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PALM KERNEL SHELL SUPPLY CHAIN PERFORMANCE ANALYSIS IN SUPPORTING NATIONAL ENERGY SECURITY: CASE STUDY OF CV.PUTRA MAHODENK IN KOTAWARINGIN BARAT REGENCY

ANÁLISIS DEL RENDIMIENTO DE LA CADENA DE SUMINISTRO DE CÁSCARA DE PALMA EN APOYO A LA SEGURIDAD ENERGÉTICA NACIONAL: ESTUDIO DE CASO DE CV.PUTRA MAHODENK EN LA REGENCIA DE KOTAWARINGIN BARAT

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Abstract
This research analyzes the palm kernel shell supply chain performance at CV. Putra Mahodenk in Kotawaringin Barat Regency to support national energy security. Using a qualitative case study approach with 150 informants from employees, consumers, partners, and communities, data were collected through participatory observation, in-depth interviews, and documentation study. Analysis employed Porter's Value Chain framework and Green Supply Chain Management (GSCM). Results show that the company has competitive advantages in inbound logistics (0.38), service (0.39), infrastructure (0.39), and procurement (0.39), supported by push forklift technology innovation as the first in Indonesia. However, weaknesses exist in promotion (0.17) and HR management (0.19). GSCM implementation remains partial, particularly at win order, pre-

Resumo
Esta pesquisa analisa o desempenho da cadeia de abastecimento de casca de palmiste na CV. Putra Mahodenk, na Regência de Kotawaringin Barat, para apoiar a segurança energética nacional. Utilizando uma abordagem qualitativa de estudo de caso com 150 informantes entre funcionários, consumidores, parceiros e comunidades, os dados foram coletados por meio de observação participativa, entrevistas aprofundadas e estudo de documentação. A análise empregou a estrutura da Cadeia de Valor de Porter e a Gestão da Cadeia de Abastecimento Verde (GSCM). Os resultados mostram que a empresa tem vantagens competitivas em logística de entrada (0,38), serviço (0,39), infraestrutura (0,39) e aquisição (0,39), apoiadas pela inovação tecnológica em empilhadeiras push, pioneira na Indonésia. No entanto, existem pontos fracos em

delivery support, and delivery stages. The total activity value of 22.97 indicates fairly good overall performance with some areas requiring strategic improvement. Recommendations include digital marketing transformation, productivity-based HR development, and transition to environmentally friendly operations.

Keywords: Green Supply Chain Management. Palm Kernel Shell. Porter's Value Chain. Supply Chain Performance. Energy Security.

promoção (0,17) e gestão de RH (0,19). A implementação da GSCM permanece parcial, particularmente nas etapas de obtenção de pedidos, suporte pré-entrega e entrega. O valor total da atividade de 22,97 indica um desempenho geral bastante bom, com algumas áreas que requerem melhorias estratégicas. As recomendações incluem a transformação do marketing digital, o desenvolvimento de RH baseado na produtividade e a transição para operações ecologicamente corretas.

Palavras-chave: *Gestão da Cadeia de Suprimentos Verde. Casca de Palmiste. Cadeia de Valor de Porter. Desempenho da Cadeia de Suprimentos. Segurança Energética.*

1 INTRODUCTION

Biomass has become a popular source of bioenergy feedstock in recent years as a strategic alternative to fossil fuels to support Indonesia's national energy security. According to Doan *et al.* [1], biomass feedstock sources include forest-based materials, agricultural residues, energy crops, biodegradable substances from finished products, and industrial solid waste used to produce bioenergy and bioproducts. Putra *et al.* [2] affirm that effective management and utilization of biomass sources in energy generation can significantly reduce CO_2 emissions while maintaining substantial carbon mass in the bio-products produced. Based on data from the Ministry of Energy and Mineral Resources [3], Indonesia has biomass waste potential of 885.2 million Gigajoules (GJ) per year with power generation potential from biomass reaching 32.6 Giga Watts.

