach to supplier involvement, particularly for fertilizer suppliers meeting required quality standards, while strengthening compliance with international certifications such as RSPO and ISPO to gain access to premium markets. This supports the proposition of Fernando et al. (2024) that integrating sustainable supply chain practices serves as a foundation for sustainable operational excellence [19,55].

5 Conclusion

This article developed and empirically validated an integrated *Green Lean-Agile Management* (GLAM) framework to ensure the long-term sustainability of operational excellence initiatives in the crude palm oil industry of Riau Province, Indonesia. The findings confirm that *Lean Management* plays a pivotal role in fostering *Eco-Innovation*, thereby enhancing both *Organizational Agility* and *Sustainable Operational Excellence*

(SOE). Among the observed pathways, *Eco-Innovation* emerged as the most influential mediator, explaining over 65% of the total effect of Lean Management on SOE. This supports the core assumptions of the *Natural Resource-Based View (NRBV)* and *Dynamic Capabilities Theory*, emphasizing that operational efficiency and innovation capabilities collectively drive long-term sustainability outcomes.

Conversely, *Organizational Agility* did not exhibit a significant direct influence on SOE, suggesting that responsiveness and flexibility, while essential in volatile industries, may hold limited strategic importance in traditional agro-industrial sectors characterized by long production cycles and relatively stable market dynamics. This insight challenges the universal applicability of agility-based frameworks and underscores the need for contextual adaptation when applying modern management concepts to mature, resource-intensive industries such as palm oil. Overall, the results extend theoretical understanding by establishing *Eco-Innovation* as a critical mechanism linking lean operational practices to sustainable organizational performance.

From a practical perspective, this article proposes three strategic directions to advance sustainability-driven operational excellence in the palm oil industry. First, developing *eco-innovation capability* should be a top priority. Palm oil mills should invest in adopting green technology, developing organic fertilizer R&D, and implementing regulatory compliance systems, such as RSPO and ISPO audits. These initiatives will enhance environmental performance while maintaining operational efficiency, ensuring alignment with international sustainability standards.

Second, the institutionalization of collaborative partnership models is essential. The KKPA cooperative scheme demonstrated superior sustainability outcomes compared to independent smallholders. Replicating this model across Riau Province, with institutional backing, capacity-building programs, and financial literacy initiatives, can accelerate the diffusion of sustainable practices and promote socio-economic equity within the sector.

Third, strengthening cross-functional coordination and compliance mechanisms is vital for sustaining long-term excellence. Establishing regular multi-stakeholder forums that involve farmers, local governments, and NGOs can foster transparency, stimulate innovation, and improve responsiveness to sustainability challenges. Building robust communication infrastructures and supplier engagement systems will further enhance the mediating role of *eco-innovation* in achieving *sustainable operational excellence*.

Finally, this article recommends that future research adopt longitudinal and cross-regional designs to capture the dynamic evolution of sustainability transformations. Incorporating digital transformation variables, such as Industry 4.0 adoption, data-driven decision-making, and environmental performance analytics, could further enrich the GLAM framework and expand its applicability to other resource-based industries.

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