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Cost Analysis of Conventional Antimicrobial Resistance Diagnostics in Zambia: Evidence for Sustainable Laboratory Investment in Resource-Limited Settings

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Abstract

Antimicrobial resistance (AMR) is a growing global health threat, particularly in low- and middle-income countries (LMICs) like Zambia, where diagnostic capacity is limited, and funding constraints hinder effective response. This study aimed to assess the per-test cost of conventional AMR diagnostic methods, Gram stain, culture, and antimicrobial susceptibility testing (AST), to support sustainable investments and policy decisions. Between December 2024 and March 2025, data were collected from 13 laboratories across nine provinces in Zambia using structured questionnaires. Inputs related to labour, reagents, and equipment were analysed using the WHO Laboratory Testing Costing Tool (LTCT) and Julius AI. Pricing adhered to Zambia's Public Procurement Act, and ethical approvals were obtained from UNZABREC and NHRA. Results showed that test costs varied widely by input type. Gram stains were the least expensive at $3.15 per test, while enriched media like Blood/Chocolate agar reached $4.92 due to high labour and reagent requirements. Biochemical test costs ranged from $4.25 to $7.99, with Coagulase being the most expensive due to reagent costs. Testing for WHO-priority pathogens, such as E. coli and K. pneumoniae, costs approximately $37–38 per test, while testing for Neisseria gonorrhoeae costs $42. Sensitivity analysis identified reagents as the primary cost driver across all test types. Batch testing was cost-effective only for tests with high fixed costs, such as Blood Culture. This study underscores the importance of standardized costing, context-specific planning, and bulk procurement in sustaining affordable diagnostics in resource-limited settings. Future research should incorporate indirect costs to provide a comprehensive understanding of laboratory financial needs.

Keywords: *Costs and Cost Analysis, Drug Resistance, Laboratories, World Health Organization, Zambia.*

Introduction

Antimicrobial resistance (AMR) has emerged as one of the most pressing global health challenges of the 21st century, threatening to reverse decades of medical progress [1, 2]. The World Health Organization (WHO) recognizes AMR as a top global public health threat, capable of rendering common infections untreatable and increasing mortality, morbidity, and healthcare costs worldwide [3]. The massive burden of

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AMR is attributable to a list of bacteria referred to as the WHO Bacterial Priority Pathogen List (BPPL) [4]. While the burden of AMR is global, it disproportionately affects low- and middle-income countries (LMICs) like Zambia, where diagnostic capacity is limited, surveillance systems are weak, and access to appropriate antimicrobial therapies is inconsistent [5, 6]. In 2019 alone, AMR caused an estimated 255,000 deaths in Africa, mainly due to antimicrobial misuse, poor vaccination coverage, environmental contamination, limited access to quality diagnostics and medicines, and insufficient public and healthcare worker awareness [6].

In Zambia, bacteriology testing remains critically limited, with only 1% of public health laboratories equipped for such diagnostics [7, 8]. Health investments have historically focused on vertical programs like HIV, TB, and malaria, leaving diagnostic infrastructure underdeveloped [1, 7]. As a result, only 55% of second-level and 23% of third-level hospitals provide culture and AST, with negligible access at the primary care level [8, 41]. Of over 3,400 health facilities nationwide, just 19 offer these essential services. This diagnostic gap promotes empirical antibiotic use, undermining antimicrobial stewardship and accelerating the spread of antimicrobial resistance (AMR). AMR surveillance capacity is also low, present in only 19% of public and 34% of faith-based facilities [10]. A study across seven mission hospitals reported an average laboratory capacity score of 39%, echoing a broader assessment by ASLM, which found only 14% of Zambian laboratories had adequate testing capacity, highlighting a pressing need to strengthen AMR diagnostic systems nationwide [41].

Health costing, the estimation and analysis of healthcare service expenses [35, 36], is essential in Africa, particularly amid declining donor aid. Accurate costing informs strategic decisions on resource allocation and service delivery, especially for critical services like AMR laboratories. Standardization of costing methods, as recommended by [36, 37], is vital for transparency and policy uptake.

Economic evaluation strengthens this process by comparing costs and outcomes of alternative interventions [32]. It provides the evidence base for investment decisions, highlighting opportunity costs and value-for-money. With overstretched government budgets and limited donor funding, prioritizing affordable, equitable, and impactful health services is critical [33, 34, 38]. Laboratory investments, though often undervalued, yield broader public health benefits, yet traditional evaluations usually miss cross-sectoral impacts [32, 33].

Health services in Africa are often subsidized, but access remains limited due to cost and distance [8, 40]. The African Union has also recognized socio-economic barriers as a driver of rising AMR [39]. Therefore, robust health costing is crucial for advocating sustainable laboratory systems and ensuring efficient, equitable health investments.

The economic impact of AMR is immense, with the World Bank projecting a 3.8% annual loss in global GDP by 2050, amounting to nearly $100 trillion if unaddressed [7]. Health cost analysis helps quantify this burden and supports advocacy for integrating AMR diagnostics into essential health packages [11]. Despite higher upfront costs, diagnostic-driven treatment improves outcomes and curbs unnecessary drug use [12]. Microscopy, culture, and AST remain vital for appropriate antimicrobial therapy in resource-limited settings [13, 14]. However, few cost studies focus on microbiology diagnostics, as most existing data emphasize clinical chemistry and newer diagnostic tests [15].

