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Integration of Counter Shaft Shedding Mechanism into Indigenous Two-Heddle Loom: A Novel Approach

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Abstract

Purpose: The study aims to enhance weaving efficiency by integrating the shedding mechanism from a countershaft loom into the traditional two-heddle loom. This approach seeks to maintain simplicity and affordability while improving functionality.

Methodology/Design: A mixed-methods approach was employed. The research involved direct observation of traditional weaving practices to identify operational challenges. Interviews with local weavers and textile experts ensured cultural relevance in the design process. Studio experiments were conducted to develop and test three conceptual designs: Modular Integration, Hybrid Frame Integration, and Adaptable Shedding Mechanism. Each design was evaluated based on functionality, compatibility with existing looms, and impact on weaving efficiency.

Findings: The Modular Integration approach emerged as the most viable solution in the study's final analysis. While the Hybrid Frame Integration initially demonstrated notable improvements in weaving efficiency and design complexity, Modular Integration ultimately proved more adaptable and compatible with the structural and cultural context of traditional two-heddle looms. Modular Integration enabled the production of complex weave patterns, enhanced fabric quality, and increased productivity while preserving the loom's affordability and simplicity.

Practical and Social Implications: The study's outcomes offer practical solutions for rural weavers by expanding their capabilities to meet contemporary market demands. This innovation fosters economic empowerment, opens access to wider markets, and supports the preservation of traditional weaving heritage. Additionally, the modular design promotes sustainable weaving practices through the use of locally sourced, eco-friendly materials.

Originality: This study provides a novel framework for integrating advanced weaving mechanisms into traditional looms. By prioritizing cultural relevance and simplicity, the Modular Integration approach ensures that traditional weavers can adopt modern techniques without compromising heritage. The study contributes to bridging the gap between traditional craftsmanship and contemporary demands, offering a sustainable pathway to enhanced weaving efficiency and market competitiveness.

Keywords
Hybrid loom, shedding mechanism, indigenous weaving, textile innovation, rural empowerment

1 | INTRODUCTION

Weaving has been an important part of human culture for centuries, with traditional looms evolving over generations to meet community needs. The indigenous two-heddle loom has been a key tool in rural textile production, valued for its simplicity and affordability (Clifford, 2017). However, its manual shedding mechanism limits weavers to plain weave structures, with occasional variations like long floats in rib

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weaves. This loom can create only a few weave types; plain weave, the most common, alternates warp and weft threads to form simple fabrics. Warp-faced weaves highlight warp threads for bold designs, while weft-faced weaves emphasize weft threads for added texture (Clifford, 2017). Double weave allows two fabric layers for reversible patterns, and brocade uses extra weft threads for decorative designs (Karunaratne et al., 2024). Lattice weave adds a grid-like texture and visual appeal. This limitation stifles creativity, reduces varying design production, and confines artisans to tapestry-like designs, hindering structural innovation (Karunaratne et al., 2024). The preservation of cultural heritage associated with these traditional methods often reinforces such limitations, creating a tension between maintaining tradition and meeting the demands of modern textile markets.

Efforts to address these limitations necessitate innovative adaptations that preserve the cultural significance of the two-heddle loom while enhancing its functionality. Recent advancements in textile technology have spurred interest in hybrid solutions that integrate modern mechanisms into traditional looms. These solutions aim to enhance functionality and adaptability without diminishing the cultural value of traditional tools (Mamidipudi, 2019; Hazarika, et al., 2016). For instance, counter-shaft looms, equipped with advanced shedding systems using multiple shafts and treadles, allow the formation of complex sheds and intricate weave structures. These mechanisms provide weavers with improved control over shed formation, reducing thread interference and expanding design possibilities (Zhao et al., 2016; Ahiabor et al., 2018; Piper, 2019). However, the direct application of counter shaft technology to indigenous two-heddle looms remains largely unexplored, particularly in maintaining their simplicity and affordability.

A review of existing studies highlights a significant gap in research on adapting counter shaft shedding mechanisms to traditional looms in a culturally sensitive manner. While much of the research focuses on technological innovations in weaving, there is limited exploration of how these advancements can empower local artisans while preserving traditional practices (Kamiya et al., 2000; Hazarika et al., 2016). This study seeks to bridge this gap by investigating the integration of a counter-shaft shedding mechanism into the indigenous two-heddle loom frame. The proposed hybrid model aims to enhance the functionality of the loom while respecting its cultural and economic relevance.

The uniqueness of this study lies in its approach to technological integration, which emphasizes transformation rather than replacement. By developing a prototype that incorporates advanced shedding mechanisms within a traditional framework, the research provides rural artisans with a versatile tool to produce higher-quality textiles that cater to modern markets. The hybrid loom model not only supports the preservation of traditional craftsmanship but also fosters economic empowerment by enabling innovation and facilitating access to broader market opportunities. This research makes a significant contribution to the discourse on integrating modern and traditional weaving technologies. It bridges the gap between heritage craftsmanship and contemporary technological demands, offering a practical framework for improving productivity and textile quality. Furthermore, the study highlights the importance of diversity measured through the promotion of sustainability in traditional crafts through culturally adaptive technology.

The paper is organized into four sections: (1) Methodology, detailing the qualitative research design and development of three conceptual designs; (2) Results, evaluating these designs and identifying Modular Integration as the most viable; (3) Discussion, analysing the findings' broader implications, including the balance between tradition and innovation; and (4) Conclusion and Future Studies, summarizing key findings and proposing directions for further research.

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2 | METHODOLOGY

This study employed a qualitative research design to investigate the integration of a counter-shaft loom's shedding mechanism into the Indigenous two-heddle loom. Observations of traditional weaving practices provided insights into the operational limitations of the two-heddle loom, such as its reliance on manual shedding, which restricts weaving efficiency and design variety (Clifford, 2017). The research was based on a descriptive experimental research approach. Studio experimentation followed a modular design approach to create a shedding mechanism that is flexible, user-friendly, and adaptable. Three design concepts; Modular Integration, Hybrid Frame Integration, and Adaptable Shedding Mechanism were developed and iteratively tested for functionality and compatibility. Feedback from weaving experts (6 Apprentice; 3 Master Craftsman; 10 Students; 4 Technicians) and prototype evaluations ensured that the final design enhanced shedding efficiency while retaining cultural relevance (Mamidipudi, 2019).

