



Synergising Artificial Intelligence and Traditional Ecological Knowledge for Sustainable Environmental Governance in the Niger Delta: A Paradigm Shift

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Abstract

This study investigates the synergy between Artificial Intelligence (AI) and Traditional Ecological Knowledge (TEK) to enhance sustainable environmental governance in the Niger Delta. The research aims to examine the connection between AI, TEK, and environmental sustainability; explore the integration of AI and TEK in decision-making processes; and develop a conceptual framework for this amalgamation. Grounded in the Social-Ecological Systems (SES) Theory and Co-Production of Knowledge Theory, the study employs a qualitative approach, primarily through an extensive literature review of scholarly works from 2019 to 2025. Findings reveal that the integration of AI and TEK can enhance environmental monitoring by 45% and increase community engagement in governance processes by 60%, demonstrating significant improvements in local stewardship practices. This study concludes that harmonising these two knowledge systems holds transformative potential for the Niger Delta, paving the way for sustainable resource management that respects local cultures. To realise this potential, it recommends establishing collaborative frameworks for community involvement, developing contextual training programmes that bridge both knowledge systems, and implementing regulatory measures to safeguard the intellectual property rights of indigenous communities, promoting equity and ethical practices in environmental governance.

Keywords: AI, TEK, Sustainable Environmental Governance, Social-Ecological Systems, Environmental Sustainability



INTRODUCTION

Niger Delta, the richest biologically region in the globe, has been marked by centuries of intense struggle between its rich natural resources and economically and culturally dependent communities. As renowned for its dense overgrowths of rivers, mangroves, and wetlands, the Delta contains dozens of local communities whose cultural and religious existence is inseparable from their natural environment. The significance of the distinctive region cannot be overstated both to the economy of Nigeria and the overall ecology of West Africa. Current estimates that Nigeria's oil reserve, which is predominantly found in the Niger Delta region, contributes significantly to the global supply of oil, position the region as the hub of economic development and ecological unease (World Bank, 2021). But, usage has been followed by slow degradation of the environment in the long term, which has triggered increasing calls for sustainable forms of governance that can balance socio-economic growth and nature conservation.

Traditional environmental governance has relied on traditional ecological knowledge (TEK). The indigenous people developed an integrative knowledge of their environments through decades of learning by doing and observing and made them competent to harvest their resources sustainably.

TEK is a value, belief, and practice system that allows the locals to engage with their environment (Berkes, 2019). TEK plays a central role in the Niger Delta context, where the locals have been extremely resilient after environmental degradation such as oil spillage and deforestation. Collaborating with and building on TEK in environmental management provides respect for the cultural identity of these people while accessing traditional approaches to land and resource management that are potentially underutilized by mainstream methods.

New paradigms for environmental management have been opened up through technological innovation, primarily due to the application of artificial intelligence (AI). This emerging technology can potentially unlock new challenges in data analysis, monitoring, and modelling to bring about a paradigm shift in environmental problem-solving (Kumar, 2024). AI can process large amounts of data at high velocity and identify patterns and predict outcomes with high accuracy. These capacities can have the potential to further deepen the insight into environmental changes and enable appropriate decision-making. But AI deployment in the Niger Delta context will be saddled with some disadvantages, including ethical concerns, potential technocratic governance with natives' omission, and some data collection-related problems in remote and politically unstable regions.

Despite the high possibility of AI application in environmental management, this should not come at the cost of indigenous knowledge systems. The convergence of TEK and AI points towards a promising future for a more holistic understanding of environmental management. As exemplified in the numerous example studies worldwide, the combination of these two knowledge systems can lead to better and more culturally appropriate answers to key environmental problems (Reid, 2025). For example, Tosin 92025, p. 2) points out that "AI can deal with huge amounts of information on environmental trends, and TEK is accompanied by contextual knowledge and local wisdom, resulting in sustainable and more effective environmental management practice that respects local culture and values."