This study aims to assess the cost per test of Gram stain, culture, and AST to detect AMR and to generate a cost analysis, particularly for WHO-priority bacterial pathogens in Zambia. The need to establish the cost of testing

tailored to geographical settings is now more urgent than ever. Over the past two decades, PEPFAR has invested approximately $120 billion, with annual funding rising from $1.9 billion in FY2004 to $6.5 billion in FY2024. This support has significantly strengthened laboratory systems across Africa through technical training, mentorship, data management, and direct service delivery, including equipment procurement and personnel hiring [31]. However, the U.S. Government and other funding agencies are reviewing their funding support to Africa and other developing countries, potentially disrupting critical public health laboratory services.

Despite being time-consuming and having longer turnaround times than newer methods such as sequencing and molecular testing, conventional methods remain the gold standard for testing for AMR [29]. This study focuses on these methods as a recommendation for potential scale-up in laboratories with less advanced infrastructure and equipment, compared with newer tests that require specialized instruments and trained personnel [29, 30] in Zambia.

The findings are expected to inform and influence policy on financing and insurance reimbursement for AMR testing scale-up using conventional methods, and on promoting testing before antibiotic prescription and use. Culture and antimicrobial susceptibility testing (AST) are available in only a small proportion of health facilities, forcing empirical prescribing and accelerating AMR. Yet, there is little evidence on the actual costs of implementing these diagnostics to guide policy and investment. This study provides Zambia's first comprehensive costing analysis of Gram stain, culture, and AST, identifying cost drivers and efficiencies to inform sustainable financing, strengthen stewardship, and expand equitable access to diagnostics.

The study's limitation is that it focused narrowly on direct operational costs, excluding indirect expenses such as infrastructure, utilities, maintenance, and regulatory compliance. While useful for lab-level budgeting and procurement, the findings should be considered in light of these limitations. Infrastructure design, driven by risk and needs assessments, significantly impacts costs and may hinder lab operations despite investments in reagents, equipment, and training [42].

This study presents the first comprehensive micro-costing analysis of conventional antimicrobial resistance (AMR) diagnostics, Gram stain, culture, biochemical, and AST, in Zambia. Using data from local supplies and 13 laboratories across nine provinces, it provides context-specific cost estimates essential for national planning and sustainable investment. The integration of WHO's LTCT and Julius AI enhances analytical rigor. Unlike prior studies, this research disaggregates cost drivers, highlights the dominant role of reagents, and assesses the impact of batch testing on cost efficiency. These findings offer actionable insights for optimizing laboratory workflows, informing procurement strategies, and guiding evidence-based policy for AMR diagnostic scale-up in resource-limited settings.

Materials and Methods

Data for this study were collected between December 2024 and March 2025 from 13 laboratories performing culture and antimicrobial susceptibility testing (AST) across nine provinces in Zambia: Muchinga (2), Lusaka (4), Northwestern (1), Southern (1), Northern (1), Eastern (1), Central (1), Western (1), and Luapula (1). Of these, five are rural, and 3 are urban provinces. A structured questionnaire was administered to collect standardized data on the human and material resources required for microbiological testing from the 13 laboratories. Specifically, the questionnaire captured detailed information on the time

spent during key steps of bacteriological testing, including media preparation, culture, and AST inoculation and reading. In addition, data were collected on Gram stain procedures, including the average time spent reading smears and the volume of staining reagents used per test. Data on staff wages are based on the Ministry of Health full-time salaried staff for a Biomedical technologist and hence did not vary from laboratory to laboratory. Once data saturation was reached, defined as the point at which no new significant information [16, 17] emerged across facilities, the responses were averaged and summarized. These consolidated values were then entered into WHO LTCT [21] to compute the unit cost per microbiological test. The use of WHO LTCT enabled standardized calculation of direct and indirect costs, ensuring comparability and reliability in estimating the cost per diagnostic procedure in resource-limited settings.

Information on the testing requirements for microscopy, culture, and AST was collected from various sources, including standard operating procedures (SOPs) from local laboratories, the American Society for Microbiology [18], and manufacturer protocols from Himedia [19], the latter chosen to align with quotations from local suppliers. Three Zambian vendors provided detailed cost estimates in Zambian Kwacha, converted to U.S. dollars using OANDA exchange rates [20]. All reported costs exclude tax to ensure consistency in the financial analysis.

The request for quotations process for laboratory reagents and equipment was conducted in accordance with the Zambia Public Procurement Act of 2020, which defines “simplified bidding and selection” as a method that invites bids from a minimum of three bidders [40]. Based on the testing requirements, requests for quotations were sent to eight pre-identified laboratory supplier companies. Of these, three companies submitted quotations for laboratory reagents and consumables, thereby satisfying the simplified bidding threshold. However, only one company submitted a quotation for laboratory equipment, highlighting the limited number of suppliers operating in this market segment. In such cases, the Act permits the use of limited selection, which may be applied where goods or services are only available from a few suppliers [40]. Furthermore, single sourcing is also permitted under the Act when there is only one known supplier available, particularly in cases where no reasonable alternatives or substitutes exist [40]. The reliance on a single quotation for laboratory equipment was therefore both necessary and legally compliant, ensuring adherence to procurement principles while acknowledging the constraints of a limited supplier landscape. These structural limitations are important contextual factors in interpreting the scope and completeness of the study’s data. The above information was used to calculate the cost per test using the current market prices.

