

Techno-Institutional Fit In Aceh Patchouli Downstream Industry: Technology Absorptive Capacity And Cooperative Pentahelix Innovation Ecosystem

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Abstract

This conceptual study develops a techno-institutional fit model for cooperative-based downstream development of patchouli oil in Aceh, Indonesia. It asks how collaboration among innovation actors could support the organizational learning required to translate technology access into downstream value. The study synthesizes the institutional narrative reported for Aceh's patchouli industry with absorptive-capacity and pentahelix literature. Its evidence consists of reported planning priorities, stakeholder labels, and descriptions of value-chain constraints, rather than independently audited implementation records or cooperative-level measurements. The synthesis identifies four analytical themes: interdependent technical and institutional constraints; a planning sequence linking institutional development and processing innovation; differences in stakeholder classification; and insufficiently specified responsibilities for cooperative learning. Differences between actor labels do not, by themselves, establish the exclusion of cooperative members, while counts of assigned tasks cannot establish institutional effectiveness. The proposed model links pentahelix collaboration to knowledge acquisition and assimilation, then to transformation and exploitation, with techno-institutional fit supporting the conversion of knowledge into organizational practice. Three propositions specify relationships for subsequent empirical investigation. The contribution is a bounded explanation of how cooperative

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learning routines, member representation, and complementary actor responsibilities could connect innovation support to downstream outcomes. Policy implications emphasize pairing suitable technical investment with capacity-building and accountable follow-up, rather than replacing technical intervention with additional administrative mandates. The model remains a conceptual proposition requiring verification against authenticated documents and cooperative-level evidence.

Keywords : Absorptive Capacity; Pentahelix Innovation; Patchouli Cooperative; Techno-Institutional Fit; Agroindustry Downstreaming

INTRODUCTION

Patchouli oil downstream development in Aceh raises a problem that extends beyond access to processing equipment: how can external knowledge and multi-actor support become repeatable organizational practices that create value for producers? The institutional account cited as Muhammad (2023) places cultivation, processing, marketing, and supporting institutions within a connected industry-development agenda. This paper uses that reported agenda to examine the interface between technology and cooperative organization, without treating planning statements as evidence of completed implementation.

The reported industry diagnosis includes difficulties obtaining certified planting material, inconsistent cultivation and raw-material management, inefficient distillation, variable product quality, limited development of derivative products, and underutilized processing residues. It also identifies weaknesses in coordination, infrastructure, financing, regulation, and research support (Muhammad, 2023). Together, these descriptions motivate an institutional interpretation of downstream development. They do not establish the prevalence of each problem, its persistence at the time of writing, or a single cause common to all cooperatives.

Published research provides complementary, although case-specific, evidence for examining this organizational dimension. Zikri et al. (2022) report that cooperation and solidarity were particularly weak components of empowerment among the patchouli farmers they surveyed in Aceh Jaya. Their findings concern farmer-level associations, not a causal test of cooperative learning. Using an analytical hierarchy process, Cantika et al. (2022) identify human-resource quality, transparent partnerships, and integrated access to technology and information as relevant priorities for patchouli agroindustrial institutions in the same regency.



Market and supply-chain studies also show why downstream value should not be reduced to installed processing capacity. Vonna et al. (2020) identify the farmer-cooperative-exporter-consumer channel as the most efficient of the channels they examine, based on marketing margins and farmers' share. Ulya et al. (2026), in an exploratory case involving the PP NILAS Cooperative and PT Ugreen, report traceability gaps and limited smallholder documentation. These studies motivate attention to organizational routines and market coordination; neither tests the absorptive-capacity pathway proposed here.

Institutional responses also appear in the planning narrative. The ARC-PUI Nilam Aceh Roadmap 2017-2027 reportedly emphasizes network strengthening, while the Aceh Patchouli Industry Roadmap 2020-2030 connects institutional and business-system development with processing innovation and subsequent market development. Secondary-cooperative formation and innovation-cluster development are presented as planning priorities (Muhammad, 2023). Their inclusion indicates intended directions, not independently verified legal obligations, implementation achievements, or organizational performance.

The conceptual issue is therefore not simply whether collaboration is desirable. It is how a cooperative could acquire external knowledge, make it understandable to members, adapt it to local operations, and use it consistently. Absorptive-capacity theory addresses these organizational learning processes (Cohen & Levinthal, 1990; Zahra & George, 2002), whereas pentahelix approaches draw attention to relationships among different innovation actors (Calzada, 2020). This paper proposes that connecting the two perspectives can clarify responsibilities that remain indistinct when policy discussion focuses only on equipment provision or organizational formation.