Regular consultations with loom builders and academics refined the prototypes to address technical challenges and improve practicality (Nieveen, 1999). This iterative process enabled the study to propose a viable hybrid model, offering weavers enhanced capabilities to produce complex and high-quality textiles while maintaining the simplicity and cost-effectiveness of the traditional loom.

2.1| Shedding Mechanism & Principle of Operation

2.1.1| Counter-shaft shedding mechanism

The shedding mechanism in a counter shaft loom is based on the principle of counter-marching shafts and offers more intricate pattern capabilities and automation through its multiple counter shafts. As the weaver presses down on a treadle, it raises and lowers specific counter shafts, which in turn raises and lowers the heddles attached to those shafts. Figure 1 illustrates the counter-shaft shedding systems. The counter-shaft loom’s weaving process involves heddling warp yarns through heddles on counter shafts according to a predetermined draft. Operating the treadles, the weaver raises and lowers specific counter shafts, creating a shed for passing the weft yarn. After inserting the weft pick, the treadles are released, securing the weft yarn to fell of the cloth with the reed. This process repeats, following the weaving pattern determined by the draft and treadling sequence.

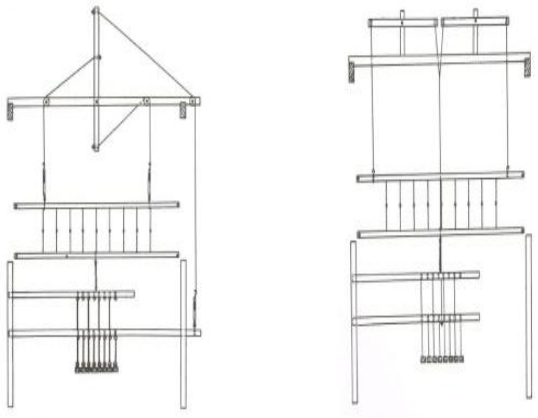


Figure 1. Counter-shaft shedding systems (Von Tresckow, 2017)

2.1.2| Two-heddle shedding mechanism

The shedding mechanism in a two-heddle loom is based on the principle of manually raising and lowering the heddle rods to create the shed opening and is a simpler and more manual setup, suitable for basic weaving patterns and techniques. One heald shaft is raised while the other is lowered, separating the warp yarns into two distinct layers and forming the shed. The shedding mechanism in a two-heddle

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loom involves manually raising and lowering heddle shafts to create a shed opening. This process is repeated for each weft pick, following a specific weaving pattern determined by the threading draft. Figure 2 illustrates the two-heddle shedding system.



Figure 2. Two-heddle shedding system (Source: Authors own creation)

Table 1. Component Identification for Shedding Mechanism

Components	Description	Modularity Considerations	Attachment Mechanisms
Shafts/harnesses	rectangular bar contains heddles responsible for lifting and lowering threads.	Modular shafts should be easily replaceable.	Quick-release clamps or adjustable brackets for easy installation and removal.
Heddles/healds	Eyelets through which warp threads pass, mounted on shafts.	Standardized sizes for easy interchangeability.	Slide-in mechanisms for quick heddle changes.
Treadles	Depressed Foot pedals control the movement of the shafts via the tie-up system.	Adjustable treadles to accommodate different weaving patterns.	Bolt-on systems that allow treadles to be removed without tools.
Tie-Up System	Connects treadles to shafts, determining which shafts are raised or lowered when a treadle is pressed.	Modular tie-up cords or chains that can be easily reconfigured.	Hook-and-loop connectors for quick changes.
Pulley System	Guides and redirects the cords in the tie-up system, ensuring smooth operation.	Modular pulleys that can be added or removed as needed.	Screw-on pulleys that are easy to adjust.
Reed	A comb-like device that keeps warp threads spaced evenly.	Modular reeds of various sizes and densities that can be swapped out quickly.	Snap-in or magnetic holders for fast reed changes.

(Source: Authors own creation)

2.1.3| Design and Prototyping

Conceptual design refers to the initial phase of the design process where ideas, concepts, and visions are explored and translated into visual representations (Gray & Malins 2004; Myrup Andreasen et al., 2015). It involves brainstorming, sketching, and creating mock-ups to define the overall direction and key elements of a design project. The goal of conceptual design is to lay the foundation for the final design by exploring different possibilities and refining the initial ideas (Bakırlıoğlu & Kohtala 2019; Chandrasegaran, et al., 2013). This stage allows designers to experiment, innovate, and evaluate various design options before moving forward with the implementation. A well-executed conceptual design

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ensures that the final product or solution aligns with the intended goals and objectives. (Pereira and Jauregui, 2020; Bortamuly and Goswami, 2015).

Conceptual Design 1: Modular Integration

In this design, the shedding mechanism components from the counter-shaft loom, such as the shafts, treadles, and tie-up system, are designed as separate modular units. This unit can be attached or integrated into the existing structure of the two-heddle loom. The modular unit is adjustable and customizable, allowing for different configurations to accommodate various weave structures and patterns.