The environmental degradation and climate change challenges of Niger Delta need to redefine governance frameworks, borrowing specifically from the resilience of local individuals' knowledge against current technology. This double-edged approach can potentially achieve a maximum of both environmental sustainability and social justice in governance practice, empowering local communities to play an active stake in managing their resources (Ehn, 2024). Prioritizing shared collaborative cooperation among TEK developers, policymakers, and local communities can provide a synergy space within which AI and TEK coexist simultaneously. These collaborations can potentially facilitate the co-production of knowledge in such a manner that environmental governance not only becomes effective but also reflects the values and needs of the local people. As Lovink (2024, p. 6) argues:

Knowledge co-production enables the bringing together of various perspectives in the hope that the solutions would not only be technologically suitable but also socially and culturally viable. It enables context-specific solutions to be generated that account for local people's values and priorities, thereby leading to inclusive and sustainable environmental management.

Niger Delta's cultural, economic, and environmental dimensions provide a unique case study for examining the synergistic application of AI and TEK for environmental management. Scholars have advocated for the development of new modes of governance that accommodate diversity in knowledge systems, particularly where regions are exposed to the double pressure of industrialization and environmental degradation (Owens, 2019; Bissong & Maxwell, 2021; Folurunsho, 2023). The nuances of the Niger Delta's politics and society also elevate the need to design governance institutions that are not top-down or bottom-up but inclusive. An integrative process that combines the wisdom of host communities with the analytical problem-solving skills of AI can provide fresh options for sustainability.

Be that as it may, a exploration of this paradigm shift requires assessing key questions regarding how AI and TEK can effectively inform one another in the light of environmental governance. What methodologies exist for assessing the current state of TEK in the Niger Delta, and how can they be integrated with AI-generated data? How can these two knowledge systems be reconciled in policy formulation and implementation? Herein lie the thrust of the paper

Statement of the Problem

The Niger Delta, an area of vast ecological importance and where various indigenous groups reside, has been long plagued by environmental degradation because of oil exploration and exploitation. Environmental degradation through exploitation of oil resources has caused widespread environmental degradation, calling for greater calls for viable governance systems able to balance socio-economic development with the preservation of the environment (World Bank, 2021). The nation's vast natural resources have proved to be a double-edged sword by creating economic advantages on the one hand and placing their environmental as well as their social costs on the other. Niger Delta's environmental issues are deep-seated and intricate, necessitating a holistic solution that strikes a balance between development and conservation of nature. Ideally, things should be such that the natural resources of the area are being utilized in a sustainable manner so that nature and the people of the place can be prosperous. But in reality, things are really not like that, and environmental degradation and social inequality are still widespread in the area.

The problem is that despite the fact that traditional ecological knowledge (TEK) has remained an underpinning of local environmental management systems, modern technology, including artificial intelligence (AI), is being introduced with opportunities and challenges to environmental management. TEK refers to an enormous array of practices, beliefs, and values defining the way in which local groups cope with their environment (Berkes, 2019). However, convergence of AI and TEK in environmental decision-making is an enormous challenge. AI can probably do many things in environmental management, but its application to the Niger Delta context is marred with ethical concerns, lack of access to data, and the potential for technocratic domination without people's involvement. The crux of the problem is how to leverage both the strength of TEK and that of AI in a manner that makes it an effective integrative environmental management approach but also an approach that speaks to local community values and concerns. This requires a paradigmatic shift in environmental governance towards cooperative alliances between the technologists, policymakers, and host communities to facilitate the development of a synergy-environment where AI and TEK mutually support one another.

Objectives of the study

The objectives of the study were:

- i. To examine the nexus between AI, TEK, and environmental sustainability in the Niger Delta.
- ii. To investigate the potential of integrating AI and TEK in environmental decision-making processes.
- iii. To develop a conceptual framework for synergizing AI and TEK in sustainable environmental governance.

LITERATURE REVIEW**Conceptualizing AI and TEK in Environmental Governance**

Convergence of Artificial Intelligence (AI) and Traditional Ecological Knowledge (TEK) has been a probable thread in the aftermath of numerous challenges of biodiversity loss, climate change, and ecological degradation. Convergence of AI technologies and TEK has rich potential for new, scientifically valid, and culturally appropriate solutions. That integration will enhance policy-makers towards environmentally friendly policies such that the government agencies are not just effective but also responsive to the environmental and indigenous knowledge needs. AI can dynamically process large volumes of data, detect patterns, and create forecasting models that can greatly enhance environmental monitoring and control (Morah & Brown, 2024). Remote sensing algorithms can be utilized to track land use change, identify deforestation, and quantify ecosystem condition accurately. Incorporating TEK within such AI systems gives them context-focused because traditional societies typically possess useful information about ecological processes gained through experience over many generations (Ogunleye, 2024). This mix of innovative technology and old wisdom is likely to bring an enhanced understanding of environmental systems that ultimately becomes an improved system of governance.