The study asks how reported institutional arrangements can be interpreted in relation to cooperative absorptive capacity, and what relationships should be specified in a techno-institutional fit model. Its contribution is a context-specific conceptual synthesis, not a claim to have established the first such model or demonstrated a causal mechanism. The cooperative is the focal organizational unit; regional roadmaps provide its institutional context. This distinction prevents regional expansion or policy activity from being treated as a direct measure of cooperative learning.



LITERATURE REVIEW

Cohen and Levinthal (1990) conceptualize absorptive capacity in terms of recognizing the value of external information, assimilating it, and applying it commercially. Their account emphasizes the relevance of prior knowledge and organizational learning. Zahra and George (2002) subsequently distinguish four processes: acquisition, assimilation, transformation, and exploitation. Acquisition and assimilation constitute potential absorptive capacity, while transformation and exploitation constitute realized absorptive capacity. The four-process formulation used here is therefore attributed to Zahra and George, rather than directly to Cohen and Levinthal.

The distinction between potential and realized capacity also matters for organizational design. Jansen et al. (2005) report different associations of coordination and socialization mechanisms with the two dimensions, indicating that access-oriented arrangements and internal integration should not be treated as interchangeable. Arndt et al. (2023) further emphasize the multidimensional, ongoing nature of knowledge absorption and the contribution of individuals and their coordination. These perspectives support examining learning routines rather than assuming that equipment acquisition is a sufficient proxy for absorptive capacity.

For this paper, cooperative technology absorptive capacity means the collective ability to obtain relevant technical knowledge, develop a shared understanding of it, adapt it to the cooperative's circumstances, and incorporate it into recurring operations. Illustrative routines include discussing technical guidance, comparing processing experiences, adapting operating procedures, and reviewing production records. These are proposed analytical indicators, not activities demonstrated to exist in the Aceh cooperatives. Werlang and Fiates (2026), whose study concerns rural producers integrated into a Brazilian agroindustrial company, provide a comparative setting for examining absorptive capacity, but not direct evidence about Aceh's cooperative institutions.

Pentahelix is not treated as a universally fixed set of organizational labels. Calzada's (2020) formulation includes public and private actors, academia, civic society, and social entrepreneurs or activists. The Aceh cluster-planning configuration reported in the case narrative instead includes community, academia, government, business, and media (Muhammad, 2023). The latter is used as the contextual classification in this paper. Calzada provides a perspective on



multistakeholder relationships and intermediation, not a warrant to equate these two classifications.

A functional interpretation of collaboration is also supported by agricultural innovation research. Klerkx and Leeuwis (2008) examine intermediary functions that connect farmers' needs with knowledge and service providers, including demand articulation and partner matching. Kilelu et al. (2013) show how innovation platforms in a Kenyan smallholder dairy programme involve continuing alignment of technical and institutional change rather than coordination at a single meeting. More recently, Cholez et al. (2023) identify heterogeneous collaboration arrangements and forms of farmer involvement in agrifood sustainability-oriented innovation. Together, these perspectives justify distinguishing the presence of partners from the functions they perform.

Related agricultural literature supports examining institutional connections without establishing the proposed mechanism in Aceh. Rosiana et al. (2025) use a descriptive qualitative pentahelix approach to develop an institutional model in Girirejo Village; their discussion of information access and productivity should not be read as an identified causal effect. Astrima et al. (2025) connect agrifood supply-chain innovation with human-resource capacity, infrastructure, and collaboration. Anggraeni et al. (2018) likewise situate processing innovation within interactions among innovation actors. These studies inform the synthesis but differ in sector, organizational form, and evidentiary design.

Closer to this study's own institutional setting, Lubis and Simanullang (2026) examined how business partnerships shape farmer empowerment among Arabica coffee smallholders in two cooperatives in Tapanuli Selatan, North Sumatra, finding that the partnership effect on empowerment operated partly indirectly, through improvements in farmer capability, rather than through the presence of a partnership alone. Although patchouli and coffee differ as commodities, this finding from a structurally similar Indonesian smallholder-cooperative setting supports treating capability, not the mere existence of a partnership or institutional mandate, as the operative mechanism connecting institutional support to farmer-level outcomes, consistent with this paper's absorptive-capacity framing.

