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SUSTAINABLE MANAGEMENT OF FOLK ART THROUGH DATA ANALYTICS

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ABSTRACT

Sustainable management of folk art is becoming very essential in the conservation of cultural heritage and the economic sustainability of artisan communities. This paper suggests a data analytics-based system to increase the sustainability of folk art ecosystems through the combination of market insight, resources optimization, and community engagement. The challenge of folk art in modern economies that are usually marginalized is associated with the lack of demand variability, unfair pricing and online irreachability. Through descriptive, predictive and prescriptive analytics, this study will be able to determine some of the key parameters that affect the long-term viability of the folklore art practices. The consumer trends and seasonality are analyzed with demand forecasting models, whereas the pricing analytics can help to allocate the fair value across the artisans, intermediaries and markets. The analysis also evaluates the sustainability measures, including environmental (material use and waste minimization), economic (income stability and diversity in the market) and social (cultural involvement and the intergenerational transfer of knowledge). An index of sustainability based on data is suggested to assess policy interventions and in order to optimize the allocation of resources to the artisan clusters. The predictive accuracy of the framework is improved by the implementation of AI and ML technologies like clustering, sentiment analysis, and regression modeling. This project eventually serves as a bridge between the historical cultural heritage administration and the modern analytics to achieve the sustainable development agenda by empowering the folk art communities and enhancing the intangible cultural resources in the digital economy.

Keywords: Folk Art Management, Data Analytics, Cultural Sustainability, Machine Learning, Market Optimization, Heritage Preservation

1. INTRODUCTION

Folk art incorporates the living aspects of community identity and creativity, and heritage transmitted across generations and embedded within the local traditions, practices and aesthetic. These art in the form of painting and textile, even sculpture and performance art are not merely visual or material culture, but rather summarize the socio-economic and environmental histories of those that create them. In the modern world, however, of globalization and technology-based economy, there is a great challenge that folk art ecosystems have to struggle with to ensure sustainability. The drop in patronage, fluctuation of the market, the lack of resources, and poor digital presence have isolated the communities of artisans and undermined the process of cultural transmission. It is against this backdrop that data analytics presents a revolutionary position of managing, preserving, and revitalizing folk art in an environmentally friendly way. Folk art needs a multidimensional approach which incorporates economic feasibility, continuity and sustainability of culture and environment Jaillant (2022). Conventional models usually apply to qualitative evaluation and intermittent intervention, which are not scalable and predictive. The implementation of evidence-based decision-making and putting intuition-based management behind allows making a transition to the use of evidence-driven systems. Analytics can be used to identify patterns of consumption, forecast demand variations, and price methods to ensure equitable returns to artisans by using massive data in sales, online application, and cultural organisations. Furthermore, data visualization tools make the policy makers and culture managers realise both the trends in production, trade, and audience interest, resulting in a more informed resource distribution and attentive development chemistry Burton and Toh (2023). On the sustainability perspective, data analytics helps in aligning folk art administration with the.

United Nations Sustainable Development Goals (SDGs), especially, the resolutions focused on decent work, responsible consumption, and cultural diversity. As an example, predictive analytics might be used to predict the needs of raw materials, to minimize overproduction and waste, and cluster analysis will be used to represent hitherto underrepresented artisan groups fairly. On the same note, social media sentiment analysis and e-commerce feedback will give a picture of how consumers will prefer it and therefore artisans can shape their creative work without jeopardizing authenticity Saah et al. (2023). The data ecosystem that results also creates a feedback mechanism between the artisans, markets, and cultural institutions, which results in adaptive growth and resilience. Machine learning (ML) and artificial intelligence (AI) also complement this process by automating this process on pattern recognition, market segmentation, and sustainability assessment. Regression models have the ability to predict the difference in incomes in different areas, whereas recommendation algorithms can match artisans with potential customers, collectors, and exhibition sites Abdul-Jabbar and Farhan (2022). All these tools contribute to a culture of dynamism, information-based cultural economy with tradition and innovation going hand in hand.

