Mongolian Journal of Economic Review-MJER **Volume 30/19 (2026)**
ARTICLE
https://doi.org/10.69588/mjer.v30i19.5124

Primary article

Activity-Based Unit Cost Estimation for Pathology Services in Mongolia: Evidence from the National Center for Pathology

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Received: 28 February 2026 | Accepted: 21 May 2026 | Published online: 29 June 2026

Kye words: *Activity-Based Costing, pathology services, unit cost, healthcare financing, Mongolia*

Abstract: *Evidence on service-level pathology costs in Mongolia is limited, despite its importance for tariff setting and efficient resource allocation.* ***Objective:*** *To estimate unit costs of pathology services using Activity-Based Costing (ABC) and examine cost structures in Mongolia's pathology sector.* ***Methods:*** *A mixed-methods study was conducted at the National Center for Pathology, Mongolia. Using ABC, 24 diagnostic tests and services were costed for 2022–2024 based on financial records, procurement data, time logs, and operational statistics. Indirect costs were allocated using defined cost drivers. One-way ANOVA and Pearson correlation analyses were performed.* ***Results:*** *Unit costs ranged from MNT 48,036 for telepathology consultation to MNT 703,865 for complete autopsy. Direct labor was the main cost driver ($r=0.94$, $p<0.01$), followed by direct materials ($r=0.76$, $p<0.01$). Molecular diagnostics showed the highest material intensity (62–82%), while overhead remained relatively stable (8–15%). Cost differences across service categories were significant ($F=3.85$, $p=0.025$).* ***Conclusions:*** *ABC generated transparent, service-specific cost estimates and identified substantial variation across pathology services, supporting tariff revision, improved resource allocation, and performance-based financing in Mongolia.*

https://doi.org/10.69588/mjer.v30i19.5124

I. INTRODUCTION

Healthcare financing systems increasingly require accurate, service-level cost information to support efficient purchasing, tariff setting, and accountability. In many health systems, provider payment reforms have shifted from input-based budgeting toward output-based, diagnosis-related, or performance-linked financing. However, such reforms can only function effectively when payment rates reflect the real resources consumed by services. If tariffs are set without reliable cost evidence, providers may be underpaid for complex services, overpaid for simple services, or encouraged to cross-subsidize activities in ways that distort clinical and managerial decision-making (Mogyorosy & Smith, 2005; World Health Organization, 2020).

Mongolia has experienced substantial growth in healthcare expenditure and increasing reliance on health insurance-based purchasing. The Health Insurance Fund budget has expanded considerably in recent years, yet concerns remain regarding allocative efficiency, cost control, and the alignment between reimbursement mechanisms and actual service costs (Ministry of Health Mongolia, 2021). These challenges are particularly relevant for diagnostic services, including pathology, because such services are often embedded within broader case-based or diagnosis-related payments rather than reimbursed according to their real resource consumption.

Pathology services are a fundamental component of modern healthcare delivery. They contribute directly to cancer diagnosis, staging, treatment selection, surgical decision-making, quality assurance, mortality surveillance, and public health monitoring. In Mongolia, the National Center for Pathology serves as the national reference institution and provides a broad range of services, including autopsy, surgical pathology, biopsy interpretation, cytology, histochemistry, immunohistochemistry, molecular diagnostics, quality-control review, and telepathology consultation. These services differ substantially in labor intensity, reagent use, equipment dependence, turnaround requirements, and professional expertise. Therefore, a single average cost or simple volume-based allocation method is unlikely to capture their true economic burden.

Traditional costing systems commonly allocate indirect costs using simple measures such as service volume, labor hours, or general departmental expenditure. Although administratively convenient, these methods assume that services consume resources in proportion to a single allocation base. This assumption is problematic in pathology, where a small biopsy, complete autopsy, frozen section, immunohistochemistry test, and molecular diagnostic assay require very different combinations of professional time, technical work, reagents, equipment, quality-control activities, and overhead support. As a result, traditional costing may overestimate routine high-volume services and underestimate complex, urgent, or material-intensive services (Blocher, 2019; Cooper, 1988).

