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Environmental Scanning and Early Warning Against Counterfeit Heritage Textiles: Systematic Review and Conceptual Framework

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Abstract: Counterfeit and imitation goods have posed a persistent commercial threat to heritage textile industries, batik and ikat among a wider family of regionally distinctive crafts. Environmental scanning (ES) and early warning systems (EWS) would seem the natural instruments for meeting that threat, embedded as both constructs are within strategic management and supply chain risk scholarship. The difficulty lay elsewhere. Work applying them to counterfeit detection in heritage textiles had accumulated in scattered pockets across management, law and engineering, with little sustained exchange between them. This study accordingly undertook a systematic literature review pursuing four lines of inquiry, namely how ES and EWS were operationalised to surface counterfeit risk, which technological and procedural components sustained systems that produced usable alerts, what systematic scanning yielded relative to unsystematic monitoring, and which barriers obstructed deployment among small and medium sized enterprises (SMEs) in developing economies. A fifth aim drew the four together into a conceptual framework. Retrieval proceeded through the Consensus academic search engine, which aggregates Semantic Scholar, Scopus, PubMed and arXiv. Nine thematic clusters returned 179

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matched records, of which 90 unique records were screened in detail and 54 retained for narrative synthesis. Four patterns emerged. No system built expressly for heritage textile settings was found; the architectures encountered belonged to generic supply chain risk and brand protection frameworks, leaving the provenance concerns peculiar to heritage products unaddressed. Enabling technologies, among them RFID, blockchain, anomaly detection through artificial intelligence, and optical or fluorescent security materials, matured at considerable speed, yet their cost structures often placed them beyond the reach of artisan scale producers. Technological availability was less often the limiting factor than affordability and the capacity to implement and act on these technologies. The reviewed evidence consistently favoured systematic monitoring over ad hoc alternatives, although returns on protective investment were nonlinear. Adoption among SMEs stalled less on technical grounds than on the familiar triad of constrained finance, uneven digital literacy and thin institutional support, a pattern intensifying sharply in the Indonesian batik industry, where geographical indication and copyright registration among artisans remained sparse. The review advances a cooperative level conceptual framework that integrates scanning, early warning, affordability tiered technology, moderating conditions, and collective response pathways for heritage textile protection.

Keywords: Environmental Scanning; Early Warning System; Counterfeit Products; Brand Protection; Heritage Textile Industry;

1. Introduction

Heritage textile industries occupied an unusual position within the global economy. Batik in Indonesia, ikat weaving across much of Southeast Asia, and analogous craft traditions elsewhere circulated simultaneously as tradable commodities and as living vessels of intangible cultural heritage [1]. That duality carried a cost. It exposed these industries to a competitive threat with a very particular anatomy: the mass manufacture of textiles printed by machine, imitative in motif, marketed alongside authentic pieces and frequently mistaken for goods produced by hand or stamped by hand [2], [3], [4]. The distinction from ordinary counterfeiting is not merely semantic. Where a conventional fake mimic a specific branded article owned by a specific firm, imitation in the heritage textile sector appropriated a cultural expression held collectively by a community, and that collective ownership unsettled both the juridical remedies available and the commercial defenses a single producer might mount [5], [6].

Two management constructs bear directly on how firms and whole industries perceived such a threat and acted upon it before market damage became irreversible. The first, environmental scanning (ES), was defined as the systematic acquisition and interpretation of information concerning a firm's external environment [7], [8]. The second, early warning systems (EWS), referred to structured mechanisms that translated scanned signals into alerts that were timely and, more importantly, actionable [9], [10]. Scholarship on both constructs ran deep, anchored in strategic management and in supply chain risk research. Their extension to counterfeit and imitation risk within traditional, artisan-based textile industries, by contrast, was never

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consolidated in any systematic fashion. The relevant work instead accumulated inside at least four disciplinary silos that seldom communicated: strategic management, which theorized ES; supply chain engineering, which built EWS architectures and traceability technology; intellectual property law, which debated geographical indications and copyright; and marketing, which examined why consumers knowingly purchased counterfeits. To the authors' knowledge, no earlier review drew these strands together around the protection of heritage textile products specifically.