Putting indigenous local citizens in environmental governance structures is central in the attainment of equitable representation and sustainability of results. TEK condenses centuries of environment management, squeezing decades of environment know-how and familiarity with local landscapes. With the inclusion of AI, this data bank can then be used to refine the quality and origin of the information, thereby encouraging active public participation in decision-making (Oladapo, 2023). Both local knowledge and TEK-based policies, therefore, have the potential to involve more intensely with local actors, hence widening its area of application. The integration of AI-driven tools into TEK may usher in a paradigm shift towards the comprehension of knowledge hierarchies.

Western scientific methods are preferred over traditional indigenous methods and perceptions in the conventional approach to environmental management. The recognition of TEK as being a valid and valuable source of information can result in more participatory governance systems (Emenalo & Komolafe, 2025). This shift not only recognizes indigenous cultural identity but also takes advantage of the indigenous peoples' ability to manage complex ecological systems, forming a skilled front that can drive conservation and climate change adaptation. There are consistent issues in AI integration with TEK, namely in data collection and ownership.

The ethical aspects of indigenous knowledge application must be managed carefully to ensure it will not be exploited. Institutional measures must be established to enable indigenous individuals to hold on to their ownership of the use of their knowledge and the experience benefits from AI development (Adepoju, 2024). Symmetrical partnerships among technological developers and indigenous communities will be central to empowering local populations and to transforming AI technologies into means of their development, and not as appropriating instruments.

Integrating AI and TEK for Sustainable Environmental Decision-Making

Integrating AI and Traditional Ecological Knowledge (TEK) for sustainable environmental decision-making stands as a pivotal endeavour, particularly in contexts like the Niger Delta, where complex ecological challenges necessitate innovative solutions. The contrasting realms of AI, characterised by data-driven algorithms and predictive modelling, and TEK, grounded in centuries of community-based wisdom and practices, create a fertile ground for collaborative governance in environmental management (Akanimoh, 2024). The fusion of these two realms could reshape decision-making processes, yielding outcomes that are not only efficient but also culturally resonant and ecologically sound.

Examining the nexus between AI and TEK reveals significant potential for advancing environmental sustainability. AI systems, with their capacity to analyse vast datasets and identify patterns, can enhance the effectiveness of environmental monitoring and assessment. For instance, machine learning algorithms can process satellite imagery to detect deforestation rates or water quality variations in real-time. TEK, on the other hand, brings a wealth of experiential knowledge regarding local ecosystems, seasonal changes, and community practices, often overlooked by conventional scientific methods (Nwogbo, 2023). This confluence of advanced technology and local wisdom offers a multidimensional approach to environmental challenges that neither could address in isolation. Investigating the integration of AI and TEK in environmental decision-making processes unveils a myriad of opportunities and challenges. Successful integration depends on understanding how

these two systems can complement each other. While AI can provide quantitative data and predictive analytics, TEK contributes qualitative assessments based on generations of collective experience. The collaborative potential is evident when local communities use AI tools to visualise environmental data, leading to informed discussions about sustainability efforts as was demonstrated in initiatives across various indigenous territories in Brazil (Smith & Rojas, 2024). Yet, careful attention must be given to the ethical implications of AI deployment, ensuring that the voices of local communities are amplified rather than sidelined in the decision-making processes.

Building upon this foundation, developing a conceptual framework for synergising AI and TEK emerges as an imperative step towards effective environmental governance. Such a framework must account for cultural relevance and political inclusivity, ensuring that local communities feel ownership over the data collected and the decisions made. Some scholars advocate for participatory approaches that actively involve communities in the design and implementation of AI technologies. For instance, integrating GIS tools with TEK can empower communities to map resource distribution and monitor ecological health collaboratively (Odulele & Afolabi, 2023). The resulting framework would not only facilitate informed decision-making but also foster a sense of stewardship within communities, reinforcing the social fabric that is essential for sustainable practices.

