

Handloom 4.0: An AI-Assisted D2C Framework for Sambalpuri Saree Weavers - A Participatory Design Study in Kardola Village, Odisha

Mr. Abhinandan Tripathy

Technical Manager (Production) Odisha State Open University, Sambalpur Odisha, India

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ABSTRACT

Background. Kardola Village in Sambalpur district, Odisha-formally adopted by Odisha State Open University (OSOU) under the Unnat Bharat Abhiyan (UBA)-comprises forty-five weaving households (142 members) whose livelihoods depend on the production of Sambalpuri Ikat (Bandha) handloom sarees. Field data indicate monthly household incomes of ₹4,500-₹8,000, with variation driven largely by differential market access rather than craft quality. Because nearly all output is sold through local trader intermediaries, weavers realise only a fraction of the eventual retail value of their products.

Objective. This study documents the current production and marketing conditions of the Kardola weaving community and, on that empirical basis, develops and specifies the Handloom 4.0 framework: an AI-assisted, Direct-to-Customer (D2C) digital commerce model intended to reduce trader dependence and improve income realisation.

Methods. A Participatory Design methodology was applied. Primary data were collected through a household census (N = 45), semi-structured interviews with primary earning members, four focus group discussions, structured observation of production and transaction practices, and iterative co-design workshops. Qualitative data were analysed using reflexive thematic analysis; quantitative baseline indicators were triangulated across interview, observation, and group-verification sources. The framework was refined through member checking and expert review.

Findings. The baseline analysis indicates that income suppression is primarily a function of channel structure and credit dependence rather than production capacity, and that the community already possesses substantial latent digital assets (smartphone access in 38 of 45 households; active WhatsApp use in 36). The Handloom 4.0 framework is specified in five integrated layers: an AI-assisted product catalogue, WhatsApp-first social commerce, QR/UPI-based direct payment, aggregated community logistics, and a producer-company governance structure.

Projected outcomes and limitations. Using an income model derived from observed price differentials, the framework is projected-under stated adoption and demand assumptions-to raise monthly household income toward ₹12,000-₹18,000 and to reduce trader dependence over an eighteen-month horizon. These figures are analytical projections rather than measured results; empirical validation through a controlled pilot is identified as the essential next stage. The study contributes a transferable, community-centred model for artisan D2C transformation while explicitly delineating its evidentiary boundaries.

Keywords: Sambalpuri saree; Handloom 4.0; direct-to-customer commerce; participatory design; AI-assisted commerce; rural artisan livelihoods; digital transformation; Odisha

INTRODUCTION

Kardola Village lies in the Sambalpur district of western Odisha, within the heartland of the Sambalpuri handloom tradition. Each of the forty-five weaving households in the community practises Bandha (Ikat)

weaving, in which individual warp and weft threads are resist-dyed before setting on the loom so that the finished saree carries intricate geometric and naturalistic motifs. A single quality saree typically requires ten to fourteen days of skilled work and reflects a precision textile tradition that is difficult to reproduce through mechanised processes.

The economic returns to this work, however, are not commensurate with the market value of the finished product. Field data collected for this study indicate that a weaver who spends approximately twelve days producing a saree sells it to a visiting trader for ₹1,500-₹3,800, while comparable sarees retail in Sambalpur, Bhubaneswar, or Mumbai showrooms for ₹7,000-₹15,000. Under the prevailing trader-mediated channel, the weaver retains an estimated 18-28 per cent of final consumer value. This distribution reflects the structural position of the weaver within the supply chain rather than any deficiency in craft quality, and it is this structural constraint that the present study seeks to address.

Odisha State Open University adopted Kardola Village under the Unnat Bharat Abhiyan (UBA) as part of its community-engagement mandate. Within that framework, the authors conducted structured household interviews, focus group discussions, observational visits to weaving rooms, and participatory co-design workshops between 2023 and 2024. This article is grounded in primary data generated through those interactions; it does not rely on external statistical databases or census figures to characterise the community, and it distinguishes throughout between observed field findings and model-based projections.

The study makes three contributions. First, it provides a primary, household-level account of the production, income, and digital-asset profile of a Sambalpuri weaving cluster. Second, it specifies Handloom 4.0-a five-layer, AI-assisted D2C framework co-designed with the community-as a concrete and transferable response to the intermediary problem. Third, it presents a transparent income-projection model together with an explicit statement of its assumptions, limitations, and the empirical validation required before the projected outcomes can be claimed as results.

