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Effects of Modernization/Upgradation of Handloom on Silk Weavers: A Study in Kanchipuram Handloom Cluster

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Abstract: The handloom weaving sector is highly unorganized and decentralized. Most handloom weavers belong to the marginalized and weaker sections of society, working both to meet household needs and contribute to the textile industry. They play a vital role in preserving the traditional craft of handloom weaving, which varies across different states in the country. The artistry and intricacy of hand-woven fabrics are unmatched, with certain weaves and designs still beyond the capability of modern machinery.

Handloom weaving demands high skill & labour to operate the loom which demoralizing the youth in adopting this traditional. India's rich textile heritage clusters are shrinking due to this fact. So, the labor-intensive nature of handloom weaving, combined with non-ergonomic tools and workspaces, discouraging the younger generation from adopting this traditional craft, leading to the gradual decline of India's rich textile heritage.

Ministry of Textiles & its sub-ordinate offices like Central Silk Board & Weavers Service centers etc. are continuously working to uplift the weaver's life standard by providing upgraded machineries on subsidized rate. In last 10-15 years' efforts was taken to modernize the traditional loom set up with upgraded loom set ups like CATD (Computer Added Textile Designing), PLM (Pneumatic Lifting Mechanism & Electronic Jacquard etc.

Traditionally, weavers have relied on mechanical jacquards with limited hook capacities; however, increasing market demand for intricate, multi-colour, and fine-patterned designs has pushed the adoption of advanced systems such as Pneumatic Lifting Mechanisms (PLM) and Electronic Jacquards. This study provides a comparative analysis of three jacquard Mechanisms-Mechanical (Traditional), Mechanical with PLM, and Electronic-based on lifting force, ergonomic comfort, design flexibility, productivity, and income enhancement. Real-time force measurements using a digital weighing system and structured interviews across multiple weaving locations form the basis of this assessment. Findings demonstrate that PLM and electronic systems substantially reduce drudgery, enable complex design weaving, and improve productivity, resulting in a 25–50% rise in income. The study underscores the importance of technological upgradation to sustain the economic and cultural vitality of the Kancheepuram handloom sector.

Keywords: *Handloom, Jacquard, PLM, Weaver, Silk, Cluster, Kanchipuram, Pneumatic.*

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I. INTRODUCTION

Kancheepuram, one of India's most celebrated silk handloom clusters, is renowned for its centuries-old tradition of producing high-quality silk sarees characterized by rich motifs, vibrant colours, and structural durability.13During the early Christian era, this cluster was a significant center of urban concentration. Its geographical setting along the banks of the Palar River was key, as it facilitated access to trade. By the 7th century, the area had transformed into a Royal Centre

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supported by a robust commercial and craft economy. The process of urbanization began under the Pallava rule in the 7th century, but it accelerated dramatically during the Chola period in the 10th century. This was when the craft of weaving became particularly important and highly prestigious, primarily producing silk fabrics for the temples and the royal court13.

The cluster forms a socio-economic backbone for the region, supporting nearly 50,000 functioning handlooms and engaging around 80,000 artisans in weaving and related activities. Design formation in these looms predominantly relies on jacquard mechanisms, making the performance of jacquard systems critically important for productivity, design complexity, and economic sustainability.

Historically, mechanical jacquards generally operating with 120–240 hooks have served as the primary design apparatus. Although functional and widely adopted, these systems demand considerable foot-operated lifting force from weavers. Repetitive high-force treadling contributes to musculoskeletal strain, fatigue, and reduced long-term weaving capacity. Numerous ergonomic studies emphasise the physical challenges associated with mechanical loom operation, particularly foot-treadle and repetitive lifting motions, which often lead to lower limb discomfort and occupational health concerns among handloom weavers [1–4].

So, the labor-intensive nature of handloom weaving, combined with non-ergonomic tools (Primitive loom set up) and workspaces, discourages the younger generation from adopting this traditional craft, leading to the gradual decline of India's rich textile heritage. To revive and sustain the industry, it is crucial to integrate innovative modern technologies and ergonomic solutions that enhance the weaving process.

To address these limitations & constraints, several technological interventions have emerged. One such improvement is the Pneumatic Lifting Mechanism (PLM), which assists in lifting hooks using pneumatic pressure. Studies on assisted lifting mechanisms in weaving have shown substantial reductions in drudgery, improved energy efficiency, and enhanced ability to handle higher hook capacities without compromising design accuracy [5,6]. PLM-enabled jacquards allow operators to weave more intricate patterns with reduced physical strain, thus enhancing productivity and quality.

