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Silent Data Waste in Public Laboratories: A Conceptual Framework for Sustainable Data-Driven Management

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Abstract:

Public medical laboratories generate extensive volumes of routine operational data, including test workloads, turnaround times, quality control results, reagent consumption records, and equipment performance indicators. Despite this abundance, a substantial proportion of these data remains underutilized in managerial and strategic decision-making. This phenomenon is conceptualized in this paper as silent data waste, defined as the systematic loss of informational value arising not from data scarcity, but from weak governance, limited analytical capacity, and fragmented information systems.

This conceptual paper positions silent data waste as a managerial and organizational challenge rather than a purely technical limitation. Drawing on a focused and critical review of recent literature in laboratory management, health data governance, and sustainable healthcare systems, the study develops an integrated conceptual framework linking routine data utilization to quality performance and resource efficiency outcomes. Key operational indicators, such as median turnaround time, specimen rejection rates, and quality control compliance metrics, are used as quantifiable managerial performance measures to illustrate how improved data utilization can support evidence-based management, reduce material and environmental waste, and enhance service reliability. The proposed framework advances the discourse on sustainable laboratory management by reframing routine operational data as a strategic leadership asset. By strengthening data governance structures, analytical tools, and managerial data literacy, public laboratories can transition from reactive operations toward proactive, sustainable, and performance-oriented management aligned with relevant sustainable development goals.

The review synthesizes evidence indicating that 30–50% of routine laboratory data remains underutilized, with measurable performance and sustainability implications.

Keywords: Data utilization, public laboratories, Silent data waste, Specimen rejection, Sustainable management, Turnaround time.

1. Introduction:

Public medical laboratories operate at the core of healthcare delivery systems and generate large volumes of routine operational data on an everyday basis. These data encompass indicators such as turnaround time (TAT), specimen rejection rates, workload distribution, quality control performance, and equipment utilization (Alhammad et al., 2024, Cai et al., 2025). Empirical reviews indicate that laboratories routinely collect more than 70–80% of the operational data required for performance monitoring, yet only a limited proportion of these data are systematically analyzed for managerial decision-making (Tuladhar et al., 2023).

Recent literature in healthcare management has described this underutilization as silent data waste, referring to the latent loss of informational value when routinely collected data are not translated into actionable managerial insights (Tuladhar et al., 2023; An et al., 2025). Studies on clinical data life cycles suggest that up to 30–50% of routinely generated health data remain underused due to governance gaps, limited analytical capacity, and system fragmentation (An et al., 2025).

From a sustainability perspective, effective data utilization is increasingly recognized as a critical enabler of resilient health systems (OECD, 2021; World Bank, 2021). Recent global health strategies emphasize digital governance and structured data stewardship as foundational pillars for resilient health systems (World Health Organization, 2021). Data-driven decision-making supports the achievement of Sustainable Development Goal (SDG 3) by improving healthcare quality and (SDG 12) by promoting responsible resource use and waste reduction (OECD, 2021; World Bank, 2021; Uçar, 2023). In laboratory settings, systematic analysis of operational data enables managers to identify bottlenecks, reduce unnecessary test repetition, and allocate resources based on actual service demand rather than assumptions.

Despite these recognized benefits, significant gaps persist in the translation of routine laboratory data into managerial and strategic actions, particularly within public laboratory systems (Worku, 2025). Addressing these gaps is essential for improving both operational performance and sustainability outcomes.

2. Problem Statement:

In many public medical laboratories, routine operational data are systematically collected but inadequately incorporated into managerial decision-making. As a result, laboratories fail to detect and address process inefficiencies in a timely manner (Tuladhar et al., 2023). Published studies report median turnaround times exceeding recommended benchmarks by 20–40% in resource-constrained public laboratories, largely due to the absence of data-driven monitoring and feedback mechanisms (Cai et al., 2025).

3. Significance of the Study:

This study contributes to the growing body of literature on sustainable healthcare management by offering a structured conceptualization of silent data waste in public laboratory settings. By emphasizing managerial data utilization rather than data availability alone, the paper highlights an often-overlooked determinant of laboratory performance.