The remainder of the article is organised as follows. Section 2 reviews and critically synthesises relevant literature and identifies the research gap. Section 3 details the study setting, participatory design process, data collection and analysis procedures, framework validation, and ethical safeguards. Section 4 reports the empirical baseline findings for the Kardola community. Section 5 specifies the Handloom 4.0 framework. Section 6 presents the implementation roadmap and the projected-rather than observed-outcomes, with their governing assumptions. Section 7 discusses implications, distinguishes findings from projections, and examines limitations, scalability, and long-term sustainability. Section 8 concludes.

LITERATURE REVIEW AND RESEARCH GAP

This review synthesises four literatures that bear on the study-artisan intermediation, digital and social commerce for producers, AI tools for micro-enterprise, and participatory technology deployment-and reads them against one another to locate the specific gap this study addresses.

Handloom Intermediation and the Persistence of the Price Spread

The subordination of handloom weavers to trader intermediaries is a recurring finding in the literature on Indian artisan economies, yet accounts differ in where they locate the binding constraint. Chari (2017) attributes weaver dependence chiefly to information asymmetry and credit capture, whereas Roy (2019) frames the same phenomenon structurally as "supply chain feudalism"-a self-reinforcing configuration of credit, information, and logistics control that resists incremental reform. For the Sambalpuri context specifically, Das (2015) and Nayak and Mishra (2020) document a durable price spread in which weavers retain roughly 18-25 per cent of retail value. Read together, these studies converge on the magnitude of the problem but diverge on its remedy: cooperative-based responses, examined by Mishra and Mishra (2016), yield only modest gains and are limited by weak market connectivity and managerial capacity. The unresolved question in this literature is therefore not whether intermediation is extractive, but which intervention can alter the output channel itself rather than merely the input side-a distinction the present study treats as central.

Digital and Social Commerce as Channel Alternatives

A second literature suggests that mobile-first digital commerce can reconstruct the artisan channel. Kumar and Priya (2018) report that direct digital channels yielded 35-60 per cent higher producer prices than trader channels among Tamil Nadu cooperatives, and Ghosh and Bhattacharyya (2022) show that UPI adoption reduces transaction friction while creating auditable income records that can support formal credit access. A parallel strand treats handloom textiles as experience goods for which weaver identity and craft process are integral to the purchase decision, making social platforms particularly apt channels (Hajli, 2015; Bai et al., 2015). These findings are, however, qualified in two ways that the present study takes seriously. Sharma et al. (2020) establish that digital trust-rather than platform access per se-is the decisive mediating factor for first-generation rural sellers, while Prakash and Tejasvi's (2019) analysis of GoCoop identifies content quality, logistics reliability, and institutional mentoring as prerequisites that most artisan communities lack. The optimistic price findings therefore hold only where trust, content, and logistics are actively constructed; existing studies document the opportunity more thoroughly than the mechanism by which a low-readiness community crosses that threshold.

AI Tools for Micro-Enterprise: Promise and Evidentiary Limits

A third literature examines AI tools now accessible through smartphone applications. Xu et al. (2020) demonstrate that NLP-based chatbots reduce the customer-communication burden for small sellers, and Randhawa et al. (2021) identify demand forecasting, recommendation, and dynamic pricing as high-value applications for craft enterprises. Computer-vision authentication of textile provenance, reported at above 92 per cent accuracy by De Souza Mendes et al. (2021), is directly pertinent to Sambalpuri sarees, which face systematic imitation by machine-made products. This work establishes technical feasibility; what it does not establish is field-level adoption among low-literacy, low-bandwidth producer communities, where most demonstrations remain proof-of-concept rather than sustained deployment. The gap between demonstrated capability and community-level use is precisely the interval in which most interventions fail.

Participatory Design and the Adoption Problem

The fourth literature explains that failure. Studies of rural technology adoption consistently attribute failure to top-down deployment, in which systems designed by external experts are introduced to communities without their involvement (Chambers, 1994; Whyte, 1991). Participatory Design, in which end users shape the design, testing, and refinement of tools, is associated with higher adoption and more contextually appropriate outcomes (Barab & Squire, 2004), and Freire's (1970) formulation provides the ethical grounding: communities as agents rather than beneficiaries of change. This literature supplies the method by which the trust, content, and adoption preconditions identified in Sections 2.2 and 2.3 might actually be met, but it is rarely integrated with the technical and commercial literatures in a single, operational design.

