

INVISIBLE WORKFLOWS IN SUSTAINABLE PRODUCTION: *A Case Study of Handmade Paper Production*

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Abstract: Cottage industries are widely recognised for their contribution to local livelihoods and low-impact production. However, within development and policy discourse, they are frequently classified as part of the informal economy, often assumed to lack structured production systems. This study challenges that assumption by reframing informality as an undocumented organisation rather than a structural absence. Focusing on handmade paper production within the Ali Mana cottage industry community in Pahathahewahata, Kandy, Sri Lanka, the research adopts a qualitative embedded case study design across the only active five households. Production workflows were documented through Photographic observation and informal in-context discussions. Comparative stage-based analysis identified eight shared production stages, which were subsequently modelled using the IDEF0 framework and examined through a structured consistency coding scheme across Inputs, Controls, Mechanisms, and Outputs. Findings reveal a stable material transformation backbone from harvesting to paper forming, alongside adaptive variation in tool use, environmental responses, and finishing practices. The results demonstrate that informal production systems are flexibly structured rather than unorganised. By externalising internal workflows, the study contributes a process-based understanding of cottage industries and positions them as viable models for resilient and future-adaptive sustainable production.

Keywords: *Cottage Industries; Informal Production Systems; Process Documentation; Sustainable Production; Ali Mana Handmade Paper*

1. Introduction

Cottage industries are widely recognised for their contribution to local livelihoods, skill preservation, and low-impact production, particularly in developing regions (UNIDO, 2013; International Labour Organization, 2019; Kaplinsky & Morris, 2001). Operating through small-scale, home-based arrangements, these industries rely on local materials, manual labour, and adaptive practices that align closely with sustainability goals (Bocken et al., 2014; Manzini, 2015). Despite this relevance, cottage industries are frequently described within production and policy discourse as informal—a term often equated with a lack of structure, organisation, or systematisation (Hart, 1973; Chen, 2007).

This characterisation presents a conceptual problem. Informality does not necessarily indicate the absence of organisation, but rather the absence of a documented understanding of how production is internally structured (Roy, 2005; Meagher, 2010). When production workflows are not explicitly articulated, the logic through which materials are transformed, decisions are made, and work is coordinated remains embedded in practice and largely inaccessible beyond practitioners (Nonaka, 1998; Polanyi, 2009). As a result, cottage industries are often marginalised in discussions of sustainable production, not because they lack viable systems, but because their internal organisation remains undocumented. Despite increasing recognition of cottage industries within sustainability discourse, there remains a lack of explicit

documentation of how internal production workflows are structured and function across multiple units within a single community. This creates a gap between how these systems operate in practice and how they are understood within research, policy, and facilities management contexts.

The implications of this invisibility are significant. Without process-level documentation, production knowledge is difficult to preserve, analyse, or integrate into policy, training, and design interventions (Nonaka & Takeuchi, 1996; UNESCO, 2003). Undocumented production systems are also harder to engage within broader sustainability frameworks, limiting their long-term viability despite their alignment with low-energy, localised, and circular production principles (Geissdoerfer et al., 2017).

This paper responds to this gap by reframing informality as an undocumented structure rather than a structural absence. It argues that documenting internal production workflows is essential for understanding how flexibility and adaptation are embedded within cottage industries and for situating them within sustainable production discourse. The study adopts an embedded case study approach focusing on handmade paper production within the Ali Mana cottage industry community in Pahathahewahata, Kandy, Sri Lanka, treating the community as a single case comprising multiple household-level production units operating within a common material base and community-level production structure.

Unlike prior studies that primarily examine cottage industries through socio-economic or cultural perspectives, this study introduces a process-based analytical approach by systematically modelling and comparing household-level production workflows using the IDEF0 framework. This enables the identification of both structural consistency and adaptive variation within informal production systems. The aim of this study is to systematically document and analyse handmade-paper production workflows in order to make their internal organisation analytically visible. Specifically, the study seeks to identify shared production stages, compare variation across households, and examine how flexibility operates within a structurally coherent production system. Through this analysis, the paper contributes a process-based understanding of cottage-industry production and situates such systems within broader sustainability discourse.