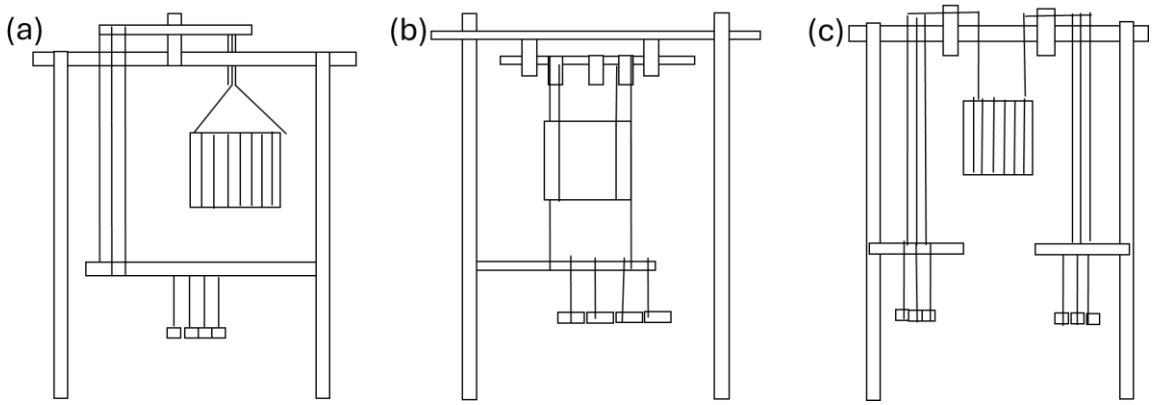


Figure 3. (a) Modular Integration, (b) Hybrid Frame Integration, (c) Adaptable Shedding Mechanism (Source: Authors own creation)

Conceptual Design 2: Hybrid Frame Integration

The hybrid frame design combines elements from both the counter-shaft loom and the two-heddle loom. It involves developing a frame that accommodates the shedding mechanism components of the counter-shaft loom while retaining the essential components of the two-heddle loom. The hybrid frame is constructed using culturally relevant materials and techniques, ensuring a connection to traditional practices.

Conceptual Design 3: Adaptable Shedding Mechanism

In this design, the shedding mechanism components, including the shaft system, treadling system, and tie-up system, are designed as a modular unit that can be retrofitted onto existing two-heddle looms. The adaptable shedding mechanism is adjustable and customizable, allowing for different configurations to accommodate various weave structures and patterns. The attachment mechanisms are designed to be user-friendly and easy to install or remove.

These conceptual designs aim to integrate the shedding mechanism from the counter-shaft loom into the indigenous two-heddle loom in different ways, offering flexibility and options for weavers.

Table 2. Evaluation of cultural relevance and functional appropriateness of each shedding mechanism.

Evaluation Criteria	Modular Integration	Hybrid Frame Integration	Adaptable Shedding Mechanism
Durability	Uses traditional hardwood; culturally significant and durable.	Combines hardwood with modern materials; strong and long-lasting.	Uses modern materials; highly durable, less traditional.
Ease of Use	Traditional methods; are familiar but require more skill.	The mix of traditional and modern methods; is user-friendly.	Modern mechanisms; are very user-friendly, and intuitive.

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Aesthetic Qualities	Traditional look with natural materials and finishes.	A blend of traditional and modern aesthetics; appeals broadly.	Modern, sleek design; less traditional but contemporary.

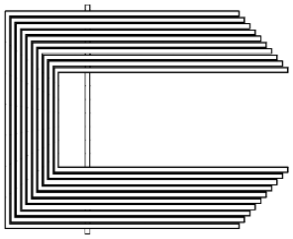
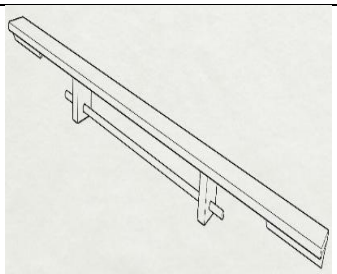
For traditional weaving communities that prioritize preserving cultural heritage and maintaining traditional methods, the Modular Integration shedding mechanism is the most culturally appropriate choice. This mechanism utilizes traditional hardwood, aligning with historical materials, ensuring both durability and cultural relevance. Additionally, its traditional attachment methods, while requiring more skill, are familiar to artisans, fostering a sense of continuity and respect for their craft.

For communities that value both tradition and innovation, the Hybrid Frame Integration mechanism offers a balanced solution. This approach combines traditional hardwood with modern reinforcement materials, enhancing durability and ease of use without compromising traditional aesthetics. By engaging with the community and understanding their preferences and practices, the mechanism can be tailored to align with cultural values and functional needs. A modern traditional weaver would likely embrace the Hybrid Frame Integration mechanism because it respects cultural heritage while providing practical improvements. This system integrates the familiar aesthetics of hardwood with the added strength of modern materials, making it more durable and easier to use. Additionally, it aligns with the weaver's values by being cost-effective (Pons, 2008), requiring minimal maintenance, and supporting environmental sustainability. The inclusion of community input in the decision-making process ensures that the innovation remains true to the weaver's identity and practices while offering practical enhancements.

2.2| Testing and Iteration

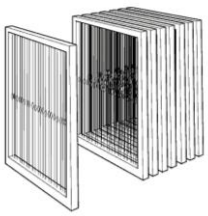
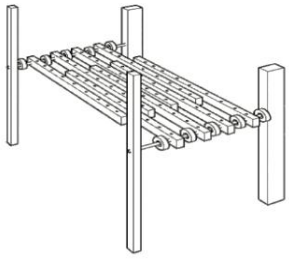
Throughout the development process, a participatory and co-creation approach was maintained, engaging weavers, cultural representatives, and other stakeholders at various stages. This ensured that the integrated shedding mechanism remained culturally relevant, user-friendly, and aligned with the aspirations and needs of the target weaving communities. Table 3 illustrates the components of the shedding mechanism.

Table 3. Components of the shedding mechanism

Components	Description	Diagram
Lever system	These levers are made from flat steel bars of width 15.88mm and a thickness of 3mm. The bar was measured and made into U-shaped with the dimensions below. (38 x 15 x 1.5, 38 x 16.5 x 1.5 38 x 17.5 x 1.5, 38 x 19 x 1.5 38 x 20 x 1.5, 38 x 21.5 x 1.5 38 x 23 x 1.5, 38 x 24 x 1.5) cm	
Lever Support bar	The lever support bar is made of redwood and fixed horizontally across the top serrated bar, and it carries the levers with dimensions of (32 x 7.62 x 2.54)cm.	

