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A Study on Enhancing Sustainability in Circular Supply Chains through Green Innovations

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Abstract
Redefining product and service lifecycles with eco-friendly and sustainable processes, circular supply chains are green breakthroughs. Minimising waste, environmental effect, and resource efficiency are its goals. In a circular supply chain, green innovations can include product design that facilitates recycling or reuse, process improvements that reduce energy consumption and emissions, logistics solutions that optimise transportation for lower carbon footprints, and service innovations that promote sustainability. These green ideas improve supply chain efficiency and competitiveness while helping the environment. Businesses may reconcile economic growth and environmental stewardship by rethinking and rebuilding linear supply models into circular and sustainable ones, paving the way for a more sustainable future. This study examines how green innovations affect circular supply chains in Andhra Pradesh's durable goods industry. It analyses how product, process, logistical, and service green innovation improves supply chain efficiency. The quantitative research uses structured surveys to obtain data from 150 industry professionals and customers. Convenience sampling was used to acquire varied supply chain performance metrics responses. SPSS is used for rigorous regression analysis in the study. This method lets you study how green innovation affects circular supply chain performance. All green innovations improve supply chain efficiency, but green service innovation has the greatest benefit. This research provides strong evidence for green innovations in durable goods industry circular supply networks. The study emphasises ecologically friendly product creation, logistics, service delivery, and process management.

Keywords: Green Product, Green Process, Green Logistics, Green Services, Circular Supply Chain.

Introduction

Amidst the imminent threat of natural resource depletion, there is a growing apprehension regarding the sustainability of raw material sources. The growing intricacy of supply chains, many of which are spread across many locations, has resulted in reduced efficiency and a heightened risk of interruption. Furthermore, market volatility and exogenous occurrences such as conflicts and the COVID-19 pandemic also provide a significant risk to the stability of the supply chain. Given the current situation, the circular supply chain has emerged as a viable method for enhancing supply chain resilience in comparison to old methods. Companies frequently employ a circular methodology to promote recycling and remanufacturing, which in turn generates additional on-site employment opportunities to enhance labour intensity. The circular supply chains have made a substantial contribution to sustainable development by positively impacting the social sustainability aspects. Circular supply networks are essential components in the shift towards a circular economy and provide new prospects for enhancing the sustainability of supply chain operations. In a conventional supply chain, the transformation of raw materials into goods takes place, and these goods are subsequently transported to the final consumer for utilization. Following the conclusion of the usage term, the products are frequently disposed of in landfills, resulting in a significant accumulation of garbage and causing ecological degradation issues. Meanwhile, circular supply chains prioritize the aspects of regeneration and recovery. Hence, the safeguarding of consumers' interests in the procurement of recycled goods will be ensured by the establishment of suitable benchmarks, the formulation of assurance protocols, and the validation of certifications for recycled or remanufactured products.

A circular supply chain employs the 6R principles of reuse, recycling, repair, remanufacture, reduce, and refurbishment to produce a closed loop system that reduces resource input, waste, pollution, and carbon emissions across the supply chain. When the value of used products is restored by the original manufacturer or a third party, this procedure can increase efficiency across the whole product lifecycle. The combination of the circular economy and supply chain management can

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also help with environmental sustainability thanks to this loop process. The circular supply chain investigates the retained value of discarded or underused materials, presenting organizations with new options. When waste can be mined as a resource, the residual value of the trash or underused resource can be discovered. Most businesses have realized economic gains, owing to reduced material and energy use, maximum resource use, and lower disposal costs. Some businesses have created new revenue streams by selling garbage and byproducts.

The utilization of circular resources at the company and supply chain levels enables businesses to conduct business without making large expenditures in manufacturing equipment. This contributes to the reduction of capital limitations and market entrance hurdles, which are especially significant for SMEs. The increased usage of recycled items leads in significant cost savings in manufacturing and lower purchase costs that can be improved. The importance of a circular supply chain model is especially relevant in the context of increased demand for agricultural products with food safety regulations. Circular supply chains aid in the development of a self-sustaining manufacturing system that safeguards the flow of resources against price volatility, seasonality, and supply disruptions. The implementation of procurement in a circular supply chain necessitates the redefinition of fundamental concepts such as price, time, quality, and associated value (Meehan & Bryde, 2011).