Research Gap

Across these literatures a consistent pattern emerges: the extractive character of intermediation is well established; digital channels can, in principle, raise producer prices; AI tools are technically feasible; and participatory methods improve adoption. What is largely absent is an integrated, empirically grounded specification that combines all four-an AI-assisted D2C model, co-designed with a specific low-readiness weaving community, built on the digital assets that community already holds, and presented with an explicit and honest account of what has been observed versus what remains to be validated. Handloom 4.0 is offered as a response to this gap, and the study is careful to claim only what its primary data support.

MATERIALS AND METHODS

Study Design and Setting

The study employed a Participatory Design (PD) approach within a single-cluster case study, conducted in Kardola Village, Sambalpur district, Odisha, between 2023 and 2024. PD was selected because the research objective was not merely to describe the community but to co-develop, with its members, a commerce framework

that they would themselves operate; the literature reviewed in Section 2.4 indicates that such co-design is a precondition for adoption. The setting was defined by OSOU's adoption of Kardola under the Unnat Bharat Abhiyan, which provided institutional access, community trust, and a sustained engagement horizon.

Participants and Sampling

A complete household census rather than a sample was used: all forty-five weaving households (142 members) participated, eliminating selection bias at the household level. Within each household, the primary earning member was the principal interview respondent, with additional participation from women weavers, aged design-holders, and, where relevant and with guardian consent, older adolescents. Of the 142 members, 50 individuals were identified as trained in the weaving process and formed the core of the production-focused enquiry. Focus group discussions used purposive composition to ensure representation across gender, age, and loom-role, with separate women-only groups convened at the community's request (see Section 3.7).

Data Collection Procedures

Four complementary instruments were used, applied over repeated village visits to allow rapport-building and iterative verification:

- **Household census and structured survey.** A structured schedule recorded household composition, loom count, production cadence, pattern repertoire, income band, outstanding trader credit, and a digital-asset inventory (device access, connectivity, WhatsApp/UPI use, prior online selling). Income figures were reported by respondents and subsequently cross-checked in group sessions.
- **Semi-structured interviews.** Interviews with primary earners followed an open guide covering the sale process, pricing, trader relationships, credit, aspirations, and perceived barriers to selling directly. Interviews were conducted in Odia, audio-recorded where consent was given, and otherwise recorded through contemporaneous notes.
- **Focus group discussions (FGDs).** Four FGDs (including women-only groups) explored shared perceptions of the price gap, channel preferences, and willingness to adopt specific digital tools. FGDs also served a triangulation function, allowing individually reported income and price figures to be tested against collective knowledge.
- **Structured observation.** Weaving-room visits and observation of trader transactions documented production practice, product handling, and the mechanics of sale, providing a non-self-reported check on interview accounts.

The Participatory Design Process

Co-design proceeded in four stages consistent with established PD practice. In the problem-identification stage, weavers articulated the constraints they most wanted to resolve, from which the primacy of the output channel (rather than input subsidy) emerged. In the solution co-design stage, candidate interventions-ranging from dedicated e-commerce sites to Instagram Shopping to WhatsApp Business-were presented and evaluated by participant groups against their own capacity; the WhatsApp-first orientation of the framework is a direct output of this stage. In the prototyping stage, specific tools (guided product photography, catalogue generation, UPI setup) were demonstrated in workshops so that participants could assess feasibility first-hand. In the refinement stage, participant feedback modified the design-for example, the separation of women's training and the assignment of household UPI accounts to women where possible. These formative, feasibility-oriented observations are reported as such in Section 5 and are not treated as outcome evidence.

Data Analysis

Qualitative data (interview notes, transcripts, FGD records, and observation logs) were analysed using reflexive thematic analysis following Braun and Clarke (2006): familiarisation, initial coding, theme construction, review,

and definition. Coding was conducted by the research team with periodic cross-checking to improve consistency, and emergent themes-channel dependence, credit capture, latent digital capacity, and gendered economic agency-structure the findings in Section 4. Quantitative baseline indicators (income bands, price points, and the digital-asset inventory) were compiled descriptively and triangulated across the census, interviews, FGDs, and observation, so that no single self-reported figure stands unverified. Given the census design and the descriptive purpose, no inferential statistical testing was undertaken; the quantitative material is reported as documented distributions rather than as estimates for a wider population.

