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EXPLAINABLE ARTIFICIAL INTELLIGENCE FOR FINTECH INCIDENT RESPONSE WITH AUDITABLE DIAGNOSTIC EVIDENCE

Emmanuel O Ozioma [1] and Ogechi M. Ikeakaonwu [2, *]

[1] Department of Software Engineering, The University of Salford, 43 Crescent, Salford, Greater Manchester, M5 4WT, United Kingdom.
[2] Department of Business Analytics, University of Dundee, Perth Road. Dundee. DD1 4HN United Kingdom.
* Corresponding Author

ORCID Details
Ogechi M. Ikeakaonwu: https://orcid.org/0009-0003-5788-1099

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ABSTRACT

Financial technology services depend on interconnected microservices, where failures can propagate across payment, identity, ledger, and risk components. Incident response must restore service while preserving a defensible account of diagnostic decisions. This article develops an explainable, human-supervised incident-response framework that links telemetry, ranked causal hypotheses, counterfactual tests, privacy controls, and tamper-evident evidence. It specifies a controlled comparison between standard dashboard-led investigation and an AI-assisted workflow in a synthetic fintech testbed. Outcomes include time to correct diagnosis, top-k accuracy, false leads, audit completeness, and unauthorised action rate. A prespecified regression framework is proposed to estimate workflow effects while accounting for incident and analyst variation, with suitable distributional models for time, counts, and bounded audit scores. The supplied material contains mock-data code rather than observed trial data; therefore no treatment effect is asserted. The contribution is a reproducible protocol and an operational definition of evidence-preserving diagnosis, suitable for prospective evaluation. The framework treats speed, diagnostic validity, privacy, and reviewability as joint design constraints rather than interchangeable benefits.

Keywords: Fintech; Microservices; Incident Response; Explainable Artificial Intelligence; Audit Provenance

1 INTRODUCTION

Financial services increasingly depend on distributed applications in which a customer-facing transaction crosses multiple independently deployed services. This architecture can improve deployment flexibility, yet it complicates fault localisation: a visible payment error may originate in an upstream identity provider, a dependency timeout, a certificate rotation, or inconsistent state between services. Logs, metrics, and traces expose different parts of the event, and the responder must reconstruct their temporal and causal relationships under pressure. Research on causal discovery and trace-based diagnosis has begun to address root-cause localisation in microservice systems [90]–[93]. Operational guidance also emphasises coordinated incident command, reliable timelines, and learning-oriented post-incident records [94], [95].

The operational problem in a regulated financial setting is broader than finding the most likely faulty component. A diagnosis should be supported by evidence that can be reconstructed later: which telemetry was consulted, how candidate causes were tested, what uncertainty remained, and who authorised a change. Auditability is especially important where diagnostic tooling can access sensitive transaction metadata or recommend actions affecting payment integrity. PCI DSS requirements address logging and monitoring of access to system components and cardholder data [96], while the NIST AI Risk Management Framework offers a lifecycle-oriented approach to mapping, measuring, and managing AI risks [97]. These instruments do not prescribe a specific RCA algorithm; they make governance, traceability, and controlled access part of the system context.

Explainability is often presented as a property of a model output, such as a ranked list or feature attribution. Incident response needs a more operational concept: an explanation must connect a claim to timestamped evidence and distinguish an observed fact from an inference. A useful explanation should also preserve rejected alternatives. For example, a hypothesis that database saturation caused payment timeouts is weakened if database latency remains stable while connection acquisition waits rise after a certificate renewal. The resulting record should make the reasoning inspectable without exposing raw personal or payment data unnecessarily. AI governance research in the supplied references similarly highlights the gap between high-level commitments and institutional mechanisms for accountability [67], [68], [75].

This study asks: can an explainable, AI-assisted workflow reduce the time required to identify a root cause while maintaining or improving the completeness and integrity of diagnostic evidence? The proposed contribution has three parts. First, it defines a synthetic, domain-neutral fintech testbed and a blinded crossover protocol. Second, it defines a provenance-aware diagnostic workflow that constrains the agent to read-only investigation until a human approves remediation. Third, it specifies an outcome model that treats speed, accuracy, false leads, evidence completeness, and safety as distinct endpoints. This is a methodological contribution; it does not assume that automation will improve every endpoint or that a synthetic benchmark predicts production performance.

