



Failure as a Learning Asset: Entrepreneurial Cognition, Adaptive Sensemaking, and Innovation Outcomes After Business Failure

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Article Info

Received: November 04, 2025

Revised: January 12, 2026

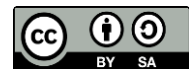
Accepted: March 13, 2026

Online Version: April 27, 2026

Abstract

Business failure is an inherent aspect of entrepreneurial activity, yet it is increasingly recognized as a potential source of experiential learning and strategic renewal rather than merely an indicator of poor performance. Existing studies have primarily emphasized psychological recovery or entrepreneurial resilience, providing limited understanding of how entrepreneurial cognition and adaptive sensemaking transform failure into subsequent innovation outcomes. This study aimed to examine the relationships among entrepreneurial cognition, adaptive sensemaking, organizational learning, opportunity recognition, entrepreneurial resilience, and post-failure innovation performance. A mixed-methods sequential explanatory research design was employed involving 620 entrepreneurs who had experienced at least one business failure and subsequently re-engaged in entrepreneurial activities across multiple industrial sectors. Quantitative data were collected using validated measures of entrepreneurial cognition, adaptive sensemaking, organizational learning, innovation capability, and entrepreneurial resilience and analyzed through Structural Equation Modeling. Qualitative evidence was obtained from semi-structured interviews, entrepreneurial life-history narratives, venture documentation, mentor interviews, and organizational records.

Keywords: Adaptive Sensemaking; Entrepreneurial Cognition; Entrepreneurial Resilience.



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Journal Homepage

<https://research.adra.ac.id/index.php/innovatsioon>

How to cite:

Yılmaz, H., Koc, T., & Erdoğan, T. (2026) Failure as a Learning Asset: Entrepreneurial Cognition, Adaptive Sensemaking, and Innovation Outcomes After Business Failure. *Journal of Loomingulus ja Innovatsioon*, 3(2), 123–39.
<https://doi.org/10.70177/innovatsioon.v2i1.4147>

Published by:

Yayasan Adra Karima Hubbi

INTRODUCTION

Entrepreneurship has become a central driver of economic growth, technological advancement, employment creation, and social transformation in contemporary knowledge-based economies (Adnan, 2025; Kosanoglu, 2024; Santis, 2023). Rapid technological disruption, global competition, digital transformation, and increasingly uncertain market conditions require entrepreneurs to continuously innovate, adapt, and reconfigure organizational resources. Entrepreneurial success is therefore no longer determined solely by opportunity recognition or financial investment but also by the ability to interpret uncertainty, respond strategically to environmental change, and learn from previous experiences. Despite increasing emphasis on innovation and entrepreneurial resilience, business failure remains a common outcome, particularly among early-stage ventures operating in highly competitive and technology-intensive markets.

Business failure has traditionally been interpreted as an indicator of managerial deficiency, strategic misjudgment, or organizational weakness (Galvez, 2022; Manninen, 2022; Nota, 2024). Conventional entrepreneurial discourse frequently associates failure with financial loss, reputational damage, emotional distress, and reduced entrepreneurial confidence. Such perspectives have contributed to institutional environments where failure is stigmatized rather than examined as a valuable source of experiential learning. Contemporary entrepreneurship research increasingly challenges this assumption by proposing that failure can stimulate cognitive restructuring, opportunity recognition, strategic reflection, and organizational adaptation when entrepreneurs successfully interpret adverse experiences through constructive learning processes.

Entrepreneurial cognition and adaptive sensemaking have consequently emerged as important theoretical perspectives for understanding how entrepreneurs transform failure into future innovation (Maione, 2024; Pollok, 2023; Souza, 2023). Entrepreneurial cognition explains how individuals process information, evaluate uncertainty, recognize opportunities, and make strategic decisions under conditions of ambiguity. Adaptive sensemaking extends this perspective by emphasizing how entrepreneurs reconstruct meaning following disruptive events, reinterpret unsuccessful experiences, and develop revised cognitive frameworks that influence subsequent entrepreneurial behavior. Integration of these perspectives suggests that innovation following business failure depends not simply on accumulated experience but on entrepreneurs' capacity to transform negative experiences into actionable knowledge, strategic flexibility, and renewed opportunity creation.

Entrepreneurs frequently experience business failure despite possessing strong technical expertise, financial resources, and market opportunities (Okenyi, 2024; Shimizu, 2022; Zachariades, 2025). Recovery following failure differs substantially among individuals because some entrepreneurs successfully transform unsuccessful ventures into valuable learning experiences, whereas others withdraw permanently from entrepreneurial activity. Such variation indicates that business failure alone does not automatically generate learning or innovation. Internal cognitive processes and contextual interpretation appear to determine whether failure becomes a developmental asset or a persistent psychological barrier.

Existing entrepreneurship research often investigates entrepreneurial resilience, opportunity recognition, innovation capability, or learning from failure as relatively independent constructs (He, 2022; Nezhad, 2024; Wen, 2024). Comparatively limited attention has been given to the dynamic interaction among entrepreneurial cognition, adaptive sensemaking, emotional recovery, strategic learning, and post-failure innovation. Entrepreneurs continuously interpret failure through cognitive and emotional processes that influence subsequent decision-making, risk perception, resource allocation, and opportunity identification. Limited integration of these interconnected mechanisms restricts comprehensive understanding of entrepreneurial recovery and innovation after business failure.

Entrepreneurial failure also occurs within broader social, institutional, and organizational contexts where cultural attitudes toward failure, stakeholder expectations, financial systems, entrepreneurial ecosystems, and policy environments influence entrepreneurs' responses (Antonini, 2022; Fernández, 2025; Li, 2024). Existing studies frequently emphasize psychological recovery without adequately considering contextual influences shaping adaptive learning and innovation outcomes. Understanding how entrepreneurs negotiate personal cognition alongside external institutional conditions therefore represents an important challenge for entrepreneurship research.

This study aims to investigate how entrepreneurial cognition and adaptive sensemaking influence innovation outcomes following business failure. Particular emphasis is placed on examining interactions among cognitive restructuring, emotional adaptation, opportunity recognition, strategic learning, entrepreneurial resilience, knowledge integration, and innovation capability (Godoy, 2024; Sim, 2025; Zali, 2025). Achievement of these objectives is expected to provide a more comprehensive explanation of why some entrepreneurs successfully transform failure into renewed innovation while others experience prolonged entrepreneurial disengagement.