The urgency of this research is based on the pressing need to optimize palm kernel shell supply chain performance in supporting the national energy security program mandated by the government. Based on the Minister of Energy and Mineral Resources Regulation Number 16 of 2020 concerning the Strategic Plan 2020-2024, the government targets the utilization of biofuel to reduce fuel imports with a target of 23% renewable energy mix by 2025 [4]. Martínez-Vázquez *et al.* [5] state that the acceleration of biofuel development through domestic biofuel utilization reached 17.4 million kL in 2024 as an effort to reduce Indonesia's current account deficit. CV. Putra Mahodenk as a company engaged in fulfilling palm kernel shell supply availability in Kotawaringin Barat Regency

has an important contribution to regional GDP with domestic and export market scale to Thailand, Japan, and Taiwan.

The objective of this research is to analyze the palm kernel shell supply chain performance at CV. Putra Mahodenk in fulfilling supply availability to support national energy security. Specifically, this research aims to identify and evaluate the company's competitive advantages in primary activities including inbound logistics, operations, outbound logistics, promotion, and service, as well as secondary activities covering infrastructure, procurement, technology, and human resource management. This research also examines the implementation of Green Supply Chain Management (GSCM) across four operational stages namely *win order*, *pre-delivery support*, *delivery*, and *post-delivery support*. Using Porter's Value Chain analysis framework and GSCM framework from Dubey *et al.* [6], this research provides a comprehensive picture of the company's performance.

The novelty of this research lies in the study of company performance that has implemented *push forklift* technology innovation as the first in Indonesia in the palm kernel shell industry. Chorda and Toha [7] explain that forklift usage provides various advantages including acceleration of loading and unloading processes, reduction of physical labor burden, and increased carrying capacity in one operational cycle. Axon and Darton [8] affirm that companies operating in biomass supply chains with technological innovation play an important role in creating sustainable and resilient energy systems against changes in global market conditions. CV. Putra Mahodenk modified the forklift function into a pushing and moving tool for shell waste into containers which differs from the general forklift function to improve production efficiency.

This research provides theoretical and empirical contributions to the development of Green Supply Chain Management (GSCM) concepts in Indonesia's palm oil biomass industry. Dubey *et al.* [6] explain that a GSCM framework that considers soft and hard dimensions can help improve business sustainability from environmental, social, and economic aspects. Corton *et al.* [9] affirm that utilization of agricultural residues for bioenergy generation can lead to environmental and social improvements, including air quality enhancement, waste mass reduction, and creation of new employment opportunities in communities.

2 METHOD

2.1 Research design

This research uses a qualitative research design with a case study approach to explore and understand the palm kernel shell supply chain performance at CV. Putra Mahodenk in depth. According to Creswell [10], qualitative research is an approach to explore and understand the meaning that some individuals or groups of people ascribe to social or human problems with research processes involving questions and procedures that emerge naturally. Yin [11] explains that case study is an appropriate research strategy when researchers want to answer 'how' and 'why' questions about a series of contemporary events in real-life contexts.

This research was conducted at CV. Putra Mahodenk located in Kotawaringin Barat Regency, Central Kalimantan in 2024 with a focus on palm kernel shell supply chain performance analysis. According to Sugiyono [12], research location selection is very important because along with research location, the objects and objectives to be studied are also determined. Marshall and Rossman [13] explain that in qualitative research, research location must be selected based on suitability with research questions and accessibility to key informants.

2.2 Informants and sampling

Informants in this qualitative research were selected using *purposive sampling* technique with a total of 150 informants who have knowledge and experience related to green supply chain activities at CV. Putra Mahodenk. According to Patton [14], *purposive sampling* in qualitative research aims to select information-rich cases that can provide deep understanding of the phenomena being studied. Miles *et al.* [15] affirm that informant selection must be based on informant's ability to provide relevant and in-depth information. Informants consist of four stakeholder groups: 10 CV. Putra Mahodenk employees, 60 consumers, 30 partners, and 50 surrounding community members.