Data Analysis

Data were analyzed using the WHO Laboratory Testing Costing Tool (LTCT) [21] to estimate costs per test for microscopy, culture, biochemical tests, and AST, including those used to diagnose organisms on the WHO Bacterial Priority Pathogen List (BPPL) [4]. Key cost components included reagents and consumables, equipment (based on depreciation and usage), and staff time (converted from minutes to wage costs) for test preparation, inoculation, and test reading. Additional descriptive analyses were conducted using Julius AI [22]. Julius is an AI assistant specializing in statistical analysis, data science, and computations [22]. It selects the most suitable large language model (LLM) for each task and generates code to analyze the data based on the given prompts [22]. The datasets generated and analyzed during this study are available from the corresponding author upon reasonable request. Figure 1

outlines the flow of events during data collection and analysis, highlighting the sequential steps followed in the study.

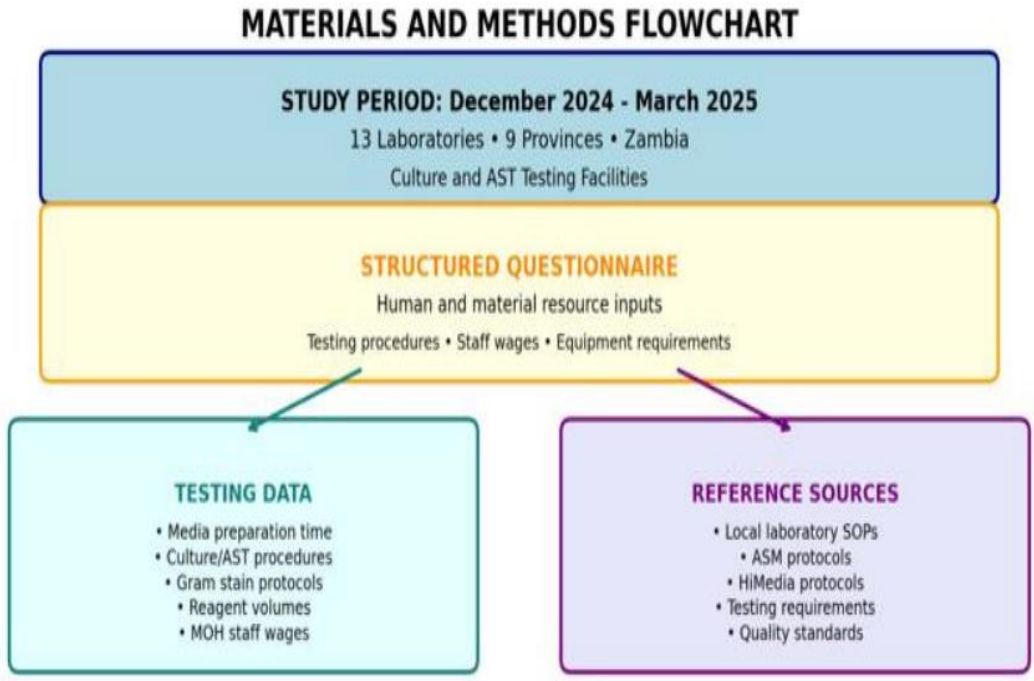

Figure 1. Outlines the Flow of Events during Data Collection and Analysis

Results

Per Test Cost Analysis by Type of Input

The per-test cost analysis of microbiological tests calculated the amount of money needed to conduct one test. The per-test costs analysed include costs associated with preparation, inoculation, reading of gram stains, different types of primary media, identification tests, and a battery of ASTs per organism, as shown in table 1. The per-test cost analysis revealed significant variation across input types. Time inputs differed widely, with Blood/Chocolate agar preparation requiring 117 staff minutes per test, the highest, while Gram staining needed only 39 minutes. Reagent and consumable costs were higher for enriched media, such as Blood/Chocolate agar, due to additives like sheep blood, compared to simpler media such as MacConkey or DCA. Equipment costs varied by frequency of use and equipment lifespan, with media preparation needing autoclaves, fridges, and incubators, unlike Gram staining, which required minimal equipment. Staff costs mirrored time requirements; tests with longer preparation times incurred higher labor costs. Total test costs ranged from $3.15 for Gram stain to $4.92 for Blood/Chocolate agar. Intermediate costs were observed for DCA, MacConkey, SS, and XLD media, depending on complexity and resource use. Overall, enriched media had the highest costs, driven by reagent, equipment, and labor requirements. Table 1 outlines the various cost-per-test contributions of microbiological testing stains and culture, providing a breakdown of the main cost drivers. At the same time, Figure 2 illustrates the percentage distribution of these components across the Gram stain and different culture media.