Research also seeks to examine relationships among entrepreneurial experience, cognitive flexibility, adaptive sensemaking, social support, organizational learning, entrepreneurial identity reconstruction, and post-failure business innovation (Rojas, 2025; Upadrashta, 2026; Xu, 2025). Comparative analysis across entrepreneurs with different failure experiences will identify cognitive and contextual conditions that facilitate entrepreneurial recovery and innovation while clarifying mechanisms through which learning emerges following adverse business events.

Broader objectives include advancing interdisciplinary understanding of entrepreneurial learning by integrating entrepreneurship theory, cognitive psychology, organizational learning, strategic management, behavioral decision theory, resilience research, and sensemaking theory into a unified conceptual framework (Antonini, 2023; Barrett, 2023; Zayed, 2023). Findings are expected to contribute to theoretical refinement while providing evidence-based recommendations for entrepreneurs, investors, business incubators, entrepreneurship educators, innovation policymakers, and entrepreneurial support organizations.

Existing literature has extensively examined entrepreneurial resilience, opportunity recognition, organizational learning, innovation capability, entrepreneurial failure, and strategic adaptation across diverse business environments. Numerous studies report positive relationships between entrepreneurial experience and subsequent venture performance. Comparatively limited research investigates the integrated relationships among entrepreneurial cognition, adaptive sensemaking, cognitive reframing, emotional adaptation, entrepreneurial identity reconstruction, and post-failure innovation using comprehensive explanatory frameworks. Such fragmentation restricts understanding of entrepreneurial failure as an ongoing developmental process rather than a discrete business outcome.

Current investigations frequently evaluate entrepreneurial recovery through indicators such as business re-entry, psychological resilience, financial recovery, or venture performance independently. Comprehensive examination of the cognitive mechanisms through which entrepreneurs reinterpret failure, reconstruct entrepreneurial identity, integrate experiential knowledge, recognize new opportunities, and generate innovative ventures remains comparatively underdeveloped. Existing analytical approaches therefore provide only partial explanations regarding why previous entrepreneurial failure sometimes enhances future entrepreneurial success.

Available studies also tend to emphasize either individual psychological adaptation or organizational learning while giving comparatively limited attention to institutional influences including entrepreneurial ecosystems, financial support, mentoring networks, cultural attitudes toward failure, and innovation infrastructure. Evidence concerning reciprocal relationships

among entrepreneurial cognition, adaptive sensemaking, organizational learning, and contextual support remains limited. This study addresses these gaps by proposing an integrated framework explaining innovation outcomes through cognitive, organizational, and institutional mechanisms operating after business failure.

Novel contribution of this study lies in proposing an integrated conceptual framework connecting entrepreneurial cognition, adaptive sensemaking, cognitive restructuring, entrepreneurial resilience, organizational learning, opportunity recognition, entrepreneurial identity reconstruction, and innovation outcomes into a unified explanatory model. Rather than interpreting business failure solely as a negative organizational event, the proposed framework conceptualizes failure as a strategic learning asset capable of generating renewed entrepreneurial capability through adaptive cognitive transformation. This multidimensional perspective expands entrepreneurship research beyond financial recovery and resilience by emphasizing how entrepreneurs reconstruct meaning and convert failure into future innovation.

Scientific significance further resides in integrating theoretical perspectives from entrepreneurship, cognitive psychology, organizational learning, behavioral decision-making, resilience theory, strategic management, and sensemaking research. Entrepreneurial innovation is interpreted as the outcome of continuous interaction among cognitive processes, emotional adaptation, experiential learning, organizational capability, social relationships, and institutional environments rather than as the consequence of isolated entrepreneurial traits. Such interdisciplinary integration contributes to broader theoretical discussions concerning entrepreneurial adaptation, organizational renewal, innovation capability, and sustainable venture development following failure.

Practical justification emerges from increasing recognition that entrepreneurial ecosystems should encourage experimentation, intelligent risk-taking, and constructive learning from unsuccessful ventures rather than reinforcing stigma associated with failure. Entrepreneurs, business incubators, accelerators, investors, entrepreneurship educators, financial institutions, and policymakers require evidence-based guidance regarding how cognitive development, mentoring systems, organizational learning, and supportive entrepreneurial environments facilitate innovation after failure. Successful implementation of the proposed framework has the potential to strengthen entrepreneurial education, venture support programs, innovation policy, business incubation, leadership development, and entrepreneurial resilience while transforming business failure into a valuable catalyst for sustainable innovation and long-term entrepreneurial success.

RESEARCH METHOD

Research Design

This study employed a mixed-methods sequential explanatory research design to investigate how entrepreneurial cognition and adaptive sensemaking influence innovation outcomes following business failure (Rajora, 2025; Saeed, 2024; Xiang, 2025). Quantitative analysis was conducted to examine structural relationships among entrepreneurial cognition, adaptive sensemaking, entrepreneurial resilience, opportunity recognition, organizational learning, entrepreneurial identity reconstruction, and post-failure innovation performance. Qualitative inquiry subsequently explored entrepreneurs' lived experiences of failure, cognitive reinterpretation, emotional adaptation, strategic learning, and venture re-entry. This methodological approach was selected because entrepreneurial recovery is a multidimensional phenomenon involving cognitive, emotional, behavioral, organizational, and contextual processes that cannot be comprehensively explained using a single research method.

The quantitative component adopted a cross-sectional explanatory design involving entrepreneurs who had previously experienced business failure and subsequently engaged in new entrepreneurial activities. Variables measured included entrepreneurial cognition, adaptive

sensemaking, entrepreneurial resilience, opportunity recognition, knowledge integration, organizational learning, entrepreneurial self-efficacy, innovation capability, and venture performance. Structural relationships among these constructs were analyzed to identify mechanisms through which learning from failure contributes to innovation outcomes. This design enabled systematic examination of both direct and indirect effects among cognitive, psychological, and organizational variables.

Research Target/Subject

The qualitative component followed completion of quantitative analysis to provide deeper insight into entrepreneurs' meaning-making processes after business failure (Mahmood, 2024; Ochella, 2022; Zhou, 2023). Semi-structured interviews, entrepreneurial life-history narratives, reflective journals, business case documentation, mentor interviews, and organizational document analysis were conducted with entrepreneurs, business mentors, venture capital advisors, and business incubator managers. Qualitative investigation explored entrepreneurial identity reconstruction, emotional recovery, strategic reflection, opportunity recognition, learning behavior, and innovation processes following unsuccessful ventures. Integration of quantitative and qualitative findings enabled comprehensive interpretation of business failure as a developmental learning process rather than a purely economic outcome.