Agricultural cooperative governance adds a further distinction between participation in innovation networks and control within the enterprise. Bijman et al. (2014) examine changes in European cooperatives' internal governance, including the relationship between member control and professional management. Their findings motivate attention to accountability and member



representation, while not establishing how Aceh cooperatives are governed. In this model, organizational learning and member control are complementary analytical concerns rather than interchangeable indicators.

Techno-institutional fit is defined here as the alignment between a technology's operating requirements and the responsibilities, support resources, and accountability arrangements needed for a cooperative to learn and use it. Absorptive capacity describes what the organization can do with knowledge; fit describes whether its institutional arrangements support those activities. Downstream value realization is a separate outcome, potentially reflected in product consistency, processing efficiency, market access, and benefits retained by members. Neither cooperative registration nor equipment ownership alone is defined as evidence of these outcomes. This definition is informed by systemic approaches to agricultural innovation that emphasize interactions between technical change and its institutional context (Wigboldus et al., 2016). It remains a construct proposed for this synthesis, not an independently validated scale for patchouli cooperatives.

RESEARCH METHOD

The study is a qualitative, document-informed conceptual synthesis. It draws on principles of document analysis and directed content analysis to relate reported institutional material to explicit theoretical categories (Bowen, 2009; Hsieh & Shannon, 2005; Krippendorff, 2018). It does not present a new field survey, an exhaustive systematic literature review, or a statistically tested model. The purpose is to formulate a transparent interpretive framework and propositions whose validity can subsequently be examined. Following Jaakkola's (2020) guidance on conceptual articles, the design combines theory synthesis with model development: absorptive capacity supplies the learning mechanism, pentahelix supplies the actor perspective, and cooperative governance specifies representation and accountability.

The case narrative is attributed to Muhammad (2023), including descriptions of the ARC-PUI Nilam Aceh Roadmap 2017-2027, the Aceh Patchouli Industry Roadmap 2020-2030, the Stakeholders Analysis, and the Klaster Inovasi Nilam Aceh diagram. These elements are treated as a related institutional source family. Supplementary agency documents and national statistical releases are not treated as a separately verified corpus because complete bibliographic identifiers, versions, and source locations are not established in the available material. The literature supplies theoretical concepts and comparative arguments, while published Aceh



studies provide contextual evidence on empowerment, partnership priorities, marketing, and traceability (Cantika et al., 2022; Ulya et al., 2026; Vonna et al., 2020; Zikri et al., 2022). Their findings are used as published evidence, not reanalyzed primary data or independent verification that the roadmap's planned activities were implemented.

The supplementary literature is selected purposively for its relevance to Aceh's patchouli value chain, cooperative governance, agricultural innovation intermediation, and the definition or measurement of absorptive capacity. Foundational works are combined with recent research to support and qualify the propositions. This targeted synthesis does not claim comprehensive coverage of all published studies.

The units of interpretation are reported statements about value-chain constraints, planning priorities, actor categories, and assigned functions. The synthesis makes three analytical moves: it groups the reported constraints by their place in the value chain; compares actor labels through a common functional classification; and connects the resulting institutional questions to the four absorptive-capacity processes. It separates reported documentary content from the author's theoretical interpretation and from proposed policy actions. An activity is not assigned to a learning process solely because a particular agency is named.

The actor comparison distinguishes the source label from its possible functional equivalent. Government and the regional legislature are considered related public-governance actors, without assuming identical roles. An NGO label may indicate civic participation but does not automatically establish representation of cooperative members. Similarly, a cooperative may exercise both member-representation and business functions. These distinctions avoid interpreting every difference in diagram labels as a substantive governance contradiction.

No page-indexed extraction matrix, complete task register, or independently authenticated versions of the planning diagrams are available in the material supporting this synthesis. Consequently, exact task-frequency comparisons are not used as validated findings. The analysis does not claim intercoder reliability, field validation, or independent triangulation across the related institutional documents. Its credibility rests on bounded claims and explicit alternative interpretations; verification of the underlying source passages and implementation records remains necessary.



RESULT

The conceptual synthesis produces four analytical themes. They are interpretations of the reported case narrative, not measurements of cooperative performance or an independently replicated assessment of public-agency effectiveness.

First, the reported constraints are interdependent across the value chain. Upstream issues concern planting material and cultivation; processing issues concern distillation, raw-material handling, and quality consistency; downstream issues concern product development and residue utilization. Coordination, infrastructure, financing, and research support cut across these activities (Muhammad, 2023). This organization of the material motivates examining technical and institutional conditions together. It does not demonstrate that every technical problem originates in an institutional failure.