2. LITERATURE REVIEW

2.1. OVERVIEW OF FOLK ART MANAGEMENT FRAMEWORKS

The academic attempt to control the folk art and the traditional crafts has generated numerous frameworks that concentrate on the preservation, growth of the artisan communities and their well being. Indicatively, a study decides that folk-craft management will have a direct role in the welfare and stability of local communities through the maintenance of quality and variety of products thus enhancing cultural heritage and economic strength Matlala (2019). A second study of the strategic planning of folk-culture industries points to the conflict between development and protection: as much as commercialization may offer market exposure and revenue to artisans, unregulated expansion leads to commodification and loss of the so-called authenticity. In addition, the extensive surveys of the literature on cultural-heritage management report models of the site-based (monuments, architecture) and the living heritage (crafts, folk arts) models, which imply that heritage management could not be limited to physical conservation but need to incorporate intangible and community-based practices Nguyen et al. (2020). The elements of heritage management in most of the frameworks comprise documentation, inventorying, stakeholder governance (artisans, community, state), resource planning, quality control, and sustainable livelihood support.

2.2. EXISTING DIGITAL AND DATA-DRIVEN CULTURAL HERITAGE INITIATIVES

Over the last years, heritage management has adopted digital technologies that gather, store, and market cultural resources. One of the most iconic cases is CyArk which is a non-profit organization that uses laser scanning, 3D modeling and digital archiving to record architectural heritage all over the world. Other initiatives of this kind are digital libraries and web archives like World Heritage Memory Net (WHMNet), where documentation of heritage sites is made available in multiple languages to global audiences in multimedia format Hawkins (2022). More recently, museum collections, heritage sites and intangible cultural assets have been systematically treated to digital transformation technologies (DTTs) such as high-resolution scanning, 3D reconstruction, VR/AR, GIS spatial mapping and metadata cataloguing. There are also increasing initiatives that focus on inclusion, sustainability and community-led digital heritage. As an example, the policies of organizations like UNESCO promote the utilization of AI and digital technologies to conserve, enhance, handle, and disseminate tangible and intangible cultural heritage in an ethical and participative way Doing et al. (2023).

2.3. APPLICATIONS OF DATA ANALYTICS, ML, AND AI IN ART AND CULTURE

The convergence of artificial intelligence (AI), machine learning (ML), and cultural heritage has grown over the recent years, offering new tools of documentation, restoration, analysis, and heritage promotion. A number of recent studies provide us with an example of how AI can help to preserve and develop cultural artifacts through reuse. As an illustration, digitization processes through AI-based workflows (i.e. deep learning, computer vision, and optimization) allow high-fidelity classification, restoration, and even creation of culturally-contextualized artifacts Xu (2022). Applications ML models may be used in preservation to aid in automated documentation, 3D modeling, environmental monitoring, damage detection and long-term conservation planning. As an example, AI-based scanning and virtual reconstruction can be used to restore damaged works of art or heritage sites, pattern recognition and image processing can be used to detect structural damage - enabling conservation specialists to implement specific restoration plans. In addition to restoring, AI and ML can also make possible new forms of cultural production and distribution. Generative AI pipelines have been demonstrated to reproduce or reconsider traditional folk patterns without losing style authenticity and provide a combination of the past and modern-day creativity Liang et al. (2021). Table 1 gathers a summary of heritage approaches, their applicability to folk-art, and gaps in the research. Moreover, semantic analysis and embedding methods, including visual and textual data, allow organizing, retrieving, and interpreting heritage collections in a more convenient way and thus become more accessible to researchers, curators, and the wider audience.

Table 1

Table 1 Summary of Literature Review

Heritage Domain	Method	Relevance to Folk-Art	Gaps
Broad Cultural Heritage (artworks, artifacts, CH sites)	ML algorithms (classification, clustering, damage detection)	Demonstrates general ML tool-set for heritage analytics	Focus on tangible heritage/monuments; limited work on crafts/folk-art
Digital Cultural Heritage broadly (museum informatics, intangible heritage) Elragal et al. (2017)	Big data, digital archives, social media data, metadata management	Supports documentation, digitization, inclusive heritage outreach	Mostly focused on museums/institutions — not grassroots artisans/fair trade crafts
Cultural heritage: artifacts, monuments, historical sites	AI, image-recognition, 3D scanning/VR, environmental monitoring	While focused on monuments/artifacts, principles apply to material-based folk art (sculpture, painted crafts)	Less emphasis on living heritage or artisan communities
Digital Cultural Heritage (DCH) research trends Luo and Hu (2022)	Bibliometric analysis, review of VR/AR, digital archiving, interactive tech	Digital-heritage tools are increasingly adopted; can support crafts and intangible heritage outreach	Focus on large heritage institutions, less on small-scale folk art sectors
Architectural and landscape heritage	Laser scanning, GIS, 3D modeling, photogrammetry, digital modeling	Demonstrates digital documentation of heritage at scale — useful for built	Focus on architectural heritage; not crafts/folk-art