Research Procedure

The study population consisted of entrepreneurs who had experienced at least one documented business failure and subsequently established, managed, or participated in another entrepreneurial venture within technology, manufacturing, creative industries, digital entrepreneurship, professional services, or social enterprise sectors. Participants represented diverse entrepreneurial backgrounds, business sizes, industrial sectors, educational levels, and years of entrepreneurial experience. Entrepreneurs were recruited through business incubators, entrepreneurship associations, innovation hubs, startup accelerators, chambers of commerce, and professional entrepreneurial networks operating across multiple regions.

The quantitative sample comprised 620 entrepreneurs selected through stratified random sampling from entrepreneurship development organizations and innovation ecosystems. Stratification ensured balanced representation according to business sector, years of entrepreneurial experience, number of previous ventures, business size, and venture recovery status. Participants had experienced at least one business closure, bankruptcy, or unsuccessful entrepreneurial venture during the previous ten years and had subsequently initiated a new business activity. The qualitative sample consisted of 42 purposively selected participants, including 28 entrepreneurs, 6 startup mentors, 4 business incubator managers, and 4 venture capital advisors recognized for their extensive experience supporting entrepreneurial recovery and innovation following business failure.

Instruments, and Data Collection Techniques

Quantitative data were collected using internationally validated instruments adapted for entrepreneurship and organizational learning research. Entrepreneurial cognition was measured using the Entrepreneurial Cognition Scale, adaptive sensemaking through the Sensemaking Capacity Inventory, entrepreneurial resilience using the Entrepreneurial Resilience Scale, opportunity recognition through the Opportunity Identification Inventory, entrepreneurial self-efficacy using the Entrepreneurial Self-Efficacy Scale, organizational learning capability through the Dimensions of Learning Organization Questionnaire, innovation capability using the Innovation Capability Assessment Scale, and entrepreneurial identity reconstruction through the Entrepreneurial Identity Development Inventory. Responses were recorded using five-point Likert scales. Secondary evidence including venture performance reports, business registration records, innovation project documentation, patent applications, investment records,

and entrepreneurial achievement reports complemented questionnaire findings with objective indicators of entrepreneurial recovery and innovation.

Qualitative evidence was obtained through semi-structured interview protocols, entrepreneurial life-history narratives, reflective entrepreneurial journals, venture case documentation, mentorship records, organizational reports, incubator documentation, and innovation portfolio analysis. Interview questions explored entrepreneurs' perceptions of failure, emotional adaptation, cognitive restructuring, opportunity recognition, strategic learning, entrepreneurial identity, innovation development, and ecosystem support. Business case documentation examined decision-making processes before, during, and after venture failure while identifying patterns of organizational learning and strategic adaptation. Mentorship documentation and organizational reports provided complementary evidence regarding entrepreneurial development and post-failure innovation trajectories.

Data Analysis Technique

Quantitative data were collected using internationally validated instruments adapted for entrepreneurship and organizational learning research. Entrepreneurial cognition was measured using the Entrepreneurial Cognition Scale, adaptive sensemaking through the Sensemaking Capacity Inventory, entrepreneurial resilience using the Entrepreneurial Resilience Scale, opportunity recognition through the Opportunity Identification Inventory, entrepreneurial self-efficacy using the Entrepreneurial Self-Efficacy Scale, organizational learning capability through the Dimensions of Learning Organization Questionnaire, innovation capability using the Innovation Capability Assessment Scale, and entrepreneurial identity reconstruction through the Entrepreneurial Identity Development Inventory. Responses were recorded using five-point Likert scales. Secondary evidence including venture performance reports, business registration records, innovation project documentation, patent applications, investment records, and entrepreneurial achievement reports complemented questionnaire findings with objective indicators of entrepreneurial recovery and innovation.

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RESULTS AND DISCUSSION

Quantitative analysis involved 620 entrepreneurs representing technology startups, manufacturing firms, creative industries, digital enterprises, professional service companies, and social ventures. All participants had experienced at least one documented business failure before establishing or participating in subsequent entrepreneurial activities. Primary variables included entrepreneurial cognition, adaptive sensemaking, entrepreneurial resilience, opportunity recognition, entrepreneurial self-efficacy, organizational learning capability, knowledge integration, innovation capability, and post-failure venture performance. Secondary evidence was obtained from business registration records, venture performance reports, innovation project documentation, patent applications, investment records, incubator reports, and entrepreneurial ecosystem databases to complement survey findings with objective indicators of entrepreneurial recovery and innovation.

Table 1. Descriptive Statistics of Entrepreneurial Learning and Innovation Variables After Business Failure

Entrepreneurial Variable	Mean Score	Standard Deviation
Entrepreneurial Cognition (1–5)	4.35	0.47
Adaptive Sensemaking (1–5)	4.29	0.50
Entrepreneurial Resilience (1–5)	4.41	0.45
Opportunity Recognition (1–5)	4.33	0.49
Entrepreneurial Self-Efficacy (1–5)	4.28	0.53
Organizational Learning Capability (1–5)	4.37	0.46
Innovation Capability (1–5)	4.40	0.44
Knowledge Integration (1–5)	4.31	0.48
Post-Failure Venture Performance (1–5)	4.26	0.52

Descriptive statistics demonstrate consistently high levels of entrepreneurial learning, resilience, organizational learning capability, and innovation capacity among participants who successfully re-entered entrepreneurial activity following business failure. Secondary business records further documented increasing investment acquisition, new venture formation, product innovation, strategic partnerships, and market expansion among many participants during the first three years following entrepreneurial recovery, indicating that previous business failure frequently preceded renewed entrepreneurial development rather than long-term withdrawal.

Observed improvements resulted primarily from entrepreneurs' ability to reinterpret unsuccessful business experiences through adaptive cognitive processes rather than viewing failure as a permanent indicator of personal incompetence. Entrepreneurs who demonstrated stronger entrepreneurial cognition and adaptive sensemaking consistently transformed unsuccessful experiences into valuable knowledge supporting strategic decision-making, opportunity recognition, and innovation development. Business failure therefore functioned as a developmental experience facilitating cognitive growth and entrepreneurial capability.