Second, the reported roadmap sequence connects organizational preparation with subsequent technological and commercial ambitions. Network strengthening appears in the ARC-PUI roadmap, while the industry roadmap places institutional and business-system strengthening in the 2020-2024 planning phases before proposed processing innovation in 2024-2026 and later market development (Muhammad, 2023). These dates identify planned phases. They do not establish whether earlier targets were completed or later activities actually followed the proposed sequence.

Third, the reported actor classifications differ. The cluster diagram lists Masyarakat, Perguruan Tinggi, Pemerintah, Dunia Usaha, and Media. The stakeholder diagram instead lists Pemerintah, DPRD, Pengusaha/BUMN, Akademisi, and NGO (Muhammad, 2023). A preliminary crosswalk relates Pemerintah and DPRD to public governance, the two business labels to business functions, and Perguruan Tinggi and Akademisi to academic functions. NGO may relate to civic participation, but its relationship to cooperative membership requires verification. Media is not explicitly identified in the second reported list. The defensible finding is therefore a need to clarify functional equivalence and representation, not proof that cooperative members have been excluded.

Fourth, the reported task examples leave the coverage of cooperative learning responsibilities unclear. The Industry and Trade Office (Disperindag) is associated with equipment provision, quality-control training, and packaging support; the Cooperatives Office (Diskop) is associated with skills development and cooperative formation (Muhammad, 2023). These functions are not directly comparable by counting their mentions. A short task description may



cover substantial work, and a technical training assignment may also support assimilation. Without the complete task list, joint-assignment rules, resources, and implementation evidence, the material supports asking who is responsible for continuing cooperative learning, but not concluding that mandate numbers measure institutional neglect.

DISCUSSION

The four themes suggest a conceptual problem of connection rather than a demonstrated absence of technology or policy attention. The model proposed here links pentahelix collaboration to cooperative potential absorptive capacity, then to realized absorptive capacity and downstream value realization. Techno-institutional fit is proposed as an enabling condition for translating learning opportunities into organizational practice. This is an analytical synthesis of the case narrative and theory; the direction and strength of its relationships remain untested (Calzada, 2020; Cohen & Levinthal, 1990; Zahra & George, 2002).

The mechanism can be illustrated without assuming it has been observed in Aceh. Acquisition involves identifying relevant processing knowledge and obtaining access to it. Assimilation involves members and operators understanding why a procedure matters. Transformation involves adapting that knowledge to available equipment, raw materials, skills, and working arrangements. Exploitation involves incorporating the adapted procedure into recurring production and business routines. Delivery of a machine does not establish that all these processes have occurred, while regional cultivation growth does not directly measure any one of them. These distinctions translate the learning framework into an organizational proposition rather than a diagnosis of measured deficiencies. The stages are analytical distinctions rather than a claim that learning always follows a fixed, one-way sequence; a process perspective allows for recurring adaptation over time (Arndt et al., 2023).

Proposition 1 (P1): More coherent pentahelix collaboration is expected to support cooperative knowledge acquisition and assimilation when partner roles are complementary and cooperative members have meaningful opportunities to communicate their needs. The proposed relationship concerns the quality of knowledge exchange, not the number of actors named in a diagram, drawing on the distinction between intermediary functions and organizational coordination mechanisms (Jansen et al., 2005; Klerkx & Leeuwis, 2008). The Aceh actor-label differences motivate examining this relationship; they do not verify it.



Proposition 2 (P2): Potential absorptive capacity is expected to contribute to downstream value realization through transformation and exploitation routines, rather than through information access alone. This is a proposed mediated pathway, not a demonstrated mediation effect. Its theoretical basis is the separation of potential and realized capacity and their organizational antecedents (Jansen et al., 2005; Zahra & George, 2002). It would be weakened if comparable cooperatives realized similar outcomes without such routines, or if access to suitable equipment explained outcomes independently of the proposed learning processes.

Proposition 3 (P3): Stronger techno-institutional fit is expected to strengthen the conversion of potential into realized absorptive capacity when responsibilities, support resources, and follow-up arrangements match the learning demands of the technology. Fit is thus proposed as a conditioning relationship, not an additional outcome inferred from successful performance. Testing it would require measuring institutional arrangements separately from organizational learning and downstream results. This expectation draws on the need to align technical and institutional change in agricultural innovation (Kilelu et al., 2013; Wigboldus et al., 2016). However, Pertiwi et al. (2024) find that integration mechanisms do not uniformly strengthen the potential-to-realized relationship. P3 therefore concerns the appropriateness of specific arrangements, not the assumption that more coordination is always better.