The study is positioned at the intersection of automated fault localisation, human-AI decision support, and operational governance. Prior microservice RCA work demonstrates the value of causal relations and service dependency structure [90]–[93]. Research on AI governance and accountability in the supplied corpus provides adjacent conceptual context [67], [68], [75], but is not direct evidence about fintech incident outcomes. A credible test must therefore compare the proposed workflow against a well-specified baseline and measure both diagnostic performance and the quality of the evidence trail. It must also predefine failure cases, including misleading explanations, incomplete telemetry, privacy leakage, and a correct diagnosis reached through an incorrect chain of reasoning.

The proposed question has immediate practical relevance because incident records may later inform service reliability decisions, customer communication, internal control reviews, and external assurance. These uses impose different evidentiary demands. An engineer needs a concise explanation linked to actionable signals; an auditor needs reproducible access paths and an accountable decision record; a privacy officer needs assurance that diagnostic processing did not unnecessarily propagate personal data. The workflow must therefore make the provenance layer usable during an incident, not merely complete after it. This requirement motivates evaluation of the diagnostic interface and evidence artifact as one sociotechnical system.

2 LITERATURE REVIEW AND RESEARCH GAP

Automated root-cause analysis spans anomaly detection, dependency-graph reasoning, causal inference, and multimodal correlation of logs, metrics, and traces. Causal discovery is attractive because temporal association alone does not establish that a component caused an observed failure. Yet causal models depend on adequate observability, assumptions about confounding, and sufficiently varied fault scenarios. Top-k diagnosis metrics are useful for triage, but can obscure whether the correct cause was eventually found, whether the proposed evidence was valid, and whether the operator was misled by a plausible but false explanation. Work on causal localisation in microservices [90]–[92] supports the technical premise that dependencies can structure diagnosis, while leaving open how an operational workflow should preserve evidence and human accountability.

Incident management practice treats documentation as part of response rather than an afterthought [96], [97]. In regulated contexts, this record has two audiences: responders who need concise actionable guidance, and reviewers who need provenance and integrity. Cryptographic hashes can reveal later alteration, but cannot prove that source telemetry was accurate or that a causal inference was valid. Likewise, an immutable store can preserve a poor or privacy-invasive record. The framework therefore combines data minimisation, explicit evidence links, calibrated uncertainty, human sign-off, and tamper evidence. AI risk guidance [98] and payment-card logging requirements [99] inform governance requirements, although neither should be interpreted as certifying an AI diagnostic tool.

The gap is thus not simply an absence of another model. It is the lack of a controlled evaluation that measures diagnosis speed and quality together with provenance completeness, privacy exposure, and intervention control. The attached reference file contains 89 entries spanning many unrelated fields. Only a small subset bears directly on this question; the remainder are retained in the appended reference inventory for traceability but are not treated as evidence for the claims in this paper.

3 METHODOLOGY

3.1 Testbed and protocol

The synthetic testbed comprises a payment orchestrator, account verification, ledger, fraud-screening, and notification services connected through a documented dependency graph. A proctor injects blinded cases of dependency latency, resource exhaustion, expired credentials, schema incompatibility, or state inconsistency. Use generated transactions, structured logs, traces, metrics, and deployment events; redact tokens and secrets before model access.

Analysts investigate matched tasks using either conventional dashboards and runbooks or the AI-assisted interface, with order counterbalanced and variants used to limit recall. The agent is read-only; an authorised analyst must approve every mutation. Randomise by scenario family and experience, record period and analyst identifiers, and analyse incident-task observations with analyst-clustered uncertainty estimates.