Reducing resource consumption in the production process has become essential for manufacturing industries to remain competitive and survive in the current era of sustainability (Ridaura, et.,2018). Manufacturers are consistently striving to integrate sustainable production strategies into their supply chains in order to mitigate adverse environmental effects. Furthermore, this contributes to the enhancement of competitive advantage through the reduction of resource consumption, which is particularly significant in light of the fact that production has evolved into a critical component of sustainable development. Green production has thus gained widespread acceptance as a strategic model. The production process of this model integrates principles including waste minimization, environmental protection, resource, and energy conservation. The pursuit of material efficiency through the reduction of energy consumption, carbon emissions, industrial refuse generation, and resource extraction and consumption has prompted the formulation of numerous production strategies (Shahbazi et al.,2016).

The adoption of green manufacturing enhances investor interest, brand image, and regulatory compliance, while also generating long-term cost savings, according to a number of studies (Dubey et al.,2015). In response to regulatory and consumer demands, businesses have redesigned their logistics networks to be more cost-effective and environmentally sustainable. Green logistics is the optimal approach for ensuring the sustainable production and distribution of products, with an emphasis on environmental and social factors. Diverse distribution strategies are impacted by green logistics, which reduces the amount of energy required for logistics-related operations, waste, and the disposal of residual refuse. While both conventional and green logistics involve the movement of goods from the supplier to the consumer, green logistics is particularly significant in its contribution to sustainable development (Hazen et al.,2017). Green product innovation pertains to advancements in product design that prioritize the environmental consequences that persist beyond the product's service life (Arfi et al., 2018). In contrast to conventional product innovation, green product innovation is an approach adopted by companies to accommodate customer demands and environmental shifts, minimize unwarranted risks to customers' health and safety resulting from product-related uncertainties, and reduce excessive consumption of raw materials and energy in accordance with environmental standards (Chen et al.2015). Green product innovation not only satisfies consumer demands for environmental protection but also facilitates market entry for firms, thereby impeding competitors' ability to replicate their offerings and sustain product competitiveness. Moreover, it enables firms to gain competitive advantages and enhance resource utilization efficiency. Green process innovation involves the incorporation of stakeholder concerns regarding the environment into the design of production methods, resulting in cost reductions and product compliance with environmental regulations (Wang & Liu, 2022). Green service innovation consists primarily of environmental service design, green invention, and environmental service combinations (Chen, Y.S. et al., 2015). It prioritizes environmental social responsibility and mitigates environmental harm through the provision of environmental protection services (Lin & Chen, 2017). In the context of transportation, warehousing, packaging, offloading, and processing, "green logistics" encompasses a range of operations that prioritize environmental sustainability, energy conservation, and optimal utilization. Innovative logistics technologies that benefit society and the economy (Liu & Ma, 2022). Green logistics is practically significant in that it reduces energy consumption, prioritizes environmental protection, and increases economic efficiency (Agyabeng-Mensah et al., 2020). Clarifying the interrelation among green product innovation, green process innovation, green logistics, and green service innovation in relation to the performance of circular supply chain in addressing environmental challenges and the strong correlation between green innovation strategy and the aforementioned factors.

In the pursuit of innovation and circular supply chain performance, it is imperative to conduct empirical analysis and address the existing research gaps. This study has the potential to offer a fresh outlook on the investigation of the integration of circular supply chain and green innovation, enhance the comprehension of firms regarding the interplay between circular

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supply chain and green innovation strategies, and provide manufacturing firms with practical guidance and theoretical benchmarks for circular supply chain and green innovation. Additionally, in recent years, the protracted COVID-19 pandemic and the instability of the international situation have contributed to an intensification of volatility on the global market. In the pursuit of green innovation, numerous businesses are confronted with the unpredictability of economic policies and market volatility, as well as the degradation of resources and economic conditions recessionary period.

Research Question

How does green product innovation affect the performance of the circular supply chain?
How does green process innovation affect the performance of the circular supply chain?
What is the impact of green logistics innovation on the performance of the circular supply chain?
How does green service innovation affect the performance of the circular supply chain?