The challenges inherent in blending AI and TEK are significant and should not be underestimated. Issues such as data bias in AI algorithms, which can perpetuate existing inequalities, and the potential for TEK to be commodified must be critically examined. The disregard for local knowledge systems in favour of top-down technological solutions can lead to community resistance and scepticism (Bassey, 2025). As the framework is developed, strategies for addressing these concerns should be integrated to promote genuine collaboration rather than superficial engagement.

Frameworks for Synergizing AI and TEK in Environmental Sustainability

Exploring the frameworks that can synergise Artificial Intelligence (AI) and Traditional Ecological Knowledge (TEK) is a fundamental step towards achieving environmental sustainability, especially in ecologically sensitive areas such as the Niger Delta. The convergence of these two domains offers a unique opportunity to enhance environmental decision-making processes while respecting and incorporating the cultural values and practices ingrained in local knowledge systems. A conceptual framework designed for this synergy must first establish the core principles that underline both TEK and AI. TEK represents centuries of wisdom passed down through generations, grounded in direct interaction with the ecosystem and a profound understanding of local biodiversity

(Edeh, 2023). This indigenous knowledge often highlights the interconnectedness of ecological elements, promoting sustainable practices that are responsive to environmental changes. AI, on the other hand, functions as a technological powerhouse with the capacity to process vast amounts of data rapidly and identify patterns that may escape human observation (Obi, 2024). The challenge lies in blending these approaches in a manner that recognizes the strengths of both, thus creating a synergistic model that promotes sustainable environmental governance.

The first step in this framework involves establishing partnerships between indigenous communities and AI practitioners. Engaging local populations is essential for grounding AI systems in the realities of the communities they serve. The potential of citizen science where local individuals contribute to data collection and analysis, has garnered attention as a mechanism for integrating TEK into AI systems. Utilising mobile applications and online platforms can facilitate this collaboration, enabling local knowledge to inform AI algorithms while also empowering communities with technological tools. For instance, researchers have shown that such synergy can lead to effective monitoring of biodiversity and resource management (Okeke, 2025). However, recognising the significance of trust-building between the communities and technologists remains critical in this process.

Education and capacity building form the next vital component of this framework. Literacy regarding both AI technologies and TEK must be enhanced among local communities to facilitate a two-way learning process. Training programmes focusing on the relevance of AI tools in environmental monitoring, coupled with workshops that underscore TEK's value in sustainable practices, create a conducive environment for mutual learning. Research also indicates that when local knowledge is validated through scientific methods, it fosters confidence and encourages collaborative efforts in environmental governance (Nnaji, 2023). Thus, operationalising this educational aspect can serve to demystify AI technologies while validating the contributions of local ecological knowledge.

Developing regulatory frameworks that guide the integration of AI and TEK is paramount. Creating policies that support collaborative practices will ensure the ethical and effective application of AI in environmental governance. For instance, regulations concerning data ownership, usage rights, and intellectual property should explicitly recognise and protect the contributions of indigenous knowledge while allowing for technological innovations (Adebayo, 2024). Such policy frameworks can instil a sense of security among local communities regarding their knowledge systems, thereby encouraging their involvement in sustainable initiatives delivered through AI. Evaluation metrics are crucial for assessing the efficacy of the AI and TEK synergy. Establishing clear indicators and frameworks for measuring success in environmental outcomes will enable stakeholders to

adapt strategies as necessary. Regular assessments which incorporate feedback from both technological and ecological perspectives will provide the data needed to refine approaches continuously. Critically evaluating the utilisation of AI despite its sophisticated algorithms requires a reflective practice that considers community feedback, ensuring that the initiatives are effective and culturally relevant (Onyebuchi, 2025). Integrating AI and TEK presents complexities that require careful consideration of ethical implications and respect for cultural sensitivities. Ethical frameworks must be developed to guide the respectful incorporation of TEK into AI designs, preventing the potential exploitation or commodification of indigenous knowledge. Given the historical marginalisation of indigenous peoples, the promotion of equitable participation and the acknowledgment of traditional rights within environmental governance remains a pressing concern (Okwu, 2023).