Parallel to mechanical upgrades, the introduction of Electronic Jacquards has transformed the design capabilities of handlooms. With digital pattern control, electronic jacquards support large hook capacities extending from 960 up to several thousand hooks and enable rapid pattern switching, fine-motif detailing, and multi-colour weft insertions. Research indicates that electronic jacquards not only increase productivity but also significantly reduce design development time, improving commercial responsiveness in traditional weaving sectors [7–11]. Several cluster modernization reports highlight that electronic jacquards have enabled weavers to transition from limited traditional patterns to contemporary and export-oriented designs, thereby improving market competitiveness [12].

Despite increasing adoption, there is limited comparative research exploring mechanical, mechanical with PLM, and electronic jacquard systems within the same weaving environment. Prior studies have focused on ergonomics, productivity, or technological design in isolation, but few integrate these factors with socio-economic outcomes in a real-world cluster setting. Given Kancheepuram's unique position as a high-value silk weaving hub with both traditional and technologically advanced systems coexisting- a comprehensive comparative assessment is needed.

This study therefore aims to evaluate the performance of three jacquard systems-Mechanical Jacquard, PLM-assisted Mechanical Jacquard, and Electronic Jacquard using field data collected from multiple weaving sites across the Kancheepuram cluster. The assessment covers operational force requirements, ergonomic impacts, design complexity, production rate, and income variations. The findings provide insights into how technological modernization can sustain traditional weaving heritage while improving livelihood security and productivity in one of India's most prominent handloom clusters.

II. MATERIALS AND METHODS

➢ *Study Area and Participants:*

The study was conducted across various weaving sites within the Kancheepuram cluster, including Silk Park units, private weaving households, and cooperative societies. 13 Location and climate of temple city i.e. Kanchipuram also written as Kancheepuram located in Tamil Nadu, a southern state of India. It is located 72 km from Chennai with co-ordinates 12.83° N – 79.70° E. It is situated on the banks of the Vegavathy River which is a tributary of the Palar River. Kanchipuram has two subdivisions-Shiva Kanchi which occupies the western portion of the city and houses several Shiva temples, and Vishnu Kanchi which is located in the eastern part of the city and consists of Vishnu temples. The city covers the area of 36.14 km2 and has an elevation of 83 m (275 ft) above sea level. The city has a warm and humid climate, where the air temperature varies from 16 °C (60.8°F) to 37.5 °C (99.5°F) in a year. The annual relative humidity varies from 58 to 84%, and the city receives the majority of its rainfall during the northeast monsoons which occur from September (average of 150 mm) to December (average of 237 mm) [13]

Weavers ranging from young professionals to highly experienced artisans with over four decades of weaving history were selected for detailed interviews and observational assessments. These weavers represented diverse jacquard technologies in active use:

- Mechanical Jacquards: 120, 240, and 480 hooks
- PLM-enabled Mechanical Jacquards: 240–480 hooks
- Electronic Jacquards: 960–1800 hooks

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This sample provided broad visibility into current weaving practices and technology adoption patterns within the cluster.

➢ *Digital Force Measurement Setup*

To quantify the physical effort required for lifting jacquard hooks, a digital weighing sensor was integrated into the lifting cord mechanism. The device was positioned between the jacquard's top-mounted lifting cord and the underside treadle, capturing real-time lifting force data while the weaver operated the loom. Figure 1 illustrates the force measurement setup.

Each force reading was recorded over ten successive lifting cycles, and the average value was calculated for each jacquard type. This method ensured consistency in measurement and eliminated variability associated with weaving rhythm or foot pressure.

Fig 1 Digital Weighing Setup for Jacquard Lifting Force Measurement

➢ *Weaver Interviews and Observations:*

The A structured questionnaire was administered to collect data on:

- Nature and severity of physical discomfort
- Daily weaving duration and efficiency
- Monthly saree production before and after technology upgrades
- Complexity of woven designs
- Income variations linked to jacquard type
- Perceived usability and challenges of new technologies.

Responses were categorized and analyzed to understand the ergonomic and economic impacts of each jacquard mechanism.

➢ *Data Analysis*

Both qualitative and quantitative data were analyzed using descriptive and comparative techniques. Key performance indicators included:

- Mean lifting force
- Change in production rate
- Variations in income after upgradation
- Design capability expansion
- Subjective comfort ratings

III. RESULTS AND DISCUSSION

➢ *Lifting Force Requirement*

The force measurement experiments revealed a substantial difference in the physical effort required to operate mechanical jacquards of varying hook capacities. The 120-hook mechanical jacquard required an average lifting force of 5.4 kg, whereas the 240-hook mechanical jacquard demanded approximately 8.75 kg. This sharp increase in force over 60% indicates a disproportionately higher level of physical exertion as the design complexity grows and more hooks are engaged during pattern formation.