The omission is consequential on two fronts. Theoretically, it left open a question of transferability. ES and EWS frameworks were formulated largely with reference to large manufacturing concerns and financial institutions, and whether their logic survived translation into production contexts that were artisan in scale and culturally embedded in character remained unverified [11], [12], [13]. The practical deficit is arguably sharper. Policymakers and industry associations, those in Indonesia above all, were obliged to design protection mechanisms for batik and comparable crafts without a consolidated evidence base to draw upon. This review responds to that condition by synthesizing the dispersed literature with five objectives in view. The first is to map how environmental scanning techniques and early warning systems were implemented for the identification of counterfeit or imitation products across industries structurally comparable to traditional textiles. Building on that map, the second objective is to isolate the technological and procedural components that distinguished effective early warning systems from those that merely registered activity without producing usable alerts. The third is to evaluate the effect of systematic environmental scanning on counterfeit detection and mitigation, assessed against the reactive and unsystematic monitoring that prevailed in much of the sector. The review closes with a fourth objective, to identify the challenges and barriers that constrained deployment of both constructs, with particular attention to SMEs and artisan producers operating in developing economy contexts such as Indonesia's batik industry. A fifth objective followed from the other four: to draw their findings into one conceptual framework for scanning and early warning, oriented toward the scale at which heritage textiles are produced.

2. Materials and Method

PRISMA supplied the organising logic for this review, its four phases of identification, screening, eligibility and inclusion giving shape to the process throughout. Retrieval was adapted in one important respect. Rather than pursuing a comprehensive strategy across several databases, the search was conducted in a single session through one aggregating academic tool. What follows should accordingly be read as a rapid systematic synthesis, one that placed transparent and focused consolidation of the evidence ahead of exhaustive coverage. The design was intended to consolidate a body of work scattered across strategic management, supply chain risk, intellectual property and technology research.

2.1 Search Strategy

Records were retrieved through Consensus, an academic search engine indexing more than 200 million peer reviewed records aggregated from Semantic Scholar, Scopus, PubMed and arXiv.

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An early attempt to combine environmental scanning, early warning systems, counterfeiting and traditional textiles within a single query returned almost nothing of substance, a result that was itself diagnostic of the fragmentation described in the introduction. The search was accordingly decomposed into nine thematic clusters aligned with the first four objectives and with their theoretical antecedents (Table 1).

Table 1. Search clusters and records identified

Search cluster	Records found
Environmental scanning / early warning systems + counterfeit + textile / fashion	20
Environmental scanning, strategic management, competitive intelligence	20
Early warning systems in supply-chain risk management	20
Anti-counterfeiting strategy and brand protection management	19
Geographical indication and traditional-craft IP protection	20
Batik intellectual-property protection, Indonesia	20
RFID, blockchain, and AI-based counterfeit authentication technology	20
SME technology-adoption barriers, developing / emerging economies	20
Consumer counterfeit-purchase behavior, fashion	20

The nine thematic searches returned 179 matched records in total. The ten highest-ranked records from each cluster were carried forward for detailed screening, yielding 90 unique records.

2.2 Inclusion and Exclusion Criteria

Inclusion criteria**.** Four conditions governed entry into the corpus. Publication had to take the form of a peer reviewed journal article, peer reviewed conference proceedings, or a scholarly book chapter. The publication window ran from 2000 through 2026, though within the clusters oriented toward technology, priority went to work appearing from 2016 onward, a decision reflecting how quickly technological capability advanced; studies predating that threshold nonetheless remained eligible where the other conditions held. Substantive engagement with at least one of the first four review objectives was likewise required, whether the record addressed environmental scanning and systems for early warning or risk monitoring, the detection and mitigation of counterfeit and imitation products, brand protection, intellectual property protection for heritage products, or the

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barriers bearing on their implementation. Availability in English or Indonesian, accompanied by a retrievable abstract, completed the requirements.

Exclusion criteria. Records fell away on four grounds: absence of substantive relevance to the review objectives; confinement wholly to materials science or chemistry, with no managerial, organisational, or protection related bearing; duplicate or near duplicate reporting of a single study or dataset; and methodological detail too sparse to permit appraisal.