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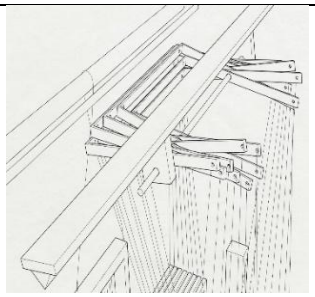
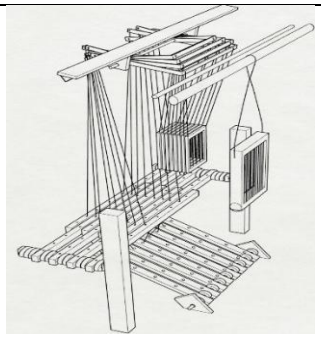
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Heald shafts/Harnesses	The harnesses were cut from a flat steel bar 5mm x 19.1mm and cut and welded to form a rectangular shape (10 x 7.5) cm.	
Lams	The lams are made from redwood and cut with the dimensions (70 x 1 x 30) cm. They are fixed at the side of the loom with a steel rod passed through one end and secured unto the sidebar.	
Treadles	The treadles are made from redwood measuring (62 x 1.9 x 2.5) cm. A steel rod is passed from one end through the others secured in the centre of the loom and secured onto a wooden support bar.	

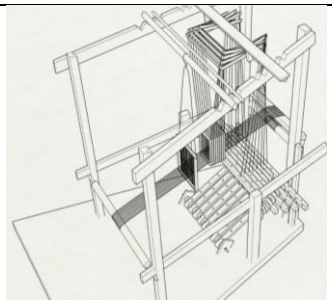
(Source: Authors own creation)

Furthermore, sustainability considerations, including the use of eco-friendly materials and energy-efficient processes, were integrated into the design and production phases to enhance the long-term viability and environmental impact of the innovation. Table 4 illustrates the assemblage of the mechanism.

Table 4. Assemblage of the Mechanism

Assembly	Description	Diagram
Lever assembly	The lever rod was passed through the drilled portion of the lever and fixed onto the lever bar. After assembly bar and the lever were mounted across the top serrated bar attached to the upright post.	
The connection between the lams, treadle, and harnesses	The open and closed ends of the levers were drilled, and a cord was passed through and secured with a snitch knot. After that, an additional length of cord was joined to those ends and the front was secured to the harnesses and the rear to the lams. Another set of Cords is then fixed onto the lams and tied up to the treadle depending on the design pattern to be produced per the stepping and heddling order.	

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The warp beaming, heddling, reeding and warp tie-up.	The warp yarns were beamed onto the warp roller after warping or milling. The warp ends were drawn through the heald wire according to the design to be woven. After that, the ends passed through the reed dents and finally, the warp ends were secured onto the cloth roller with the required tension. Finally, the pre-testing is done to correct all drawn mistakes made.	

(Source: Authors own creation)

The initial material used for the construction was wood, but it proved unable to withstand the strain and stress during the trials. Additionally, the heald wires were replaced with nylon cords to increase the size of the heald eye, allowing the warp yarns to slide more freely during the lifting of the harnesses to form the shed. The treadles were initially secured from the back of the loom but posed some form of uneasiness when depressing the treadle because the treadle ends were too high, and the weaver needed to lift the foot too high in the process of depressing the treadle. The challenge was solved by securing the treadles in the near-centre of the loom and that made the depressing of the treadle easy to control and manipulate.

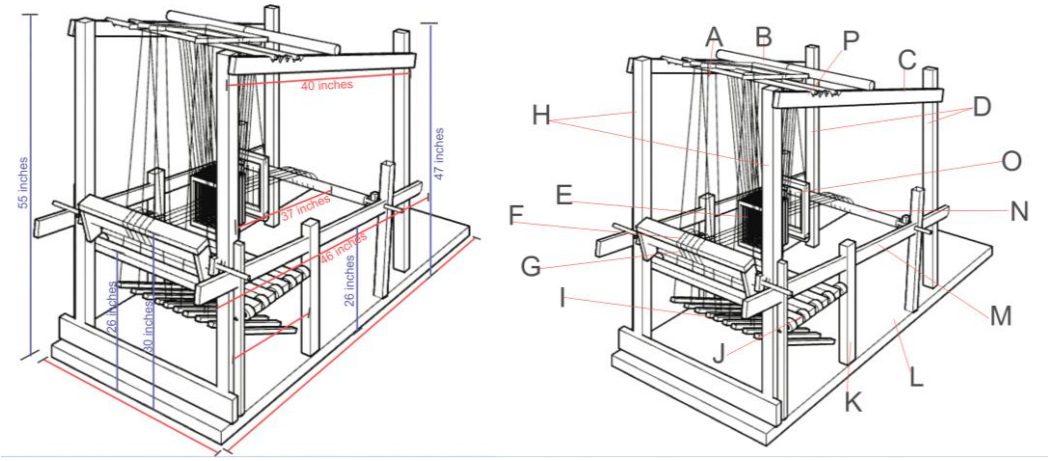


Figure 5. A – lever, B – cross beam, C – serrated side beam, D – upright post, E –held shafts, F – warp guide, G -warp roller, H – upright post, I – treadles, J – lams, K – lam support, L – flat wooden base, M – side beam support, N – cloth roller, O – reed, and P – fulcrum rod
(Source: Authors own creation)

2.3| Stakeholder Insights on Loom Designs

The evolution of textile weaving technology presents an opportunity to balance the preservation of cultural heritage with the demands of modern efficiency. This study explores stakeholder responses to three conceptual loom designs; Modular Integration, Hybrid Frame Integration, and Adaptable scheduling mechanism through a qualitative experimental approach. The findings highlight how these designs align with traditional practices while addressing contemporary weaving challenges. Stakeholder evaluations, including traditional weavers, loom builders, textile experts, and technicians, provided nuanced insights into the cultural, ergonomic, and operational implications of the conceptual loom designs.