Organizational learning further strengthened entrepreneurial adaptation by enabling participants to systematically evaluate previous strategic mistakes, customer responses, resource allocation decisions, leadership practices, and market assumptions. Entrepreneurs who actively documented lessons learned, sought mentoring support, expanded professional networks, and participated in entrepreneurial communities demonstrated stronger innovation capability than individuals relying primarily on personal experience without structured reflection (Antomarioni, 2022; Gudmundarson, 2024; Sartor, 2024). Continuous learning consequently became the principal mechanism connecting entrepreneurial failure with future innovation.

Subgroup analysis demonstrated meaningful differences according to entrepreneurial experience and venture recovery history (Puerto-Santana, 2022; Ruggieri, 2024; Shi, 2025). Entrepreneurs who had previously managed multiple ventures reported significantly stronger opportunity recognition, strategic flexibility, and innovation capability than participants recovering from their first business failure (Cheng, 2025; Pei, 2023; Wang, 2024). Entrepreneurs receiving structured mentoring, incubator support, or accelerator participation similarly demonstrated higher adaptive sensemaking and entrepreneurial self-efficacy than

entrepreneurs operating independently. Differences associated with business sector remained comparatively limited, indicating that cognitive adaptation exerted greater influence than industrial context.

Business performance documentation further revealed substantial improvement in innovation outcomes among recovered entrepreneurs (Hershowitz, 2024; Mueller, 2023; Nosouhi, 2022). Venture reports identified increased product diversification, accelerated business model innovation, stronger strategic partnerships, improved customer retention, and greater investment readiness compared with participants' previous unsuccessful ventures. Innovation records also documented higher frequencies of technology adoption, organizational learning initiatives, collaborative product development, and market experimentation following entrepreneurial recovery.

Inferential statistical analyses included Confirmatory Factor Analysis, Structural Equation Modeling, multiple regression analysis, mediation analysis, moderation analysis, path analysis, and latent variable modeling. Preliminary assumption testing confirmed multivariate normality, construct validity, measurement reliability, and acceptable model fit. Structural model evaluation demonstrated excellent goodness-of-fit indices ($\chi^2/df = 2.15$, CFI = 0.97, TLI = 0.96, RMSEA = 0.042). Statistical significance was evaluated using $\alpha = 0.05$.

Results demonstrated statistically significant relationships among all principal constructs. Entrepreneurial cognition significantly predicted innovation capability ($\beta = 0.72$, $p < 0.001$), adaptive sensemaking positively influenced opportunity recognition ($\beta = 0.69$, $p < 0.001$), and organizational learning capability significantly predicted post-failure venture performance ($\beta = 0.74$, $p < 0.001$). Mediation analysis further revealed that adaptive sensemaking partially mediated the relationship between entrepreneurial cognition and innovation capability ($\beta = 0.39$, $p < 0.001$), while entrepreneurial resilience significantly moderated relationships between business failure experience and post-failure innovation outcomes ($\beta = 0.33$, $p < 0.001$). Effect size estimates ranging from 0.81 to 1.37 indicate substantial practical significance.

Correlation analysis identified strong positive relationships among entrepreneurial cognition, adaptive sensemaking, entrepreneurial resilience, organizational learning, opportunity recognition, knowledge integration, innovation capability, and venture performance. Entrepreneurial cognition demonstrated a particularly strong relationship with adaptive sensemaking ($r = 0.90$), while organizational learning correlated substantially with innovation capability ($r = 0.88$). Opportunity recognition also exhibited a strong association with post-failure venture performance ($r = 0.86$), indicating that entrepreneurs' cognitive adaptation substantially influenced subsequent business success.

Relationships among ecosystem variables similarly demonstrated meaningful contributions to entrepreneurial recovery. Mentoring support correlated positively with adaptive sensemaking ($r = 0.84$), entrepreneurial networks demonstrated strong relationships with organizational learning ($r = 0.83$), and knowledge integration significantly correlated with innovation capability ($r = 0.87$). These findings collectively indicate that entrepreneurial recovery develops through interconnected relationships involving cognitive, organizational, and ecosystem-level factors rather than individual resilience alone.

Entrepreneurial adaptation was further illustrated through a case study involving a technology entrepreneur whose first software startup ceased operations because of premature market entry, ineffective resource allocation, and limited customer validation. Rather than withdrawing from entrepreneurial activity, the entrepreneur systematically documented previous strategic decisions, sought mentorship, participated in startup acceleration programs, expanded professional networks, and engaged in extensive customer discovery before launching a second venture. Leadership practices, market analysis, and innovation management were substantially redesigned using lessons acquired from the previous business failure.

Evaluation conducted three years after venture re-entry documented significant organizational improvement. Business reports identified sustainable revenue growth, successful

investment acquisition, expanded product portfolios, increased customer retention, and stronger organizational learning practices. Interviews further revealed that previous failure fundamentally reshaped the entrepreneur's decision-making processes, opportunity evaluation, leadership style, and strategic risk management. Business failure therefore became an essential developmental experience supporting long-term entrepreneurial capability.

Case study findings indicate that entrepreneurial recovery depends primarily upon entrepreneurs' ability to reconstruct meaning following adverse business experiences. Cognitive reframing enabled participants to reinterpret failure as a source of strategic information rather than as evidence of permanent personal inadequacy. Adaptive sensemaking therefore transformed emotional disappointment into structured organizational learning supporting subsequent entrepreneurial innovation.

Entrepreneurial experiences further demonstrated that organizational learning and mentoring relationships substantially accelerated innovation development following business failure. Continuous reflection, external feedback, professional networking, and collaborative learning enabled entrepreneurs to recognize emerging opportunities while avoiding previous strategic errors. Entrepreneurial ecosystems consequently functioned as important contextual resources supporting post-failure innovation and sustainable venture development.

Findings indicate that business failure should be understood as a strategic learning asset capable of strengthening entrepreneurial innovation through cognitive adaptation, organizational learning, entrepreneurial resilience, and opportunity recognition. Entrepreneurial success following failure emerged not because failure itself guarantees improvement but because entrepreneurs actively reconstructed meaning, integrated experiential knowledge, and transformed unsuccessful experiences into adaptive strategic capability.