Such elevated force demands have direct implications for weaver ergonomics. Higher lifting loads contribute to fatigue, slower weaving rhythm, and greater musculoskeletal stress. Now Kanchipuram weaver's not using more than 240 hooks capacity mechanical jacquard without any aided lifting mechanism due to above said reason. In contrast, PLM-enabled jacquards demonstrated a drastic reduction in lifting force, lowering the manual effort by more than 70%, enabling smooth operation even at 240–480 hook capacities. Electronic jacquards eliminated the need for manual lifting entirely, thereby removing the primary source of physical strain associated with jacquard shedding.

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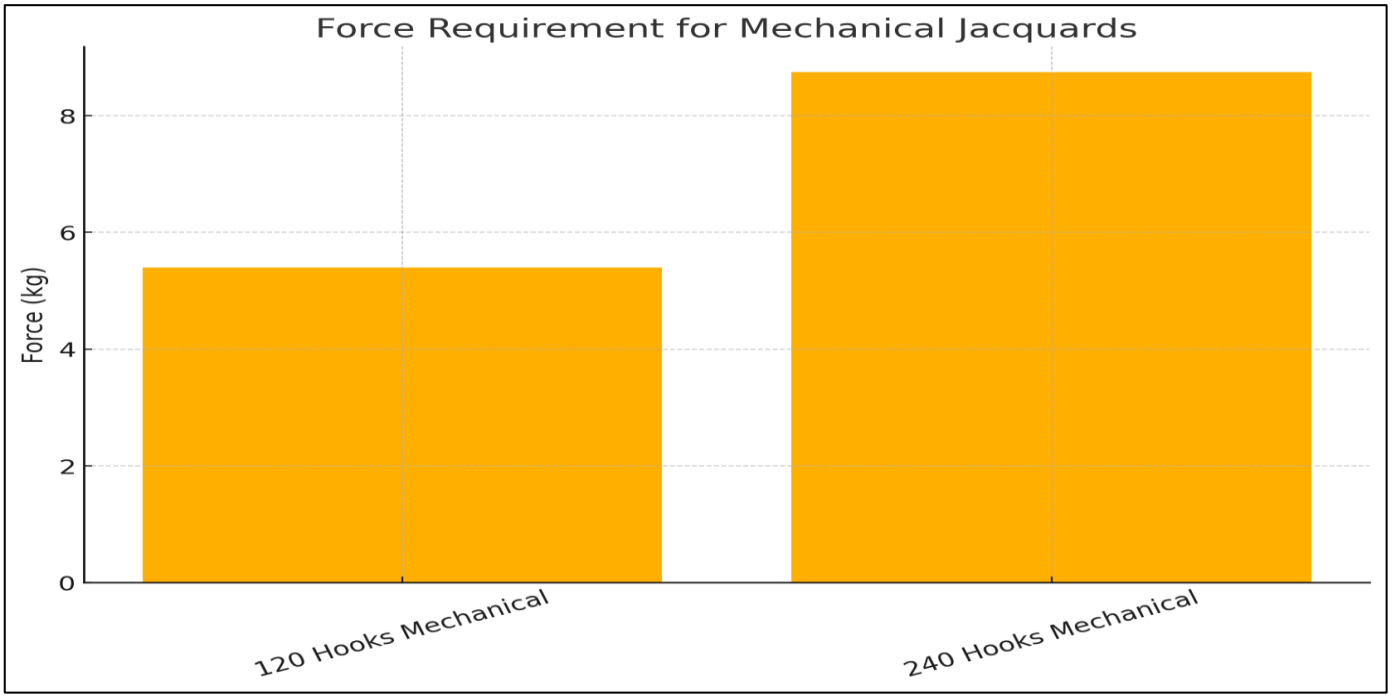

Fig 2 Force Requirement for 120-Hook and 240-Hook Mechanical Jacquards.

➢ *Productivity and Income Gains*

The transition from conventional mechanical jacquards to PLM-assisted and electronic jacquard systems resulted in substantial improvements in weaving productivity, operational efficiency, and income generation for the weavers. A detailed comparison of production levels before and after technology upgradation is presented in Table 1. The data show that weavers adopting PLM or electronic jacquards consistently experienced an increase in their monthly output and earnings.