Objective of the Study

To analyse the effect of green product innovation on circular supply chain performance.
To assess the influence of green process innovation on circular supply chain performance.
To analyse the effect of green logistics innovation on circular supply chain performance
To assess the influence of green service innovation on circular supply chain performance

Literature Review

Significantly understudied in the literature is the impact of particular green innovation strategies on the efficacy of circular supply chains, as well as the contribution of green innovation as a whole. In light of the growing significance that organisations place on implementing green innovation-focused strategies to improve their circular supply chains and gain a competitive edge, there is considerable knowledge that should be gathered regarding the potential impact of such a strategy on the circular supply chain's performance and the extent to which the circular supply chain's performance may be influenced by the level of perceived economic uncertainty. In order to fill these gaps in the existing research and enhance understanding of the impact of green innovation on the operational efficiency of circular supply chains in emerging markets, we construct our arguments through theorising and proposing a research model grounded in dynamic capability theory and circular economy theory, as illustrated in Figure. In particular, we postulate that the implementation of green service innovation, green product innovation, green process innovation, and green logistics innovation could have a positive influence on the operational efficiency of the circular supply chain. Additionally, it is anticipated that the extent to which economic policy uncertainty affects the performance of the circular supply chain will substantially moderate the contributions of these particular green innovation dimensions.

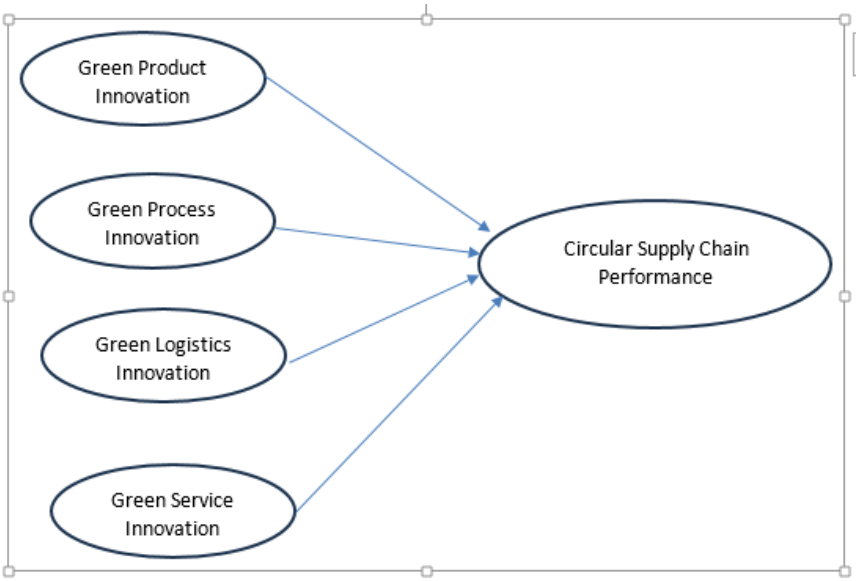

Figure -1 Conceptual Framework

Green Product Innovation and Circular Supply Chain Performance

By incorporating ecological innovation into their operations, businesses can increase product quality and popularity, market share, and product sales volume. Additionally, it aids organisations in inventory management and supply chain

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oversight (Xie et al, 2019; Dev NK et al., 2021). In light of growing consumer consciousness and demand regarding environmental preservation, organisations that offer products that are more environmentally sustainable in comparison to their rivals will be able to penetrate untapped markets and attain a competitive edge (Chen et al., 2006). By encouraging green product innovation, businesses increase the likelihood of successfully executing a differentiation strategy, thereby enhancing the perceived value of their products among consumers. Green product innovation can facilitate knowledge flow, coordination, and cross-functional integration, as well as assist organisations in establishing and managing close communication and knowledge flow with external actors (Dangelico, 2016). Green products provide businesses with a greater variety of raw material options. Multi-line production alleviates inventory pressure and satisfies the demand for greener manufacturing (Dev NK et al., 2021). The primary objective of firms' circular supply chains is to increase the ratio of remanufacturing, recycling, and reprocessing of technical materials via innovative product design (Lopes de Sousa Jabbour et al.,2018). Green product innovation, which aims to minimise environmental impact throughout the product design process, has the potential to enhance the operational efficiency of a company's circular supply chain.