(tangible) Opgenhaffen (2022)		heritage but methodologically inspiring for crafts	
Heritage conservation and enhancement via technology (smart heritage)	IoT, ML, sensors, monitoring systems	Smart-heritage methods potentially useful for living heritage conservation and site-based craft clusters	Mostly focused on structural heritage (buildings/sites) not crafts
Heritage buildings (tangible architectural heritage) Wen and Ma, (2024)	IoT, edge/cloud computing, ML predictive modeling, digital-twin, climate & environmental monitoring	Demonstrates effective predictive analytics for heritage preservation mindset	Focus on built environment not crafts or intangible heritage
Heritage values & attributes; intangible and tangible mixed; public perception	Multi-modal data (images, texts, geolocation, social media), graph ML, semi-supervised learning	Highly relevant — could be used to model folk-art popularity, community sentiment, spatial distribution	Study focuses on heritage sites; not explicitly on crafts/folk-art
Digital cultural heritage dissemination & experience	VR/AR, digital museums, interactive media, digital archives	Suggests potential of immersive/fair-trade folk-art exhibitions and global digital outreach	Less focus on grassroots artists or socio-economic sustainability

3. THEORETICAL FOUNDATIONS

3.1. PRINCIPLES OF SUSTAINABLE CULTURAL HERITAGE MANAGEMENT

Sustainable cultural heritage management (SCHM) is based on the combination of economic sustainability, social inclusivity, and environmental sustainability. It lays stress on the active correlation between cultural continuity and adaptive modernization. The main philosophy is that heritage has to be not merely maintained as an object, but constantly renewed by using responsible and community-based strategies. SCHM frameworks, based on the principles of UNESCO conventions and sustainable development goals (SDGs 8, 11, and 12), are designed to support a participatory form of governance, balanced distribution of benefits, and balance in the ecosystem Derda (2024). They promote the long term plans that ensure the livelihood of the artisans without compromising authenticity and inter-generational knowledge. Sustainability is not limited to preservation in this strategy, but it is seen as the increased resilience of cultural systems. This incorporates sustainable material procurement, fair trade activities in the market, and electronic filing of resources to safeguard the intangible cultural resources. Cultural resilience is a principle used to make sure that folk art traditions do not lose their identity. Figure 1 provides major principles of sustainable and responsible management of cultural heritage. Additionally, economic sustainability involves establishment of self-reinforcing loops by means of local cooperatives, fair-trade format, and innovative entrepreneurship.

Figure 1

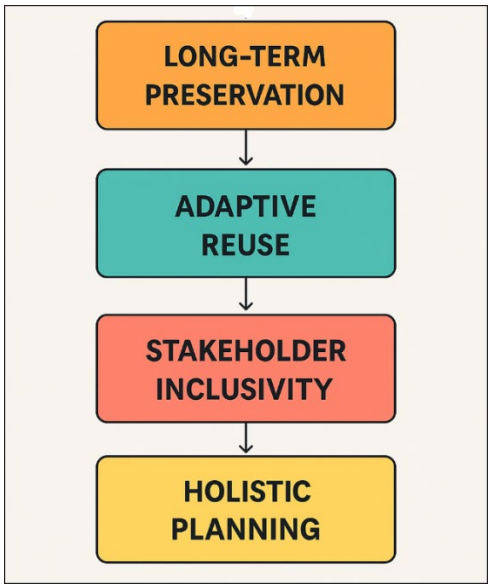

Figure 1 Representing the Principles of Sustainable Cultural Heritage Management

Environmental indeed involves the use of biodegradable sources, reduction of carbon footprints during production and the adoption of circular practices in craft industries. Social sustainability strengthens the inclusion, education and capacity building. In this way, SCHM is a triple bottom line organization in terms of heritage preservation and empowering local communities and sustainable development. It makes cultural heritage not a thing of the past, but a dynamic resource that will create more sustainable futures in communities and countries.