Table 1 Comparison of Production Levels Before and After Technology Upgradation

Sl. No.	Weaver Name	Technology Upgrade	Previous Production	Current Production	Income Increase (%)
1	Karunakaran	PLM→ Electronic Jacquard	4Sarees/month	5 sarees/month	25%
2	Sundramurthy	PLM→ Electronic Jacquard	3 sarees/month	4 sarees/month	33.3%
3	Padmavathi	Mechanical Jacquard → PLM (240h)	10 days/saree	8 days/saree	25%
4	Muniyandi	Mechanical Jacquard → PLM (240h)	3 sarees/month	4-5 sarees/month	50%

Overall, PLM users reported completing each saree approximately 20–25% faster, primarily due to reduced physical effort and smoother lifting movement during shedding. Weavers operating electronic jacquards observed even greater gains, with monthly production increasing by 25–50%, particularly for intricate multicolour and high-density design work. The range of income improvement 25% for PLM-assisted jacquards and up to 50% for electronic jacquards highlights the significant economic advantages associated with technological modernization.

Furthermore, the ability to comfortably operate higher hook capacities enabled weavers to accept complex, high-value saree orders, which typically command premium wages in the market. This expanded capability contributed directly to increased monthly earnings and enhanced livelihood security for the weaving households.

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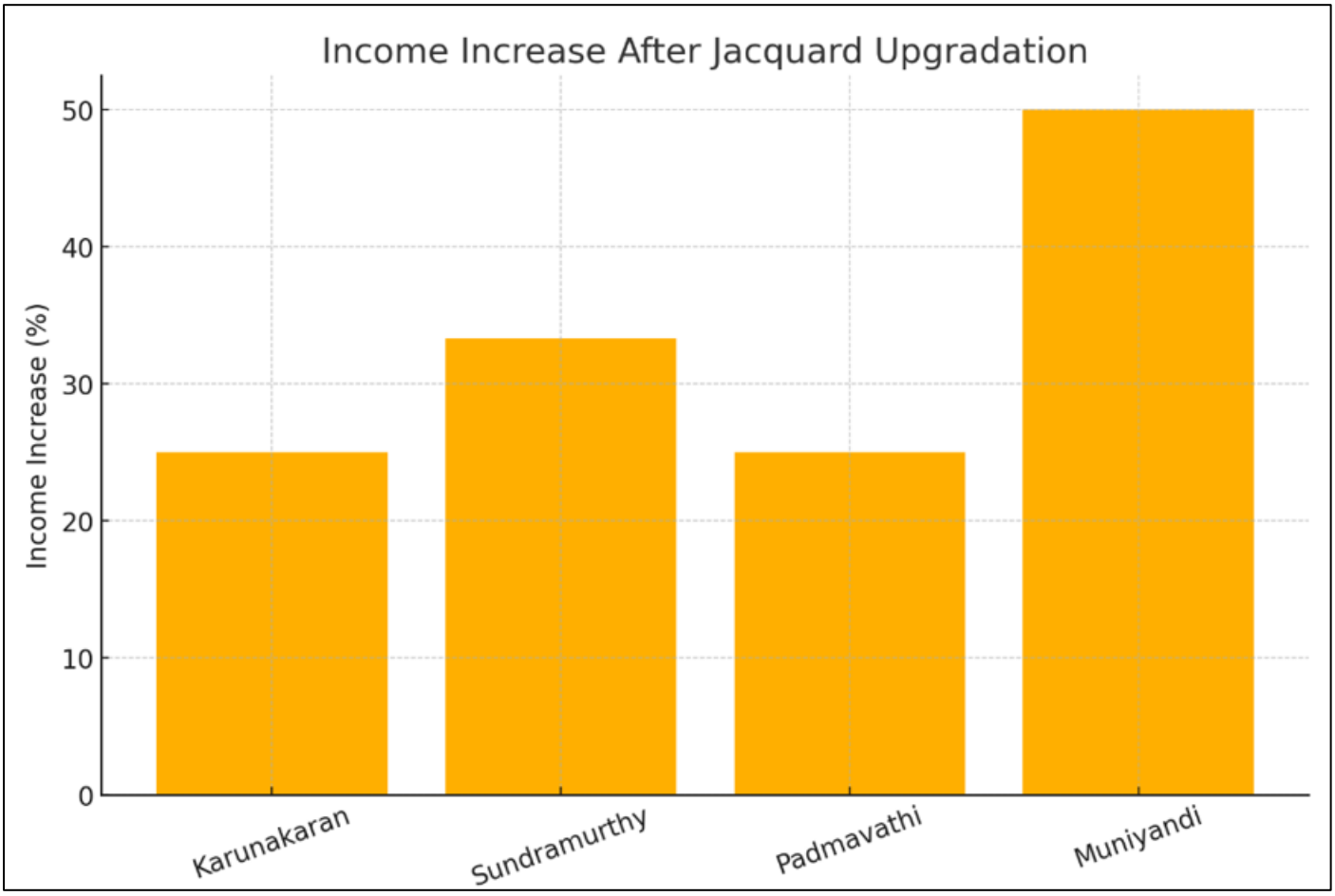

Fig 3 Income Increase After Jacquard Upgradation.