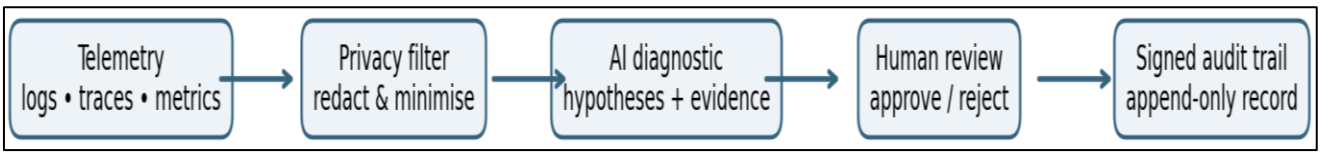


Figure 1: Proposed evidence-preserving incident-response workflow.

3.2 Measures and evidence artifact

The primary endpoint is time from incident disclosure to a correct root-cause declaration, with a prespecified timeout. Secondary endpoints are top-1/top-3 correctness, false hypotheses pursued, audit completeness, privacy events, and unauthorised action attempts. Score audit completeness against a preregistered checklist covering query provenance, evidence for each hypothesis, rejection rationales, uncertainty, timestamps, actor identity, approval, and integrity checks. Blinded assessors use a written rubric.

Each event record stores incident and scenario identifiers, timestamp, actor, tool/query, redaction status, evidence locator, hypothesis, confidence, rationale, decision, approval state, and previous-record hash. Keep raw telemetry in controlled source systems; retain model, configuration, and retrieval versions for reproducibility. Signatures can reveal later alteration, but cannot establish that telemetry or inference is correct.

3.3 Statistical model

For positive diagnosis time T, fit a Gamma generalized linear model (GLM) with log link. Let A denote AI assistance, D cascade depth, X prespecified controls, and γs scenario fixed effects:

$T_i \sim \text{Gamma}(\mu_i, \varphi)$; $\log(\mu_i) = \beta_0 + \beta_1 A_i + \beta_2 D_i + \beta_3 (A_i \times D_i) + X_i\beta + \gamma_s$. Use sandwich standard errors clustered by analyst.

The interaction β_3 tests whether assistance changes the complexity penalty (directional hypothesis $\beta_3 < 0$). Use negative-binomial regression for false-lead counts, logistic regression for top-3 correctness, and fractional-logit quasi-likelihood for bounded audit scores. Report marginal effects, confidence intervals, calibration, and absolute and relative contrasts. A constrained utility may summarise trade-offs: $J(a) = w_1 E[\log T(a)] + w_2 E[FL(a)] - w_3 E[C(a)] + \lambda_1 P(\text{unauthorised action}|a) + \lambda_2 P(\text{privacy breach}|a)$, subject to $P(\text{correct}|a) \geq \kappa$ and $P(\text{approval before mutation}|a)=1$. Set weights and κ in advance, test sensitivity, and report each endpoint separately.

A constrained utility function may summarise trade-offs but should not replace endpoint reporting:

$J(a) = w_1 E[\log T(a)] + w_2 E[FL(a)] - w_3 E[C(a)] + \lambda_1 P(\text{unauthorised action} \mid a) + \lambda_2 P(\text{privacy breach} \mid a)$, subject to $P(\text{correct diagnosis} \mid a) \geq \kappa$ and $P(\text{approval before mutation} \mid a) = 1$.

Here FL is the false-lead count, C audit completeness, and weights and κ are prespecified stakeholder choices. The penalty terms prevent speed from compensating for unauthorised action or privacy breach.

4 RESULTS AND PLANNED ANALYSIS

No observed experiment was supplied, so treatment estimates, p-values, confidence intervals, and performance percentages cannot be reported. The Python snippet in the source material generates synthetic records from stipulated coefficients; it is useful for checking code paths but is not a dataset and does not support inferential claims. In particular, the draft values $\beta = -0.08$, the stated 16.2% and 3.1% per-hop changes, IRR = 0.49, and near-perfect audit completeness are assumptions or generated outputs, not observed findings. They are therefore excluded as findings here.

For the actual study, the primary analysis should report adjusted geometric mean diagnosis-time ratios for AI versus baseline at prespecified cascade depths, alongside the interaction estimate. The principal interpretation is whether any time reduction is accompanied by non-inferior or improved diagnostic correctness and audit completeness. A faster but less accurate diagnosis would not support the proposed benefit. False leads should be reported as incident-level counts and rates, with dispersion diagnostics determining whether a negative-binomial model is adequate. Audit score distributions should be shown, including floor and ceiling effects and item-level omissions.