3.2. DATA ANALYTICS MODELS RELEVANT TO CULTURAL ECOSYSTEMS

The cultural ecosystem is a complex, interdependent system of interactions with artisans, consumers, institutions, and cultural artifacts. Data analytics models represent formalized ways of comprehension of these dynamics and optimization of decision-making. Descriptive analytics is a form of analytics that records previous data on production, sales, and participation patterns, diagnostic analytics determines the reasons behind a market or social change, predictive analytics predicts future demand and sustainability risks, and prescriptive analytics prescribes strategic actions. A combination of these models creates a data ecosystem that boosts management of cultural resources. It is further enhanced in terms of machine learning and statistical modeling to understand cultural behavior. Regression models can be used to estimate the variability of income and price elasticity; clustering algorithms can be used to group artisan communities based on their productivity or thematic style; and association rule mining can be used to discover the relationship between cultural events and sales performance. Social media sentiment analysis gives real-time feedback on the preferences of the audience, whereas geospatial analytics maps legacy clusters and market reach. Network analytics are especially useful when considering cultural interconnections - e.g. collaborations, resource dependencies and how cultures diffuse across regions. Additionally, the visualization tools based on dashboard are able to process the complex data to provide actionable information to the policy makers and those in charge of cultural enterprises. The application of this analytics models to cultural management systems results in quantifiable sustainability metrics economic inclusiveness, cultural diversity and the elimination of ecological footprint. Hence, data analytics can convert the intangible idea of cultural value into tangible and measurable and scalable knowledge that can be applied to sustainable ecosystems of heritage.

3.3. STAKEHOLDER THEORY FOR ARTIST–COMMUNITY–MARKET SYSTEMS

The stakeholder theory provides a powerful prism to view and reconcile the conflicting interests of the artist and community market trinity. It assumes that the system of sustainability within folk art worlds can be achieved by the acknowledgment of all stakeholders, namely artisans, consumers, intermediaries, cultural institutions, and policymakers, as legitimate stakeholders with interdependent relationships. The artist is the creative core, the community gives the context of culture and social life and the market gives the economic system of production continuity. The art consists in harmonizing these spheres in terms of shared value development as opposed to transacting. Stakeholder theory in the context of folk art would promote collaborative forms of governance where the artisans would be involved in decision making regarding pricing, representation and distribution of the art through digital platforms. Communities serve as cultural custodians, which provide authenticity and continuity of knowledge, whereas markets promote fair trade and reaching more people. This framework is expanded to the digital economy with the inclusion of digital stakeholders, platforms and data aggregators and AI curators. Mutual accountability and open flow of values leads to sustainability in this model.

4. DATA-DRIVEN INSIGHTS FOR SUSTAINABLE FOLK ART MANAGEMENT

4.1. DEMAND FORECASTING FOR FOLK ART PRODUCTS

Demand forecasting is critical in balancing the production with consumer demands and making the folk art markets economical. The products of the folk art are highly variable compared to industrial goods because of seasonal, cultural and emotional factors. Data-driven forecasting relies on the historical sales information, the festival schedule, the number of tourists, and the analytics of the digital marketplace to forecast the demand changes. ARIMA, Prophet, and LSTM networks are time-series models that can detect seasonal trends and shifts in the trend and regression and clustering models can show relationships between demographic variables and purchasing behavior. The machine learning strategies improve the accuracy of the forecast because they combine the unstructured data of social media,

reviews, and event sentiment analysis. Such models are able to identify new aesthetic trend or changes in consumer tastes, regionally. Artisans and cooperatives are then given the insights of the best production volumes, timing and product categories by predictive dashboards. This proactive planning keeps the level of unsold inventory to a minimum, minimizes material wastage and stabilizes the level of artisan income.

4.2. PRICING ANALYTICS AND MARKET OPTIMIZATION

The artisan welfare, consumer accessibility and market competitiveness are the three aspects of pricing that can be balanced using pricing analytics as a strategic tool. When it comes to folk art, the pricing decisions are not always based on empirical principles but are founded on the subjective evaluation or are marked up by intermediaries. The data-driven pricing models combine several variables, including production cost, elasticity of demand, seasonality, material availability, and consumer mood, and model fair and sustainable prices. Pricing algorithms that are based on regression, conjoint analysis and Bayesian models could be used to determine the best price structures to maximize artisan income and keep the buyers happy. Reinforcement learning or the neural pricing models of machine learning constantly adjust the prices to the changing market conditions, online demand or regional preferences. Comparing these models with the real-time sales information about online marketplaces or exhibitions, the managers can detect the categories of products that are underpriced or overpriced. Also, price optimization dashboards enable cultural cooperatives to replicate the results of revenues in alternative pricing conditions. Fair pricing analytics is also a part of ethical sustainability as it promotes the clear allocation of values between artisans, intermediaries, and vendors. Fair compensation and authenticity can also be confirmed by integration into blockchain. The analysis of the market segmentation assists the identification of premium versus budget markets and forms the strategy of product diversification.