Framework Validation

The Handloom 4.0 specification was validated through two procedures short of full field implementation. Member checking returned the framework and the baseline interpretation to community representatives and the KWDP working group to confirm that both accurately reflected their situation and preferences. Expert review drew on OSOU faculty and practitioners in rural livelihoods and digital commerce to assess internal consistency, feasibility, and risk. The authors emphasise that these procedures establish design validity and feasibility, not effectiveness; effectiveness requires the controlled pilot described in Sections 6 and 7.

3.7 Ethical Considerations and Informed Consent

The study was conducted under OSOU's Unnat Bharat Abhiyan community-engagement framework, with institutional consent for the research and its community-development purpose [institutional ethics-approval reference to be inserted]. Because a substantial proportion of participants had limited literacy, informed consent was obtained verbally in Odia after a plain-language explanation of the study's purpose, the voluntary nature of participation, the right to withdraw at any time without consequence, and the intended use of the data. Participation involved no payment and no penalty for non-participation.

Confidentiality was protected by reporting all data in aggregate; no individual is identified by name, and household-level figures are presented in banded form. Audio recording was undertaken only with explicit permission. Where adolescents (aged 15-17) participated in feasibility activities, guardian consent and the young person's assent were obtained, activities were scheduled so as not to interfere with schooling, and no data capable of identifying a minor are reported. The research team observed a child-protection protocol throughout, consistent with the study's explicit commitment that no child's education be compromised by the project. Handling of participants' financial and transactional information followed data-minimisation principles, and any personally identifiable transaction data generated during setup activities were stored securely and used solely for the participant's own account configuration.

Baseline Findings: The Kardola Weaving Community

This section reports the empirical baseline established through the procedures above. All figures are observed field data; they describe the conditions the Handloom 4.0 framework is designed to address and provide the reference point against which the later projections (Section 6) are stated.

Demographic and Productive Structure

The forty-five weaving households comprise 142 persons. Table 1 presents the demographic composition recorded in the census; of the total, fifty members are trained in the weaving process itself.

Category	Description	Count	% of community
Working-age men	Men aged 18-55 engaged in weaving or loom-related work	39	27.5%

Working-age women	Women aged 18-55 engaged in weaving, thread preparation, dyeing support, and finishing	42	29.6%
Boy children	Males aged 6-17 in school; some assist with thread winding after school hours	23	16.2%
Girl children	Females aged 6-17 in school; some assist with yarn sorting at weekends	17	12.0%
Aged men	Men aged 56+ engaged in design advice, thread-quality assessment, and simpler weaving	13	9.2%
Aged women	Women aged 56+ engaged in yarn preparation, natural-dyeing knowledge, and inspection	8	5.6%
Total	All members across 45 weaving households	142	100%

Table 1. Demographic profile of the Kardola weaving community (household census; N = 45 households, 142 persons).

The productive structure carries a gender dimension relevant to the framework's design. Working-age women constitute the community's largest labour group and perform most pre-loom work (thread sorting, winding, tie-resist preparation) as well as finishing; approximately twenty-six also operate looms directly. Their labour is indispensable to every saree, yet commercial negotiation and payment receipt are conducted almost entirely by male members or traders. Working-age men hold the primary loom position in twenty-eight households and undertake most external transactions, including procurement and sale. Aged members hold specialised heritage knowledge-rare pattern templates among the men and natural-dyeing expertise among the women-that is largely undocumented and that the framework seeks to preserve. Observed smartphone access is higher among men (31 of 39) than women (22 of 42) but is rising among women under 35 (18 of 22 in that group), a pattern with direct implications for the design of training and account allocation.

Household Income and the Price Spread

Income was recorded through interviews with the primary earner in each household and verified through FGD triangulation. Monthly household income ranges from ₹4,500 to ₹8,000, clustering at ₹5,500-₹6,500 (community mean $\approx$ ₹6,160). Table 2 relates income bands to their principal determinant and to the trader price received per saree.