Strengthening the use of routine operational data supports evidence-based management, improves service timeliness, reduces material and environmental waste, and enhances accountability in public health institutions. The proposed framework provides laboratory leaders and policymakers with a theoretically grounded basis for integrating sustainability considerations into routine performance management practices.

4. Aim and Objectives:

4.1 Aim:

The aim of this paper is to develop a theoretically grounded conceptual framework that explains how improved utilization of routine operational laboratory data can enhance quality performance and resource efficiency within public medical laboratories.

4.2 Objectives:

4.2.1 To conceptualize silent data waste as a managerial challenge in public laboratory systems.

4.2.2 To identify routine operational data types with high managerial and sustainability relevance.

4.2.3 To examine key organizational and managerial barriers to effective data utilization.

4.2.4 To propose a conceptual framework linking data utilization to quality and sustainability outcomes.

4.2.5 To outline practical performance indicators that support data-driven and sustainable laboratory management.

5. Conceptualizing Silent Data Waste in Laboratories:

Silent data waste in laboratory settings manifests in multiple interrelated forms. These include inaccessible data stored in fragmented or non-integrated systems, underutilized data that are available but not systematically analyzed, inconsistent data arising from variable recording practices, redundant data duplicated across platforms, and data lost due to inadequate archiving or backup procedures (WHO Regional Office for Europe, 2022; An et al., 2025).

Systematic reviews of clinical data management indicate that data fragmentation and inconsistency can reduce the effective usability of routinely collected datasets by up to 40%, thereby limiting their value for longitudinal performance monitoring and strategic planning (An et al., 2025). Although often excluded from conventional sustainability audits, these forms of data waste collectively undermine operational efficiency, data reliability, and organizational learning capacity. Their cumulative impact extends beyond managerial inconvenience to influence service quality, financial performance, and environmental sustainability outcomes in healthcare systems (Tuladhar et al., 2023; Uçar, 2023).

5.1. Forms and Impacts of Data Waste:

5.1.1 Inaccessible Data: Data frequently resides in disparate, unintegrated systems such as separate laboratory information management systems (LIMS), electronic lab notebooks (ELNs), or simple spreadsheets. Furthermore, data stored in legacy or proprietary formats can be difficult to access or interpret. This fragmentation often results from a lack of standardized data exchange protocols, leading to valuable information being siloed and effectively lost to broader analysis.

5.1.2 Underutilized Data: Even when data is accessible, it might remain underutilized. This occurs when collected data is not systematically analyzed or integrated into decision-making processes. Reasons for this can include a lack of appropriate analytical tools, insufficient expertise among staff, or unclear protocols for data usage. This represents a significant missed opportunity for scientific breakthroughs and improved public health outcomes. (Tuladhar et al., 2023).

5.1.3 Lost Data: Poor archiving practices, inadequate backup strategies, and even physical degradation of storage media can lead to the complete data loss. This not only erodes the historical record but can also compromise longitudinal studies and the ability to track long-term trends essential for public health interventions.

5.1.4 Inconsistent Data: Variations in data entry, recording methodologies, and quality assurance procedures across different personnel or over time can lead to inconsistent datasets. Such inconsistencies compromise the reliability and integrity of the data, making it unsuitable for robust analysis and decision-making

5.1.5 Data Redundancy: The duplication of data across multiple systems is a common issue. This not only consumes unnecessary storage space and processing power but also creates potential discrepancies, as updates in one system may not be reflected in another, leading to unreliable information. (An et al., 2025).

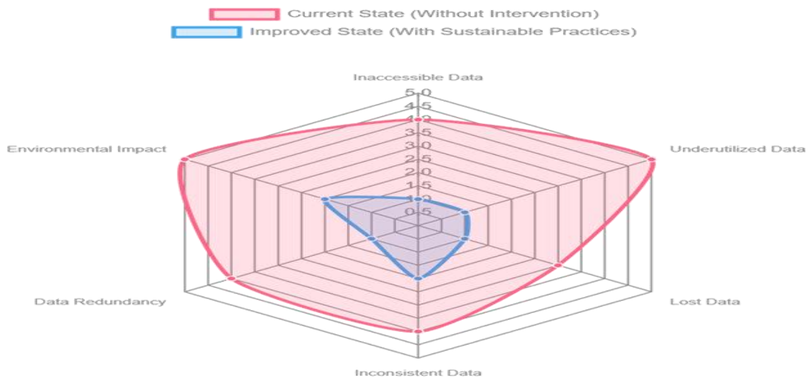

Figure 1. Conceptual framework linking data utilization with quality performance and resource efficiency outcomes

Figure 1 illustrates the proposed conceptual framework, using a radar chart to depict the relative impact of different forms of silent data waste and how improved data utilization and sustainable data management practices can reduce these effects across key laboratory performance outcomes, including environmental impact.