Table 1. Various Cost per Test Contributions of Microbiological Testing Stains and Culture Media

Description	Gram stain	Blood/ Chocolate Media	Deoxycholate Citrate media	MacConkey	Salmonella/ Shigella media	Xylose Lysine Deoxycholate media
Laboratory Financial Minutes per test	39.00	117.00	78.00	78.00	78.00	78.00
Reagents and consumables cost per test	$2.94	$3.76	$3.89	$3.84	$3.85	$3.90
Equipment cost per test	0.00	$0.53	$0.35	$0.35	$0.35	$0.35
Staff cost per test	$0.21	$0.63	$0.42	$0.42	$0.42	$0.42
Total cost of 1 test	$3.15	$4.92	$4.66	$4.62	$4.63	$4.68

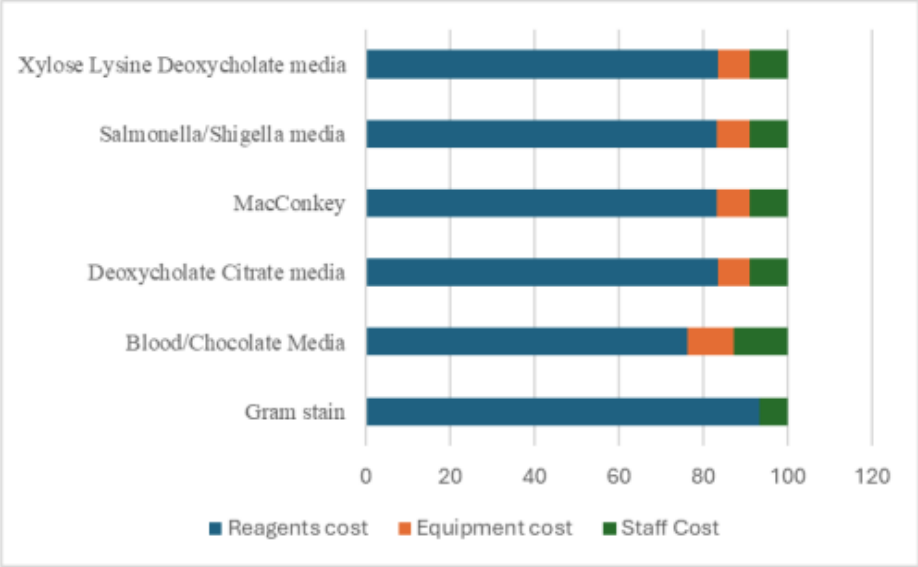

Figure 2. Per Test Cost Components of the Gram Stain and Various Culture Media (In Percentage)

Dissecting Time and Cost Per Test Structures of Common Biochemical Tests

A detailed analysis was conducted to assess both time and cost components of various biochemical tests, to understand test complexity, labour input, and cost efficiency. The tests were grouped into two clusters based on Laboratory Financial Minutes (LFMs), which reflect the technician's time investment.

High Time Intensive Tests (average 78 minutes) included Triple Sugar Iron (TSI), Kligler Iron Agar, SIM Medium, Simmon's Citrate, and Urease. These tests involve complex procedures such as solid media preparation, inoculation, and stepwise interpretation. Despite their higher time demands, they showed consistent cost per test, ranging between $4.25 and $4.49. The cost structure was stable: reagents and consumables ($3.48–$3.72), equipment ($0.35), and staff time ($0.42).

Quick Tests (average 13 minutes) included Catalase, Coagulase, and Kovac's Oxidase. These are rapid enzymatic or biochemical tests with minimal preparation and no incubation time. However, they showed greater cost variability, ranging from $4.30 to $7.99. Equipment costs were zero, staff costs were low ($0.07), but reagent costs ranged

significantly ($4.23–$7.92), with the Coagulase test emerging as a cost outlier at $7.99, due to high reagent expenses.

Among all tests, Simmon's Citrate was the most economical at $4.25, despite being time-intensive, highlighting the cost efficiency of traditional in-house biochemical media. In contrast, the Coagulase test was the most expensive, driven almost entirely by the cost of proprietary reagents rather than time or equipment. The per-test cost comparison of the biochemical tests is presented in Figure 3.