Hypothesis -1 Innovation in green products positively impacts the operational efficiency of the circular supply chain.

Green Process Innovation and Circular Supply Chain Performance

By reducing their environmental impact and fostering technological advancement through the implementation of green process innovation, businesses can earn double dividends (Xie et al, 2019). Green process innovation can assist organisations and members of the supply chain in establishing knowledge sharing and closing vulnerabilities in order to reduce risk (Sahabi & Parast, 2020). By optimising the element configuration of firms, green process innovation can enhance the performance of the economy from the standpoint of innovation economics (Wang et al.,2021). This can result in various benefits, including reduced production and operation costs, expanded production, increased market share, and the acquisition of a green technology patent licence. Green process innovation increases resource utilisation while decreasing investment and waste disposal costs (Wei & Sun, 2021). Green process innovation can improve existing production processes to reduce environmental impact, improve business environmental flexibility, and provide differentiating advantages to firms (Xie et al, 2019). Green process innovation improves the breadth and speed of information sharing while also positively impacting business risk management capacities (Sahabi & Parast, 2020). In embracing green process innovation, businesses have brought various benefits to the environment and resource reuse. As a result, this study forecasts that enterprises who implement green process innovation in market competitiveness would increase the performance of the circular supply chain.

Hypothesis -2 The implementation of green process innovation positively impacts the overall performance of the circular supply chain.

Green Logistics Innovation and Circular Supply Chain Performance.

By reusing or reselling materials, green logistics innovation can improve value and control expenses, enabling businesses to recoup lost profits and decrease operational expenses. Innovations in green logistics have the capacity to eradicate potential safety risks and diminish costs and uncertainties associated with products (Seroka-Stolka,2015). Green logistics innovation facilitates the pursuit of production objectives such as enhancing efficiency, curbing energy consumption, and averting environmental contamination by stakeholders and employees. Additionally, it aids organisations in attaining sustainable development (Agyabeng-Mensah et al., 2020). Moreover, green logistics innovation can enable organisations to swiftly adapt their conveyance systems to the ever-evolving business environment. Organisations advocate for green logistics innovation and leverage Internet of Things data to optimise work efficiency and guide warehousing operations. To mitigate carbon emissions, logistics transport vehicles are equipped with new energy vehicles, and the outer packaging of protected goods has been converted to degradable materials. These measures can aid businesses in addressing regulatory pressure from the government, industry associations, and the media all while protecting the environment (Lui & Ma,2022; (Baah et al.,2021). Considering its positive impact on sustainable development and the reduction of resource pollution, the adoption of green logistics innovation by businesses will enhance the operational efficiency of the circular supply chain.

Hypothesis-3 Positive effects of green logistics innovation on the operation of the circular supply chain.

Green Service Innovation and Circular Supply Chain Performance

In accordance with environmental concerns, green service innovation entails the repackaging of new products and services, the expansion of new production lines, and the delivery of new eco-friendly products to consumers (Chen, Y.S. et al., 2015). Green service innovation prioritises environmental concerns and has the potential to generate distinctive competitive advantages that are difficult for rivals to imitate [38]. Through the provision of innovative green services, businesses mitigate their adverse environmental effects and strengthen their ties to the global market, thereby enabling

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them to fulfil the environmental service demands of the international community (Lin & Chen,2018). Green service innovation has the potential to enhance the value of products and services, foster innovation and competitiveness among businesses, and assist organisations in attaining a competitive edge. Additionally, green service innovation has the potential to enhance employee quality and deliver superior customer service (Sahabi & Parast, 2020). Green service innovation demonstrates to clients that businesses are committed to innovation through the provision of environmentally friendly services. This satisfies clients' desire for green services, enhances their perception of value, and offers them a positive green experience. Green knowledge identification, creation, collection, organisation, storage, dissemination, and application are all facilitated by green service innovation (Lin, Y.H. & Chen, Y.S., 2017). The performance of the circular supply chain could potentially be enhanced through the implementation of green service innovation by businesses, considering the numerous environmental protection benefits associated with such innovation.