Table 1 specifies the planned endpoints and analysis. Before data collection, define the timeout, correctness adjudication procedure, missing-data treatment, minimum meaningful effect, sample-size target, and stopping rules. A simulation-based power analysis should reproduce the clustered crossover structure and plausible analyst/scenario variance. Model diagnostics should assess residual patterns, overdispersion, influential incidents, and proportionality of treatment effects. A robustness analysis should exclude scenarios with instrumentation failure and separately retain them as operational failures; both estimands are informative.

Table 1: Planned endpoints and statistical treatment.

Outcome	Operational definition	Model	Interpretive safeguard
Diagnosis time	Seconds to correct root cause; timeout censored	Gamma mixed model, log link	Report contrasts at fixed cascade depths
Correctness	Ground-truth cause at top-1/top-3	Mixed logistic model	Score evidence-supported correctness
False leads	Incorrect hypotheses pursued	Negative-binomial mixed model	Check overdispersion and exposure
Audit completeness	Checklist items satisfied / applicable items	Fractional logit or item-level binomial	Do not equate completeness with truth
Safety and privacy	Unauthorised action or sensitive-data exposure	Exact rates; prespecified safety review	Any severe event reported separately

The results should be interpreted through a prespecified decision framework rather than a single significance threshold. For diagnosis time, a treatment ratio below one is evidence of faster response only if the correctness endpoint is maintained and timeout handling is comparable across groups. For the interaction term, the relevant question is whether the difference in time scaling across cascade depth is practically meaningful and estimated with adequate precision. If depth is ordinal or incident classes are unevenly represented, marginal predictions should be reported over the observed common support rather than extrapolated to untested topologies.

The audit score requires particular care. A checklist can reward the presence of many fields while failing to measure whether the evidence actually supports the conclusion. We therefore recommend reporting each audit item separately, and a blinded validity rating of whether evidence references substantiate the associated hypothesis. Inter-rater reliability should be reported for both completeness and evidentiary validity. A high completeness score paired with weak evidentiary validity would indicate well-documented but unreliable reasoning, not a successful governance outcome.

Before the trial, the research team should publish a protocol containing scenario definitions, randomisation, endpoint adjudication, sample-size rationale, model specification, and an analysis plan. Analysts should receive equivalent training in both interfaces, and the order of conditions should be counterbalanced. Scenario creators should not score outcomes. The trial should capture interaction logs and screen events sufficient to reconstruct analyst actions while avoiding unnecessary collection of keystrokes or identifiable employee information. Participation should be voluntary, with results reported at group level and not used for individual performance management.

Safety evaluation should include adversarial and degraded-input cases: missing spans, contradictory telemetry, stale dependency maps, injected misleading log lines, prompt-injection strings in application data, and unavailable privacy filters. The system should abstain or request human escalation when evidence is insufficient. Predefined stop conditions should cover raw sensitive data reaching the model, an unapproved mutation, an integrity-check failure, or a high-confidence false diagnosis in a safety-critical scenario. Such events should be reported separately from average performance because a low-frequency severe failure can dominate the deployment decision.

The planned analysis should distinguish intention-to-treat effects, based on assigned workflow, from per-protocol effects, based on actual workflow adherence. Missing outcomes caused by a system outage should not be silently dropped: they are operationally meaningful and should be included in a failure-rate analysis, with sensitivity bounds for the diagnosis-time estimand. Analysts may learn across repeated tasks, so period and sequence effects should be modelled. Scenario and analyst random effects are justified by the repeated, crossed design; if convergence is poor, a prespecified simpler model and cluster-robust inference should be used rather than selecting a model after viewing treatment results.

A successful result would not establish universal superiority. It would support the narrower claim that, in the tested topology and task distribution, the workflow altered measured response outcomes under specified controls. Generalisation would depend on infrastructure diversity, analyst populations, model updates, telemetry quality, and the organisation's operating procedures. External replication and a shadow deployment would be necessary before a production recommendation.