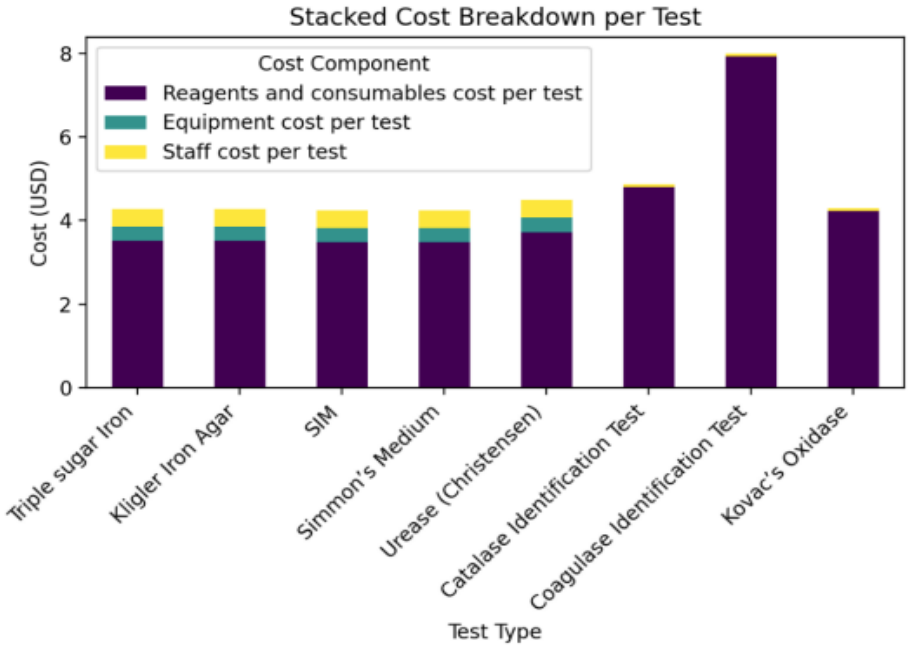

Figure 3. Per-Test Cost Comparison of Biochemical Test

Per Test Costing of WHO Bacterial Priority Pathogens Testing

The selection of pathogens for this cost analysis was informed by two main criteria: the frequency of diagnostic testing performed in Zambia and alignment with the BPPL4. The cost analysis focused on high-priority and critical pathogens identified by the WHO, including *Acinetobacter baumannii*, Enterobacterales (notably *Escherichia coli* and *Klebsiella pneumoniae*), Salmonella spp., and Shigella spp., four all of which are prevalent in the Zambian context. Additional high-priority organisms incorporated into the costing framework included *Pseudomonas aeruginosa, Staphylococcus aureus, Streptococcus pneumoniae, Neisseria gonorrhoeae,* and *Enterococcus faecium*

The per test cost analysis integrates the individual costs of media, Gram staining, biochemical identification tests (Triple Sugar Iron [TSI], Kligler Iron Agar [KIA], Sulfide Indole Motility [SIM], Simmons Citrate, Urease), and antimicrobial susceptibility testing (AST), including the cost of labour for inoculation and reading of the tests. Specific diagnostic workflows were applied for each organism, considering the tests commonly used for identification and resistance profiling in local laboratory practice.

The per test key findings from the analysis reveal consistent consolidated costs for *E. coli, K. pneumoniae, Acinetobacter baumannii,* Salmonella spp., and Shigella spp., all ranging around $37–38 per test. In contrast, *Neisseria gonorrhoeae* exhibited a higher total cost of approximately $42.30 due to higher cost of biochemical tests. *Staphylococcus aureus* and *Streptococcus pneumoniae* had comparatively lower testing costs of approximately $29.46. Figure 4 below delineates the proportion of expenses attributed to media, gram staining, biochemical tests, and AST. Figure 4 presents the cost breakdown by media, biochemical

tests, and antimicrobial susceptibility testing (AST) for each organism, providing a detailed comparison across the different diagnostic components.

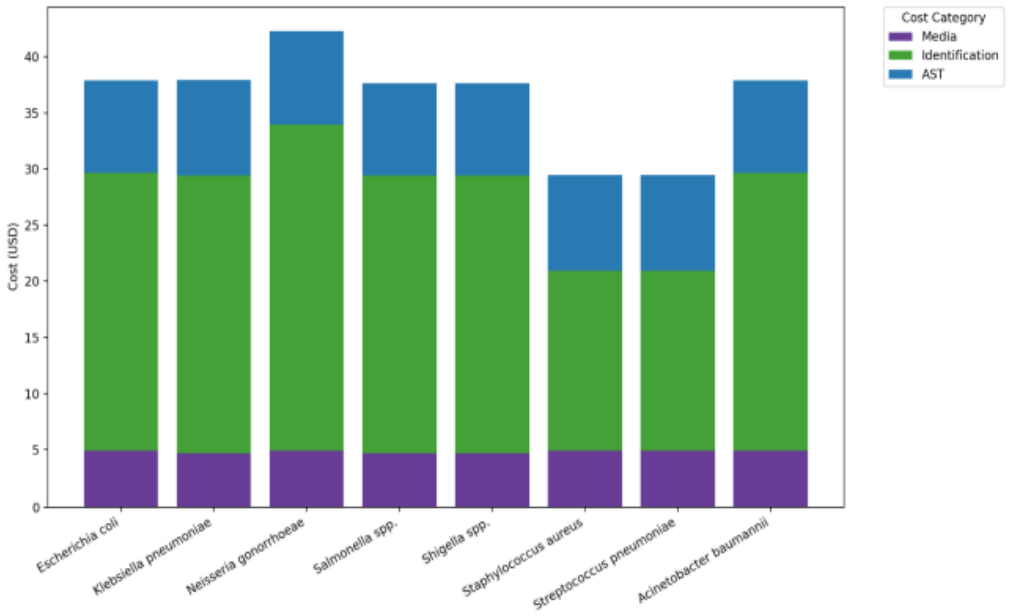

Figure 4. Cost Breakdown by Media, Biochemical Tests and AST for Each Organism

Sensitivity Analysis of Per Test Cost Components in Microbiological Testing

Reagents were the primary driver of cost variability across all test types, with particularly pronounced impact in rapid-turnaround assays, where they accounted for over 95% of the baseline cost. Equipment costs were only noteworthy for the five 78-minute agar/biochemical tests, contributing approximately 8% to the baseline. A 20% increase in equipment pricing would raise the per-test cost by approximately USD 0.06–0.08, a modest increment, though not negligible when scaled across large volumes. In contrast, changes in labour costs have minimal effect, shifting total costs by no more than USD 0.10 even under ±20% variation scenarios.