Hypothesis-4 The implementation of green service innovation positively impacts the overall performance of the circular supply chain.

Methodology

Quantitative approaches were used in the investigation. Conducting surveys with structured questions to collect responses from 150 professionals and customers of durable goods industry in Andhra Pradesh, with a focus on metrics related to supply chain performance. In quantitative research, convenience sampling is used. Through regression analysis, this study intends to demonstrate correlations between supply chain performance and green innovations using statistical analysis software such as SPSS.

Results and Discussion

Cronbach Alpha

Variables	Numbers of Items	Cronbach Alpha
Green Product Innovation	4	.918
Green Process Innovation	4	.938
Green Logistics Innovation	4	.915
Green Service Innovation	4	.902
Circular Supply Chain Performance	4	.895

(Table -1: Reliability Analysis of Variables**)**

The Cronbach's Alpha values for all the variables exceed the recognised threshold of 0.7, suggesting that the items within each variable demonstrate strong internal consistency and reliability for research purposes. The scores for green product innovation (0.918) and green logistics innovation (0.915) are quite similar, suggesting a remarkable degree of internal consistency. The variables contain items that are dependable for assessing their corresponding constructions. The variable "Green process innovation" has a Cronbach's Alpha value of 0.938, indicating excellent internal consistency. The scale utilised for assessing green process innovation is exceedingly dependable. Green service innovation has a score of 0.902. Although somewhat below that of Green Product and Logistics Innovation, this score nevertheless signifies a high level of dependability, assuring that the scale is strong for research purposes. The variable circular supply chain performance" (0.895) has a high degree of internal consistency, somewhat lower than the other variables but still falling within the good range.

Hypothesis Testing Using Regression Analysis

Hypothesis	Regression Weights	Beta Coefficient	R^2	P-Value
H1	Green Product Innovation & Circular Supply Chain Performance	.887	.787	.000
H2	Green Process Innovation & Circular Supply Chain Performance	.880	.775	.000
H3	Green Logistics Innovation & Circular Supply Chain Performance	.929	.863	.000
H4	Green Service Innovation & Circular Supply Chain Performance	.980	.960	.000

(Table -2: Regression Analysis**)**

Hypothesis 1 (H1): The high positive beta coefficient (0.887) indicates a significant correlation between Green Product Innovation and the performance of the Circular Supply Chain. The P-value of 0.000 signifies a high level of statistical

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significance. This suggests that there is a strong relationship between an increase in Green Product Innovation and a big improvement in Circular Supply Chain Performance.

Hypothesis 2 (H2): There is a positive relationship between Green Process Innovation and Circular Supply Chain Performance, as indicated by the beta coefficient of 0.880 and regression weight of 0.775. The P-value of 0.000 confirms the statistical significance of this link. Therefore, it can be inferred that implementing advancements or breakthroughs in environmentally-friendly procedures within a company are highly probable to augment the efficiency of its closed-loop supply network.

Hypothesis 3 (H3): Green Logistics Innovation, with a beta coefficient of 0.929, has a significant and positive influence on Circular Supply Chain Performance. The regression weight of 0.863 provides additional evidence for the robustness of this strong association. The P-value of 0.000 indicates that this finding is statistically significant, emphasising the crucial impact of green logistics technologies in improving circular supply chain performance.

Hypothesis 4 (H4): There is a strong positive association between Green Service Innovation and Circular Supply Chain Performance, as indicated by the highest beta coefficient (0.980) βand regression weight (0.960). The P-value of 0.000 indicates a high level of statistical significance for this link. These findings indicate that advancements in environmentally-friendly services have a significantly beneficial effect on the efficiency of circular supply chains.