Activity-Based Costing offers a more refined approach. ABC is based on the principle that resources are consumed by activities, and activities are consumed by services. Instead of assigning costs directly to final services through broad averages, ABC first identifies major activities, groups resource costs into cost pools, and then assigns costs using cost drivers that represent actual resource consumption (Cooper, 1988; Kaplan & Anderson, 2007). In healthcare, ABC and related approaches such as Time-Driven Activity-Based Costing have been used to improve transparency in hospital costing, surgical care, diagnostic services, and value-based health economic analysis (Kaplan, 2007; Mogyorosy & Smith, 2005; Thandar Myint et al., 2022).

https://doi.org/10.69588/mjer.v30i19.5124

Pathology service costing presents several methodological challenges. First, many services involve sequential activities, including specimen reception, accessioning, gross examination, tissue processing, embedding, microtomy, staining, microscopic interpretation, reporting, archiving, and quality control. Second, direct material costs differ widely because some services require inexpensive routine consumables, while others require costly antibodies, probes, primers, reagents, or specialized kits. Third, professional labor varies by case complexity, reporting requirements, and need for consultation. Fourth, equipment depreciation and facility costs must be allocated fairly across services that differ in volume and use intensity. These features make pathology an appropriate setting for ABC because the method can trace costs through specific activities and cost drivers rather than relying on broad departmental averages (Mogyorosy & Smith, 2005; World Health Organization, 2020).

International evidence indicates that ABC can reveal substantial variation in unit costs across service types and can identify inefficiencies hidden by traditional costing systems. Than et al. (2017) demonstrated that service-level costing in public hospitals provides valuable information for pricing, budgeting, and resource allocation. Similarly, costing studies in hospital settings have shown that more refined costing systems improve the interpretation of labor, material, and overhead contributions to total cost (Sodani et al., 2011; Zhang et al., 2021). However, implementation requires careful activity mapping, reliable time estimates, appropriate allocation bases, and transparent assumptions (Kaplan, 2007; Mogyorosy & Smith, 2005).

Despite the importance of pathology services, empirical evidence on pathology unit costs in Mongolia remains scarce. Previous Mongolian studies on costing have mainly focused on general budget organizations, education-related institutions, or broader cost accounting approaches rather than diagnostic pathology services (Ariunbold, 2011; Davaajargal, 2020; Munkhzul, 2013). No published study has systematically applied ABC to a broad set of pathology services using operational data from Mongolia's national reference pathology institution. This evidence gap limits the ability of policymakers and health insurance purchasers to design cost-reflective tariffs, assess underfunded services, and plan investments in diagnostic capacity.

This study addresses that gap by applying Activity-Based Costing to estimate unit costs for 24 pathology services at the National Center for Pathology, Mongolia. The specific objectives were: first, to estimate service-specific unit costs using ABC; second, to describe the cost structure of pathology services by direct labor, direct material, and overhead components; third, to examine statistical associations between cost components and total unit cost; and fourth, to explore the implications of ABC-derived cost information for tariff setting, resource allocation, and performance-based financing.

METHODS

2.1 Study Design and Setting

This study used a mixed-methods Activity-Based Costing design to estimate unit costs of pathology services at the National Center for Pathology, Mongolia. The institution functions as the national reference center for pathology and provides diagnostic, consultative, quality-control, and autopsy services. The costing analysis covered the period from January 2022 to December 2024. Operational service-volume data for 2024 and January–October 2025 were also reviewed to describe recent workload patterns. The study adopted the institutional provider perspective. Therefore, costs borne directly by the National Center for Pathology were included, while patient out-of-pocket costs, transportation costs, productivity losses, and broader societal costs were excluded. This approach is consistent with healthcare costing guidance, which recommends clearly defining the costing perspective before selecting data sources, cost categories, and allocation methods (Mogyorosy & Smith, 2005; World Health Organization, 2020).