The data for each test were analysed at ±10 % and ±20 % on each cost component (reagents, equipment, staff) for the biochemical tests. Because Catalase, Coagulase and Kovac's Oxidase have zero equipment cost, changes in Equipment have no effect on their totals (the numbers stay fixed). Coagulase is most sensitive to reagent swings (moves from 6.41 → 9.57 USD over –20 % to +20 %). The longer 78-minute agar/biochemical tests show moderate dual sensitivity to both reagents and equipment because both components contribute materially to their baseline totals. Staff shifts are modest because labour is a small slice of cost.

A sensitivity analysis for E. coli showed that altering AST costs by ±20% shifted the total price to between 36.22–39.50 USD. Reagent heavy components like AST and media had the greatest impact, each ±20% change affecting the total by approximately1 USD. Staff and equipment changes had smaller, embedded effects. Figures 5 and 6 below depict every scenario's dollar change for Triple sugar Iron and *E. coli*, relative to its baseline cost.

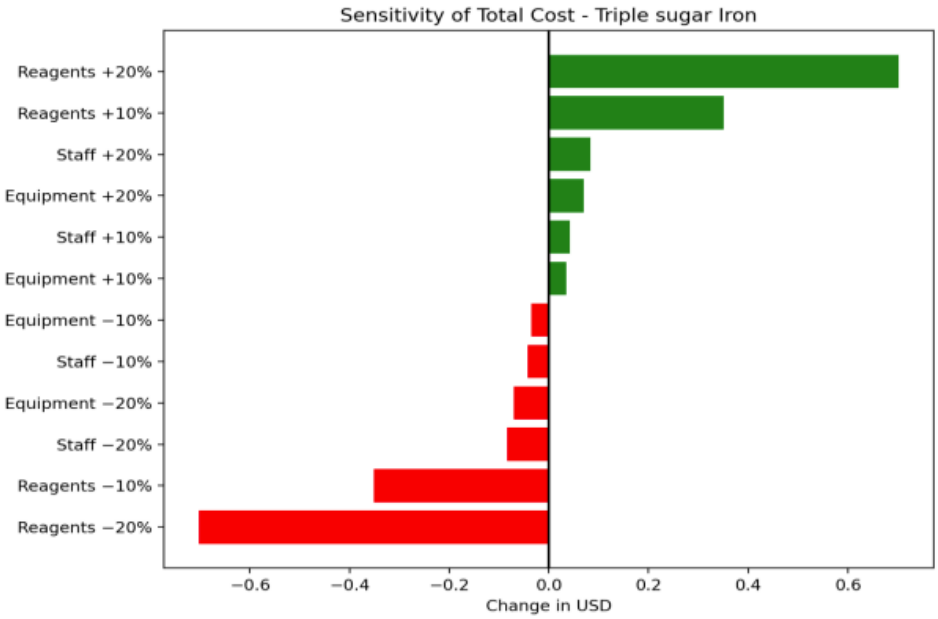

Figure 5. Sensitivity Analysis of Total Cost for Triple Iron Sugar

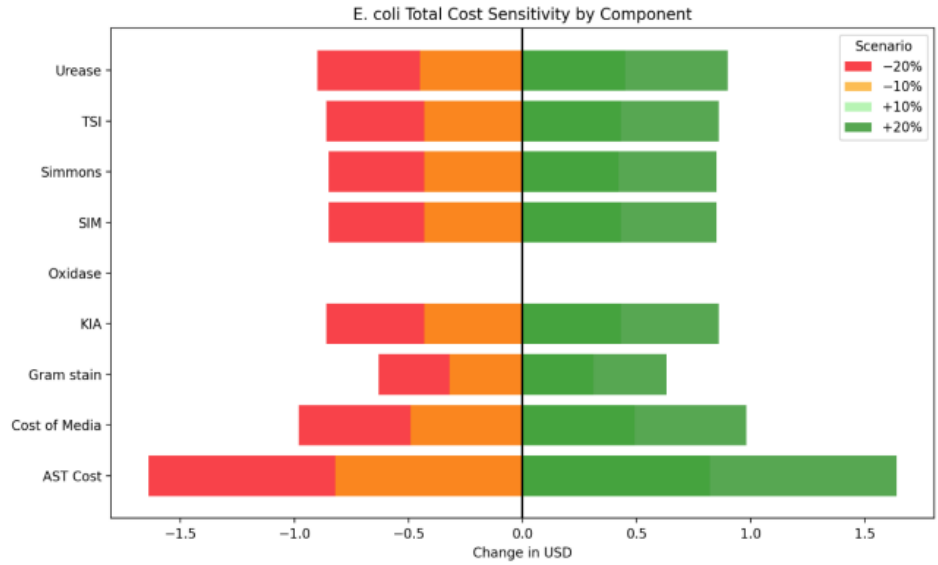

Figure 6. Sensitivity Analysis for *E. coli*

Impact of Batch Testing on Cost Efficiency: *E. coli* Case Study

Batch testing modelling demonstrated variable impact on cost efficiency across different diagnostic procedures for *E. coli*, depending on the proportion of fixed versus variable cost components. Analysis revealed that most *E. coli* diagnostic tests are heavily weighted toward variable costs, particularly reagents and consumables, which accounted for up to 95.6% of the total cost in tests such as antimicrobial susceptibility testing (AST). In such cases, batch testing provided limited cost reductions, as variable costs remain constant regardless of test volume.