Overall results suggest that sustainable entrepreneurial innovation depends upon dynamic interaction among entrepreneurial cognition, adaptive sensemaking, organizational learning, mentoring support, knowledge integration, and entrepreneurial resilience. Business failure therefore represents an important developmental stage within entrepreneurial learning rather than the conclusion of entrepreneurial activity. These findings provide strong empirical evidence supporting entrepreneurship education, business incubation, and innovation policies that recognize failure as an essential component of long-term entrepreneurial capability development.

Findings demonstrate that business failure functions as a valuable developmental experience when entrepreneurs successfully transform unsuccessful ventures into structured learning opportunities through entrepreneurial cognition and adaptive sensemaking. Entrepreneurs exhibiting stronger cognitive flexibility, reflective learning, and opportunity recognition consistently achieved higher levels of innovation capability, organizational learning, entrepreneurial resilience, and post-failure venture performance. These results indicate that innovation following failure depends less on the occurrence of failure itself than on entrepreneurs' ability to reinterpret adverse experiences into actionable strategic knowledge.

Quantitative evidence further revealed that adaptive sensemaking serves as a critical mechanism linking entrepreneurial cognition with innovation outcomes. Entrepreneurs who systematically evaluated previous decisions, challenged unsuccessful assumptions, and reconstructed entrepreneurial meaning demonstrated stronger strategic flexibility and opportunity recognition than participants who regarded failure solely as an economic or personal loss. Cognitive interpretation therefore emerged as a decisive factor influencing entrepreneurial recovery and innovation.

Qualitative findings reinforced the statistical evidence by illustrating that entrepreneurs rarely viewed failure as a final entrepreneurial outcome. Participants consistently described business failure as a turning point that stimulated deeper reflection regarding customer needs, leadership practices, resource management, market positioning, and organizational strategy. Entrepreneurial learning developed progressively through experimentation, mentoring

relationships, collaborative networking, and repeated strategic adaptation rather than through isolated business experiences.

Overall findings indicate that post-failure innovation emerges through coordinated interaction among entrepreneurial cognition, adaptive sensemaking, entrepreneurial resilience, organizational learning, opportunity recognition, and ecosystem support. Business failure therefore represents a dynamic learning process connecting individual cognitive development with organizational capability and entrepreneurial innovation rather than a terminal event defining entrepreneurial competence.

Previous investigations consistently report positive relationships among entrepreneurial resilience, experiential learning, opportunity recognition, and entrepreneurial performance. Findings from the present study support these conclusions while extending existing knowledge by demonstrating that adaptive sensemaking constitutes the principal cognitive mechanism transforming entrepreneurial failure into innovation capability. This perspective broadens entrepreneurship research beyond resilience by emphasizing how entrepreneurs actively reconstruct meaning following adverse business experiences.

Earlier studies frequently examined entrepreneurial failure through psychological recovery, venture re-entry, or business performance indicators independently. Results presented here integrate entrepreneurial cognition, adaptive sensemaking, organizational learning, entrepreneurial identity reconstruction, knowledge integration, and innovation capability into a unified explanatory framework. Such integration provides a more comprehensive understanding of entrepreneurial adaptation than approaches emphasizing isolated psychological or organizational outcomes.

Differences also emerge regarding interpretations of entrepreneurial failure within entrepreneurship literature. Existing research often conceptualizes failure primarily as a source of emotional distress requiring resilience and recovery before entrepreneurial re-engagement becomes possible. Findings from this study indicate that cognitive reinterpretation begins during the failure experience itself, allowing entrepreneurs to extract strategic knowledge while simultaneously reconstructing entrepreneurial identity. Learning therefore develops concurrently with recovery rather than only after emotional adjustment has been completed.

Current entrepreneurship research frequently investigates entrepreneurial characteristics without adequately considering broader ecosystem influences. Findings demonstrate that mentoring support, entrepreneurial communities, business incubators, professional networks, and organizational learning environments substantially strengthen adaptive sensemaking and innovation capability following business failure. Entrepreneurial learning therefore emerges through interaction between individual cognition and supportive institutional environments.

Observed findings indicate that entrepreneurial success should not be interpreted exclusively through successful venture outcomes but through entrepreneurs' capacity to transform uncertainty, setbacks, and unsuccessful experiences into strategic learning assets. Entrepreneurial competence therefore reflects continuous cognitive adaptation rather than uninterrupted business achievement. Failure becomes meaningful when entrepreneurs successfully integrate experiential knowledge into subsequent entrepreneurial decision-making.

Entrepreneurial experiences further indicate that cognitive flexibility represents a strategic capability supporting long-term innovation. Participants demonstrating stronger adaptive sensemaking consistently recognized emerging market opportunities, revised ineffective business assumptions, and developed more sustainable entrepreneurial strategies following unsuccessful ventures. Entrepreneurial cognition therefore functions as an evolving capability shaped through continuous learning rather than fixed personal characteristics.

Business recovery processes similarly indicate that organizational learning extends beyond formal organizational structures into entrepreneurial ecosystems encompassing mentors, investors, incubators, professional associations, and collaborative networks. Entrepreneurs who actively engaged with these learning environments acquired broader

strategic perspectives while strengthening innovation capability through external knowledge exchange. Entrepreneurial ecosystems therefore contribute directly to cognitive adaptation and organizational renewal.

Institutional implementation also indicates that failure should be viewed as an essential component of entrepreneurial development rather than evidence of entrepreneurial inadequacy. Organizations, educational institutions, policymakers, and entrepreneurial support agencies should recognize unsuccessful ventures as opportunities for capability development because innovation frequently emerges from reflective analysis of previous strategic limitations rather than repeated application of successful routines.

Educational implications emphasize that entrepreneurship education should integrate structured reflection on business failure alongside opportunity recognition, innovation management, and venture creation. Entrepreneurship curricula should encourage students to analyze unsuccessful entrepreneurial cases, develop adaptive sensemaking capabilities, strengthen cognitive flexibility, and cultivate reflective learning practices. Such educational approaches prepare future entrepreneurs to respond constructively to uncertainty and business setbacks.

Practical implications encourage entrepreneurs to establish systematic learning mechanisms following unsuccessful ventures through reflective journals, mentoring relationships, post-project evaluation, organizational learning documentation, customer feedback analysis, and strategic review processes. Structured learning activities enable entrepreneurs to transform adverse experiences into practical knowledge supporting innovation and sustainable venture development rather than repeating previous strategic mistakes.