2.3 Screening and Synthesis

Of 90 unique records screened in detail, 54 met the inclusion criteria and were retained for narrative synthesis (Figure 1, described in text below in the absence of graphic rendering). Reasons for exclusion at the eligibility stage included: no substantive link to ES/EWS constructs (n = 14), materials-science focus without managerial framing (n = 9), duplicate or near-duplicate coverage of an already-included theme (n = 8), and insufficient methodological detail (n = 5). Included studies were coded thematically against the first four objectives. Narrative synthesis was the only defensible route here, since the corpus mixed conceptual argument, qualitative case study, survey research analysed through structural equation modelling, and technical design papers, a spread of designs that ruled out meta-analytic pooling. A second step addressed the fifth objective. Components recurring across the coded material were extracted, examined for how they related to one another, and assembled into the conceptual framework presented in section 3.5. Derivation was inductive. Nothing in the framework was fixed in advance, and while its components came from the reviewed evidence, their arrangement rested on relations no single study could state, since none covered all four preceding objectives at once.

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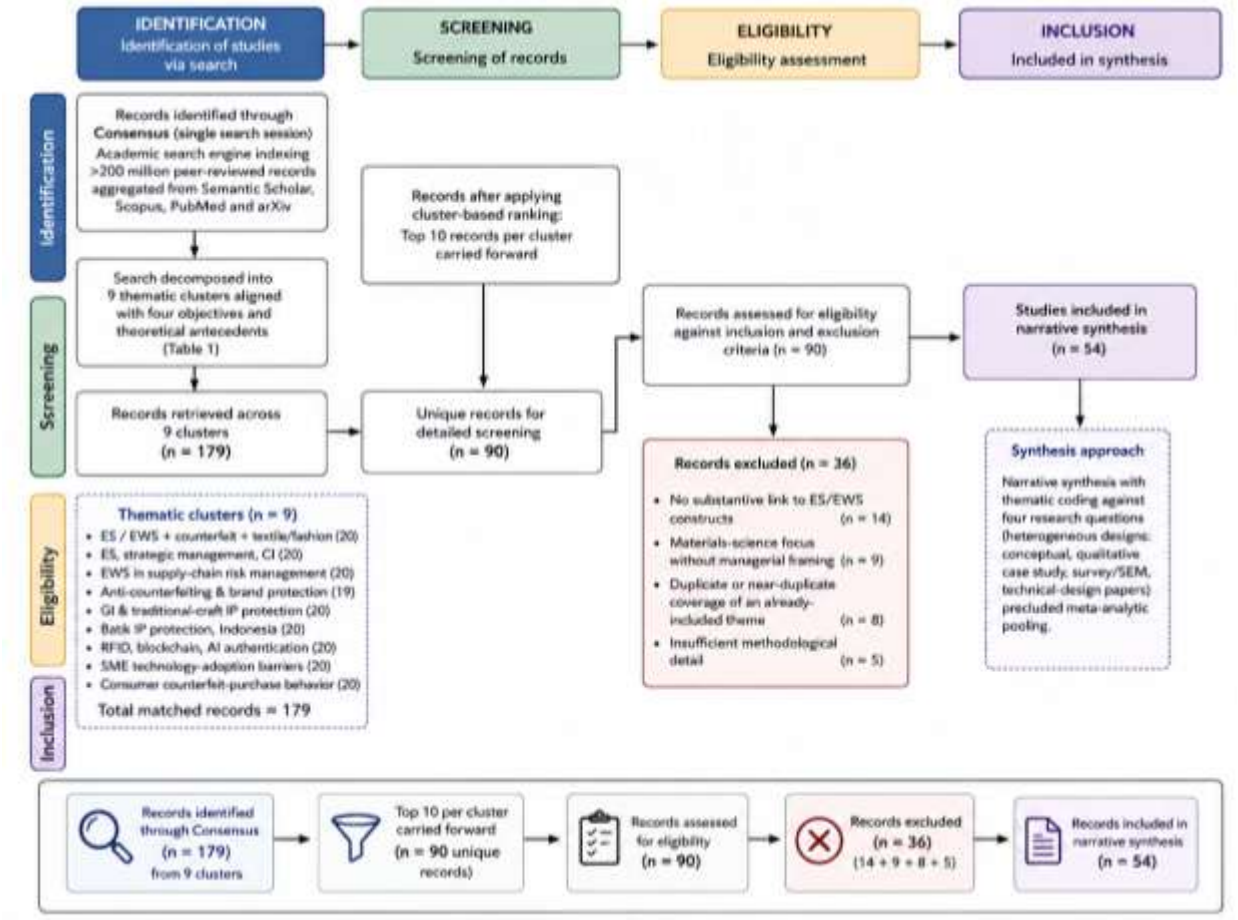

Figure 1. Study selection flow following the general logic of PRISMA flow from 179 identified records to 54 included studies.