2.3 Data collection and analysis

Data collection techniques use three main methods: participatory observation, in-depth interviews, and documentation study. According to Creswell [10], qualitative data collection is conducted in a natural setting where the researcher as a key instrument collects data through various sources. Merriam and Tisdell [16] explain that data collection method triangulation is an important strategy to increase internal validity. Qualitative data validity is ensured through four criteria: credibility, transferability, dependability, and confirmability [17].

Qualitative data analysis techniques use the interactive model from Miles *et al.* [15] consisting of data condensation, data display, and conclusion drawing/verification. According to Saldaña [18], the coding process in qualitative analysis is a cyclical activity that involves assigning labels to data segments. Porter's Value Chain framework was used to evaluate primary and secondary activities, while the GSCM framework from Dubey *et al.* [6] was used to assess sustainability implementation.

3 RESULTS AND DISCUSSION

3.1 Supply chain performance analysis

Observation and in-depth interview results show that CV. Putra Mahodenk is a company engaged in palm kernel shell trading with a focus on fulfilling supply availability to support the biomass energy industry at national and international levels. The company is located in Kotawaringin Barat Regency, Central Kalimantan which is a strategic area with access to various Palm Oil Mills (PKS) and export ports. Documentation data shows that the company has an extensive supplier network covering more than 20 palm oil mills spread across Central Kalimantan and surroundings.

The main findings from field observations show that CV. Putra Mahodenk has implemented *push forklift* technology innovation which is the first in Indonesia in the palm kernel shell industry. Interview results with the operational department reveal that the company modified the forklift function into a pushing and moving tool for shell waste into containers. Observation data shows that *push forklift* usage has significantly

increased carrying capacity and accelerated loading and unloading processes. However, informants from the technical department stated that the forklift used still uses diesel fuel which contributes to carbon emissions [19].

Analysis results on Green Supply Chain Management (GSCM) implementation show that CV. Putra Mahodenk has not applied this concept optimally across all supply chain stages. At the *win order* stage, supplier selection is still based on product quality and trust relationships without specifically considering environmental sustainability aspects. At the *pre-delivery support* stage, green logistics planning has been applied by arranging more efficient distribution routes. At the *delivery* stage, distribution processes still use fossil fuel vehicles. However, at the *post-delivery support* stage, the company has implemented responsible waste management systems [20].

Table 1

Competitive Advantage Analysis Results

No	Activity	Relative Weight	Value	Score
Primary Activities				
1	Inbound Logistics	0.13	2.97	0.38
2	Operations	0.10	2.33	0.23
3	Outbound Logistics	0.10	2.33	0.23
4	Promotion	0.09	2.00	0.17
5	Service	0.13	3.00	0.39
Secondary Activities				
1	Company Infrastructure	0.13	3.00	0.39
2	HR Management	0.10	2.00	0.19
3	Technology	0.11	2.33	0.25
4	Procurement	0.13	3.00	0.39

Findings regarding *push forklift* technology innovation implementation at CV. Putra Mahodenk align with research by Chorda and Toha [7] stating that forklift usage provides various advantages including acceleration of loading and unloading processes. This finding also supports the view of Axon and Darton [8] that companies operating in biomass supply chains with technological innovation play an important role in creating sustainable energy systems. However, the challenge of diesel fuel usage in forklifts is consistent with warnings from Pangestu and Ayuningsasi [19] regarding impacts of fossil fuel usage on carbon emissions.

The finding that inbound logistics and service activities have the highest scores aligns with the view of Hasanuddin *et al.* [21] stating that good service is an important

element in maintaining customer trust. Three delivery service schemes (Port FOB, Stuffing & Handling, and Port to Door) have provided flexibility that increases customer satisfaction. This finding is consistent with Siahaan [22] who affirms that supply sustainability is a key element in supporting production efficiency and customer satisfaction. The view of Agyabeng-Mensah and Tang [23] that greener logistics optimization can support GSCM principles provides further development direction.

The finding that promotional activity has the lowest score (0.17) shows significant weakness in digital marketing strategy which according to Rizki *et al.* [24] is very important for market expansion in the biomass industry. The company still relies on conventional promotional methods without optimally utilizing digital platforms. HR management activity has the second lowest score (0.19) indicating the need for improvement in workforce management which according to Kusnadi *et al.* [25] is a determining factor for organizational performance.