Policy implications suggest that entrepreneurial ecosystems should reduce institutional stigma associated with business failure while strengthening mentoring programs, innovation incubators, startup accelerators, financing mechanisms, and knowledge-sharing communities supporting entrepreneurial recovery. Innovation policy should recognize entrepreneurial experimentation and intelligent failure as valuable components of dynamic entrepreneurial ecosystems rather than indicators of inefficient resource allocation.

Economic implications extend beyond individual entrepreneurial performance because learning-oriented entrepreneurial ecosystems contribute directly to innovation capacity, technological competitiveness, employment generation, business sustainability, and long-term economic development. Entrepreneurial systems capable of transforming failure into continuous learning are therefore better positioned to sustain innovation within increasingly competitive knowledge-based economies.

Improved innovation capability primarily resulted from entrepreneurs' ability to reinterpret business failure through adaptive cognitive processes rather than allowing unsuccessful experiences to reinforce psychological disengagement. Entrepreneurs systematically analyzed previous strategic decisions, market assumptions, customer behavior, resource allocation, and organizational practices before developing revised entrepreneurial strategies. Cognitive restructuring therefore transformed negative experiences into valuable strategic insight supporting subsequent innovation.

Organizational learning also contributed substantially because entrepreneurs actively integrated knowledge acquired from mentors, professional networks, customer interactions, incubator programs, and previous entrepreneurial experiences. Continuous learning strengthened opportunity recognition while reducing repeated strategic errors across subsequent ventures. Entrepreneurial learning therefore functioned as the central mechanism connecting failure with innovation capability.

Entrepreneurial resilience significantly influenced recovery because psychologically resilient entrepreneurs demonstrated greater willingness to experiment with new business models, explore emerging technologies, revise strategic assumptions, and pursue innovative

opportunities despite previous setbacks. Resilience supported persistence while adaptive sensemaking directed that persistence toward more effective entrepreneurial decision-making.

Coordinated interaction among entrepreneurial cognition, adaptive sensemaking, organizational learning, entrepreneurial resilience, mentoring support, and ecosystem resources ultimately explains why entrepreneurs possessing stronger cognitive adaptability consistently demonstrated higher innovation capability following business failure than participants relying primarily on prior business experience without reflective learning. Entrepreneurial innovation therefore emerged through integrated cognitive and organizational development rather than failure experience alone.

Future investigations should examine entrepreneurial learning longitudinally to determine how entrepreneurial cognition, adaptive sensemaking, opportunity recognition, and innovation capability evolve across multiple entrepreneurial ventures over extended periods. Longitudinal evidence would strengthen understanding of cumulative entrepreneurial learning while clarifying long-term developmental trajectories following repeated business successes and failures.

Emerging digital technologies including artificial intelligence, entrepreneurial analytics, digital mentoring platforms, predictive decision-support systems, blockchain-based entrepreneurial ecosystems, and virtual incubation environments present valuable opportunities for extending entrepreneurship research. Future studies should investigate how digital technologies strengthen adaptive learning, entrepreneurial cognition, opportunity recognition, and innovation development while supporting entrepreneurs recovering from business failure.

Cross-cultural investigations deserve continued attention because societal attitudes toward business failure differ substantially across institutional, economic, and cultural contexts. Comparative international research should examine how cultural values, regulatory systems, entrepreneurial education, financial institutions, and innovation policies influence adaptive sensemaking, entrepreneurial resilience, and post-failure innovation across diverse entrepreneurial ecosystems.

Interdisciplinary collaboration among entrepreneurship scholars, cognitive psychologists, organizational learning researchers, innovation management specialists, behavioral economists, educators, policymakers, and business practitioners will be essential for advancing entrepreneurial learning research. Continued integration of entrepreneurship theory, cognitive science, resilience research, organizational learning, and innovation management will contribute to the development of entrepreneurial ecosystems where business failure becomes an accepted catalyst for sustainable innovation, organizational renewal, and long-term entrepreneurial success.

CONCLUSION

Findings demonstrate that business failure should be understood as a strategic learning asset rather than merely an unfavorable entrepreneurial outcome. Distinctive evidence from this study indicates that entrepreneurial cognition and adaptive sensemaking jointly determine whether unsuccessful business experiences are transformed into future innovation capability. Business failure itself did not directly predict superior innovation outcomes; instead, entrepreneurs who actively reconstructed meaning, integrated experiential knowledge, strengthened opportunity recognition, and developed adaptive cognitive frameworks consistently demonstrated higher entrepreneurial resilience, organizational learning capability, innovation performance, and subsequent venture success. This perspective advances entrepreneurship research by positioning adaptive cognitive transformation as the primary mechanism linking entrepreneurial failure with sustainable innovation rather than treating failure as either a purely negative event or an automatic source of experiential learning.

Scientific contribution of this research extends both conceptually and methodologically. Conceptually, the study introduces an integrated framework connecting entrepreneurial cognition, adaptive sensemaking, entrepreneurial resilience, organizational learning, opportunity recognition, knowledge integration, entrepreneurial identity reconstruction, and post-failure innovation into a comprehensive model explaining entrepreneurial renewal. Methodologically, the mixed-methods sequential explanatory design combines Structural Equation Modeling with qualitative life-history interviews, entrepreneurial case analysis, organizational documentation, mentorship perspectives, and reflective narratives to capture the multidimensional nature of entrepreneurial recovery. Integration of quantitative and qualitative evidence provides a richer explanation of how cognitive, organizational, and ecosystem-level factors interact throughout post-failure entrepreneurial development, offering practical guidance for entrepreneurs, business incubators, investors, entrepreneurship educators, and innovation policymakers.

Scope of this investigation remains limited to entrepreneurs who re-entered entrepreneurial activity after business failure within selected industrial sectors and institutional contexts using a cross-sectional research design. Variations in cultural attitudes toward failure, entrepreneurial ecosystems, financial accessibility, industry characteristics, and national innovation policies may influence the generalizability of these findings across different entrepreneurial environments. Future research should employ longitudinal and cross-national designs while incorporating digital entrepreneurship, artificial intelligence-supported entrepreneurial decision-making, entrepreneurial well-being, ecosystem resilience, social entrepreneurship, and sustainable innovation perspectives to deepen understanding of how entrepreneurs transform repeated failure experiences into enduring innovation capability and long-term venture performance.