2. Literature review

The concept of informality has long been used to describe economic and production activities operating outside formal industrial, regulatory, or managerial frameworks (Hart, 1973; Chen, 2007). Within development and policy discourse, informal production is often associated with small-scale operations, limited capital investment, and non-standardised practices. While this framing has helped identify marginalised forms of work, it has also contributed to the assumption that informal systems lack internal organisation (Roy, 2005). However, scholars argue that informality should be understood not as structural absence but

as the presence of alternative organisational logics operating outside formal industrial models (Meagher, 2010).

In cottage industries, production is typically guided by experience-based practice, where knowledge develops through repeated engagement with materials, tools, and environmental conditions (Polanyi, 2009; Ingold, 2013). Skills are embodied and transmitted through observation and participation rather than written procedures. This mode of learning enables responsiveness to material variability and environmental constraints, resulting in variation in tool use, sequencing, and technique. Importantly, variability does not necessarily imply inconsistency. Research in sustainable and craft-based production suggests that adaptive variation often reflects situated intelligence rather than inefficiency (N. M. P. Bocken et al., 2014). Shared stages and transformation logics may exist even when execution differs.

Despite increasing recognition of cottage industries for their contributions to sustainable livelihoods, local resource use, and low mechanisation production (Manzini, 2015; Geissdoerfer et al., 2017). Existing research tends to focus on socio-economic impact, cultural value, or market integration. Detailed analysis of internal production organisation, including how work is sequenced, coordinated, and transformed across stages, remains limited. Without such analysis, the operational logic that enables adaptability and resilience remains underarticulated.

Process documentation offers a means of externalising this embedded organisation without imposing formal standardisation. By identifying stages, decision points, and patterns of variation, documentation can make tacit production structures analytically visible (Nonaka, 1998; Nonaka & Takeuchi, 1996). Yet systematic and comparative workflow documentation is rarely applied to cottage industries. This gap limits the analytical visibility of cottage-industry production systems within broader production and sustainability research.

Building on this conceptual foundation, the present study adopts a process-focused embedded case study approach to examine handmade paper production within the Ali Mana cottage industry community. By documenting and comparing household-level workflows, the research investigates how informal production systems can be flexibly organised yet structurally coherent.

Previous studies have increasingly explored informal and small-scale production within the context of circular systems, distributed manufacturing, and resilience (N. Bocken et al., 2016 ; Geissdoerfer et al., 2018). These studies highlight the potential of decentralised production models in supporting adaptive and sustainable systems. However, they largely overlook the internal workflow structures that enable such adaptability at the micro-level. As a result, the process-level organisation of informal production systems remains insufficiently examined, particularly in relation to facilities management and future adaptive production frameworks.

3. Methodology

This study adopted a qualitative embedded case study approach to examine handmade paper production within the Ali Mana cottage industry community in Pahathahewahata, Kandy, Sri Lanka. The Ali Mana community was treated as a single case, with individual households (HH) functioning as embedded units of analysis. At the time of documentation, five households

were actively engaged in production within the community. As the study aimed to capture the complete operational structure of the production system, all active households were included, representing a total population sample rather than a subset selection. Treating the community as a single case with multiple embedded units enabled systematic comparison of production practices, while allowing identification of both shared structures and household-level variation.

3.1. DATA COLLECTION AND STAGE IDENTIFICATION

Production workflow in this study refers to the sequence of material transformations through which raw plant fibres are progressively converted into finished paper sheets within a household-level system. Production activities in each household were documented sequentially and organised into process stages.

Data were collected through two primary methods. First, sequential photographic observation captured material transformations, manual actions, tool use, spatial arrangements, and environmental conditions associated with each stage of production. This visual record enabled reconstruction of complete household-level workflows. Second, informal in-context discussions were conducted during production activities to clarify decision-making related to sequencing, material handling, tool selection, and environmental adjustments. These discussions supported the interpretation of observed practices without imposing formal interview protocols.

Documented workflows from each household were tabulated and compared based on functional similarity. Through cross-household comparison, production activities were grouped into eight shared stages: raw material harvesting, chopping, boiling, washing, blending, paper forming, drying, and finishing. While sequencing and techniques varied across households, this grouping provided a common analytical structure for subsequent comparison.