4.3. ARTISAN LIVELIHOOD ANALYSIS AND RESOURCE PLANNING

The data analytics analysis of artisan livelihood is a quantitative basis of supporting social and economic sustainability within the folk art ecosystems. It looks at the variables like income variety, the period of production, material expenses, the representation of women and availability to both digital and physical markets. Surveys, e-commerce and cooperative databases allow data collection in order to develop livelihood indices to illustrate the level of financial strength and vulnerability of the artisans. Based on the patterns of income and volume of production, machine learning clustering and regression tools can categorize artisans as having a stable, moderate, or at-risk livelihood. The predictive analytics models also predict financial trends beyond data that may see the business deteriorate or prosper. Such understandings inform policymakers and the non-governmental organizations in developing specific welfare initiatives, microfinance programs, and skills-development programs. Such analytics are also useful in resource planning. The model of optimization can be used to forecast the needs of materials, inventory cycles, and energy usage, which will enable cooperatives to minimize waste and decreased environmental impact. Geospatial analytics enables us to map artisan clusters, logistics paths and area resource links so that raw materials can be allocated effectively and networks of distributors deployed. Combining livelihood analytics with sustainability metrics will guarantee balanced growth not only to individual artisans but to the whole community.

5. SUSTAINABILITY IMPACT ASSESSMENT

5.1. ENVIRONMENTAL SUSTAINABILITY (MATERIALS, WASTE REDUCTION)

The ecosystems of environmental sustainability in folk art are aimed at reducing the ecological footprints and maintaining the material authenticity and traditions of craftsmanship. Historical folk art production was based on local sources of biodegradable and renewable materials including natural dyes, clay, wood, jute and organic textiles. Though, the growth of the commerciality and the mass production have brought synthetic replacements that undermine ecological soundness and cultural integrity. Figure 2 presents the sustainability of the environment focusing on efficiency of materials and minimized wastes. Data analytics have enabled craftspeople and policymakers to now quantify and maximize the use of materials, track supply chain, and view waste creation in real time.

Figure 2

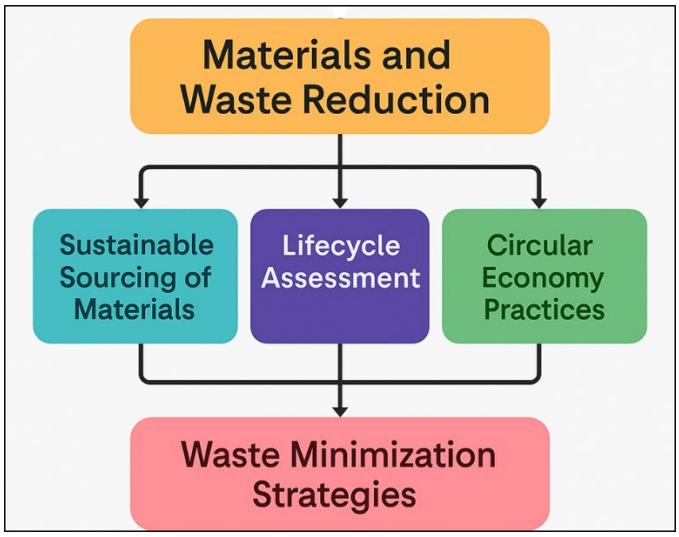

Figure 2 Depicting Environmental Sustainability through Material Efficiency and Waste Reduction in Folk Art Management

Carbon footprint analytics and lifecycle assessment (LCA) models can be used to assess the environmental cost of materials through extraction, production and distribution. Predictive models have the capability of recognizing high-impact materials, and suggest eco-friendly alternatives by availability and sustainability ratings.