Note: (The radar chart uses a conceptual scale (1–5), where higher values indicate greater negative impact).

6. The Managerial Barriers to Data Utilization:

The persistence of silent data waste is closely linked to managerial and organizational constraints rather than technological limitations alone, as health systems

performance literature consistently demonstrates that information use, accountability structures, and organizational learning mechanisms are central determinants of institutional effectiveness (Arah et al., 2020). Key barriers identified in the literature include limited analytical capacity among laboratory leaders, fragmentation between laboratory and hospital information systems, and the absence of standardized performance dashboards for routine monitoring (Worku, 2025; Cai et al., 2025).

Digital transformation studies further indicate that technological implementation alone does not guarantee performance improvement without managerial integration and organizational readiness (Kruse et al., 2020; Shaw et al., 2022).

Without structured tools for data visualization and interpretation, routine performance indicators remain isolated data points rather than drivers of managerial action. Empirical and conceptual studies consistently emphasize that addressing these barriers is a prerequisite for embedding data-driven decision-making into sustainable laboratory management practices (An et al., 2025).

7. Critical Synthesis of the Literature:

Despite the growing body of research on laboratory data management and performance indicators, several conceptual and structural limitations remain evident within the existing literature.

- Much of the published research addresses individual operational metrics in isolation, such as turnaround time or specimen rejection rates, without embedding these indicators within an integrated governance framework. This fragmented analytical orientation restricts the strategic value of operational data and limits its contribution to long-term institutional performance improvement.
- Contemporary studies frequently approach laboratory data challenges from a technical or informatics-centered perspective, emphasizing automation, digital systems, and analytical tools. While such approaches enhance efficiency, they often underemphasize managerial accountability, leadership engagement, and organizational data culture as determinants of sustainable data utilization.
- Sustainability considerations in laboratory research are commonly framed in environmental or cost-containment terms, with limited conceptual integration between routine data governance and measurable sustainability outcomes. Few studies explicitly position routine operational data as a strategic asset capable of simultaneously improving quality performance and advancing institutional sustainability objectives.

These conceptual gaps indicate the need for a structured framework that bridges governance mechanisms, managerial decision-making, and sustainability-oriented performance management. The present study responds to this gap by developing an integrated conceptual model that reconceptualizes routine laboratory data as a strategic managerial resource rather than a passive operational byproduct.

8. Methodological Approach:

This study adopts a conceptual analytical approach based on a structured and focused review of recent peer-reviewed literature published between 2020 and 2025. Sources were identified through leading academic journals and edited volumes in the fields of laboratory management, healthcare quality improvement, data governance, and sustainable health systems (Worku, 2025; An et al., 2025).

Rather than generating primary empirical data, the paper synthesizes existing theoretical frameworks, empirical findings, and best-practice guidelines to develop an integrating conceptual model. This approach is consistent with established methods for conceptual research in health management and sustainability studies (Tuladhar et al., 2023). Common laboratory performance indicators, such as turnaround time and specimen rejection rates, are used illustratively to demonstrate the practical relevance of improved data utilization for managerial decision-making (Uçar, 2023, Cai et al., 2025).

8.1. Literature Review Approach:

This conceptual paper is grounded in a structured literature review of recent scholarly work published between 2020 and 2025. The review aimed to identify and synthesize contemporary research addressing laboratory data governance, operational performance indicators, healthcare sustainability, and managerial data utilization in public healthcare institutions.

Relevant publications were identified through searches conducted in major academic databases, including PubMed, Scopus, Web of Science, and Google Scholar. The search strategy employed combinations of the following keywords: “laboratory data governance,” “healthcare data utilization,” “laboratory performance indicators,” “turnaround time management,” “specimen rejection rates,” and “sustainable healthcare management”.