Modular Integration Design: This design was notable for its cultural relevance and compatibility with traditional practices. Loom builders particularly valued its alignment with existing looms, seeing it as a

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bridge between tradition and innovation. Weavers noted its intuitive design, although the initial setup required guidance. Textile experts, however, expressed concerns about its efficiency for high-volume production, highlighting its potential limitations for scaling operations. Despite these challenges, the Modular Integration Design demonstrated promise for introducing modern adaptability into traditional workflows.

Hybrid Frame Integration Design: Commended for balancing tradition and innovation, the Hybrid Frame Integration Design emerged as the most promising for comprehensive adoption. Stakeholders admired its scalability, adaptability, and potential to enhance productivity without compromising cultural values. Textile experts appreciated its versatility, while loom builders noted its seamless integration into existing production frameworks. Traditional weavers, however, emphasized the need for training to ensure ease of operation, reflecting the design's steep learning curve.

Adaptable Shedding Mechanism: Ergonomic benefits were the standout feature of this design. Stakeholders reported reduced physical strain during weaving and increased operational efficiency. Loom builders emphasized its practicality for accelerating weaving processes, while traditional weavers raised concerns about its cultural alignment. Textile technologists highlighted its innovative potential but noted the need for greater consideration of traditional aesthetics to ensure acceptance among heritage weavers.

2.4| Comparison of Modular and Traditional Designs

Ease of Use: While the Modular Integration Design required initial skill for assembly and adjustment, stakeholders noted its user-friendly operation once familiarized. In contrast, traditional designs demand extensive experience and physical effort in structural and hand-picking designs, making them less accessible to novice weavers.

Efficiency: The Modular Design was observed to reduce physical strain and improve workflow efficiency, providing consistency in weaving patterns. Traditional designs, while maintaining cultural significance, were found to be more labour-intensive and time-consuming as auxiliary butts, and hand pulling of healds are all involved.

Adaptability: The Modular Design's flexibility to accommodate adjustments and integrate modern components marked a significant departure from the fixed structures of traditional looms. This adaptability was seen as a critical advantage for blending contemporary designs with traditional techniques.

2.5| Thematic Observations from Experimental Trials

Cultural Relevance: Traditional weavers found the Modular Integration Design culturally resonant, reflecting familiar practices. However, its reliance on modern components prompted discussions about authenticity and heritage preservation.

User Experience: Loom builders appreciated the ergonomic improvements in the Adaptable Shedding Mechanism, noting its potential to make weaving less physically taxing while maintaining efficiency.

Training and Usability: Across all designs, stakeholders emphasized the need for targeted training to maximize usability and encourage adoption among weavers unfamiliar with modern tools.

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2.6| Finalization and Production

To design the weave structure to be woven, WeavePoint software version 7.2 was utilised. This software facilitated the integration of the weave, draft, lifting or stepping order, and the tie-up of the treadles (Figure 6). These elements are interconnected in a complete weave plan.



Figure 6. (a) Installed Mechanism, (b) Heddling & Denting, (c) Tie up and test weaving

3 | RESULTS

3.1| Test Weaves on the Shedding Mechanism

The lever lam expansion shedding made possible wide heddling order for possible diversification of structural design. In the case of the test weave a 5 and 6-harness was used with a total of 220 warp ends, and a 24-size reed was employed. The fabric design was created using the weave point application 7.2, which provided the design, draft, lifting plan, and tie-up information. Using this design information, the individual warp ends were drawn according to the heddling order through the appropriate heald's eyes and, after that passed through the reed. The warp ends were then tied onto the cloth roller.

Sample 1: In Figure 7, the weave structure was constructed on five harnesses with the following heddling and stepping order and the tie-up of the treadles. A diamond weave structure was produced in purple and blue weft colours.

Heddling order: - (121, 232, 343, 454,515, 454,343,232)

Stepping order: - (1 2 3 4 5,4 3 2)

Tie-up: - T1 – S (1 & 2); T2 – S (2 & 3); T3 – S (3 & 4); T4 – S (4 & 5); T5 – S (5 & 1);
T6 – S (1, 3 & 5); T7 – S (2 & 4)

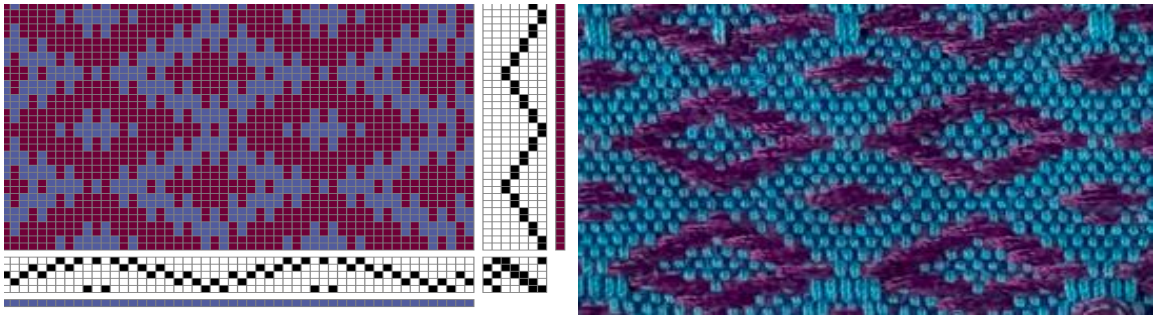


Figure 7. Diamond Weave (Source: Authors own creation)

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Sample 2: In Figure 8, the weave structure was constructed on five harnesses with the following heddling and stepping order and the tie-up of the treadles. A diamond weave structure was produced in yellow and blue weft colours.