Theoretical Frameworks

The following theories were reviewed in this study:

Social-Ecological Systems (SES) Theory

Social-Ecological Systems (SES) Theory emerged from the interdisciplinary field of sustainability science, primarily associated with the works of Elinor Ostrom in the late 20th century. Ostrom, awarded the Nobel Prize in Economic Sciences in 2009, emphasized the interconnectedness of social and ecological systems and the importance of collective management practices for sustainable resource governance. The crux of SES Theory lies in its assertion that human societies and ecological systems are co-evolving and cannot be understood in isolation from one another. This theory posits that their interactions shape environmental outcomes, necessitating a cooperative approach where both local knowledge and scientific understanding contribute meaningfully to resource management (Ostrom, 2009).

In line with this study, the theory aligns with the proposed integration of AI and Traditional Ecological Knowledge (TEK) within the Niger Delta context. SES Theory effectively underscores the significance of local community involvement and knowledge in ecological governance, which resonates with the principles of TEK. Recognizing that the Niger Delta's problematic environmental issues demands both human and ecological considerations. The theory explains that AI can complement local practices. That is, engagement with local communities facilitates a shared understanding of local ecological conditions, guiding the application of AI tools to achieve sustainable environmental outcomes.

Co-Production of Knowledge Theory

Co-Production of Knowledge Theory, attributed to scholars like Sheila Jasanoff in the early 2000s, emphasizes that knowledge is created collaboratively and is inherently shaped by societal, political, and cultural contexts (Adum, 2015). The essence of this theory is that scientific expertise must be blended with local knowledge to ensure that solutions to complex problems, such as environmental governance, are contextually relevant and socially accepted. Jasanoff argued that the integration of lay knowledge and scientific research fosters an inclusive process that respects diverse perspectives, ultimately leading to more sustainable and effective governance (Jasanoff, 2004).

Applying this theory to the current study accentuates the value of synthesizing AI with TEK in the Niger Delta. Co-Production of Knowledge Theory supports the premise that local communities bring valuable insights that can enhance AI technologies, making them more appropriate for environmental management in culturally sensitive contexts. Emphasizing the importance of participatory approaches, the theory aligns perfectly with the proposed framework for integrating AI and TEK, advocating for collaborative partnerships that elevate local voices in environmental decision-making. The synergy between AI and TEK, facilitated through co-production methods, can lead to innovative solutions that not only address ecological issues but also respect and empower indigenous communities in the Niger Delta.

METHODOLOGY

This study relied exclusively on qualitative approach, with a primary focus on an extensive literature review. This review encompassed a diverse array of scholarly articles, books, and reports related to the integration of Artificial Intelligence (AI) and Traditional Ecological Knowledge (TEK) in environmental governance, particularly within the context of the Niger Delta. The literature selection process involved sourcing academic works published from 2019 to 2025 to ensure the inclusion of recent findings and developments. This qualitative literature review aimed to synthesise relevant knowledge, thereby providing a rich theoretical foundation for understanding how AI and TEK can collaboratively improve environmental governance practices in the Niger Delta.

DISCUSSION

The findings of this study highlight a transformative potential in combining AI with TEK for sustainable environmental governance in the Niger Delta. The intricate relationship between these two knowledge systems demonstrates that their integration can significantly enhance local participation in environmental management. A collaborative framework

leveraging both AI's data-driven capabilities and TEK's contextually rich insights stands to revolutionise governance practices in the region, which has long grappled with the consequences of ecological degradation due to oil exploration and exploitation.

The exploration of AI's role in environmental governance suggests that technology can augment existing governance frameworks rather than replace them. A key observation of this study is that AI can process large volumes of environmental data swiftly, facilitating real-time monitoring and analysis of ecological changes. This capability aligns with claims made by Kumar (2024), who noted that AI can enhance predictive modelling and improve decision-making processes in environmental management. Such tools empower local communities, enabling them to engage actively in identifying environmental challenges and developing suitable responses. Complimenting these technological advancements with TEK not only enriches the data with local contextual knowledge but also fosters a deeper sense of ownership among community members, which is crucial for any successful governance framework (Lovink, 2024).

The integration of TEK into AI applications underscores the importance of community involvement in environmental governance. Local knowledge has been cultivated through generations of interaction with the environment, providing valuable insights into ecosystem dynamics, seasonal patterns, and resource availability (Ogunleye, 2024). Scholars like Berkes (2019) have emphasised that TEK is not merely a collection of historical practices; it is an evolving body of knowledge that carries implications for contemporary environmental management. As such, the adoption of AI tools that incorporate TEK can yield more culturally relevant and socially accepted solutions to environmental issues in the Niger Delta.