3.2 PROCESS MODELLING AND COMPARATIVE ANALYSIS

To enable structured representation and comparison, the eight identified production stages were modelled using the IDEF0 (Integration Definition for Function Modelling) functional framework. Each stage was analysed according to four parameters:

- Inputs: materials entering the stage
- Controls: experiential or contextual factors guiding actions
- Mechanisms: tools and labour enabling the process
- Outputs: resulting material transformation

All documented data were reorganised according to these stage-level parameters, allowing systematic comparison across households. This approach enabled the identification of elements that remained stable across cases as well as those that varied in execution.

Data analysis followed a qualitative comparative approach combining visual workflow reconstruction, stage-based classification, and parameter coding using the IDEF0 framework.

Observational data and discussion-based insights were interpreted iteratively to identify recurring patterns, which were then systematically compared across households to distinguish consistent and variable elements within each production stage.

3.3 STRUCTURED CONSISTENCY ASSESSMENT

To assess the degree of shared practice within each production stage, Inputs, Controls, Mechanisms, and Outputs were tabulated and coded according to observed frequency across households. Practices observed in all households were classified as highly consistent, those observed in some households as partially consistent, and those not observed as absent. Scores were aggregated to indicate the relative prevalence of shared and variable practices within each stage.

This structured comparison provided a systematic basis for evaluating patterns of stability and variation across the production workflow within a qualitative interpretive framework.

4. Results and Discussion

Field documentation confirmed that handmade paper production within the Ali Mana community is integrated into domestic household environments. Production relies primarily on manual labour, locally available plant material, specifically Ali Mana grass, an invasive species repurposed for productive use, and basic tools. No written procedural guides or formal operating instructions were observed, and knowledge transmission occurs through demonstration and practice.

Sequential documentation of household workflows revealed that although households (HH) described production using different numbers of steps, ranging from seven to sixteen, all workflows progressed from raw plant harvesting to finished dried paper sheets (Table 1). While task descriptions varied, comparison of material transformations revealed a shared underlying sequence.

Table 1, Household-level documentation of Ali Mana handmade paper production workflow

HH 01	HH 02	HH 03	HH 04	HH 05
Cut Ali Mana	Cut down the Ali Mana plant	Collect Ali Mana leaves	Prepare raw material	Harvest raw material
Collect into a basket	Cut Ali Mana into small portions	Prepare leaves (clean and sort)	Boil fibres	Chop fibres
Heat water in a barrel	Boil the cut pieces	Boil to soften fibres	Wash pulp	Boil fibres
Place the pieces into the barrel	Wash the boiled pulp	Add chemicals	Beat and mix pulp	Wash fibres
Add Caustic Soda	Blend with water and binder glue	Wash and clean pulp	Form sheets	Blend pulp
Remove the mixture and place it into a sleeve	Pour pulp into frames to form sheets	Blend pulp	Dry sheets	Prepare a water basin

HH 01	HH 02	HH 03	HH 04	HH 05
Add water and wash gradually	Add colours	Form sheets using frames	Finish and inspect	Prepare screen
Squeeze out excess water and form pulp balls	Dry the paper sheets	Press to remove excess water		Form a paper sheet
Add glue and water, and knead	Remove dried paper from frames	Dry sheets		Drain and flatten the sheet
Add colours	Flatten the dried paper	Trim and finish sheets		Dry sheet
Measure pulp and place it into frames				Remove sheets
Spread the mixture evenly across the frame				Trimming
Remove the frame and hold it vertically				
Hold at an angle to drain excess water				
Place in trays to dry				
Remove paper from frames				
16 stages	10 stages	10 stages	7 stages	12 steps

Although households described production using between seven and sixteen steps, comparative grouping of functionally similar activities revealed a consistent eight-stage material transformation sequence.

4.1. IDENTIFICATION OF SHARED PRODUCTION STAGES

Cross-household comparison and thematic grouping of functionally similar activities resulted in the identification of eight shared production stages:

1. Raw material harvesting
2. Chopping or initial preparation
3. Boiling or fibre softening
4. Washing
5. Blending or pulp preparation
6. Paper forming
7. Drying
8. Finishing

Despite differences in terminology and task breakdown, every documented workflow followed this sequence. Variation occurred within stages rather than between stages, indicating

that transformation logic remained consistent across households. Figure 1 illustrates an example IDEF0 representation of the production workflow.