3.2 Technology innovation and operational efficiency

The implementation of *push forklift* technology at CV. Putra Mahodenk represents a significant paradigm shift in biomass handling operations within the Indonesian palm kernel shell industry. This technological modification fundamentally transforms the conventional material handling approach by converting a standard lifting mechanism into a horizontal pushing system specifically designed for bulk shell waste transfer into shipping containers. The engineering rationale behind this modification lies in the recognition that palm kernel shells, due to their irregular granular structure and low bulk density, require different handling characteristics compared to palletized goods typically managed by conventional forklifts.

The operational efficiency gains observed from this technological innovation manifest across multiple performance dimensions. First, the volumetric throughput capacity has increased substantially as the pushing mechanism enables continuous material flow rather than discrete lifting cycles. This continuous flow characteristic reduces the cycle time per unit volume transferred, thereby enhancing overall operational productivity. Second, the physical ergonomics of the operation have improved significantly, as the horizontal pushing motion requires less precise positioning compared

to the vertical lifting and placement sequences demanded by conventional forklift operations. This reduced precision requirement translates into faster operator learning curves and decreased operational fatigue.

However, the technological advancement is not without environmental considerations that warrant critical examination. The continued reliance on diesel-powered equipment creates an inherent tension between operational efficiency gains and environmental sustainability objectives. The carbon footprint associated with diesel combustion during intensive loading operations contributes to greenhouse gas emissions that partially offset the environmental benefits of utilizing biomass as a renewable energy source. This paradox highlights the importance of viewing supply chain sustainability through a holistic lifecycle perspective rather than focusing solely on individual operational improvements.

3.3 Green Supply Chain Management implementation assessment

The assessment of Green Supply Chain Management implementation at CV. Putra Mahodenk reveals a differentiated pattern of sustainability integration across the four operational stages examined in this study. This heterogeneous implementation profile reflects the complex interplay between operational pragmatism and environmental idealism that characterizes many emerging market supply chain contexts. The analysis demonstrates that sustainability initiatives tend to concentrate in areas where environmental benefits align closely with operational efficiency gains, while remaining underdeveloped in areas requiring dedicated environmental investments without immediate operational returns.

At the *win order* stage, the absence of environmental criteria in supplier selection processes represents a significant gap in upstream sustainability integration. The current emphasis on product quality and trust-based relationships, while commercially rational, fails to leverage the potential for cascading environmental improvements throughout the supply network. Implementing green purchasing criteria would not only enhance the environmental profile of sourced materials but could also incentivize supplier mills to adopt cleaner production practices, creating positive externalities beyond the immediate transactional relationship.

The *pre-delivery support* stage demonstrates partial sustainability implementation through route optimization initiatives. The development of efficient distribution routes connecting to three main ports Bumiharjo Port (Kumai), Bagendang Port (Sampit), and Trisakti Port (Banjarmasin), reflects strategic logistics planning that simultaneously reduces transportation costs and associated emissions. However, the sustainability potential at this stage remains incompletely realized due to the absence of systematic fuel consumption monitoring, carbon footprint tracking, and alternative fuel exploration initiatives.

The *delivery* stage presents the most significant environmental challenge within the current operational framework. The fleet of 18 dump trucks, while providing substantial capacity for domestic distribution, operates entirely on fossil fuels without any hybrid or alternative fuel integration. The cumulative emissions from these vehicles during regular operations between collection points and port facilities represent the largest single source of environmental impact within the company's direct operational control. Transitioning even a portion of this fleet to cleaner technologies would substantially improve the overall environmental profile of operations.

Conversely, the *post-delivery support* stage exhibits the strongest sustainability characteristics among all operational stages. The implementation of responsible waste management systems and sustainability-oriented customer service practices demonstrates that environmental considerations can be successfully integrated when they align with customer expectations and competitive differentiation strategies. This stage's relative strength suggests that market-driven sustainability pressures, particularly from environmentally conscious international buyers in Japan, Thailand, and Taiwan, can effectively catalyze green practices adoption.