Heddling order:- (121, 232, 343, 454,515, 454,343,232)

Stepping order:- (121, 232, 343, 454,515, 454,343,232)

Tie-up:-T1 – S(1,4&5); T2 – S(3,4&5); T3 – S(2,3&4); T4 – S(1,2&3); T5 – S(1,2&5)

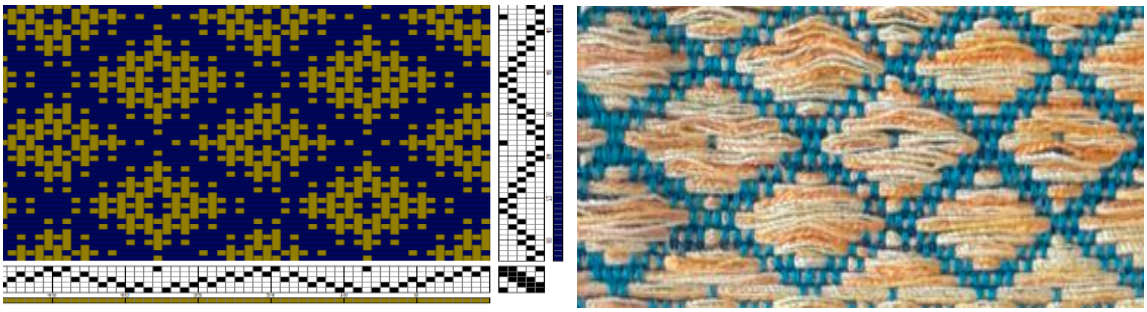


Figure 8. Diamond Weave (Source: Authors own creation)

Sample 3: In Figure 9, the weave structure was constructed on five harnesses with the following heddling and stepping order and the tie-up of the treadles. A zig-zag twill weave structure was produced in green and purple weft colours.

Heddling order:- (12345;12345)

Stepping order:- (1, 2, 3, 4, 5, 4, 3, 2)

Tie-up:- T1 – S (1& 2);T2 – S (2 & 3);T3 – S(3 & 4);T4 – S(4 & 5);T5 – S (5 & 1);T6 – S (1 & 3); T7 – S (2 & 4)

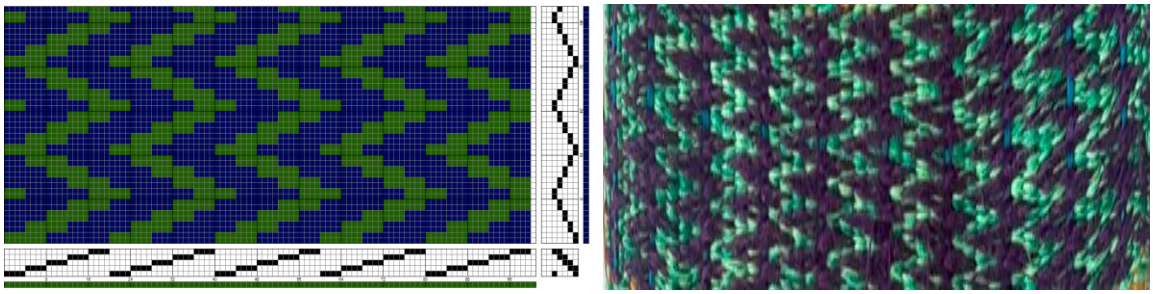


Figure 9. Zig-zag twill weave (Source: Authors own creation)

Sample 4: In Figure 10, the weave structure was constructed on five harnesses with the following heddling and stepping order and the tie-up of the treadles. An overlapping diamond weave structure was produced in blue and white weft colours.

Heddling order:- (12123234345456561656545434323212161656545434323212161 6)

Stepping order:- (123456; 5432)

Tie-up:- T1 – S(1,2&3); T2 – S(2,3&4); T3 – S(3,4&5); T4 – S(4,5&6); T5 – S(5,6&1); T6 - S(6,1&2); T7 – S(1,3&5); & T8 – S(2,4&6)

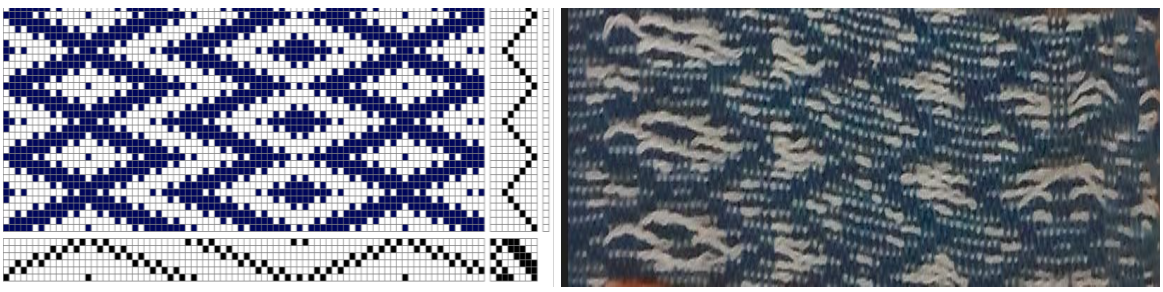


Figure 10. Overlapping diamond weave (Source: Authors own creation)

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Sample 5: In Figure 11, the weave structure was constructed on five harnesses with the following heddling and stepping order and the tie-up of the treadles. An Interlocking Diamond weave structure was produced in green and blue colours.