2.2 Services Included

Twenty-four pathology services were included in the ABC analysis. These represented the main service categories delivered by the institution: autopsy services, surgical pathology, histochemistry, immunohistochemistry, molecular diagnostics, cytology, quality-control review, and telepathology consultation. For consistency, the manuscript should report 24 services throughout. If the final dataset truly includes 28 services, then the abstract, methods, tables, and results should all be updated consistently. At present, the safest correction is to standardize the manuscript to 24 services, because Table 2 lists 24 services.

2.3 ABC Implementation Framework

ABC was implemented through five sequential steps, following the general principle that resources are consumed by activities and activities are consumed by final services (Cooper, 1988; Kaplan & Anderson, 2007). First, major pathology activities were identified through direct observation, review of service workflows, and staff consultation. Activities included specimen reception, registration, gross examination, tissue processing, embedding, microtomy, staining, immunohistochemistry preparation, molecular test preparation, microscopic interpretation, reporting, quality-control review, archiving, and administrative support. Second, resource costs were identified from institutional records. Direct labor costs were estimated from salary records and staff time logs. Direct material costs were estimated from procurement records, reagent price lists, and standard consumption rates. Equipment costs were estimated using depreciation schedules. Indirect costs included administration, utilities, facility maintenance, general supplies, and shared support services. Third, costs were grouped into cost pools according to their relationship with pathology activities. Directly traceable costs were assigned to services whenever possible. Shared costs were allocated using cost drivers selected to reflect causal resource consumption. This is important because inappropriate allocation bases can distort unit cost estimates, particularly in services with heterogeneous workflows and resource intensity (Blocher, 2019; Mogyorosy & Smith, 2005). Fourth, activity cost-driver rates were calculated by dividing the total cost of each activity pool by the total quantity of the relevant cost driver. For example, labor-related activity costs were allocated using staff time, reagent-related costs using standard consumption per test, equipment costs using equipment-use time or test volume, and administrative overhead using service volume or workload share. Fifth, unit cost for each service was calculated as the sum of all activity costs consumed by that service:

Unit cost per service = Direct labor cost + Direct material cost + Allocated overhead cost

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More formally: Unit $cost_i$ = Σ(Activity cost-driver $rate_j$ × Quantity of $driver_j$ consumed by $service_i$) where i represents the pathology service and j represents each activity or cost pool.

2.4 Cost Pools and Allocation Logic

Cost pools and allocation bases were defined according to the Activity-Based Costing principle that resources are consumed by activities, and activities are then consumed by final services (Cooper, 1988; Kaplan & Anderson, 2007). Directly traceable costs, such as labor time and consumable materials, were assigned to each pathology service whenever possible. Shared or indirect costs, including equipment depreciation, utilities, facility support, administrative overhead, and quality-control activities, were allocated using cost drivers that reflected the most plausible pattern of resource consumption. The selected cost pools, main cost items, and allocation bases are presented in **Table 1**. The following cost pools and cost drivers were used:

Table 1. Cost Pools, Main Cost Items, and Allocation Bases Used for Activity-Based Costing of Pathology Services

Cost pool	Main cost items	Allocation basis / cost driver
Direct labor	Pathologists, laboratory technicians, assistants	Staff time per service, measured in minutes
Direct materials	Reagents, slides, cassettes, stains, antibodies, probes, primers, consumables	Standard material consumption per service
Equipment depreciation	Tissue processors, microtomes, stainers, microscopes, IHC and molecular equipment	Equipment-use time or service volume
Utilities and facility support	Electricity, heating, water, maintenance	Departmental floor area and workload share
Administrative overhead	Finance, management, reporting, quality system support	Service volume or proportional workload
Quality-control activities	Internal review, external consultation, repeat checks	Number of QC events or review time

Note: QC = quality control. Allocation bases were selected according to the expected relationship between each cost pool and actual resource consumption.

