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Integrating Technology and Sustainable Practices: Developing an Eco-Friendly Framework for Sri Lanka's Traditional Brass Craft Industry

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***Abstract*— Sri Lanka's brass craftsmanship is an essential part of its material culture, native expertise and rural sustenance. The industry, mainly based in the Kandy region, involves casting, sheet forming, engraving, repousse, polishing and other artisanal skills handed down from one generation to the next. However, the long-term sustainability of the sector is being challenged by rising raw material costs, inefficient production techniques, changing consumer preferences, limited market access, technological barriers, and environmental impacts of metal smelting and declining interest among younger generations. This research analyses the ecological, financial, social and cultural aspects of conventional brass craftmanship in Sri Lanka to identify its viability. The study employed a mixed-method qualitative approach with emphasis on the brass manufacturing communities in the Pilimathalawa area of Kandy District. We conducted semi-structured interviews, field observations and process mapping to analyze material use, production methods, energy use, waste generation, the livelihoods of the artisans, knowledge transfer, and market dynamics. The research identifies opportunities to improve sustainability by using more brass scrap, smart material design, advanced melting systems, suitable digital fabrication techniques, responsible surface treatment methods, direct engagement with the market, skill upgrades, and generational knowledge transfer. The study proposes a sustainable crafting model, which integrates the traditional artistry with appropriate technological innovations, to preserve the cultural integrity of the Sri Lankan brassware.**

Keywords: Brass craftmanship, sustainability, traditional knowledge, technological innovation.
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I. INTRODUCTION

Sri Lanka has a long tradition of metal craftsmanship and brassware is an important aspect of the island's artistic and cultural heritage. Traditional brass craft is particularly associated with communities in the Kandy region such as Pamunuwa and Pilimathalawa. Artisans make ceremonial, religious, decorative and functional objects using casting and wrought-metal techniques. The traditional common products available in the market most of the way esthetic items including oil lamps, decorated bowls, candle stands, elephants, Buddha statues, trays, wall plaques and decorative architectural building items, etc. (Jayawickrama et al., 2016).[1]

Brassware is made in a number of steps where the knowledge of materials and manual craftsmanship are combined. In casting, a model is made and a mould is formed, into which molten brass is poured. Traditional surface treatments include cutting, engraving, hammering, repousse, chasing, oxidation and polishing. These techniques are not only manufacturing processes, but also tacit knowledge that is transmitted through practical learning from one generation to another.

From a sustainability point of view, traditional brass craft has a number of inherent strengths. Brass products can be used for a long time, can be repaired and reused, and brass scrap can be reprocessed into new products. Hand tools and localised production can also lower dependence on highly industrialised production systems.

However, being handmade does not inherently make a product sustainable. In Sri Lanka's brass industry, manufacturing processes such as high-temperature melting, material transportation, grinding, polishing, and finishing can consume significant amounts of energy, generate waste, and create environmental and occupational impacts. Therefore, the adoption of sustainable practices is important for improving the overall sustainability of brass production. Practices such as efficient energy use, waste reduction and material recovery, responsible sourcing of raw materials, improved production methods, and safer working conditions can help minimize environmental impacts while enhancing resource efficiency and worker well-being. Examining the extent to which these sustainability practices can improve existing production processes is therefore essential for developing a more environmentally responsible and socially sustainable brass industry in Sri Lanka.

As a result, the sustainability of Sri Lankan brass craft should be viewed as an integrated system that encompasses social, cultural, economic, and environmental sustainability. This strategy offers a chance to preserve traditional knowledge while also enhancing resource efficiency, artisan livelihoods, and industry competitiveness.

II. BACKGROUND STUDY AND RESEARCH PROBLEM

Environmental, economic, technological, and social issues are currently plaguing Sri Lanka's traditional brass craft sector. Even though brass is a recyclable and long-lasting material, there is room for substantial resource and energy efficiency improvements in the current production method.