Income band (₹/month)	Households	Primary determinant	Trader price (₹/saree)
₹4,500-₹5,000	9	Single loom, simple patterns, few trader visits	₹1,500-₹1,900
₹5,001-₹6,000	16	One or two looms, standard Bandha patterns	₹1,900-₹2,400
₹6,001-₹7,000	13	Two looms, some complex patterns, one repeat trader	₹2,400-₹3,000
₹7,001-₹8,000	7	Two+ looms, complex Kumbha/Shankha designs, more trader competition	₹3,000-₹3,800
Community mean $\approx$ ₹6,160/month	45	Estimated retail range of comparable sarees	₹7,000-₹11,000 (retail)

Table 2. Household income distribution and trader price reality, Kardola Village (primary field data).

Two features of these data are analytically important. First, the income variation is driven principally by market access-regular trader contact, relative proximity to town, and a household member able to travel to Sambalpur-rather than by differences in skill; households in the lowest band are not less skilled than those in the highest. Second, none of these figures approximates the retail value of the product: a saree sold to a trader at approximately ₹2,000 commonly retails at ₹9,000, with the intervening ₹7,000 captured by the trader, transport chain, and retailer. The finding that channel access, not craft quality, is the binding constraint is the empirical foundation of the framework.

The Credit Relationship

Fourteen of the forty-five households reported outstanding trader credit at baseline, ranging from ₹800 to ₹4,500. Although modest in absolute terms, such credit is disproportionately consequential: a household owing ₹3,000 in yarn credit is effectively obligated to deliver its next sarees to the creditor-trader at the creditor's price, removing negotiating power for that production cycle. Respondents articulated this directly, noting that a trader who had recently advanced yarn could not be refused. The credit relationship has two compounding effects observed in the data: it depresses income by forcing below-market sales, and it discourages investment in more elaborate, higher-value patterns, since the return on additional days of work is captured at the fixed trader price. Reducing credit dependence is therefore both a financial and a craft-quality consideration.

Latent Digital Capacity

The baseline digital-asset inventory (Table 3) indicates that the community is not a zero-baseline case but is partially equipped for digital commerce, with the principal deficits lying in application to commerce rather than in device access.

Digital asset	Households	Field observation
Smartphone (≥ 1 per household)	38 of 45	Mostly entry-level Android (₹6,000-₹10,000); 7 households have a feature phone only
Active mobile-data subscription	34 of 45	Mainly Jio/Airtel prepaid; 2G/3G common; 4G near the main road
WhatsApp installed and in use	36 of 45	Used chiefly for family messaging; little product-related use
UPI app installed	29 of 45	Mostly for receiving transfers from relatives; limited commercial use
Has made/received a commercial digital payment	14 of 45	Small purchases; two households have received buyer payment via UPI
Has photographed a product on a smartphone	22 of 45	Informal; no awareness of composition, lighting, or resolution needs
Active Facebook/Instagram account	19 of 45	Mostly younger members; not used for product promotion
Has sold a saree online via any platform	2 of 45	Both via a relative in Bhubaneswar; weavers received no additional margin

Table 3. Digital-asset inventory, Kardola weaving households (field survey; $N = 45$).

The inventory shows a community that is already partially connected-through smartphones, WhatsApp, and some UPI experience-but that lacks the applied knowledge, product-presentation skills, customer network, and institutional support needed to convert existing tools into commercial capability. The framework is accordingly designed to activate existing infrastructure rather than to introduce unfamiliar systems.

The Handloom 4.0 Framework

Design Principles

Three design principles were derived directly from the co-design process. First, device accessibility: the system must operate on the phones households already own, without requiring new devices, high-bandwidth connectivity, or English literacy. Second, early and demonstrable income impact, so that participation is sustainable for households operating at subsistence margins. Third, producer control: the weaver captures the product image, sets the price within recommended ranges, and receives payment directly, rather than ceding these functions to a committee or platform. These principles govern the five-layer architecture described below.

Layer 1 - AI-Assisted Product Catalogue

The most significant capability the community currently lacks for D2C commerce is professional product presentation. The catalogue layer is a smartphone application (Android 8.0+, covering an observed 94 per cent of local devices) that guides the user through product photography using visual prompts, a standard neutral background supplied as a physical kit, and automated lighting assessment. It accepts voice descriptions in Odia and generates structured listings in Odia, Hindi, and English, drawing pattern names from a curated Sambalpuri motif library compiled in consultation with the community's aged design-holders. A pricing module suggests a recommended range based on pattern-complexity category, declared fabric composition, and prevailing comparable-market prices, which the weaver may adjust within defined limits. A single capture is distributed simultaneously to the weaver's WhatsApp Business catalogue, the collective portal, and a GoCoop listing.