Depreciation was calculated using the straight-line method over the expected useful life of each asset. Where direct measurement was not feasible, allocation assumptions were documented and reviewed with department staff. Idle capacity was not interpreted as service-specific efficiency loss unless directly attributable to a service. This distinction was made to avoid artificially inflating the unit cost of low-volume but essential reference services.

2.5 Inflation and Currency Adjustment

All costs were expressed in Mongolian tugrik. Because the costing period covered multiple years, financial values should ideally be adjusted to a common price year using the national consumer price index or a health-sector-specific inflation index if available. Costing guidance recommends standardizing monetary values when data are collected across multiple years, particularly where inflation or exchange-rate movement may affect comparability (Mogyorosy & Smith, 2005; World Health Organization, 2020).

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2.6 Statistical Analysis

Descriptive statistics were used to summarize unit costs and cost components. Unit costs were reported as total cost and as component costs for direct labor, direct materials, and overhead. Cost shares were calculated as the proportion of total unit cost attributable to each component.

One-way ANOVA was used to compare mean unit costs across service categories. Where appropriate, post-hoc pairwise comparisons were used to identify which service categories differed significantly. Because the number of services within some categories was small, non-parametric sensitivity testing using the Kruskal–Wallis test may also be considered as a robustness check. Pearson correlation analysis was used to examine associations between total unit cost and major cost components. These analyses were interpreted as descriptive associations rather than causal relationships because total unit cost is mathematically composed of labor, material, and overhead costs. This caution is important because correlation analysis can describe the relative contribution of cost components but cannot prove causal cost drivers in the econometric sense. Deterministic one-way sensitivity analysis was conducted to assess the robustness of unit cost estimates under plausible changes in key assumptions. The following scenarios were examined:

1. Direct material costs increased by 20%, reflecting reagent price fluctuation.
2. Direct labor costs increased by 10%, reflecting salary adjustment.
3. Service volume decreased by 20%, increasing allocated fixed overhead per unit.
4. Service volume increased by 20%, decreasing allocated fixed overhead per unit.

These scenarios were selected because reagent prices, salary levels, and service volumes are policy-relevant sources of uncertainty in pathology costing. Similar scenario-based approaches are commonly used in healthcare costing to assess whether conclusions remain stable under alternative assumptions (Mogyorosy & Smith, 2005; World Health Organization, 2020).

2.7 Validity and Replicability

Several procedures were used to strengthen validity and replicability. First, cost inputs were obtained from multiple institutional sources, including financial statements, procurement records, salary data, equipment registers, and operational statistics. Second, activity maps were reviewed with department staff to verify workflow accuracy. Third, time estimates were based on staff logs and cross-checked with observed workflow patterns where feasible. Fourth, cost-driver assumptions were documented in a structured allocation matrix. Fifth, sensitivity analysis was used to assess whether key conclusions changed under alternative assumptions.

Transparent documentation of activity definitions, cost pools, allocation bases, and sensitivity assumptions is essential for replicability in ABC studies because the method depends heavily on how activities and drivers are defined (Cooper, 1988; Kaplan & Anderson, 2007; Mogyorosy & Smith, 2005).

2.8 Ethical Considerations

The study used institutional financial, operational, and administrative data. No patient-level clinical records or identifiable patient information were accessed. Institutional approval was obtained from the National Center for Pathology.

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3 RESULTS

3.1 Service Volumes and Activity Patterns

During the study period, NCP processed 142,354 specimens in 2024 and 57,459 specimens in the first ten months of 2025 (**Table 2**). Surgical pathology specimens (excisional biopsies, incisional biopsies, and small biopsies) constituted the largest volume category, followed by cytology specimens. Autopsy volumes remained relatively stable at approximately 700-800 annually.