3. Results and Discussion

3.1. Implementation of Environmental Scanning and Early Warning Systems

Environmental scanning described the sustained acquisition and interpretation of information about events and trends in the external environment of a firm, undertaken so that strategic choices rested on evidence rather than [14], [15]. The construct seldom appeared in isolation. It nested inside competitive intelligence, the broader organizational function devoted to collecting and analysing information on rivals and market [16]. A considerable body of empirical work tied the frequency and scope of scanning to organizational performance and to the capacity of a firm to keep its competitive strategy aligned with a shifting environment [17], [18]. Later contributions carried the construct into supply chain settings and sharpened the causal story considerably, since scanning activity converted into performance gains chiefly through integration and responsiveness

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along the chain rather than through the sheer regularity with which managers looked outward [19]. Reviewing the field on its own terms, Robinson and Simmons [20] found scanning research fragmented and the place of digital technology within it thinly theorised. That observation bears directly on the present problem. Imitation products now surface first on online marketplaces, social platforms and commerce listings, which locates the counterfeit signal precisely where scanning theory remained least developed.

Across the corpus, implementations situated in industries structurally comparable to traditional textiles, meaning small manufacturers and enterprises dependent on longer and more fragmented chains, were organised around external environment frameworks, with PESTEL applied from the top down to surface weak signals across political, economic, social, technological, environmental and legal dimensions [21]. The pattern of association reported was itself informative: breadth of sectors monitored predicted downstream strategic alignment and performance more reliably than raw scanning frequency [22]. Scope mattered. Repetition, on its own, did not. At the level of the chain, scanning entered an interpretive sequence in which a signal acquired value only once it had been read, acted upon and absorbed into operational routine [23].

Early warning implementations clustered elsewhere. Supply chain risk [24], [25], food safety [26] and disaster [27] supplied nearly every operational architecture encountered, typically fusing data drawn from several sources, training machine learning classifiers on that fusion and, in the more recent designs, anchoring event logs in blockchain so that their integrity survived scrutiny [28]. Alerts were issued in real time or close to it. Nothing in the reviewed corpus, though, described a system built expressly to monitor the proliferation of counterfeit motifs within a traditional or heritage textile industry. The deficit was one of adaptation rather than of theory, since the constituent components already existed and had been validated repeatedly; they had simply never been assembled for this class of asset.

3.2. Technological and Procedural Components of Effective Early Warning Systems

Where scanning performed the sensing, early warning performed the translation, converting a detected signal into a timely alert and, in the more mature designs, into a triggered response [29]. The generic architecture proved unusually portable, moving across risk types with little structural modification: sense, fuse, predict, alert. Portability of architecture is not, however, portability of instrumentation, and it was at the level of instrumentation that the brand protection literature contributed most.

Three technological layers recurred. The first concerned identification and tagging, with RFID predominant, furnishing unique identifiers readable by machine and verifiable at multiple touchpoints along a chain [30], [31]. The second concerned distributed ledgers. Blockchain supplied an immutable record of ownership and transaction history and thereby addressed a well-documented weakness of tagging alone, namely the ease with which tags were cloned once goods departed the primary chain [32], [33]. Reviews that considered RFID, blockchain and artificial intelligence jointly treated the three as complements rather than substitutes, assigning physical

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layer identification to the first, integrity of the data trail to the second, and anomaly detection across high transaction volumes to the third [34], [35]. The third layer emerged from materials science and grew rapidly during the review window. Fluorescent and luminescent markers woven or coated directly onto fabric permitted authentication by eye or by handheld scanner, dispensing with dedicated infrastructure altogether [36], [37] . For artisan producers the attraction is plain, since the security feature travels with the cloth itself.