Layer 2 - WhatsApp-First Social Commerce

WhatsApp Business is the primary channel because it is already installed in thirty-six of forty-five households, is familiar to urban buyers, and requires minimal training. This orientation was selected by participants during co-design in preference to dedicated websites or Instagram Shopping. Each household operates a WhatsApp Business account populated automatically by the catalogue layer. An AI chatbot configured for Odia and Hindi handles routine enquiries-availability, customisation, care instructions, price within defined ranges, and payment confirmation-escalating complex cases to the weaver or the embedded Digital Sahayak, so that a weaver can continue at the loom while routine communication is managed. A weekly community content series (short process and heritage videos, produced with weaver participation) supports an authentic brand narrative across the community accounts and the collective's social channels.

Layer 3 - QR/UPI-Based Direct Payment

Direct-to-customer commerce requires direct-to-weaver payment. Cash-on-collection by traders is replaced by UPI payment to the weaver's account at point of sale, using a personalised merchant QR code printed on a durable card and embedded in every listing. Twenty-nine households already have UPI apps; the remainder are supported through a bank-linkage and setup session conducted in partnership with a local bank branch, in Odia and requiring only recognition of one's name and a four-digit PIN. Beyond convenience, the payment layer creates an auditable income record that can support access to formal credit-an intended route out of the trader credit relationship-and discussions toward a digital-income-based credit facility with a regional bank are in progress. A pay-on-delivery option, settled to the weaver's account within a defined window, accommodates first-time buyers.

Layer 4 - Aggregated Community Logistics

Logistics is a recognised barrier to rural artisan D2C: Kardola is 22 km from Sambalpur city, road quality degrades in the monsoon, and no courier currently offers village pickup. The framework addresses this through aggregation. Rather than each household arranging dispatch independently, a collective logistics arrangement provides scheduled pickups from a central village collection point; the aggregated volume across forty-five households supports a substantially lower per-parcel rate than individual walk-in dispatch. Each parcel is photographed before sealing to create a dispatch record that mitigates the most common D2C disputes, and dispatch confirmations with tracking are issued to buyers. Returns are managed through an authenticity document accompanying each saree-certifying technique, pattern category, and fabric composition and linked by QR code to the catalogue entry-which reduces fraudulent return claims while allowing genuine returns to be assessed and resold.

Layer 5 - Governance and Institutional Support

The Kardola Weavers Digital Producer Company (KWDP), to be registered under the Companies Act, 2013, provides the legal structure for collective contracting, logistics negotiation, financial management, and brand stewardship, governed by an elected management committee with a mandated minimum of four women members. A Digital Sahayak-a trained graduate, drawn where possible from the village-is embedded for the first two years, with transition to a community-funded role thereafter. Capacity building comprises eight structured modules over twelve weeks, delivered in Odia and combining in-village sessions with practice exercises, progressing from smartphone confidence and WhatsApp Business setup through photography, UPI use, customer communication, pricing, dispatch, and supervised live trading. At the community's request, training is delivered in separate women-only and mixed groups; adolescents participate in a parallel peer-trainer track that does not interfere with schooling.

Preliminary Feasibility Observations (Co-Design Phase)

The following are qualitative feasibility observations recorded during the co-design workshops. They are formative indicators of usability and acceptance, not measures of income or commercial outcome, and they should not be read as pilot results. During workshop sessions, several participants-including women weavers and adolescents-were able to photograph sarees against the supplied background with acceptable composition after brief guidance; participant groups independently identified WhatsApp as the channel they were most ready to use; women participants identified separate-group training and account allocation in their own names as conditions for comfortable engagement with financial tools; and the UPI setup procedure was completed successfully in workshop conditions with older, first-time users. These observations informed design refinement and indicate feasibility; they do not establish effectiveness, which requires the controlled pilot specified in Sections 6 and 7.

Implementation Roadmap and Projected Outcomes

This section presents the proposed implementation sequence and a transparent income projection. The roadmap describes intended activities and target indicators; the income figures are analytical projections derived from observed price differentials under explicitly stated assumptions, and are not measured results.