Table 2: Pathology Service Volumes at the National Center for Pathology

Service Category	2024 (Full Year)	2025 (October)
Complete autopsy with diagnosis	715	608
Surgical pathology - endoscopic/needle biopsy	18,212	17,635
Pathology - biopsy	19,167	12,728
Histochemistry	2,114	3,786
Tissue processing (per block/slide)	87,681	91,089
Immunohistochemistry (IHC) - interpretation	1,074	2,840
IHC - technical preparation	3,043	3,118
FISH analysis	0	45
Gynecologic cytology	9,953	18,757
Non-gynecologic cytology	247	471
Telepathology consultation	120	168
Total	**142,326**	**151,459**

3.2 Unit Cost Estimates

ABC analysis revealed substantial variation in unit costs across services, ranging from MNT 48,036 for telepathology consultations to MNT 703,865 for complete autopsies (**Table 3**). Cost structures differed markedly by service type.

Table 3. Unit Cost Estimates for Pathology Services (MNT)

Service	Direct Labor	Direct Material	Overhead	Total Cost
Complete autopsy	398,401	287,598	17,866	703,865
Autopsy consultation (external)	36,596	24,902	15,598	77,096
Surgical pathology - endoscopic/needle biopsy	29,773	34,206	8,553	72,532
Surgical pathology - incisional biopsy	29,773	34,206	13,255	77,234
Surgical pathology - excisional biopsy	47,184	34,206	8,557	89,947
Frozen section	29,880	34,206	41,634	105,720
Histochemistry	38,936	50,221	10,234	99,391
Tissue processing (per block)	23,799	34,206	8,547	66,552
Surgical pathology quality control review	31,697	28,719	13,255	73,672

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IHC - interpretation (per marker)	25,868	50,633	8,913	85,414
IHC - technical preparation (per marker)	20,551	50,633	8,575	79,759
IHC quality control review	65,441	0	13,255	78,697
CISH analysis	48,700	77,932	13,255	139,887
FISH analysis	48,700	81,526	13,255	143,481
RT-PCR analysis	4,872	81,526	13,255	99,653
Gynecologic cytology	35,411	41,169	9,476	86,057
Non-gynecologic cytology	38,007	29,404	10,106	77,517
Liquid-based cytology	26,622	81,526	13,255	121,403
Cell block preparation	23,263	47,257	13,255	83,776
Cell block IHC	28,118	46,044	13,255	87,418
Immunocytochemistry	30,836	46,044	13,255	90,136
Cytology preparation (gynecologic)	39,092	52,748	13,255	105,096
Cytology quality control review	39,092	0	13,255	52,347
Telepathology consultation	34,781	0	13,255	48,036

3.3 Cost Structure Analysis

3.3.1 Overall Cost Patterns

Across all services, direct labor dominated cost structures (mean proportion: 48.3%), followed by direct materials (36.7%) and overhead (15.0%). However, substantial variation existed across service categories.

3.3.2 Service Category Patterns

- Autopsy Services: Complete autopsies showed the highest absolute costs, with balanced labor (56.6%) and material (40.9%) components reflecting the intensive technical and professional input required. Consultation autopsies had lower costs but similar proportional structures.
- Surgical Pathology: Unit costs ranged from MNT 72,532 for simple biopsies to MNT 105,720 for frozen sections. Frozen sections demonstrated higher overhead (39.4%) due to the urgent, after-hours nature of the service requiring dedicated equipment availability. Molecular Diagnostics: FISH, CISH, and RT-PCR showed the highest material intensity (62-82% of total cost) due to expensive probes, primers, and reagents. Labor costs were proportionally lower but absolute values remained substantial.
- Immunohistochemistry: IHC services demonstrated balanced structures with materials (52-59%) slightly exceeding labor (31-37%). The technical preparation versus interpretation split revealed that interpretation added approximately 7% to total cost.
- Cytology: Unit costs varied substantially by technique. Liquid-based cytology (MNT 121,403) cost 41% more than conventional gynecologic cytology (MNT 86,057) due to higher material costs. Quality control reviews cost MNT 52,347—approximately 60% of primary interpretation cost.
- Consultative Services: Telepathology (MNT 48,036) and quality control reviews had no direct material costs, consisting entirely of labor and overhead.