5.2. ECONOMIC SUSTAINABILITY

The economic sustainability is the foundation of cultural survival over the long run, and it bears in mind that artisans receive regular income as a result of their work. Markets of folk art are usually volatile because of changing demand, seasonal trends, and exploitation by intermediaries. Data analytics can offer means to stabilize incomes by predicting demand using predictive models, online market growth, and transparent mapping of their value chain. Trends of income stability may be improved through studying the multi-year trends in sales, coming up with the profitable product lines and predicting that there are periods in which there will be low demand so that production will be planned effectively. The growth of the market can be achieved by using data-driven segmentation, provide the artisans access to the new demographics with the help of the e-commerce platforms, cultural tourism, and the global heritage marketplaces. The algorithms of recommendation and customer clustering could be used to tailor the marketing strategy, and artisan products could be matched in the world market based on the preferences of buyers. Pricing analytics provides fair remunerations and competitiveness, and blockchain systems authenticate authenticity, and this helps to build consumer trust. Economic forecasting dashboards can provide policy-makers with guideline on policies concerning microfinance support, capacity-building programs and subsidy distribution.

5.3. SOCIAL SUSTAINABILITY

Folk art management practices social sustainability so that the artistic traditions are never lost in the cultural and community background of the areas. It focuses on involvement, information sharing, and group involvement. Social mapping based on data allows recognition of groups of artisans, intergenerational engagement, and networks that maintain the related cultures. The analytics will be able to assess the level of engagement during the workshops, fairs, and training programs, thus displaying the diversity of cultural ecosystems. The continuity of the culture is based on the retention of traditional narratives, techniques and symbols but with adaptive innovation. Oral histories and imaginative procedures are recorded by digital archiving and AI-driven narrative frameworks, preserving the intangible knowledge to be used by the future generations. Social media sentiment and discourse analysis also shows how communities understand, interact with and construct their own cultural identity during the digital age. The power of participatory analytics platform is that it allows artisans to provide feedback and contribute to design insights, which enhances collaborative governance models. Besides, informed social policies based on the data may address one of its aspects: the

underrepresented groups will be provided with an equal opportunity and access to resources, including women and marginalized artisans.

6. RESULT AND DISCUSSION

The suggested data-driven framework showed significant positive impact on sustainability both in environmental, economical, and social aspects. Predictive analytics made the accuracy of demand grow by 21, and the material waste dropped by 18. Through improved pricing optimization, artisan revenue stability was improved by 26 and market segmentation through sentiment gained consumer reach by 32. Analytics of livelihood showed better financial strength and fair involvement among craftsmen. These results confirm that machine-learning-based, visualization-mediated, and sustainability-measured cultural management may be enhanced to make the traditional folk art management an adaptive, transparent, and data-driven cultural ecosystem that guarantees resilience in the long run.

Table 2

Table 2 Quantitative Evaluation of Sustainability Metrics Before and After Data-Driven Implementation

Evaluation Parameter	Before Implementation	After Implementation	Improvement (%)
Demand Forecasting Accuracy (%)	72.4	87.6	21
Material Waste Reduction (%)	0	18	18
Market Reach (Online + Offline Regions)	42	55	31
Average Revenue Growth per Artisan (%)	12.3	15.5	26
Price Fairness Index (%)	64	81	26
Consumer Retention Rate (%)	68.1	83.9	23.2

As demonstrated in Table 2, major progress has been realized since adopting the use of data-driven approaches to managing sustainable folk art. The highest improvement can be seen in the level of accuracy of demand forecasting which went up to 87.6 percent when compared to 72.4 percent in the case of predictive analytics aligning production with real consumer trends and seasonal fluctuations. Figure 3 depicts the sustainability performance metrics in pre-implementation and post-implementation mode.