5 DISCUSSION

The proposed framework reframes incident-response AI as a governed diagnostic process rather than an autonomous fixer. Its value proposition is conditional: automation may reduce search friction when telemetry is sufficiently linked and the model can expose evidence for its claims. It may also create new failure modes, including anchoring responders on an incorrect lead, hiding missing telemetry behind confident prose, or expanding access to sensitive logs. Consequently, a system-level evaluation should test calibration and operator reliance, not only average resolution time. Human approval is a meaningful control only if the interface communicates uncertainty and the approver can inspect the underlying evidence.

The audit artifact separates integrity from validity. Cryptographic signatures can help establish that a record has not changed since signing; they cannot prove that the record is complete, that telemetry was correctly interpreted, or that omitted evidence was immaterial. Likewise, a complete sequence of diagnostic steps is not automatically compliant with every legal or contractual obligation. PCI DSS logging requirements [99] and NIST AI RMF [98] provide governance reference points, but deployment-specific compliance decisions require qualified control mapping. The proposed record is therefore an engineering aid for post-incident review, not a compliance certification.

The evaluation has several threats to validity. Synthetic scenarios can underrepresent legacy dependencies, noisy telemetry, organisational escalation, and adversarial conditions. Repeated tasks can create learning or carryover effects. Analyst skill and familiarity with a particular interface can confound workflow effects. Ground truth in injected failures is unusually clear compared with production incidents, where multiple causes may interact. These limitations support a staged programme: first validate scenario realism and scoring reliability, then conduct a controlled analyst study, and finally run a shadow-mode field evaluation with no autonomous mutations. Only the latter stages can establish operational transfer.

6 CONCLUSION

This article defines a prospective method for evaluating explainable AI in fintech microservice incident response. The central design principle is that diagnosis speed, correctness, audit completeness, privacy, and intervention safety must be measured together. A synthetic testbed, counterbalanced analyst protocol, evidence-linked hypothesis log, human approval gate, and distribution-appropriate statistical models provide a reproducible basis for that evaluation. The attached material does not contain observations from a completed experiment; accordingly, no empirical advantage is claimed. Mock-data coefficients are not findings and should not appear as such in a submission. The proposed framework is also not a substitute for legal or standards-based compliance assessment. Its principal contribution is to make the intended trade-offs testable: an AI workflow should be considered beneficial only if it improves or preserves diagnostic quality while producing a reviewable record without unacceptable privacy or safety events. Prospective implementation, preregistration, and independent validation are required before claims of effectiveness or generalizability can be made. The next step is a preregistered pilot with independent scoring and public reporting of the analysis plan.

STATEMENTS ON COMPLIANCE WITH ETHICAL STANDARDS

Disclosure of conflict of interest

No conflict of interest to be disclosed.

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APPENDIX A REPRODUCIBLE ANALYSIS CODE

The accompanying Python file generates explicitly synthetic demonstration records, validates an approved CSV schema, fits the prespecified models, writes model summaries, and saves a model-based MTTR interaction plot. It is intended as a reproducibility scaffold; estimates from --simulate must never be reported as study findings. Install numpy, pandas, matplotlib, and statsmodels before running.

python fintech_incident_analysis.py --simulate --n 300 --seed 42 --outdir analysis_output
python fintech_incident_analysis.py --data approved_study.csv --outdir analysis_output

Core model specification

common = " + engineer_experience + C(period) + C(scenario_family) + C(scenario_id)"

mttr = smf.glm(

```
    "mttr_minutes ~ treatment * cascade_depth" + common,
    data=df, family=sm.families.Gamma(link=sm.families.links.Log())
).fit(cov_type="cluster", cov_kwds={"groups": df["analyst_id"]})
false_leads = smf.negativebinomial(
    "false_leads ~ treatment + cascade_depth" + common, data=df
).fit(disp=False, cov_type="cluster", cov_kwds={"groups": df["analyst_id"]})
audit = smf.glm(
    "audit_completeness ~ treatment + cascade_depth" + common,
    data=df, family=sm.families.Binomial()
).fit(cov_type="cluster", cov_kwds={"groups": df["analyst_id"]})
```