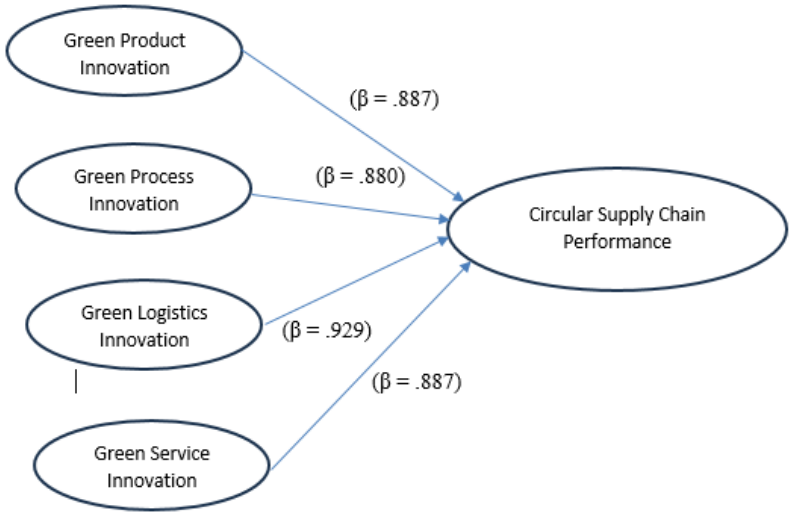

Figure – 2

Discussion

Hypothesis 1: The Influence of Green Product Innovation: The significant beta coefficient (0.887) and regression weight (0.787) indicate a robust and favourable impact of green product innovation on circular supply chain performance. This suggests that placing emphasis on green product innovation is expected to greatly improve the efficiency of circular supply chains.

Hypothesis 2: The Impact of Green Process Innovation: Consistent with the findings of H1, the implementation of green process innovation significantly improves the efficacy of circular supply chains (beta coefficient of 0.880). This indicates that environmentally sustainable and efficient processes are essential for improving the performance of the circular supply chain.

Hypothesis 3: The Significance of Green Logistics Innovation: The hypothesis with the highest beta coefficient (0.929) among the first three suggests that green logistics innovation has a significant and positive influence on circular supply chain performance. These findings indicate that implementing eco-friendly logistics technologies can significantly improve the efficiency and sustainability of circular supply chains.

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Hypothesis 4: The effect of implementing Green Service Innovations: Based on the beta coefficient of 0.980, this hypothesis suggests that green service innovation has the greatest influence on circular supply chain performance. Services that prioritise sustainability play a crucial role in the performance and efficacy of circular supply chains.

Conclusion

Green service innovation appears to have the most pronounced effect on the performance of the circular supply chain, according to the findings, which indicate that all types of green innovation—product, process, logistics, and service—have a statistically significant and beneficial impact on efficiency. Not just in the process of product design or production, but also in the logistics and services that are provided, this highlights how important it is to include sustainability into all elements of supply chain management. They identify specific areas where green solutions can be most effective, which makes these insights relevant for firms that are looking to improve the sustainability of their supply chain. Furthermore, the substantial statistical significance of these associations lends support to the idea that in order for businesses to improve their entire supply chain performance, they should invest in environmentally friendly innovations as a strategic approach.

Limitation

The study might be limited to a certain region or country, which may not truly represent worldwide trends. Should the sample be derived from durable goods industries, the results may not be applicable to all sectors universally. A reduced sample size can restrict the applicability of the results and may fail to encompass the complete spectrum of viewpoints and experiences. Data obtained through surveys or interviews is prone to self-reporting biases, where respondents may provide socially preferred answers rather than real responses. The likelihood that individuals who choose to answer to the poll can differ dramatically from those who do not. The dynamic nature of the corporate environment, particularly in relation to technology and economics, could potentially restrict the long-term relevance of the findings.

Scope for Future Research

Conduct similar research in various geographical places to compare and contrast the impact of green advances in different cultural and economic circumstances. Examine how green innovations affect circular supply chains in developing versus developed countries. Future study can be extended to investigate the influence of green innovations in circular supply chains in specific industries such as automotive, electronics, or fashion. Conduct long-term studies to see how the influence of green innovations on circular supply chains changes over time, particularly as technology and market dynamics change. Examine new green innovation trends and their long-term implications for circular supply networks. Examine the role of emerging technologies such as artificial intelligence (AI), IoT, and blockchain in increasing green innovations and their impact on circular supply chains. Investigate how organisational digital transformation affects the implementation and efficacy of green innovations. Further research into the broader economic impact of green breakthroughs, such as job creation, market growth, and investment patterns, can be conducted.

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