3.4 Service excellence and customer relationship dynamics

The service activity's achievement of the highest performance score (0.39) among primary activities warrants detailed examination of the underlying service architecture that enables this competitive advantage. CV. Putra Mahodenk's three-tier service delivery model, comprising Port FOB, Stuffing & Handling, and Port to Door options, represents a sophisticated understanding of diverse customer requirements across the domestic and

international market spectrum. This service differentiation strategy acknowledges that customers possess varying capabilities and preferences regarding logistics management and provides appropriately calibrated service levels to match these heterogeneous needs.

The Port FOB option caters to customers with established logistics capabilities who prefer to manage transportation arrangements independently, typically larger industrial buyers with dedicated shipping contracts. The Stuffing & Handling tier addresses the needs of medium-scale buyers requiring professional container loading services but maintaining their own shipping arrangements. The comprehensive Port to Door service targets customers seeking fully integrated logistics solutions, eliminating complexity and reducing coordination burden for buyers lacking dedicated logistics expertise or infrastructure.

This tiered service architecture creates multiple value propositions that strengthen customer retention and facilitate market expansion. For existing customers, the availability of escalating service levels accommodates growing operational complexity and changing requirements over time, enabling relationship deepening without necessitating supplier switching. For prospective customers, the flexible service options lower entry barriers by allowing gradual engagement with service levels appropriate to their current operational maturity and risk tolerance.

3.5 Digital transformation imperatives and marketing deficiencies

The promotional activity's position as the lowest-performing dimension (0.17) represents a critical strategic vulnerability that demands urgent attention in the context of evolving market dynamics. The contemporary biomass trading landscape is increasingly characterized by digital intermediation, where prospective buyers conduct initial supplier identification and evaluation through online channels before initiating direct commercial engagement. The company's limited digital presence effectively excludes it from this growing segment of market discovery activity, constraining customer acquisition to traditional relationship-based channels that, while valuable, offer limited scalability.

The digital marketing deficiency extends beyond mere visibility concerns to encompass broader competitive positioning implications. In the biomass industry, where product differentiation based on physical characteristics is inherently limited, the ability

to communicate sustainability credentials, quality assurance processes, and service capabilities becomes a primary competitive differentiator. Without robust digital platforms to convey these value propositions, CV. Putra Mahodenk relies entirely on direct interpersonal communication to establish competitive positioning—an approach that, while effective in relationship maintenance, proves inadequate for market expansion and new customer acquisition.

The absence of systematic social media engagement further compounds this digital deficit. International biomass buyers increasingly utilize professional networking platforms and industry-specific online communities to identify potential suppliers and gather market intelligence. The company's non-participation in these digital ecosystems represents missed opportunities for low-cost market exposure and organic relationship building with potential customers across global markets. Developing a coherent digital marketing strategy encompassing professional website development, search engine optimization, social media presence, and content marketing would address these deficiencies while requiring relatively modest investment compared to traditional marketing approaches.

3.6 Human resource management and organizational capability development

The human resource management dimension's second-lowest performance score (0.19) reflects systemic deficiencies in workforce development that potentially constrain operational improvement initiatives and long-term organizational capability building. The interview findings revealing inadequate training programs and underdeveloped incentive systems indicate an organization that has not yet fully recognized human capital as a strategic asset requiring systematic investment and cultivation.

The training program deficiencies manifest across multiple capability domains relevant to supply chain performance improvement. Technical training gaps limit the workforce's ability to maximize efficiency gains from technological innovations such as the *push forklift* system. Safety training inadequacies create operational risks that could result in workplace incidents affecting both human welfare and operational continuity. Environmental awareness training absence undermines the potential for employee-driven

sustainability improvements that could complement management-initiated green supply chain initiatives.

The incentive system deficiencies create misaligned motivation structures that fail to channel workforce effort toward organizational performance priorities. Without productivity-linked compensation components, employees lack direct financial incentives to pursue efficiency improvements beyond minimum acceptable performance levels. The absence of quality-based incentives similarly fails to motivate the attention to detail necessary for maintaining international market product standards. Developing a comprehensive performance management system incorporating productivity metrics, quality indicators, and sustainability targets would address these motivational gaps while providing management with enhanced operational visibility.