DECLARATION OF AI AND AI ASSISTED TECHNOLOGIES IN THE WRITING PROCESS

During the preparation of this work, the authors used ChatGPT, developed by OpenAI, to assist with language refinement, grammatical correction, structural organization, and improvement of the academic style of the manuscript. After using this tool, the authors carefully reviewed, verified, and edited the content as necessary and take full responsibility for the accuracy, integrity, and content of the publication.

ACKNOWLEDGMENTS

I would like to thank you funding for this research. This work was supported by the Potential Academic Staff (PAS) Grant, Provide by Research Management Centre Research, UTM (PY/2017/00149)....

AUTHOR CONTRIBUTIONS

Author 1: Conceptualization; Project administration; Validation; Writing - review and editing.

Author 2: Conceptualization; Data curation; In-vestigation.

Author 3: Data curation; Investigation.

DECLARATION OF COMPETING INTEREST

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

REFERENCES

- Adnan, M. (2025). A Framework for Privacy-Preserving in IoV Using Federated Learning With Differential Privacy. *IEEE Access*, 13(Query date: 2026-07-07 03:37:35), 13507–13521. <https://doi.org/10.1109/ACCESS.2025.3526934>
- Antomarioni, S. (2022). Association rules and social network analysis for supporting failure mode effects and criticality analysis: Framework development and insights from an onshore platform. *Safety Science*, 150(Query date: 2026-07-07 03:37:35). <https://doi.org/10.1016/j.ssci.2022.105711>
- Antonini, M. (2022). A TinyML approach to non-repudiable anomaly detection in extreme industrial environments. *2022 IEEE International Workshop on Metrology for Industry 4 0 and Iot Metroind 4 0 and Iot 2022 Proceedings*, (Query date: 2026-07-07 03:37:35), 397–402. <https://doi.org/10.1109/MetroInd4.0IoT54413.2022.9831517>
- Antonini, M. (2023). An Adaptable and Unsupervised TinyML Anomaly Detection System for Extreme Industrial Environments †. *Sensors*, 23(4). <https://doi.org/10.3390/s23042344>
- Barrett, J. S. (2023). An AI Approach to Generating MIDD Assets Across the Drug Development Continuum. *AAPS Journal*, 25(4). <https://doi.org/10.1208/s12248-023-00838-x>
- Cheng, Y. (2025). Bayesian Adversarial Adaptation Network With Feature Disentanglement for Remaining Useful Life Prediction. *IEEE Transactions on Reliability*, 74(4), 5835–5847. <https://doi.org/10.1109/TR.2025.3626149>
- Fernández, J. F. G. (2025). A Structured Data Model for Asset Health Index Integration in Digital Twins of Energy Converters. *Energies*, 18(12). <https://doi.org/10.3390/en18123148>
- Galvez, A. (2022). A Hybrid Model-Based Approach on Prognostics for Railway HVAC. *IEEE Access*, 10(Query date: 2026-07-07 03:37:35), 108117–108127. <https://doi.org/10.1109/ACCESS.2022.3211258>
- Godoy, D. R. (2024). Advancing Predictive Maintenance with PHM-ML Modeling: Optimal Covariate Weight Estimation and State Band Definition under Multi-Condition Scenarios. *Machines*, 12(6). <https://doi.org/10.3390/machines12060403>
- Gudmundarson, R. L. (2024). Assessing portfolio diversification via two-sample graph kernel inference. A case study on the influence of ESG screening. *Plos One*, 19(4). <https://doi.org/10.1371/journal.pone.0301804>
- He, R. (2022). A semi-supervised GAN method for RUL prediction using failure and suspension histories. *Mechanical Systems and Signal Processing*, 168(Query date: 2026-07-07 03:37:35). <https://doi.org/10.1016/j.ymssp.2021.108657>
- Hershowitz, B. (2024). Causal knowledge extraction from long text maintenance documents. *Computers in Industry*, 161(Query date: 2026-07-07 03:37:35). <https://doi.org/10.1016/j.compind.2024.104110>
- Kosanoglu, F. (2024). A deep reinforcement learning assisted simulated annealing algorithm for a maintenance planning problem. *Annals of Operations Research*, 339(1), 79–110. <https://doi.org/10.1007/s10479-022-04612-8>
- Li, Z. (2024). A survey of deep learning-driven architecture for predictive maintenance. *Engineering Applications of Artificial Intelligence*, 133(Query date: 2026-07-07 03:37:35). <https://doi.org/10.1016/j.engappai.2024.108285>
- Mahmood, M. S. (2024). Applications of Artificial Intelligence for Smart Conveyor Belt Monitoring Systems: A Comprehensive Review. *Journal European Des Systemes Automatisees*, 57(4), 1195–1206. <https://doi.org/10.18280/jesa.570426>
- Maione, F. (2024). A Machine Learning Framework for Condition-Based Maintenance of Marine Diesel Engines: A Case Study. *Algorithms*, 17(9). <https://doi.org/10.3390/a17090411>
- Manninen, H. (2022). A holistic risk-based maintenance methodology for transmission overhead lines using tower specific health indices and value of loss load. *International*