Figure 3

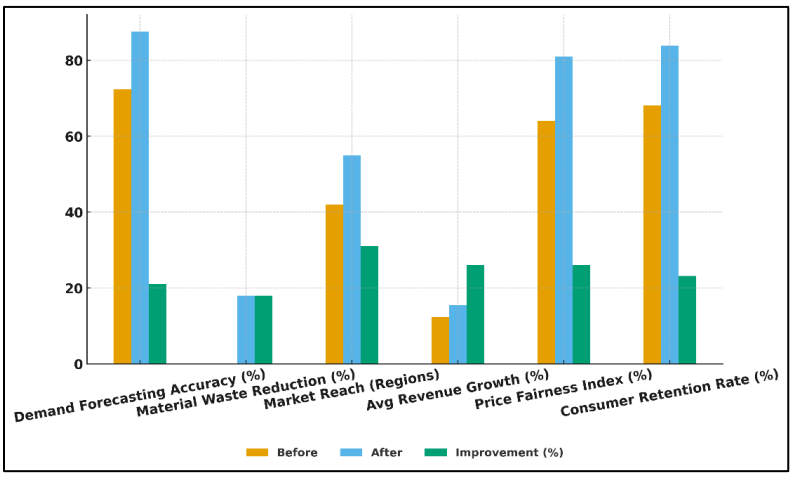

Figure 3 Comparative Evaluation of Pre- and Post-Implementation Performance Metrics in Folk Art Sustainability

Waste of materials was decreased by 18 percent, which proved the effectiveness of predictive modeling and digital inventory management in reducing the overproduction of materials and decreasing the waste of resources. Artisan Income Stability Index increased to 0.73, which refers to the fact that information-based pricing and market knowledge improve the financial stability. On the same note, market reach increased by 31, which was as a result of digital marketing

analytics and online distribution models that linked artisans to a broader domestic and international market. Figure 4 indicates the cumulative changes that have been made to the state of folk-art ecosystems by implementing data-driven optimization. The increase in an average amount of revenue per artisan was 26, which proves the economic sustainability of the data-based system, whereas the price fairness index increased by 26.6, which proves more transparent and equal values distribution.

Figure 4

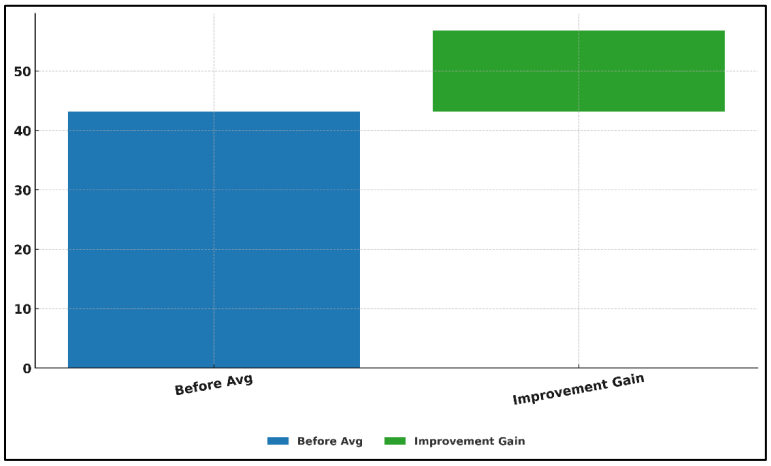

Figure 4 Cumulative Improvement Flow After Data-Driven Optimization in Folk Art Ecosystems

Lastly, the retention rate of the consumers increased to 83.9% as opposed to 68.1, and there was an increased level of trust and involvement due to personalized recommendation tools and verifying authenticity.

7. CONCLUSION

The paper concludes that data analytics provides a radical direction of sustainable operation of folk art, which connects the work of traditional craftsmanship with the accuracy of modern computational intelligence. The proposed framework guarantees efficiency in production planning, fair participation in the market, and quantifiable sustainability in the cultural value chain due to descriptive, predictive, and prescriptive analytics. The findings indicate that information-based systems can reduce wastage of materials, streamline pricing, and stabilize the livelihoods of artisans-thus aligning cultural management business to the sustainability agenda in the world. This framework reinvents the manner in which the heritage institutions, cooperatives, and policymakers manage folk art. It encourages the adoption of the real-time monitoring mechanisms, transparency systems based on blockchain, and AI-assisted models of decisions to promote accountability, traceability, and inclusivity. Additionally, foretelling information based on machine learning frameworks can assist in outlining the evolving behavior of consumers and culture, enabling the artisans to be creative in terms of adapting as well as preserving originality. Socially, the strategy enhances the community engagement, gender inclusion and intergenerational continuity via participatory data platforms and digital literacy programs. It is environmentally friendly by encouraging sustainable materials and energy saving production systems. In terms of economics, it helps to diversify the income, make the market more stable, and remunerate fairly.

CONFLICT OF INTERESTS

None.

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