Technology, taken alone, settled little. Studies drawing on practitioner samples insisted that detection capability yielded value only where it met defined organizational functions, meaning teams with explicit mandates, performance metrics against which their work could be judged, and escalation routes crossing legal, marketing and supply chain units [38], [39]. Effectiveness thus depended on two conditions holding simultaneously: the technical ability to see, and the organizational discipline to act on what was seen. The distinction separating a functioning early warning system from one that merely registered activity lay in the second condition rather than the first, since detection unaccompanied by a mandate to escalate produced records instead of alerts.

3.3. Systematic Scanning against Sporadic Monitoring

On direction the evidence was unambiguous, though on magnitude it was anything but. Firms that embedded brand protection across functions, an arrangement this literature termed a total business solution, reported materially higher perceived success in suppressing counterfeit sales than firms that consigned the problem to one legal or security unit reacting after the fact [40], [41]. Case evidence from a multinational manufacturer added useful texture. Seizure operations were concentrated where consumer safety exposure ran highest, which suggested that systematic monitoring functioned less as an instrument for pursuing every infringement uniformly than as a triage mechanism steering scarce enforcement capacity toward the most damaging instances [42].

The qualification arrives from formal modelling. Analyses grounded in game theory described a relationship between protective investment and producer profitability that was decidedly non-monotonic. Past a certain threshold, further spending on detection or heavier statutory penalties left the authentic producer worse off, because counterfeiters simply redirected effort into adjacent segments that nobody was watching [40], [43], [44]. For producers operating under tight resource ceilings the implication is precise rather than discouraging: the literature endorsed systematic in preference to sporadic scanning, and it declined to endorse unbounded expenditure on detection technology.

A branding argument ran alongside the technical one and complicated it further. Identity elements such as logos and marks were copied with ease, whereas relational meaning accumulated between producer and community resisted duplication, which pushed strategic emphasis toward collaborative, stakeholder-based approaches that technical detection could support but never replace [45]. Heritage textiles sharpen this observation considerably. Their vulnerability was structurally unlike that of branded consumer goods, since protection rested on collective, community held rights rather than on a single corporate mark, and prevailing geographical indication and copyright regimes had been drafted with individual, documented and registrable

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authorship in view rather than with knowledge transmitted orally and authored in common [46], [47], [48]. In Indonesia the consequence was legible in the filing statistics. Batik motifs enjoyed nominal recognition as cultural heritage, yet geographical indication and copyright registration among artisans remained chronically sparse [49], [50], [51], [52].

3.4. Challenges and Barriers to Deployment

Financial constraint dominated the adoption literature. Absence of capital, together with the high relative cost of digital infrastructure, ranked consistently as the principal obstacle facing enterprises in developing economies [53], [54]. Digital literacy and managerial capability followed closely behind and were compounded by thin institutional and governmental support [55], [56]. A systematic mapping of twenty-one reviews on technology adoption among smaller firms in developing countries recovered the same obstacles across widely varying contexts, naming managerial resistance, fragmented policy support and limited literacy as the recurrent triad [57], [58], [59], [60].

One further barrier belonged to heritage industries alone, and it was structural rather than financial. Traditional knowledge was transmitted orally and held collectively, a mode of custodianship fundamentally incompatible with intellectual property and geographical indication systems constructed around identifiable individual creators and documentary proof of origin [48], [51]. Field evidence from batik producing communities in Girilayu, Kei and Tanjung Rejo, and from craft sectors eligible for geographical indication elsewhere including Kasongan pottery, Balinese ikat weaving and Indian handicrafts, converged on a single pattern: legal protection existed on paper while registration rates stayed low, held down by cost, procedural complexity, limited artisan awareness and weak local institutional capacity to shepherd applications through [52], [61], [62], [63].

Demand supplied the final complication, and arguably the most stubborn. Purchase intention toward counterfeit fashion, in Indonesia as in comparable markets, was driven substantially by price consciousness and social influence rather than by any failure to recognise inauthenticity [64], [65], [66]. Buyers, very often, knew. Detection and legal protection pursued in isolation from consumer education were therefore improbable candidates for clearing the market of imitation cloth.

3.5. Synthesis and Implications

Read across the first four objectives, the conceptual infrastructure required to protect heritage textiles from imitation risk already existed, though it lay distributed across strategic management, supply chain engineering, intellectual property scholarship and marketing. What had never existed was an assembly of the four. Figure 2 proposes one.