In contrast, diagnostic procedures with a higher proportion of fixed costs, such as Blood Culture (fixed cost share: 23.6%), showed greater responsiveness to batching. Increasing batch sizes led to a noticeable reduction in per-test costs by distributing overheads, namely equipment usage and staff time, across multiple samples. Cost reductions were most pronounced when increasing batch size from 1

to 10, after which the benefit plateaued due to the dominance of variable costs.

Graphical analysis supported these findings. The cost-per-test curve showed a steep decline with small increases in batch size for tests with significant fixed cost components, whereas tests like AST exhibited minimal change. A corresponding percentage reduction curve confirmed that Blood Culture achieved up to 23% cost savings, while AST showed less than 10% even at maximum batching levels.

These results highlight that batch testing is most cost-effective for diagnostics with substantial fixed cost elements. For reagent-intensive tests, batching offers limited financial advantage. These insights are critical for laboratory planning, particularly in resource-constrained settings, where optimizing test throughput and minimizing cost per result are essential for sustainability. Figure 7 provides a visualization of batch testing for *E. coli*, illustrating how costs are distributed when multiple samples are processed together.

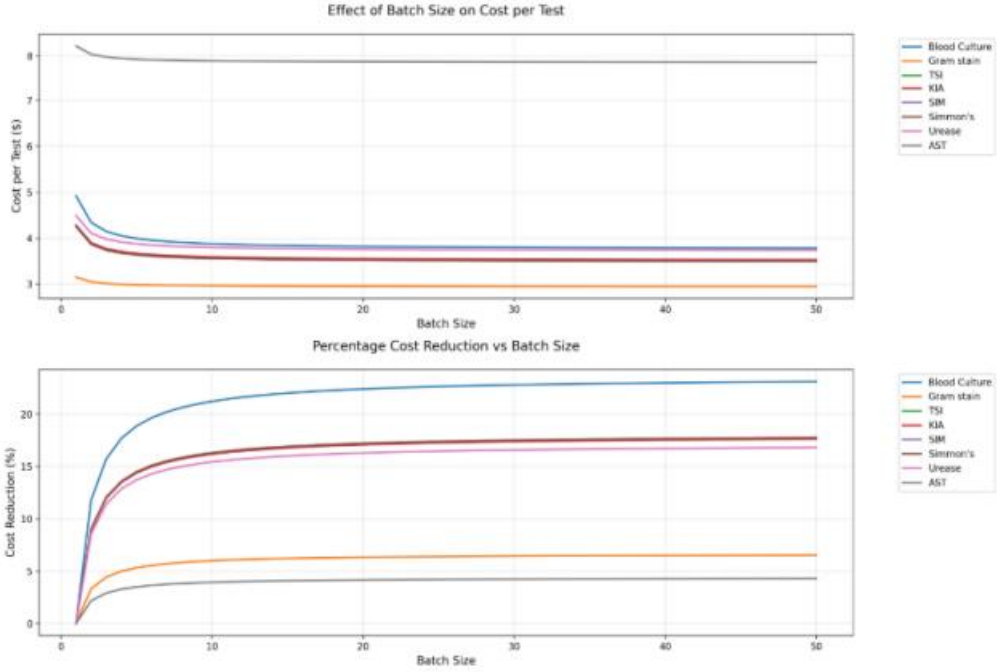

Figure 7. Visualization of batch testing for *E. coli*

Discussion

This costing analysis provides a detailed examination of microbiological diagnostic workflows, emphasizing Gram stain, culture media, biochemical, and AST as the main diagnostics for WHO designated priority pathogens [4]. The study reveals subtle cost structures, operational bottlenecks, and opportunities for efficiency in laboratory settings, especially in resource constrained environments.

1. Cost Structures and Drivers

Reagents were the dominant cost driver across all tests, contributing up to 90% in AST, while equipment and labor varied by procedure. Blood/Chocolate agar showed disproportionately high labor demand, reflected in elevated Lab Financial Minutes (LFM) relative to cost, underscoring the need for workflow optimization through batch processing and efficient staff scheduling [46]. Conversely, some rapid biochemical tests, though less labor-intensive, remained costly due to reliance on proprietary or imported

reagents. These findings emphasize the strategic importance of local reagent production and centralized procurement. Similar studies confirm reagents, consumables, equipment, and labor as key laboratory cost drivers [9, 15, 16, 23, 27].