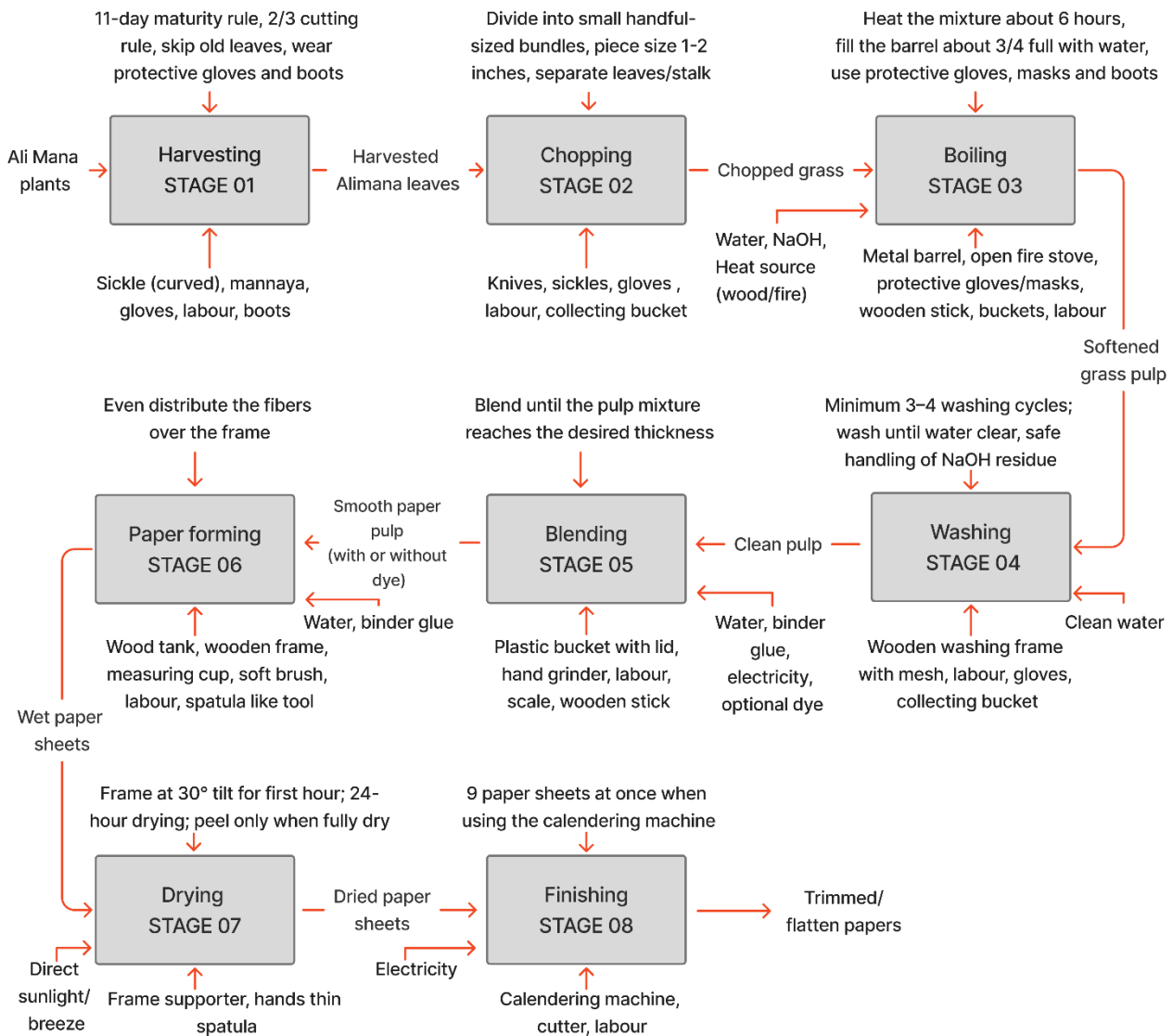


Figure 1, Example IDEF0 representation of the Ali Mana handmade paper production workflow

All documented workflows followed this shared material transformation sequence. Structural stability is concentrated in Stages 01–06, while greater variability appears in drying and finishing.