A. Environmental and Material Sustainability

Copper, zinc, or brass feedstock are needed for the production of brass, mould materials are needed for casting, and significant heat energy is needed for melting. The absence of an efficient reverse-logistics system for gathering scrap brass has been shown to be a significant problem in the Sri Lankan sector. Circular material flows might be strengthened and material losses could be decreased by increasing the recovery and reuse of brass scrap (Jayawickrama et al., 2016).[1]

B. Economic Sustainability

Price swings for raw materials, production expenses, competition from low-cost manufactured alternatives, and restricted access to lucrative markets are among challenges faced by artisans. The economic viability of traditional brass manufacture in Sri Lanka has been shown to be significantly hampered by issues with raw resources, marketing, labour availability, and technological adaption (Chanjief et al., 2015).[2] Jayawickrama et al., 2016).[1]

C. Social Sustainability and Artisan Livelihoods

Traditional brass production has traditionally relied on community networks and family-based education. Younger generations, however, could be hesitant to join the field due to physically taxing jobs, erratic pay, hazards associated with their line of work, and shifting attitudes toward employment.

D. Cultural Sustainability

Both the continuation of product sales and the dissemination of traditional knowledge are essential to the survival of brass craft. Techniques like hand engraving, repousse, chasing, and traditional finishing might gradually disappear as skilled craftspeople retire without passing on their knowledge.

Therefore, the main issue is not just the demise of a traditional business, but rather how Sri Lankan brass craftsmanship may maintain its unique character while becoming socially inclusive, economically sustainable, environmentally conscious, and culturally ongoing.

III. RESEARCH OBJECTIVES

The four main objectives pursued by this research to overcome the challenges in the Brass industry are discussed below.

- To study and assess the environmental sustainability of conventional brass production, paying special attention to the usage of raw materials, recovery of brass scrap, energy consumption, production waste, and finishing procedures.
- To investigate prospects for sustainable production using suitable technology, such as energy-efficient melting systems, CAD-supported fabrication, and CNC fibre laser cutting, while preserving traditional hand-finishing techniques.
- To evaluate the social and economic sustainability of brass craft communities, with an emphasis on prospects for sustainable enterprise development, market access, skill development, artisan livelihoods, raw material prices, and youth engagement, having site visits and interviews.
- To provide a framework to improve sustainability in Sri Lankan brass craft design and manufacturing that incorporates modern product creation, appropriate technology, traditional knowledge, circular material processes, and direct market prospects.

IV. METHODOLOGY

Using a mixed-method qualitative research approach, this study examined traditional brassware production in the *Pilimathalawa* region of the Kandy District in Sri Lanka's Central Province. The study examined sustainability as a multifaceted idea that takes into account social, cultural, economic, and environmental aspects.

The study was informed by previous research on sustainable manufacturing within the Sri Lankan brass industry, which has demonstrated the relevance of appropriate technology, material efficiency, sustainable production and knowledge development to the sector (Jayawickrama et al., 2016) [1]. Research activities were conducted through following the process as discussed below.

A. Field Data Collection & analysis:

Primary qualitative data were gathered through semi-structured field interviews and observations involving with following stakeholders within the brass craft sector.

- **Master Artisans & Workshop Owners:** Practicing artisans with a wealth of inherited expertise in sheet-metal forming, engraving, hammering, polishing, and traditional casting (Figure 1).
- **Technology-Adopting Artisans:** Craftspeople are integrating innovations including enhanced melting equipment, motorised polishing systems, and fibre laser cutting into conventional production (Figure 2).
- **Younger Family Apprentices:** Younger members of craft families whose experiences shed light on the industry's future, job

expectations, and the transmission of knowledge across generations.

Material sourcing, production techniques, waste production, energy consumption, working conditions, product development, market access, knowledge transfer, and sustainability attitudes were the main topics of discussion during the interviews.

B. Ethnographic Observation & Process Mapping

To record production operations and find sustainable opportunities throughout the manufacturing process, direct field observations were carried out.

- **Casting:** Preparing patterns, making moulds, baking moulds, melting brass, pouring, chilling, removing moulds, trimming, and hand finishing.
- **Sheet Work:** Selecting, cutting, annealing, hand-hammering, chiselling, engraving, shaping, and polishing sheets.
- **Laser-Assisted Fabrication:** Precision sheet cutting, hand-forming, surface decoration, finishing, and CAD file preparation.

Using process mapping, possible ways to cut down on energy consumption, material waste, and needless processing while preserving traditional workmanship were found.