Proper specimen management improves diagnostic accuracy, reduces unnecessary testing, and enhances workflow efficiency, leading to lower laboratory and hospital costs while supporting overall healthcare cost-effectiveness [13, 23]. Micro-costing is essential for evaluating intervention cost-effectiveness in LMICs, though challenges such as unreliable cost records, staff recall bias, wage disparities, and donated equipment complicate estimates [24]. Hamoudi's study showed automated urine analysis had higher reagent and equipment costs but reduced labor expenses due to faster testing [25]. Additionally, the underutilization of services increases per-test costs, emphasizing the need for demand-aligned resource planning to control reagent and equipment expenses [26].

2. AST, A Standardized, Scalable Test

AST procedures exhibited highly consistent cost profiles, with minimal variation in labor and equipment inputs across test types. This standardization simplifies budgeting, enables easier comparison between diagnostic options, and supports strategic decisions for service expansion. Notably, the uniformity in AST costs promotes equitable access to essential diagnostics across infection types, aligning with public health priorities for antimicrobial resistance (AMR) control. However, due to the dominant role of reagent costs, ensuring financial sustainability in AST hinges on bulk procurement, effective inventory management, and leveraging locally produced media, findings echoed in prior studies [15, 27]. Other studies emphasize that test implementation decisions should extend beyond cost alone; despite higher testing expenses, benefits such as faster turnaround times, shorter hospital stays, and reduced antibiotic use can significantly improve patient outcomes and healthcare efficiency [28, 23].

3. Pathogen Specific Insights

Cost analysis of high priority pathogens, including *E. coli, K. pneumoniae, P. aeruginosa* among others, demonstrated variability based on the diagnostic pathway. Some organisms followed a relatively fixed and predictable cost structure, while others incurred higher expenditure due to test complexity. For example, *E. coli* individual diagnostics tests ranged from $3.15 to $8.22, with cost distribution skewed rightward by procedures such as AST. Variable costs (mainly reagents and consumables) were the primary expenditure drivers, while fixed costs (equipment and permanent staff) were relatively stable. This finding is consistent with findings from other studies. One study found that apart from cost of reagents and consumables, other factors such as organism characteristics, number of samples tested per day, capital equipment and labor intensity were major cost drivers [27].

Health costing of laboratory procedures supports sustainable diagnostics by enabling accurate budgeting and efficient resource use. Context-specific planning, workload alignment, and coordinated bulk procurement are essential to control per-test costs, prevent stockouts, and ensure cost-effective, uninterrupted service delivery, especially in resource-limited settings with variable supply chains and infrastructure constraints [31].

4. Batch Testing Where Feasible

Tests with higher fixed cost components benefit most from batch processing, improving per test affordability. In the 1959 paper "Economic Batch-Size Determination for Multi-Product Scheduling' explores how to determine the most cost-effective batch size when producing multiple products on the same equipment or production line [43]. The goal

was to reduce overall costs by finding the right batch size for each product while managing machine time efficiently [43]. This principle highlighted by Eilon holds true for this study as well, especially in reagent preparation, where the greatest time investment was noted. When producing many different items using the same resources, making the right amount of each product at the right time helps reduce costs and improve efficiency [43]. This principle applies to, for example, all media that need to use the autoclave, incubator and fridges. All these tests can be done at the same cost because of batching, especially when done according to schedules and plans. Batch testing can also be optimized through centralizing testing and consolidating samples via referral networks, reducing the need for new equipment and lowering costs [26].

Conclusion

This study provides the first comprehensive cost analysis of conventional antimicrobial resistance (AMR) diagnostics in Zambia, offering critical insights into the financial and operational dimensions of Gram stain, culture, biochemical tests, and AST. Findings reveal significant variability in per-test costs, with reagents as the primary cost driver and limited gains from batch testing except in high fixed-cost procedures. The study emphasizes the need for context-specific planning, efficient procurement, standardization across laboratories, and strategic resource allocation to ensure sustainable and equitable access to AMR diagnostics. These insights can inform national laboratory policy, guide investment decisions, and support Zambia's broader efforts to combat AMR.

Ethical Consideration

Ethical approval was obtained from the University of Zambia Biomedical Research Ethics Committee (UNZABREC), 6016-2024 and the National Health Research Authority (NHRA), approval number NHRA-1802/18/12/2024. Informed consent was secured from all participants.

Data Availability

The datasets generated and analysed during this study are available from the corresponding author upon reasonable request.

Conflict of interest

The authors declare no conflict of interest.

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Author Contribution

All authors contributed to the study in specific ways as outlined below:

1. **Lutinala Nachilembo Nalomba:** Lutinala led the conceptualization and design of the study and was primarily responsible for developing the research proposal. She took the lead in reviewing the data analysis and drafting the report and also spearheaded the writing and critical revision of the manuscript.
2. **Pascalina Chanda-Kapata:** Pascalina contributed to the study's conceptualization and design and supported the development of the proposal. She also participated in reviewing the data analysis, report, and manuscript.
3. **Mox Kalumbi:** Mox played a key role in developing the data collection tool and

provided practical insights into on-site microbiology practices. He participated in data collection and contributed to reviewing both the proposal and the manuscript.

4. **Baron Yankonde:** Baron contributed to the development of the data collection tool and offered practical input on microbiology practices during fieldwork. He participated in data collection, reviewed the proposal and manuscript, and supported the compilation of technical requirements and distribution of vendor quotation requests.

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