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Figure 2. Cooperative scanning and early warning framework for heritage textiles

The framework traced a passage from the moment imitation appeared to the moment a community answered it. Three channels carried the initial signal: digital marketplaces, physical trading venues, and the geographical indication and legal records that established who could assert a claim in the first place. Holding all three within one surveillance perimeter was a deliberate choice rather than an administrative convenience, since breadth of coverage, more than diligence applied to any single channel, governed whether shifts in the environment and the threats accompanying them were registered at all [20], [67]. What the channels yielded was then worked collectively through four interlocking functions of sensing, fusion, prediction and alerting. Those functions were sited at cooperative or association level for a reason that admits little argument: an individual artisan cannot sustain the whole sequence unaided [19], [38].

Supporting instruments were ranked by cost rather than by sophistication. A low-cost layer encompassed registration and shared surveillance; a middle layer employed optical markers applied to the textile itself; an upper layer gathered RFID, distributed ledgers and artificial intelligence trained on anomaly detection. Two considerations drove that ordering, the first being the capital ceiling under which artisan producers operated, the second the finding that additional protective investment did not translate into proportionate benefit beyond a certain point [35], [54]. Technological capability, taken by itself, settled nothing about whether an alert would ever become an act.

Conversion depended instead on a set of moderating conditions: available capital, digital literacy, institutional capacity, and the collective rights and coordination underpinning any claim. None of these generated signals and none consumed them. They determined whether a warning acquired practical consequence. An alert accordingly issued in enforcement triaged by the severity of damage, in a collective claim, in consumer education, or in nothing whatever when the requisite capacity was absent [51], [56]. Outcomes were then assessed and fed back into the scope of subsequent scanning, closing the framework into a cycle of continuous learning and improvement.

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Two implications followed. The logic of detection transferred to heritage textile industries, yet its operating unit did not survive the journey intact and had to migrate from the individual enterprise toward the community, the cooperative, or the association. Scanning capacity became a shared resource, built and maintained in common. That reading sits comfortably with the collective character of the cultural asset under protection, and it displaces the theoretical question from how a firm scans its environment toward how a community coordinates a monitoring capability no single artisan could plausibly finance [23], [61]

The second implication concerns sequence, or rather its absence. Monitoring and legal registration had to proceed in parallel. Registration unaccompanied by monitoring left a community unable to detect infringement with any reliability, while monitoring unaccompanied by registration eroded the legal footing on which a claim might rest. This interdependence goes some way toward explaining the distance between statutory and practical protection in the Indonesian batik industry, and it locates responsibility with associations and policymakers charged with building an integrated system rather than with producers acting singly [49], [51], [52]. The framework nonetheless remained conceptual. Its components drew support from research in adjacent contexts; their integration within a heritage textile setting still awaits empirical validation.

4. Conclusion

This review synthesised 54 studies on environmental scanning, early warning systems, and protection against imitation, read for what they offered heritage textile industries such as Indonesian batik. The evidence itself proved solid: both constructs were mature within strategic management and supply chain settings, detection technology advanced quickly, and systematic monitoring outperformed reactive monitoring wherever the two were compared. Barriers of capital, literacy and institutional capacity nonetheless persisted among artisan producers holding rights collectively. What no study offered was an assembly of these parts. The framework advanced here closed that gap, and its novelty lay not in the components, nearly all inherited from the reviewed evidence, but in three decisions about how they related: the operating unit moved from the firm to the cooperative, since the asset under threat belonged to a community; instruments were ordered by affordability rather than sophistication; and adoption barriers were positioned as conditions governing whether an alert ever became an act.

Empirical validation is the work that follows. Longitudinal research with artisan cooperatives across heritage textile settings would establish whether the model holds at that scale, comparative enquiry among craft sectors sharing the collective rights problem would show how far it travels beyond the traditions examined here, and measuring the rate at which imitation propagates online would supply a figure no reviewed study reported.

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Declaration on the Use of Generative AI and AI-Assisted Technologies

During the preparation of this manuscript, the authors used Claude AI (Anthropic) and ChatGPT (OpenAI) in order to refine language and improve readability, and to assist in preparing the visual rendering. The conceptual framework itself, including its components, structure, and underlying propositions, was developed by the authors from the synthesised literature

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