C. The Brass Manufacturing Process

Choosing copper, zinc, brass bars, or recovered brass scrap is the first step in the traditional brass production process. Because brass can be recycled repeatedly without losing its essential metallic qualities, the utilisation of recovered brass material offers a significant possibility for circularity. Scrap collection and reverse logistics have been identified as significant sustainability concerns in the industry by earlier Sri Lankan studies. The following steps can be used to characterize the conventional manufacturing process:

1. Prepare the Mold Mixture: Sand, tile powder, bentonite and water are combined to prepare the mould material.
2. Form the Cast/Mold Model: The mould mixture is prepared within a frame to create the required form.
3. Melt the Brass: Brass feedstock is heated in a furnace until molten. This stage represents a major opportunity for sustainable intervention because melting requires considerable thermal energy.
4. Pour the Molten Brass: The molten brass is carefully poured into the prepared mould.
5. Cooling and Solidification: The filled mould is allowed to cool until the brass solidifies.
6. Remove the Cast Object: The hardened brass component is separated from the mould.
7. Trim Excess Material: Sprues, runners and excess brass are removed from the casting.
8. Surface Finishing, Repair, and Machining: The product undergoes several finishing processes:

- Grinding to remove surface imperfections.
- Spot welding where repair is necessary.
- Lathe machining to refine selected surfaces.
- Drilling and machining to create specific features.

9. Polishing and Final Detailing: The final brass component is polished and detailed to obtain the required surface quality.


(a) Prepare the mold mixture


(b) Form the cast


(c) Surface finishing, repair


(d) Final detailing

Figure 1: Traditional methods of brass products manufacturing process


Figure 2: Technological advancements: Dancing head decorations (*Wes abarana*) using Laser cutting techniques in brass.

D. Comparative Technical Analysis

In order to compare conventional manual production versus technology-assisted production in terms of material efficiency, production time, energy requirements, waste generation, manpower requirements, product quality, and occupational issues, a comparative sustainability assessment was created.
The benefit of traditional manual methods is that they require very minimal equipment and preserve highly skilled expertise. However, repetitive tasks and intricate cutting can take a lot of time and effort. Therefore, CNC fibre laser cutting can be viewed as an auxiliary technology rather than a substitute for craftsmanship. While artists are still in charge of

shaping, engraving, chasing, repousse, and other culturally significant finishing procedures, digital cutting may handle repetitive structural tasks.
However, from a sustainability standpoint, technological adoption shouldn't be assessed just based on production speed. It is also important to take into account the equipment's embedded effects, maintenance needs, material usage, accessibility for small-scale craftspeople, and the electrical demand of the machinery. Instead of only boosting production volume, an appropriate technology should offer an overall improvement in economic and environmental performance.

TABLE 1: ANALYSIS OF TRADITIONAL AND HYBRID METHODS PRACTICES OF BRASS MANUFACTURING PROCESS TO IMPROVE SUSTAINABILITY IN THE PROCESS

Selected areas to analysis	**Traditional process**	**Hybrid process**	**Sustainable target**
Material consumption	High/variable	Optimized	Minimum required
Brass scrap recovery	Informal	Organized	Closed-loop
Cutting waste	Relatively high	Optimized by CAD	Minimum
Melting energy	High/variable	Improved	Lower energy
Production time	High for detailed work	Reduced	Efficient
Manual craftsmanship	High	Retained	Preserve heritage
Occupational exposure	Potentially high	Reduced through technology	Safer workplace
Product lifespan	High	High	Repairable/durable
Market access	Intermediary-dependent	Digital/direct	Direct artisan value
Skill transmission	Declining risk	Digital + traditional	Intergenerational continuity

Based on the comparison, the hybrid process is the most suitable approach for the future sustainability of Sri Lanka's brass craft industry**.** It combines traditional craftsmanship with modern technologies such as CAD-assisted design and improved production methods, helping to reduce material waste, energy consumption, production time, and occupational risks. Simultaneously, it protects the craftsmanship and durability of traditional methods while combining digital and traditional skills to prevent skill decline. By giving creators direct, digital market access and removing middleman dependencies, the hybrid approach drives economic viability, operational safety, and environmental responsibility without sacrificing cultural value.