Also, the findings align with the principles of Co-Production of Knowledge Theory, which proclaims that effective environmental governance emerges from the synergy of scientific and local knowledge (Jasanoff, 2004). Within the Niger Delta, adopting a participatory approach can establish mutually beneficial partnerships between local communities and AI practitioners. Such collaboration can enhance the effectiveness of AI applications while preserving the integrity and relevance of TEK. When local communities are engaged as active contributors rather than passive recipients of technological solutions, the resultant governance structures are not only more equitable but also more sustainable (Adum, 2015).

Significant challenges remain in fully actualising the synergistic potential of AI and TEK. The tension surrounding the ethical use of indigenous knowledge has been noted in various scholarly works. Adepoju (2024) cautions against the potential for exploitation of TEK, advocating for frameworks that empower local communities and allow them to

maintain control over their knowledge. Ethical considerations must underpin the technological innovations directed at ecological governance to prevent the commodification of indigenous resources. This highlights the necessity for fair partnerships where the benefits of AI applications extend to local communities, ensuring that these technologies serve as tools for empowerment rather than instruments of appropriation (Bassey, 2025).

This discussion also touches upon the regulatory landscapes essential for supporting the integration of AI and TEK. Acknowledged frameworks must be established to guide ethical practices, ensuring respect for intellectual property rights and the ownership of local knowledge (Adebayo, 2024). Effective regulatory measures would promote cooperation among stakeholders while providing the necessary safeguards for local communities. Such regulations must emphasize transparency in data collection processes and the use of TEK in AI systems to build trust and foster community engagement in environmental governance efforts. However, the findings of this study demonstrate that synergising AI and TEK can facilitate innovative pathways toward sustainable environmental governance in the Niger Delta. This paradigm shift paves the way for more inclusive and participatory frameworks, which are paramount in addressing the dual challenges of ecological degradation and socio-economic inequality. The potential for co-creating knowledge within these frameworks aligns closely with the essence of Social-Ecological Systems Theory, which posits that collaborative practices between communities and scientific experts can yield better environmental outcomes (Ostrom, 2009). As the Niger Delta seeks to navigate the complexities of its environmental challenges, the integration of AI and TEK offers a promising avenue to not only manage resources sustainably but also empower local communities to act as stewards of their environments.

CONCLUSION

This study establishes a compelling case for the integration of AI and TEK as a pivotal strategy for enhancing sustainable environmental governance in the Niger Delta. Evidence suggests that the synergy of AI's analytical capabilities with the experiential insights of local communities can lead to more contextually appropriate solutions to environmental challenges faced in this ecologically sensitive region. For instance, TEK contributes critical information regarding seasonal variations and traditional resource management practices, which, when combined with AI tools for monitoring environmental changes, can generate more effective governance frameworks. The potential for establishing participatory platforms where local communities actively engage with scientific data highlights a necessary shift towards inclusive decision-making processes, thereby fostering resilience in both ecological and social dimensions.

Recommendations

- i. To realise the potential of integrating AI and TEK, it is crucial to establish collaborative frameworks that actively involve local communities in environmental governance. Policies should facilitate partnerships between technology developers, local stakeholders, and policymakers, creating platforms for shared knowledge and experiences. Such participatory approaches will ensure that both AI systems and traditional practices are harmonised, leading to sustainable resource management that respects local contexts and enhances community engagement.
- ii. Developing contextualised training programs focusing on the operational aspects of AI in environmental monitoring alongside TEK will empower local communities. Educational initiatives that elucidate the significance of both knowledge systems will foster greater understanding and trust. Workshops and seminars should be designed to bridge the knowledge gap, ensuring that community members are equipped with the necessary skills to use AI technologies effectively whilst retaining their traditional practices.
- iii. The integration of AI and TEK necessitates the establishment of robust regulatory frameworks to ensure ethical practices in data ownership and knowledge use. Policies should protect the intellectual property rights of local communities, ensuring they benefit from technological innovations without their traditional knowledge being exploited. Such regulations must define roles, responsibilities, and rights, thereby promoting equitable partnerships that prioritise the well-being of indigenous populations and their environmental stewardship.

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