Phased Implementation Plan (Proposed)

Phase	Timeline	Key activities	Target indicator
Foundation	Months 1-3	KWDP registration; UPI and WhatsApp Business setup for all 45 households; Modules 1-4; catalogue-app installation; first photography sessions	All 45 households with UPI accounts and active catalogues; ≥ 3 sarees per household listed

Activation	Months 4-6	Modules 5-7; first supervised D2C orders; logistics pickup operational; customer-network seeding	≥20 households with a completed D2C sale; measurable D2C income among active households; no logistics failures
Growth	Months 7-12	Module 8; full community active; GoCoop/GeM listing; heritage-design documentation; natural-dye line	All 45 households with an active D2C channel; rising mean D2C income; declining trader dependence
Consolidation	Months 13-18	KWDPC self-governance; Sahayak transition to community-funded role; credit-facility launch; replication planning	Mean household income toward the projected range; D2C majority share of revenue; credit-dependence reduced

Table 4. Proposed phased implementation plan, Kardola Village. Indicators are targets, not observed results.

Income Projection Model and Assumptions

The income projection is built from the price points observed in the Kardola trade chain (Tables 2 and 3), not from external market averages. Table 5 sets out the per-saree economics under the current trader channel and under the proposed D2C channel, incorporating the new transparent costs (platform, logistics, packaging) that D2C entails.

Component	Current (trader)	Projected (D2C)	Change
Sale price per saree	₹1,500-₹3,800	₹5,500-₹9,000 (retail)	+₹3,500-₹5,500
Platform/commerce cost	Nil (captured by trader)	₹60-₹90 (WhatsApp free; GoCoop ≈10%)	New transparent cost
Logistics per parcel	Nil to weaver	₹65-₹85 (aggregated rate)	New cost, offset by price gain
Packaging	Nil (trader handles)	₹35-₹50	New, small relative to gain
Net income per saree	₹1,500-₹3,800	₹5,250-₹8,750	+175% to +230% per unit
Sarees per month per household	≈2.8	2.8-3.2 (no forced increase)	No production increase required
Projected monthly household income (Month 18)	₹4,500-₹8,000 (current)	₹12,000-₹18,000 (projected)	Contingent on assumptions below

Table 5. D2C price-realisation model: per-saree economics and projected monthly household income. The Month-18 figure is a projection, not a measured outcome.

The projection rests on assumptions that are stated here so that readers can evaluate and, in due course, test them. It assumes that: (i) a substantial majority of households adopt and sustain the D2C channel; (ii) direct-buyer demand at the ₹5,500-₹9,000 price point can be generated and maintained at roughly current production volumes; (iii) craft quality is preserved under order pressure so that returns remain low; (iv) logistics and payment infrastructure function reliably; and (v) trader counter-pressure during the transition does not materially

suppress participation. The central figure therefore represents a favourable-but-plausible scenario. Under more conservative assumptions-partial adoption, slower demand growth, or higher return rates-realised income would fall below the stated range; a formal sensitivity analysis is a planned component of the pilot. The projection illustrates the arithmetic of channel substitution, in which income rises by selling existing production differently rather than by producing more; it does not assert that this arithmetic has yet been realised in the field.

Non-Income Outcomes (Anticipated)

Beyond income, the framework is expected to generate cultural-preservation and human-capital outcomes. Digital documentation of heritage patterns and natural-dyeing knowledge held by aged members would render this expertise traceable, attributable, and marketable as living heritage. The adolescent peer-trainer track positions younger members as digital-commerce operators, potentially weakening the economic case for out-migration if income improves as projected. These outcomes are anticipated rather than demonstrated and would be assessed as part of pilot evaluation.

DISCUSSION

Observed Findings versus Projected Outcomes

It is essential to state clearly what this study establishes and what it does not. The baseline analysis (Section 4) is empirical: the demographic, income, credit, and digital-asset findings are documented primary data, and they support the study's central diagnostic claim-that income suppression in Kardola is primarily a function of channel structure and credit dependence rather than of production capacity. The Handloom 4.0 framework (Section 5) is a validated design in the sense of Section 3.6: it is internally consistent, feasible on the community's existing assets, and endorsed by the community and expert reviewers. The outcomes in Section 6, by contrast, are projections. The move from a validated design to demonstrated effectiveness requires a controlled pilot with pre-registered indicators, a comparison against the trader-channel baseline, and measurement of adoption, realised price, return rates, and net household income over at least two production cycles. Until that evidence exists, the ₹12,000-₹18,000 figure should be read as a modelled target, not a result.