➢ *Enhancement in Design Capabilities*

During the study, weavers reported clear differences in the design capabilities of the three jacquard systems. According to them, mechanical jacquards operating with 120–240 hooks (and rarely 480) were adequate only for simple motifs and limited colour combinations, which restricted their ability to weave more intricate patterns. Many weavers expressed that these systems limited their creative output and were not suitable for today's design demands.

Weavers using PLM-assisted mechanical jacquards noted a significant improvement in design flexibility. With 240–480 hooks, they were able to handle medium-to-high complexity motifs with better consistency and smoother operation. They shared that the PLM allowed them to manage multicolour weft work more comfortably, making complex designs more achievable.

Those working on electronic jacquards consistently reported the highest level of design capability. With capacities ranging from 720 to 1800 hooks, electronic systems enabled them to create highly intricate, multi-colour, fine-pattern motifs. Weavers highlighted that digital design switching greatly reduced setup time and allowed them to experiment with new patterns quickly. Many expressed that electronic jacquards helped them meet modern market preferences and increased the value of their sarees.

➢ *Weaver Perspectives (Field feedback)*

During the interactions, weavers operating traditional mechanical jacquards frequently reported issues such as leg fatigue, knee strain, and slower weaving speed. They shared that the continuous high-force lifting required by these systems caused physical discomfort, especially during long weaving hours.

Weavers who had shifted to PLM-assisted jacquards expressed notable ergonomic relief. They reported smoother lifting action, reduced physical stress, and better consistency while handling higher hook capacities. Many stated that the PLM mechanism made weaving less tiring and helped them maintain a steadier pace throughout the day.

Users of electronic jacquards conveyed the highest level of satisfaction among all groups. They emphasized that operation required minimal physical effort, and the digital control allowed them to weave more complex motifs with ease. Several weavers mentioned that electronic jacquards not only improved design flexibility but also increased their productivity and earnings. The only concerns raised were the initial cost of installation and the need for occasional technical training, although most agreed that the long-term benefits outweighed these challenges.

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IV. DISCUSSIONS

The comparative assessment clearly highlights the limitations of mechanical jacquards, particularly in terms of ergonomics and design capability. The high lifting force and repetitive foot operation required by these systems are consistent with earlier ergonomic studies that identify lower-limb strain as a major concern for weavers using foot-driven mechanisms [1,2]. In contrast, the introduction of PLM-assisted jacquards has significantly reduced this physical burden, allowing weavers to operate higher hook capacities with improved comfort and without compromising design quality.

Electronic jacquards further advance this improvement by offering digital precision, faster design execution, and the ability to manage highly complex patterns with ease. The substantial gains in productivity and earnings observed during the study align with previous research documenting similar benefits of electronic jacquard adoption in other weaving clusters [4,5]. Nevertheless, widespread implementation may require structured financial support, skill-development initiatives, and reliable maintenance frameworks to ensure long-term sustainability.

Overall, the shift towards PLM and electronic jacquards is not only crucial for improving productivity and income but also vital for safeguarding the traditional craftsmanship of Kancheepuram. These technologies enable artisans to meet modern design demands while maintaining the cultural integrity and heritage value of their weaving tradition.

V. CONCLUSIONS

This study highlights significant performance differences across three jacquard mechanisms used in the Kancheepuram cluster. Mechanical jacquards, while functional, impose heavy physical strain and restrict weavers to simpler designs. PLM-equipped jacquards greatly reduce drudgery, enable higher hook capacities, and improve productivity and income. Electronic jacquards offer the most advanced capabilities, supporting high-density, multi-colour motifs with minimal physical effort and considerable economic benefits.

Weavers in most clusters use mechanical jacquards but are Underprivileged to adopt electronic jacquards directly, even with Ministry of Textiles (MoT) subsidies. To resolve this, the PLM unit offers a cost-effective solution to upgrade the primitive mechanical systems. This upgrade both increases productivity and reduces the drudgery involved in mechanical Jacquard weaving.

To strengthen the long-term sustainability of the silk industry, broader support for PLM and electronic jacquard adoption is recommended through government incentives, training programmes, and cluster-level modernization efforts.

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