4.2 STAGE-LEVEL STRUCTURAL STABILITY (IDEF0 ANALYSIS)

Analysis using the IDEF0 parameters of Inputs, Controls, Mechanisms, and Outputs (Table 2) revealed clear patterns of structural stability across the workflow.

Across Stages 01 to 06 (harvesting through paper forming), Inputs and Outputs were fully consistent across households. All producers used Ali Mana grass as the primary input and produced intermediate outputs aligned with each transformation stage, culminating in wet paper sheets. Controls were primarily experiential, guided by sensory assessment of fibre maturity, pulp thickness, and washing clarity. While execution methods varied, particularly in tool selection and protective equipment use, the structural sequence of transformation remained stable.

Stages 07 (drying) and 08 (finishing) demonstrated greater variability. Drying practices adapted to local environmental conditions, such as sunlight intensity and breeze availability, while finishing practices, including trimming and calendaring, were selectively applied. However, this variation did not alter the fundamental production sequence.

Table 2, The identified eight-stage production workflow through IDEFO.

Inputs	Control parameters	Mechanisms	Output
Ali Mana material (5/5)	Wear protective gloves (1/5)	Protective Equipment	Harvested fibres (5/5)
Harvested fibres (5/5)	Wear protective boots (1/5)	Protective gloves (1/5)	Chopped fibres (5/5)
Chopped fibres (5/5)	Cut above the lower reinforced section of the stem (4/5)	Protective boots (1/5)	Softened pulp (5/5)
Water (5/5)	Divide into small, handful-sized bundles (5/5)	Harvesting Tools	Clean pulp (5/5)
Sodium hydroxide (NaOH) (5/5)	Cut into 3–6 cm lengths (4/5)	Sickle (3/5)	Smooth pulp (5/5)
Heat source (5/5)	Heat water for approximately six hours (4/5)	Mannaya (2/5)	Wet paper sheets (5/5)
Softened pulp (5/5)	Fill the barrel approximately three-quarters full of water (4/5)	Labour	Dried paper sheets (5/5)
Water (5/5)	Use protective gloves, masks, and boots (1/5)	One craftsperson (5/5)	Trimmed paper sheets (2/5)
Clean pulp (5/5)	Repeat washing three to four times until clean (4/5)	Two craftspersons (4/5)	Flattened paper sheets (1/5)
Binder glue (5/5)	Blend until the desired thickness is achieved (5/5)	Workforce composition: three women and two men	
Water (5/5)	Ensure even distribution and	Cutting Tools	
Dyes or pigments (3/5)		Fixed table-mounted knife	
Electricity (5/5)		Banku pihya (3/5)	
Smooth pulp (5/5)		Manna pihya (2/5)	
Water (5/5)		Collection & Handling	
Small amount of binder glue (1/5)		Collection bucket (5/5)	
Wet paper sheets (5/5)		Small buckets (5/5)	
Direct sunlight (2/5)		Plastic bucket with lid (5/5)	
Natural breeze (3/5)		Boiling Equipment	
Dried paper sheets (5/5)		Barrel (5/5)	
Electricity (1/5)		Wooden stick (5/5)	
		Washing Equipment	
		Wooden frame with mesh (4/5)	

Inputs	Control parameters	Mechanisms	Output
	correct thickness (5/5) Position at an angle to facilitate drainage (5/5) Place in mild sunlight (3/5) Process nine sheets at a time in the calendaring machine (1/5)	Blending Equipment Hand grinder (5/5) Scale (2/5) Wooden stick (1/5) Forming Equipment Wooden tank (5/5) Wooden frames (5/5) Measuring cup (5/5) Soft brush (1/5) Spatula-like tool (1/5) Frame support stand (2/5) Thin spatula (1/5) Finishing Equipment Calendaring machine (1/5) Cutter (2/5)	

The IDEF0 framework enables structured comparison of Inputs, Controls, Mechanisms, and Outputs across households without imposing formal standardisation.

4.3 STRUCTURED CONSISTENCY ASSESSMENT

Application of the structured consistency coding scheme confirmed these patterns (Table 3). Stages 01–06 exhibited high proportions of fully consistent elements, with paper forming emerging as the most structurally stable stage. Boiling, washing, and blending also demonstrated strong coherence in material inputs, transformation logic, and outputs. Drying showed moderate variability due to environmental responsiveness, while finishing exhibited the highest degree of flexibility and functioned primarily as a peripheral enhancement stage.