Distinctiveness Relative to Prior Interventions

Prior programmes in the cluster-yarn subsidies, loom upgrades, cooperative support, exhibition participation-were acknowledged by weavers as valuable but, in FGD accounts, as having left the trader-set output price unchanged. The framework differs in three respects that follow from the diagnosis: it targets the output channel rather than the input side; it establishes durable infrastructure (business accounts, merchant payment, a logistics contract, a customer base) that persists beyond the programme period; and it activates tools the community already holds rather than introducing systems dependent on continued external technical support. These are design responses to specific, community-articulated failures rather than general claims of superiority.

Gendered Economic Agency

Women are the community's primary producers but secondary economic actors. The framework's allocation of household UPI accounts to women where possible, and the assignment of catalogue management to women in a substantial share of active households during training, are intended to make women's contribution economically visible and to place income under their control. The literature (Ghosh & Bhattacharyya, 2022) associates women's direct receipt of digital payments with improved intra-household financial decision-making; whether this association holds in Kardola is a question for pilot evaluation rather than a claim the present data can substantiate.

Limitations

The study has several limitations. First and most fundamentally, it presents a validated design and an income projection, not measured outcomes; effectiveness is unproven pending a pilot. Second, connectivity in the village is uneven-adequate near the main road but degrading in the interior-which may impair catalogue performance

and buyer experience despite the low-bandwidth design; this constraint depends partly on telecom infrastructure beyond the project's control. Third, the WhatsApp-first strategy creates single-platform dependency on terms set by a third party, only partially mitigated by the multi-channel design, since a large share of early volume is expected to flow through WhatsApp. Fourth, the projection assumes that premium craft quality is maintained under growing order pressure; the incentive to produce faster as income rises poses a quality risk that governance must actively manage. Fifth, the trader community has an economic interest in preventing D2C adoption, and the interval before credit independence is a vulnerable transition window. Finally, as a single-cluster case study, the findings are analytically rather than statistically generalisable.

Scalability and Long-Term Sustainability

Transferability should be claimed cautiously and conditionally. The model is most plausibly applicable to clusters that share three preconditions observed in Kardola: a distinctive, quality product with demonstrable premium appeal; basic smartphone penetration; and an anchor institution able to provide embedded support for roughly two years. Candidate clusters within Odisha include the Nuapatna Ikat, Berhampur Pattasali, and Pipili appliqué clusters; structural similarities suggest possible relevance to the Pochampally Ikat (Telangana) and Kota Doria (Rajasthan) clusters, subject to adaptation for local platform, language, and logistics conditions. Scalability is nonetheless bounded by real limits: the Digital Sahayak model is labour-intensive and does not trivially scale across many clusters at once; demand-side saturation could compress the price premium if many clusters pursue the same buyer segment simultaneously; and platform, telecom, and policy dependencies lie outside community control. Long-term sustainability rests on three transitions that remain to be demonstrated: from institutional funding to community funding of the Sahayak role by Year 3; from trader credit to formal, income-record-based credit; and from external facilitation to autonomous KWDPC governance. The eighteen-month horizon should therefore be understood as the beginning of a sustainability trajectory rather than its endpoint, and each transition is a candidate indicator for longitudinal evaluation.

CONCLUSION

This study documented the production, income, credit, and digital-asset conditions of the Kardola weaving community through primary field data and, on that basis, specified Handloom 4.0—a five-layer, AI-assisted, community-governed D2C framework co-designed with the community and validated for feasibility. The empirical contribution is the finding that income suppression in this cluster is driven principally by channel structure and credit dependence rather than by production capacity, together with evidence that the community already holds substantial latent digital capacity. The design contribution is an integrated model that combines AI-assisted presentation, social commerce, direct payment, aggregated logistics, and producer-company governance in a form that operates on assets the community already possesses.

The study is deliberate about its evidentiary limits. The projected movement of monthly household income toward ₹12,000–₹18,000 is a transparent, assumption-based projection, not a measured outcome, and its realisation depends on adoption, demand, quality maintenance, infrastructure reliability, and the management of trader counter-pressure. The clear next step is a controlled pilot with pre-registered indicators and a baseline comparison, capable of converting the present validated design into effectiveness evidence and of testing the sustainability transitions on which the model ultimately depends. Framed in this way, Handloom 4.0 offers both a concrete pathway for the Kardola community and a transferable, honestly bounded model for artisan D2C transformation elsewhere.

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