V. KEY FINDINGS AND DISCUSSION

A. Process Typologies: Traditional vs. Sustainable Hybrid Fabrication

According to the study, establishing a successful partnership between traditional craftsmanship and suitable modern technology may be essential to the sustainability of Sri Lankan brass craft in the future. While digital technology can promote accuracy, repeatability, and productivity, traditional techniques maintain knowledge, identity, and cultural worth. As a result, a hybrid production system can assign various tasks based on their cultural significance and sustainability. Digital technologies can enable preliminary fabrication and repetitive cutting, while trained artisans continue to perform culturally essential hand-finishing.

B. Material Crises and Circularity

One of the most significant sustainability issues the business is currently dealing with is material availability.
The research identifies several opportunities:

* **Scrap Brass Recovery:** Brass offcuts and rejected components can be systematically collected and returned to the production cycle.
* **Material-Efficient Design:** Product dimensions and forms can be digitally optimized to minimize cutting waste and unnecessary material use.
* **Local Material Networks:** Stronger connections between workshops, scrap collectors and material suppliers can improve the availability of recoverable brass.
* **Design for Longevity:** Products should be designed for durability, repair, maintenance and long-term use rather than short-term consumption.

C. Energy and Environmental Sustainability

Due to its high temperature needs, brass melting is a significant environmental hotspot. Prior research on brass furnaces in Sri Lanka demonstrated that furnace remodelling can improve energy efficiency and reduce interior air pollution (Peiris et al., 2016).[3]
Therefore, based on an assessment of current practices in brass production workshops, the following suggestions are proposed to enhance the application of sustainable practices in the industry.

- Improved furnace insulation and thermal efficiency
- Controlled combustion and appropriate exhaust systems
- Energy-efficient electric melting technologies where economically and technically feasible
- Monitoring of electricity or fuel consumption
- Reduction of unnecessary reheating
- Improved workshop ventilation
- Responsible handling of polishing dust and finishing chemicals

Future research should employ life-cycle assessment to measure energy usage and greenhouse gas emissions instead of presuming that a production technique is better for the environment just because it makes use of more recent technologies. Life-cycle assessment is becoming more widely acknowledged as a suitable method for assessing the effects of energy and resources on various manufacturing processes.

D. Socio-Cultural Dynamics and Youth Sustainability

Maintaining a community of skilled artisans is essential to the long-term viability of brass craft. Younger generations' involvement is especially crucial because the current business heavily relies on family-based knowledge transmission.
Therefore, a new model that combines traditional workmanship with the following could inspire younger artisans:

- Digital design
- CAD skills
- Sustainable production knowledge
- Contemporary product development
- Digital marketing
- E-commerce
- Entrepreneurship and business management

E. Economic Sustainability and Market Transformation

Because environmental and cultural sustainability cannot be sustained if artists are unable to make a living from their craft, economic sustainability is crucial.
Low-cost alternatives and shifting markets have put strain on Sri Lanka's brass sector. According to research on the Kandy brassware cluster, the industry is significantly impacted by shifting markets, globalisation, and challenges in sustaining traditional craft networks (Rathnayake & Grodach, 2022).[4]
Thus, a sustainable economic model should move beyond dependence on low-cost, conventional products and explore opportunities for value-added and contemporary brass craft applications. Considering emerging trends and market opportunities, several areas can be further developed by aligning traditional brass craft practices with contemporary product requirements. These include:

- Fashion accessories
- Jewellery and wearable products
- Interior products
- Lighting components
- Architectural fittings
- Hospitality products
- Contemporary homeware
- Limited-edition heritage collections

In addition to increasing the value produced from each brass unit, design-led diversification can open doors for upcoming designers and craftspeople.

VI. DISCUSSION AND RECOMMENDATIONS

In order to preserve Sri Lanka's cultural identity while bolstering the country's traditional brass craft sector, this study suggests a framework focused on sustainability.

1. *Circular Material Management*

Create well-organised procedures for gathering, classifying, and reintroducing manufacturing of cuts and brass scrap into workshops. To find the primary sources of waste and recovery prospects, material tracking should be promoted.

2. *Sustainable Furnace and Workshop Development*

Encourage better exhaust, ventilation, energy monitoring, and furnace technology. Small-scale workshops might be able to access cleaner and more effective technology through shared facilities, saving individual craftspeople from having to make prohibitively large capital investments.