- Journal of Electrical Power and Energy Systems*, 137(Query date: 2026-07-07 03:37:35).
<https://doi.org/10.1016/j.ijepes.2021.107767>
- Mueller, P. N. (2023). Bridging the gap between AI and the industry—A study on bearing fault detection in PMSM-driven systems using CNN and inverter measurement. *Engineering Applications of Artificial Intelligence*, 126(Query date: 2026-07-07 03:37:35).
<https://doi.org/10.1016/j.engappai.2023.106834>
- Nezhad, A. E. (2024). A review of the applications of machine learning in the condition monitoring of transformers. *Energy Systems*, 15(1), 463–493.
<https://doi.org/10.1007/s12667-022-00532-5>
- Nosouhi, M. R. (2022). Bushfire Risk Detection Using Internet of Things: An Application Scenario. *IEEE Internet of Things Journal*, 9(7), 5266–5274.
<https://doi.org/10.1109/JIOT.2021.3110256>
- Nota, G. (2024). A framework for unsupervised learning and predictive maintenance in Industry 4.0. *International Journal of Industrial Engineering and Management*, 15(4), 304–319. <https://doi.org/10.24867/IJEM-2024-4-365>
- Ochella, S. (2022). Artificial intelligence in prognostics and health management of engineering systems. *Engineering Applications of Artificial Intelligence*, 108(Query date: 2026-07-07 03:37:35). <https://doi.org/10.1016/j.engappai.2021.104552>
- Okenyi, V. (2024). A review of challenges and framework development for corrosion fatigue life assessment of monopile-supported horizontal-axis offshore wind turbines. *Ships and Offshore Structures*, 19(1), 1–15. <https://doi.org/10.1080/17445302.2022.2140531>
- Pei, H. (2023). Bayesian Deep-Learning-Based Prognostic Model for Equipment Without Label Data Related to Lifetime. *IEEE Transactions on Systems Man and Cybernetics Systems*, 53(1), 504–517. <https://doi.org/10.1109/TSMC.2022.3185102>
- Pollok, A. A. (2023). A New Approach for AI-Based DGA for Transformers and Tap-Changers. *2023 IEEE Electrical Insulation Conference Eic 2023*, (Query date: 2026-07-07 03:37:35). <https://doi.org/10.1109/EIC55835.2023.10177366>
- Puerto-Santana, C. (2022). Asymmetric HMMs for Online Ball-Bearing Health Assessments. *IEEE Internet of Things Journal*, 9(20), 20160–20177.
<https://doi.org/10.1109/JIOT.2022.3173064>
- Rajora, G. L. (2025). An Open-Source Tool-Box for Asset Management Based on the Asset Condition for the Power System. *IEEE Access*, 13(Query date: 2026-07-07 03:37:35), 49174–49186. <https://doi.org/10.1109/ACCESS.2025.3551663>
- Rojas, L. (2025). AI-Driven Predictive Maintenance in Mining: A Systematic Literature Review on Fault Detection, Digital Twins, and Intelligent Asset Management. *Applied Sciences Switzerland*, 15(6). <https://doi.org/10.3390/app15063337>
- Ruggieri, S. (2024). Automatic detection of typical defects in reinforced concrete bridges via YOLOv5. *Procedia Structural Integrity*, 62(Query date: 2026-07-07 03:37:35), 129–136.
<https://doi.org/10.1016/j.prostr.2024.09.025>
- Saeed, A. (2024). An interpretable hybrid framework combining convolution latent vectors with transformer based attention mechanism for rolling element fault detection and classification. *Heliyon*, 10(21). <https://doi.org/10.1016/j.heliyon.2024.e38993>
- Santis, R. B. de. (2023). A Data-Driven Framework for Small Hydroelectric Plant Prognosis Using Tsfresh and Machine Learning Survival Models. *Sensors*, 23(1).
<https://doi.org/10.3390/s23010012>
- Sartor, M. (2024). Assets Performance Management systems for hydroelectric power plants—A survey. *Electric Power Systems Research*, 228(Query date: 2026-07-07 03:37:35).
<https://doi.org/10.1016/j.epsr.2023.110080>
- Shi, Y. (2025). Bank financial sustainability evaluation: Data envelopment analysis with random forest and Shapley additive explanations. *European Journal of Operational Research*, 321(2), 614–630. <https://doi.org/10.1016/j.ejor.2024.09.030>

- Shimizu, M. (2022). A Real-Time Fault Detection Framework Based on Unsupervised Deep Learning for Prognostics and Health Management of Railway Assets. *IEEE Access*, 10(Query date: 2026-07-07 03:37:35), 96442–96458. <https://doi.org/10.1109/ACCESS.2022.3205352>
- Sim, Y. S. (2025). AI-based remaining useful life prediction for transmission systems: Integrating operating conditions with TimeGAN and CNN-LSTM networks. *Electric Power Systems Research*, 238(Query date: 2026-07-07 03:37:35). <https://doi.org/10.1016/j.epsr.2024.111151>
- Souza, M. L. H. (2023). A machine-learning based data-oriented pipeline for Prognosis and Health Management Systems. *Computers in Industry*, 148(Query date: 2026-07-07 03:37:35). <https://doi.org/10.1016/j.compind.2023.103903>
- Upadrashta, D. (2026). AI/ML Based Anomaly Detection and Fault Diagnosis of Turbocharged Marine Diesel Engines: Experimental Study on Engine of an Operational Vessel. *Information Switzerland*, 17(1). <https://doi.org/10.3390/info17010016>
- Wang, H. (2024). Behavior-aware Sparse Trajectory Recovery in Last-mile Delivery with Multi-scale Attention Fusion. *International Conference on Information and Knowledge Management Proceedings*, (Query date: 2026-07-07 03:37:35), 4931–4938. <https://doi.org/10.1145/3627673.3680079>
- Wen, T. (2024). A Sequential and Asynchronous Federated Learning Framework for Railway Point Machine Fault Diagnosis with Imperfect Data Transmission. *IEEE Transactions on Industrial Informatics*, 20(6), 8828–8837. <https://doi.org/10.1109/TII.2024.3378800>
- Xiang, M. (2025). An iontronic pressure sensor with high linearity and ultrawide range over 4 MPa for submarine pressure monitoring. *Chemical Engineering Journal*, 517(Query date: 2026-07-07 03:37:35). <https://doi.org/10.1016/j.cej.2025.164365>
- Xu, J. (2025). AI-Powered Digital Twin Technology for Highway System Slope Stability Risk Monitoring. *Geotechnics*, 5(1). <https://doi.org/10.3390/geotechnics5010019>
- Zachariades, C. (2025). A Review of Artificial Intelligence Techniques in Fault Diagnosis of Electric Machines. *Sensors*, 25(16). <https://doi.org/10.3390/s25165128>
- Zali, R. B. (2025). A Weighted Likelihood Ensemble Approach for Failure Prediction of Water Pipes. *Journal of Water Resources Planning and Management*, 151(2). <https://doi.org/10.1061/JWRMD5.WRENG-6655>
- Zayed, S. M. (2023). An Efficient Fault Diagnosis Framework for Digital Twins Using Optimized Machine Learning Models in Smart Industrial Control Systems. *International Journal of Computational Intelligence Systems*, 16(1). <https://doi.org/10.1007/s44196-023-00241-6>
- Zhou, T. (2023). An uncertainty-informed framework for trustworthy fault diagnosis in safety-critical applications. *Reliability Engineering and System Safety*, 229(Query date: 2026-07-07 03:37:35). <https://doi.org/10.1016/j.ress.2022.108865>

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