The inclusion criteria were defined as follows:

- Peer-reviewed journal articles and academic book chapters.
- Publications written in English.
- Studies published between 2020 and 2025.
- Research directly examining healthcare data management, laboratory operational performance, sustainability in healthcare systems, or institutional governance mechanisms.

The exclusion criteria included:

- Editorials, opinion pieces, or commentaries lacking analytical or conceptual grounding.
- Studies unrelated to healthcare or clinical laboratory contexts.
- Duplicate records or sources without accessible full-text versions.

This structured approach ensured theoretical coherence, relevance to the study objectives, and conceptual rigor in developing the proposed framework.

9. Conceptual Framework:

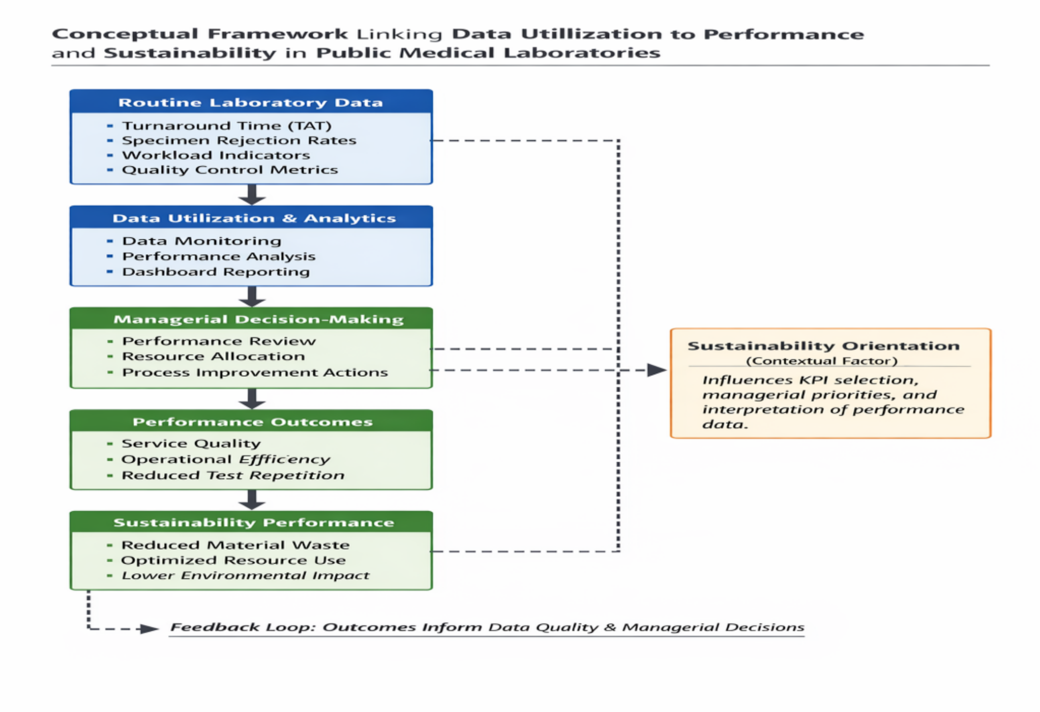

Figure 2. Conceptual framework illustrating how routine laboratory data utilization supports managerial decision-making, leading to improved performance outcomes and enhanced sustainability in public medical laboratories. The framework emphasizes a feedback mechanism through which performance outcomes inform continuous data quality improvement and future managerial actions.

The proposed conceptual framework positions data utilization as the central independent construct that influences two primary outcome domains: quality performance and resource efficiency. This conceptualization is grounded in management and health systems literature emphasizing the role of information use in organizational performance improvement (International Organization for Standardization [ISO], 2022; Tuladhar et al., 2023; Worku, 2025).

Data-driven management practices - including performance dashboards, real-time analytics, standardized indicators, and routine feedback mechanisms - act as mediating processes through which raw operational data are transformed into actionable managerial insights (Cai et al., 2025). Through these mechanisms, enhanced data utilization contributes to reduced turnaround times, lower specimen rejection rates, improved quality control compliance, and more efficient allocation of human and material resources (Uçar, 2023).