The governance implication is to examine functional coverage rather than seek equal task counts across agencies. A cooperative-learning responsibility could specify who supports operator understanding, who assists with procedure adaptation, who maintains shared records, and who reviews recurring problems. The Regional Development Planning Agency (Bappeda), Diskop, Disperindag, universities, and business partners could agree on complementary contributions with cooperative representatives. This is a proposed coordination arrangement, not a statement of their verified statutory assignments or an assertion that such arrangements are currently absent. The proposal is consistent with intermediary functions and adaptive facilitation discussed by Klerkx and Leeuwis (2008) and Kilelu et al. (2013).

Cooperative participation also needs a clearer meaning than an organizational label. The proposed model requires distinguishing member voice from external representation and cooperative ownership from program administration. Members should be able to articulate technology needs, consider operating costs, and review the distribution of benefits and responsibilities. Secondary-cooperative formation could support shared services, but its usefulness would depend on these functions rather than on formation alone. This reasoning does



not assume that an NGO, a government agency, or a commercial partner automatically represents cooperative members. This emphasis on member control and managerial accountability is informed by cooperative-governance research (Bijman et al., 2014).

Operationalization would keep learning indicators separate from performance indicators. Acquisition could be examined through the relevance and accessibility of knowledge sources; assimilation through operators' understanding of procedures; transformation through documented adaptations; and exploitation through consistent use of those procedures. Potential downstream outcomes include product-quality variation, nonconforming batches, processing cost per unit, repeat market transactions, and benefits returned to members. Fuel use per unit of output and the handling or productive use of residues could be assessed where sustainability claims are made. These are suggested measures for subsequent research, not results or validated scales reported by this study.

Flatten et al. (2011) provide a four-dimensional absorptive-capacity instrument, but applying it to patchouli cooperatives would require contextual adaptation and renewed measurement validation. Interviews and pilot testing should establish whether members and operators understand the items consistently. In light of the documentation gaps reported by Ulya et al. (2026), future studies could also inspect batch records, procedure revisions, and traceability records alongside survey responses. These are proposed ways to assess routine use, not data collected by the present study.

Alternative explanations remain important. Problems with raw-material quality, equipment condition, maintenance, financing, input availability, or market incentives could constrain outcomes even where learning arrangements are adequate. The reported institutional material cannot determine their relative importance. For example, Silvia et al. (2023) relate patchouli production in Aceh Jaya to land, labor, capital, and fertilizer inputs. Their production-level analysis does not test cooperative downstream learning, but it motivates accounting for resource conditions when examining the proposed model. Technical support and institutional capacity-building should therefore be evaluated as potentially complementary interventions. Replacing technical investment with additional administrative tasks would not follow logically from the evidence presented here.

A subsequent study could first authenticate the roadmaps and diagrams, identify their dates and institutional purposes, and reconstruct task responsibilities with page-level source references. Cooperative records, implementation reports, and perspectives from members and



partner organizations could then test whether the proposed learning processes actually connect support to outcomes. Comparisons across cooperatives or over time would help distinguish organizational learning from other influences. The present contribution is to specify those relationships and competing explanations, not to claim that documentary differences have already established causation.

CONCLUSION

This study proposes a techno-institutional fit model for cooperative-based patchouli downstream development in Aceh. The reported institutional narrative motivates examining the connection between innovation collaboration, cooperative learning, and downstream outcomes. Its actor classifications and task descriptions raise questions about representation and functional responsibility, but do not by themselves demonstrate exclusion, institutional failure, or a causal effect of mandate distribution. The model's contribution is to distinguish potential and realized absorptive capacity and specify three propositions linking them to collaboration, institutional fit, and value realization.

The resulting policy implication is to pair appropriate technical support with clearly assigned learning functions, member participation, and accountable follow-up. The interpretation of institutional plans remains bounded by a related source family and the absence of an authenticated extraction record or a direct implementation assessment. The additional published studies provide context but do not supply cooperative-level measurements of the full model. Primary-document verification and subsequent organizational research are needed to establish whether the proposed relationships hold in practice. The model should therefore be read as a framework for investigation and policy design, not as an empirically validated explanation of the performance of Aceh's patchouli cooperatives.

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