Heddling order:- (12123234345456561656545434323212161656545434323212161616)

Stepping order:- (123456; 5432;654321;23456;54321;23456)

Tie-up:- T1 – S(1&2); T2 – S(2& 3); T3 – S(3&4); T4 – S(4&5); T5 – S(5&6); T6 - S(6&1); T7 – S(1,3&5); &T8 – S(2,4&6)

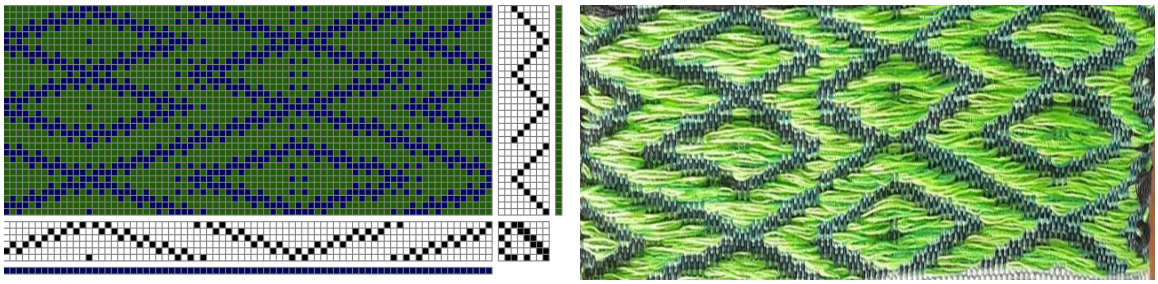


Figure 11. Interlocking Diamond weave (Source: Authors own creation)

Sample 6: In Figure 12, the weave structure was constructed on five harnesses with the following heddling and stepping order and the tie-up of the treadles. An Interlocking Diamond weave structure was produced in brown and blue colours.

Heddling order:- 1212323434545656165654543432321216165654543432321216161616

Stepping order:-123456; 5432

Tie-up:- T1 – S(1&2); T2 – S(2& 3); T3 – S(3&4); T4 – S(4&5); T5 – S(5&6); T6 - S(6&1); T7 – S(1,3&5); & T8 – S(2,4&6)

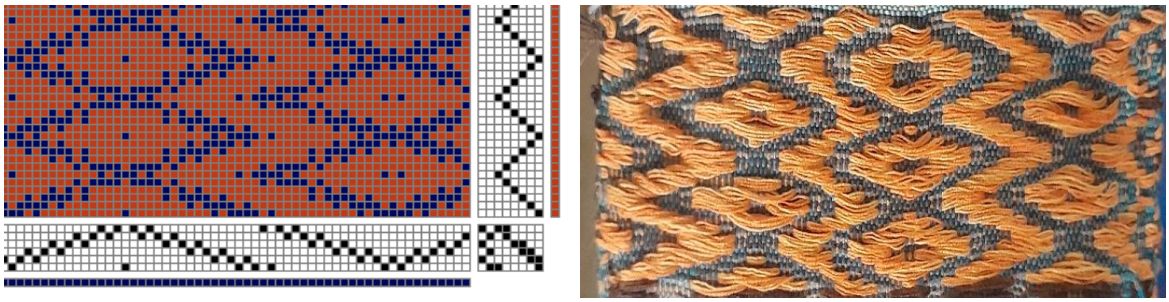


Figure 12. Zig-zag diamond weave (Source: Authors own creation)

3.2 | Key Features and Findings of the Counter-Shaft Shedding Mechanism

The experimental findings demonstrate the successful integration of the counter-shaft shedding mechanism into the traditional two-heddle loom employed by indigenous weavers. This integration has significantly transformed the weaving process, particularly in achieving accurate and controlled shed formation, which had previously posed challenges with the conventional two-heddle configuration. The new mechanism enables weavers to create precise sheds, thereby enhancing the overall accuracy and efficiency of their weaving.

Bottom Close Shed Formation: The shedding mechanism creates a bottom close shed formation, wherein the shafts are raised and lowered to their original positions after each pick is completed. This design results in a smooth and frictionless opening and closing of the shed, ensuring efficient and seamless weaving without any hindrance or resistance. The mechanism's ability to maintain consistent shed formation is crucial for producing high-quality fabrics.

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Lever System Capacity: The shedding mechanism incorporates a lever system capable of accommodating up to ten shafts without causing congestion or excessive weight on the top frame. This capability allows weavers to utilize multiple shafts during the weaving process, facilitating the production of unique and intricate patterns. The flexibility of handling multiple shafts simultaneously enhances the versatility of pattern creation, enabling artisans to expand their design repertoire.

Manipulation of Treadle: The design lever of the lams on the treadle mechanism allows for easy manipulation, enabling a smooth transition from operating individual shafts to engaging multiple shafts during the tie-up process. This feature simplifies the setup and adjustment of the mechanism, thereby facilitating the weaving of complex patterns and designs. The user-friendly nature of the treadle contributes to an overall more efficient weaving experience.

Multiple Patterns with a Single Heddling Order: The lever lam expansion shedding mechanism offers the significant advantage of achieving various patterns using a single heddling order. By adjusting the stepping order and tie-up of the mechanism, weavers can create multiple patterns without the need for extensive reconfiguration. This versatility not only fosters creativity but also allows for greater variation in woven designs, enhancing the artistic expression of the weaver.

3.3 | Respondent Perspectives on the Counter-Shaft Mechanism

Feedback collected from various respondents underscores the multifaceted benefits of the counter-shaft mechanism. Table 5 summarizes the insights regarding key aspects of the mechanism.

Additionally, the integration of the counter-shaft mechanism addresses one of the major challenges faced in indigenous weaving: thread interference. The mechanism’s ability to produce precise shed formations results in clearer separation between raised and lowered warp yarns, thereby minimizing friction and tangling of threads.

The counter-shaft shedding mechanism will not only improve the technical aspects of weaving but also enrich the creative possibilities for artisans, allowing them to produce a broader range of intricate designs while maintaining the cultural significance of their craft. The positive feedback from respondents highlights the transformative impact of this innovation on traditional weaving practices.