Continuous monitoring and feedback loops reinforce a cycle of proactive performance management, aligning laboratory operations with sustainability objectives and relevant Sustainable Development Goals (An et al, 2025).

10. Simulation-Based Analytical Scenario: Structured Application within a Public Laboratory Context:

To enhance the methodological rigor and practical interpretability of the proposed conceptual framework, this section presents a structured simulation-based analytical scenario. The purpose of this exercise is not to generate empirical findings, but to analytically model how the framework could operate within a realistic public laboratory environment using performance ranges documented in contemporary literature.

10.1 Analytical Design and Assumptions:

The simulation models a mid-sized public hospital laboratory operating in a resource-constrained setting. The laboratory is assumed to process approximately 300–400 samples per day across hematology, clinical chemistry, and microbiology units. Partial automation is available, and a laboratory information system is in place; however, full interoperability with hospital-wide digital systems is limited.

Baseline operational indicators are derived from performance ranges reported in recent peer-reviewed studies. The following analytical assumptions are therefore adopted:

- Turnaround time deviation: 25–35% above recommended benchmarks.
- Specimen rejection rate: 4–6%.
- Repeat testing rate: 8–12%.
- Manual data reconciliation steps per processing batch: 3–5.

These values reflect documented performance variability in comparable public laboratory contexts and provide a plausible analytical baseline for simulation.

10.2 Modeled Manifestations of Silent Data Waste:

Within this simulated setting, silent data waste is analytically represented through the following governance and managerial gaps:

1. Turnaround time reports are generated periodically but remain disconnected from staffing allocation or workflow redesign decisions.
2. Specimen rejection data are recorded for compliance purposes without systematic root-cause analysis.
3. Equipment performance and maintenance logs are archived but not utilized for predictive monitoring.
4. Repeat testing patterns are not correlated with pre-analytical process variability or training gaps.

These modeled conditions demonstrate that data presence alone does not ensure strategic utilization.

10.3 Structured Implementation of the Framework:

The simulation then applies the proposed conceptual framework through four coordinated managerial interventions:

1. Development of an integrated key performance indicator dashboard incorporating turnaround time, rejection rates, repeat testing frequency, and quality control compliance metrics.
2. Establishment of a formal monthly data governance review cycle with defined managerial accountability mechanisms.
3. Implementation of standardized root-cause analysis protocols targeting rejection and repeat testing trends.
4. Alignment of performance indicators with staffing models and resource allocation planning processes.

This structured intervention sequence reflects governance-centered data utilization rather than technology-driven reform alone.

10.4 Analytical Projection of Performance Outcomes:

Drawing on conservative effect ranges reported in the literature on laboratory performance improvement, the following projected outcomes may reasonably be anticipated within a 6–12month implementation horizon:

- 15–25% improvement in turnaround time compliance.
- 20–30% reduction in repeat testing frequency.
- 10–20% reduction in reagent consumption associated with preventable retesting.
- Measurable reduction in biohazard waste linked to specimen rejection

These projections represent analytically derived estimations grounded in previously documented improvement ranges and are not presented as empirical findings.

10.5 Interpretive Implications:

The simulation analytically confirms that silent data waste constitutes a governance and managerial integration challenge rather than a data availability deficit. The modeled intervention sequence demonstrates that meaningful performance and sustainability gains can be achieved through structured data governance, routine performance review mechanisms, and managerial accountability frameworks without requiring substantial additional capital investment.

Accordingly, the simulation reinforces both the theoretical coherence and the practical feasibility of the proposed conceptual model within public laboratory systems.

11. Key Performance Indicators for Sustainable Laboratory Management:

To operationalize the proposed framework, this paper highlights a set of widely accepted laboratory performance indicators with strong managerial and sustainability relevance. These include median turnaround time, specimen rejection rate, quality control compliance, and indicators related to material and environmental waste generation (Cai et al., 2025; Uçar, 2023). These indicators are consistent with internationally recognized laboratory quality and competence standards (ISO, 2022).