3. *Sustainable Design Intervention*

Encourage designers to use CAD tools to maximise material utilisation while creating brass products that are lightweight, robust, and repairable. Instead of completely discarding traditional aesthetics, modern designs should retain recognisable aspects of Sri Lankan craft expertise.

4. *Craft Knowledge and Skills Preservation*

Create training and apprenticeship programs that integrate digital design, sustainable manufacturing, entrepreneurship, and traditional brassworking. Senior craftspeople ought to be seen as instructors and knowledge holders.

5. *Direct and Fair Market Access*

strengthen direct relationships between overseas buyers, shops, interior designers, tourism companies, and craftspeople. Digital platforms can increase the percentage of final value maintained by craft producers and lessen reliance on middlemen.

6. *Sustainable Branding and Certification*

Create a sustainable brand identity for Sri Lankan brassware that emphasises local manufacture, recycled and recoverable materials, long product life, real craftsmanship, and cultural heritage. Clear standards and suitable institutional verification should underpin any future certification or geographical indicator.

7. *Designer–Artisan Collaboration*

Create cooperative networks between academic institutions, product designers, fashion designers, engineers, and brass artisans. These collaborations can produce new goods while enabling traditional craftspeople to share their specialised expertise.

8. *Sustainability Measurement*

Future development initiatives should provide quantifiable metrics for worker safety, energy use, material recovery, manufacturing waste, income generation, youth involvement, and knowledge transfer. This would enable a methodical assessment of the industry's sustainability performance instead of relying just on subjective opinions.

The conventional brass craft industry needs to shift to a hybrid production model that carefully incorporates suitable technology and thoughtful design in order to create a truly sustainable and environmentally friendly system. Before actual production starts, workshops can significantly reduce cutting waste and maximise material utilisation by using computer-aided design (CAD) tools and digital optimisation. Additionally, the significant energy footprint and environmental risks associated with conventional brass smelting are immediately addressed by combining digital fabrication with energy-efficient melting technologies and better furnace insulation. Future efforts should concentrate on creating shared technology facilities, which would enable small-scale craftspeople to obtain cleaner equipment without incurring unaffordable capital costs, and encouraging cooperative networks between engineers, designers, and skilled craftspeople to continuously innovate lightweight, robust, and repairable products.

VII. CONCLUSION

The traditional brass craft sector in Sri Lanka is a valuable blend of indigenous knowledge, skilled workmanship, cultural legacy, and rural economic activity. Rising material costs, reliance on outside raw materials, production waste, energy-intensive melting processes, shifting consumer preferences, constrained market opportunities, occupational concerns, and the diminishing involvement of younger generations, however, pose a growing threat to its long-term viability. As a result, maintaining the sector calls for a more comprehensive strategy that takes into account social, cultural, economic, and environmental factors all at once.

The study shows that increasing material efficiency and promoting the recovery and reuse of brass scrap and manufacturing offcuts can increase the sustainability of brass craft. While suitable digital fabrication techniques can support accuracy and productivity without eradicating the expert handcrafting that gives Sri Lankan brassware its cultural identity, more effective melting and workshop technologies can further reduce energy consumption and improve working conditions.

However, technological advancement by alone cannot guarantee the craft's existence. Better market access, more equitable returns for artisans, the creation of modern products, and closer ties between designers, craftspeople, tourism, and global markets are all necessary for economic sustainability. Similar to this, social and cultural sustainability depends on developing possibilities that appeal to newer generations and putting in place efficient mechanisms for passing down traditional knowledge from skilled craftspeople to upcoming practitioners.

Thus, the study comes to the conclusion that Sri Lankan brass craft should be built on a sustainable hybrid model in which appropriate technologies, circular material practices, sustainable design, and new market strategies are introduced while traditional craftsmanship and cultural knowledge are maintained. By using this strategy, brass craft can become a more resilient and sustained creative industry rather than a susceptible traditional cottage industry. Sri Lanka can preserve its historic brass history while fostering new opportunities for designers, artisans, and future generations by appreciating both the natural resources and the human expertise ingrained in brass craftsmanship.

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