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Table 5. Respondent views on the use of the counter-shaft mechanism

Respondent	Ease of Use	Productivity	Design Possibilities	Cultural Relevance	Economic Impact	Learning Curve	Challenges
Apprentice	"The counter-shaft mechanism is easier to operate and saves time and effort."	"I can weave faster now, and the fabric quality has improved."	"This mechanism allows me to create intricate patterns my customers love."	"It retains our traditional methods while introducing modern tools."	"With better designs, I can attract more buyers and sell at higher prices."	"It was difficult initially, but now it feels natural."	"Setting up the mechanism takes time, but it' s worth it."
Master Craftsman	"It simplifies warp manipulation, reducing physical strain."	"Daily output has increased significantly."	"More elaborate designs are now possible."	"Balances innovation with traditional craftsmanship."	"Improved product diversity has boosted sales."	"A steep learning curve initially."	"Adjustments during setup are occasionally needed."
Student	"Much easier to understand and operate compared to the manual system."	"Speed and efficiency have greatly improved."	"Allows experimentation with complex weave structures."	"Preserves cultural significance while modernizing processes."	"Enhanced skills translate to better market opportunities."	"Learning the system was challenging but rewarding."	"Maintenance can be tricky at first."
Technician	"Streamlines the weaving process effectively."	"Has reduced errors and improved overall output."	"Provides more flexibility in design creation."	"Supports cultural preservation with technological adaptation."	"Higher-quality textiles open up premium markets."	"Training sessions made the transition smoother."	"Mechanism alignment requires precision."

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4 | DISCUSSION

The integration of the counter-shaft shedding mechanism into the indigenous two-heddle loom offers substantial benefits to weavers, enhancing both their creative and technical capacities. This innovation significantly expanded the range and complexity of weave structures, enabling the production of advanced patterns such as twill, double weave, and supplementary weft patterns in addition to the basic plain weave (Zhao et al., 2016; Ahiabor et al., 2018). These advanced patterns provide greater design versatility, allowing weavers to produce intricate geometric and decorative motifs while preserving cultural aesthetics (Mamidipudi, 2019).

Improved Efficiency and Fabric Quality: The enhanced shedding mechanism facilitated smoother and more efficient warp manipulation, reducing manual effort in hand picking. This improvement significantly increased weaving speed and productivity, making it possible to meet higher production demands (Hazarika et al., 2016) The integration also contributed to improved fabric uniformity and texture. Complex weaves like double weave and brocade were executed with greater precision, resulting in textiles that were structurally stronger and visually more appealing (Bortamuly, and Goswami, 2015).

Cultural and Economic Relevance: Beyond technical benefits, the system fosters skill development and knowledge transfer within indigenous weaving communities. As weavers adopt and master counter-shaft weaving techniques, they enhance their expertise, broadening their skills while gaining a deeper understanding of advanced weaving technologies. This growth not only contributes to the preservation of their cultural identity but also instils a sense of pride and empowerment as they evolve their traditional practices (Karunaratne et al., 2024).

Moreover, the ability to create sophisticated textiles positions indigenous weavers to compete in markets requiring high-quality craftsmanship, such as fashion and interior design. By supporting the creation of diverse and intricate designs, the integrated loom mechanism allows weavers to appeal to modern markets while maintaining traditional aesthetics. This balance between tradition and innovation fosters the preservation of cultural heritage while creating opportunities for economic empowerment (Tadesse, 2015; Purohit & Gupta, 2023).

Socio-Economic Potential: The economic potential of this system is significant. By enabling the production of high-quality, intricate textiles, indigenous weavers can access niche markets and command higher prices for their products. This development opens doors to financial independence and creates opportunities for collaboration with industries such as fashion and interior design (Clifford, 2018). Ultimately, the integration of the counter-shaft shedding mechanism supports the socio-economic development of indigenous communities, offering pathways to economic empowerment while ensuring the continuity and evolution of their cultural traditions.

This innovative approach underscores the importance of merging tradition with technology to preserve cultural heritage while addressing the demands of modern markets. The success of this initiative highlights the potential for culturally adaptive technological interventions to empower traditional artisans and strengthen their socio-economic resilience. On the reverse, integrating a countershaft shedding mechanism into the traditional two-heald loom presents several limitations when operated manually. Increased physical strain is a concern, as pressing multiple treadles for complex patterns demands more effort compared to the simpler two-heald loom operation. This added complexity introduces a steep learning curve, especially for traditional weavers accustomed to straightforward manual methods.

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The manual operation may also reduce weaving speed and make achieving precise sheds more challenging, particularly for intricate patterns. Ergonomic issues, such as increased strain on the legs and feet, can further deter adoption. Additionally, retrofitting the mechanism often requires structural modifications, which may alter the loom's cultural authenticity and usability. Traditional weavers may resist these changes, viewing them as unnecessary for producing basic patterns. Higher maintenance needs and increased costs also pose barriers, particularly for rural weavers with limited resources. Addressing these challenges requires thoughtful design, training, and efforts to balance functionality with cultural preservation.

5 | CONCLUSION AND FUTURE STUDIES

The integration of the counter-shaft loom's shedding mechanism into the indigenous two-heddle loom represents a transformative innovation in textile weaving. By blending traditional craftsmanship with modern functionality, this approach enhances weaving efficiency, expands design possibilities, and sustains cultural heritage. The mechanism's ability to support complex patterns while retaining the simplicity and affordability of traditional looms positions it as a valuable tool for empowering rural artisans. Practically, this innovation equips indigenous weavers with the means to meet contemporary market demands, fostering economic growth and cultural preservation. Its modular design and ergonomic enhancements reduce physical strain, increase productivity, and enable the creation of intricate, high-quality textiles that cater to diverse markets. The adoption of such technology promotes the socio-economic resilience of weaving communities while contributing to sustainable production practices.

Future research should focus on optimizing the ergonomic aspects of the integrated mechanism, exploring its scalability for larger-scale production, and assessing its long-term economic impact on weaving communities. Additionally, further studies could investigate integrating digital design tools with the mechanism to expand its utility in modern textile design. These efforts will ensure that this innovation continues to bridge the gap between tradition and modernity, creating a sustainable and inclusive future for the textile industry.

DATA AVAILABILITY STATEMENT

Data sharing is applicable to this article upon reasonable request from the corresponding author.

CONFLICT OF INTEREST STATEMENT

The authors declare no conflict of interest.

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