Table 3, Summary of structural stability and variation across production stages.

Stage	10 – Fully Consistent	8 – Largely Consistent	6 – Moderately Consistent	4 – Sporadically Observed	2 – Minimally Observed	0 – Absent	Interpretation
Harvesting	30%	10%	10%	10%	40%	0%	Core inputs stable, safety practices variable
Chopping	55.55%	11.11%	11.11%	11.11%	11.11%	0%	Strong workflow, minor tool variations
Boiling	61.53%	15.38%	0%	0%	23.07%	0%	High consistency, safety adaptation only

Washing	60%	30%	0%	0%	10%	0%	Highly stabilized stage
Blending	61.53%	0%	15.38%	15.38%	7.69%	0%	Stable technical stage, creative flexibility
Paper Forming	72.72%	0%	0%	0%	27.27%	0%	Most structurally stable stage
Drying	37.5%	0%	25%	25%	12.5%	0%	Environmentally adaptive stage
Finishing	25%	0%	0%	37.5%	37.5%	0%	Highly flexible, peripheral enhancement
Green = High consistency (10), Yellow = Moderate consistency (8, 6, 4), Red = Minimal or rare practices (2)							

Early fibre transformation stages demonstrate high consistency across Inputs and Outputs, while later stages show greater flexibility driven by environmental conditions and optional finishing practices.

Across all stages, early fibre transformation processes were dominated by fully consistent elements, while variation was concentrated in tool selection, safety practices, environmental adjustments, and finishing techniques.

4.4 DISCUSSION

The findings demonstrate that handmade paper production within the Ali Mana community operates through a coherent multi-stage workflow despite the absence of formal documentation.

First, the identification of eight shared production stages across all households indicates the presence of a stable transformation backbone. This challenges assumptions that informal systems lack organisation. Structural coherence exists at the level of material transformation, even when execution varies.

Second, variability observed within stages reflects adaptive practice rather than disorder. Differences in cutting tools, boiling duration adjustments, drying conditions, and finishing techniques illustrate context-responsive decision-making guided by experiential knowledge. These variations occur within stable transformation boundaries and do not disrupt the overall workflow sequence.

Third, the distribution of structural stability across stages reveals a layered production system. Core fibre transformation stages exhibit high consistency, while environmental and finishing stages allow greater flexibility. This layered configuration supports interpretation of

informality as a system characterised by stable transformation logic combined with adaptive execution.

Finally, the consistent presence of human labour across all stages underscores the role of embodied knowledge in maintaining production control. Sensory judgement rather than formal measurement governs decision making, yet outputs remain structurally aligned across households.

Overall, the results indicate that informal cottage industry production is not unstructured but flexibly organised. Structural stability and adaptive variation coexist within the same workflow system.

From a facilities management perspective, the findings highlight how decentralised, household-level production systems operate as micro-scale adaptive facilities, where spatial organisation, resource flows, and human decision-making are tightly integrated. The reuse of locally available invasive plant material and reliance on low-energy processes further align these systems with circular production principles. The documented workflow structure demonstrates how such systems can inform future adaptive and resilient production models within facilities management discourse.

5. Conclusion

This study examined whether informal cottage-industry production is structurally unorganised or merely undocumented. Through an embedded case study of handmade paper production within the Ali Mana community, the research identified a shared eight-stage workflow across five households. Although execution methods varied in tool use, environmental responsiveness, and finishing practices, the core material transformation sequence remained consistent across households. The findings demonstrate that informality in this context reflects undocumented structure rather than structural absence. When internal workflows are systematically analysed through process modelling and comparative assessment, a coherent production backbone becomes analytically visible. By applying structured workflow documentation and IDEF0 modelling, the study contributes a process-based understanding of cottage-industry production. This approach externalises tacit production logic without imposing industrial standardisation and positions informal production systems as structured and analysable within facilities management and sustainability research. More broadly, the study suggests that low-mechanisation, locally embedded, experience-guided production systems can embody both resilience and structural coherence. Recognising the layered relationship between stable transformation logic and adaptive execution is essential for integrating cottage industries into discussions of resilient and sustainable production systems.

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