3.7 Strategic implication for national energy security

The findings of this research carry significant implications for Indonesia's national energy security strategy, particularly regarding the government's ambitious target of achieving 23% renewable energy mix by 2025. CV. Putra Mahodenk's operations demonstrate both the potential and limitations of private sector contribution to bioenergy supply chain development. The company's ability to maintain consistent supply availability across domestic and international markets validates the commercial viability of palm kernel shell as a renewable energy feedstock, while the identified operational challenges highlight systemic barriers requiring policy intervention.

The strategic importance of biomass supply chain performance extends beyond immediate energy production considerations to encompass broader economic development objectives. The palm kernel shell trading sector generates significant employment in Central Kalimantan, contributing to regional economic diversification beyond traditional palm oil production. The export orientation of companies like CV. Putra Mahodenk brings foreign exchange earnings while positioning Indonesia as a reliable supplier in global renewable energy markets. These multiplier effects amplify the strategic value of supply chain performance improvements beyond direct energy security contributions.

Policy implications arising from this research suggest the need for coordinated government intervention across multiple domains. Infrastructure investment in port facilities and transportation networks would reduce logistics costs while enabling greater throughput volumes. Technical assistance programs supporting technology adoption and workforce development would accelerate operational capability building across the sector. Financial incentives promoting green supply chain practices would address the environmental sustainability gaps identified in this study. Regulatory frameworks establishing sustainability standards for biomass trading would create level playing fields while ensuring environmental integrity of renewable energy supply chains.

4 CONCLUSION

This research provides empirical evidence regarding palm kernel shell supply chain performance at CV. Putra Mahodenk using Porter's Value Chain framework integrated with Green Supply Chain Management concepts. The analysis of 150 informants from four stakeholder groups reveals a differentiated performance profile with a total activity value of 22.97, indicating fairly good overall performance with specific areas requiring strategic improvement.

The findings demonstrate that CV. Putra Mahodenk has established competitive advantages in service delivery (0.39), company infrastructure (0.39), procurement (0.39), and inbound logistics (0.38). These strengths are underpinned by three key operational assets: a supplier network encompassing more than 20 palm oil mills across Central Kalimantan, strategic distribution access through three main ports (Bumiharjo, Bagendang, and Trisakti), and a differentiated service model offering Port FOB, Stuffing & Handling, and Port to Door delivery options. The implementation of push forklift technology innovation, the first of its kind in Indonesia's palm kernel shell industry, has demonstrably enhanced operational efficiency through increased volumetric throughput and accelerated loading processes. Conversely, critical weaknesses were identified in promotional activities (0.17) and human resource management (0.19), representing the lowest-performing dimensions requiring urgent strategic intervention. The digital marketing deficiency constrains market expansion potential, while inadequate training programs and incentive systems limit workforce productivity optimization. Furthermore,

GSCM implementation remains partial, with sustainability integration concentrated at the post-delivery support stage while remaining underdeveloped at win order, pre-delivery support, and delivery stages where fossil fuel dependency persists.

The theoretical contribution of this study extends understanding of how technological innovation in biomass supply chains can enhance operational efficiency while creating environmental sustainability tensions requiring balanced management approaches. Practically, the findings offer actionable frameworks for biomass trading enterprises regarding service differentiation strategies and capability development priorities. Policy implications suggest that achieving Indonesia's 23% renewable energy mix target by 2025 requires coordinated government support including infrastructure investment, technical assistance, and regulatory incentives for green supply chain adoption. This research acknowledges limitations including single case study design constraining generalizability, exclusive focus on palm kernel shell excluding other biomass products, and absence of quantitative cost-benefit analysis. Future research should pursue multi-site comparative studies, longitudinal performance tracking, and investigation of digital transformation impacts on biomass supply chain competitiveness.

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Authors' Contribution

All authors contributed equally to the development of this article.

Data availability

All datasets relevant to this study's findings are fully available within the article.

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