Table 1. Quantitative Evidence Supporting Data-Driven Laboratory Management

Indicator	Reported Range / Impact	Context	Key Source
Underutilized routine health data	30–50% of collected data	Health information systems and laboratory operations	An et al., 2025
Availability of routine operational data	70–80% of required indicators routinely collected	Public and hospital laboratories	Tuladhar et al., 2023
Median turnaround time deviation	20–40% above benchmarks	Public laboratories	Cai et al., 2025
Turnaround time reduction	15–35% reduction	Data-driven process improvement	Cai et al., 2025
Specimen rejection rate	2–8%	Public laboratory settings	Uçar, 2023
Rejection rate reduction	30–50% reduction	Quality improvement initiatives	Uçar, 2023
Environmental impact of rejected specimens	12.3 tons CO_2-eq; 3.7 tons medical waste	Tertiary laboratory (2 years)	Pozzan et al., 2025

The quantitative evidence summarized in Table 1 demonstrates that substantial performance and sustainability gains can be achieved when routine laboratory data are systematically analyzed and integrated into managerial decision-making processes.

12. Discussion:

The simulation based analytical scenario presented above further substantiates the practical applicability of the proposed framework by demonstrating how routine operational data can be systematically transformed into measurable performance and sustainability gains within a realistic public laboratory context.

Building on this analytical illustration, the discussion underscores that routine operational data constitute a largely untapped strategic resource in public laboratory management. Evidence from the literature demonstrates that when such data are systematically utilized, laboratories can achieve substantial performance gains, including reductions in turnaround time ranging from 15–35% and significant decreases in specimen rejection and repeat testing (Uçar, 2023; Cai et al., 2025).

From a sustainability perspective, improved data utilization contributes directly to reduced material consumption and lower environmental impact. Studies indicate that even modest reductions in rejection rates (e.g., 1–2 percentage points) can translate into meaningful decreases in medical waste volume and associated carbon emissions at the facility level (Pozzan et al., 2025). Embedding data utilization within routine managerial practices enables laboratories to transition from reactive problem-solving

toward proactive performance optimization, a transition widely recognized as essential for sustainable health system strengthening (Tuladhar et al., 2023).

While the present study is conceptual in design, its structured analytical modeling provides a replicable foundation for empirical validation within real-world public laboratory settings.

13. Recommendations:

Based on the proposed conceptual framework, the following recommendations are advanced to support sustainable, data-driven management in public medical laboratories:

13.1. Establish clear data governance structures that define responsibilities for data collection, validation, access, and use, in order to enhance the reliability of managerial decision-making. (OECD, 2021; World Bank, 2021).

13.2. Integrate laboratory information systems with broader hospital management platforms to minimize data fragmentation and improve the accessibility of routine operational indicators.

13.3. Implement standardized performance dashboards that enable regular managerial monitoring of key indicators such as turnaround time, specimen rejection, and workload trends, supporting timely and proactive intervention.

13.4. Strengthen managerial data literacy through targeted training initiatives focused on data interpretation, basic analytics, and the practical use of performance indicators in improvement planning.

13.5. Institutionalize routine data review cycles that are explicitly linked to quality improvement initiatives and sustainability-oriented performance management.

14. Conclusion:

Silent data waste represents a significant yet addressable challenge in public laboratory systems. The literature reviewed in this study consistently demonstrates that the problem lies not in data availability but in limited data utilization driven by managerial, organizational, and governance constraints (An et al., 2025; Worku, 2025).

The structured simulation-based analytical scenario developed in this paper further reinforces the practical feasibility of the proposed framework by illustrating how governance-centered data utilization can translate routine operational indicators into measurable quality and sustainability gains within resource-constrained public laboratory environments.

By strengthening data governance, analytical capacity, and managerial accountability mechanisms, public laboratories can enhance quality performance, optimize resource use, and contribute more effectively to sustainable healthcare development. The conceptual framework advanced in this study provides a theoretically grounded and operationally interpretable foundation for future empirical validation.

Addressing silent data waste should therefore be viewed not merely as an operational improvement initiative, but as a strategic imperative for sustainable public laboratory governance. Future research is encouraged to empirically test the framework

through field-based case studies, performance audits, or longitudinal institutional assessments in order to examine its measurable impact under real-world conditions.

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