https://doi.org/10.69588/mjer.v30i19.5124

3.4 Statistical Analysis

One-way ANOVA confirmed significant differences in unit costs across service categories ($F(4, 23) = 3.85$, $p = 0.025$). Post-hoc tests revealed that molecular diagnostics and complete autopsies differed significantly from routine surgical pathology and cytology services. Pearson correlation analysis (**Figure 1**) revealed that total cost was strongly and positively correlated with direct labor ($r = 0.94$, $p < 0.01$) and direct material cost ($r = 0.76$, $p < 0.01$), indicating that increases in these direct cost components were associated with higher overall service cost. Direct labor and direct material were also strongly positively correlated ($r = 0.85$, $p < 0.01$), suggesting that services requiring greater labor input also tended to consume more materials. In contrast, overhead showed negligible correlations with direct labor ($r = 0.02$), direct material ($r = 0.10$), and total cost ($r = 0.02$), indicating that overhead costs did not vary meaningfully with the major direct cost components or with overall cost in this dataset. Overall, these findings suggest that total cost was driven primarily by direct labor and direct material expenses, whereas overhead contributed little to the observed variation in total cost (**Figure 2**).

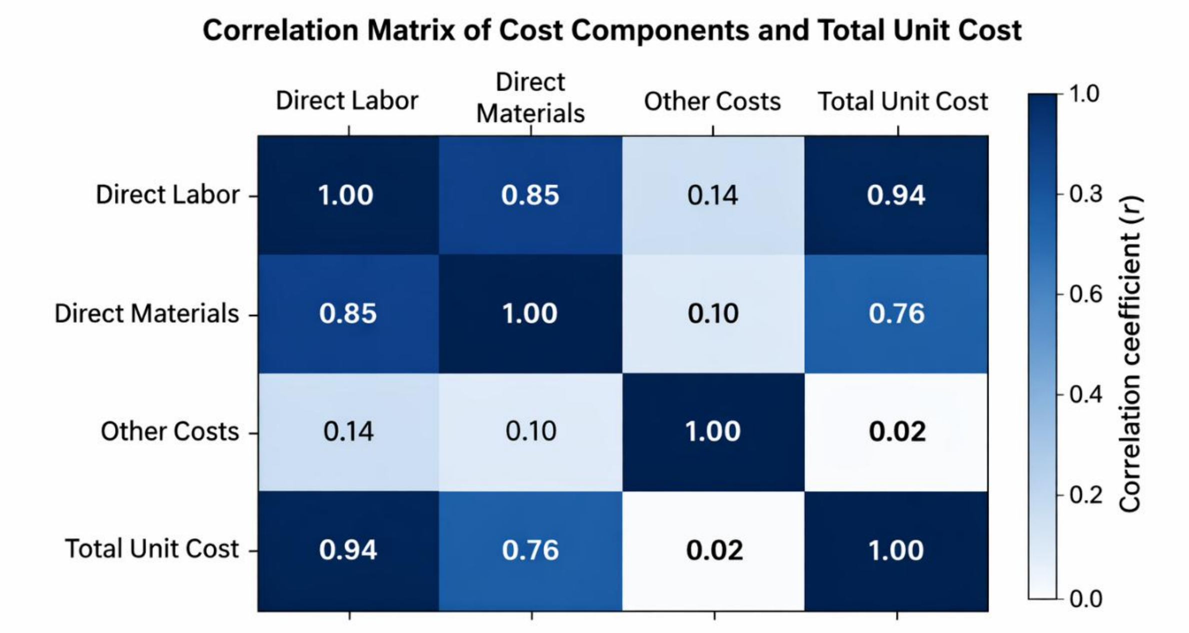

Figure 1. Correlation matrix of cost components and total unit cost. Heatmap of Pearson correlation coefficients (r) among direct labor, direct materials, other costs, and total unit cost. Darker shading indicates stronger positive correlation. Direct labor showed the strongest correlation with total unit cost ($r = 0.94$), followed by direct materials ($r = 0.76$), whereas other costs showed negligible correlation ($r = 0.02$).

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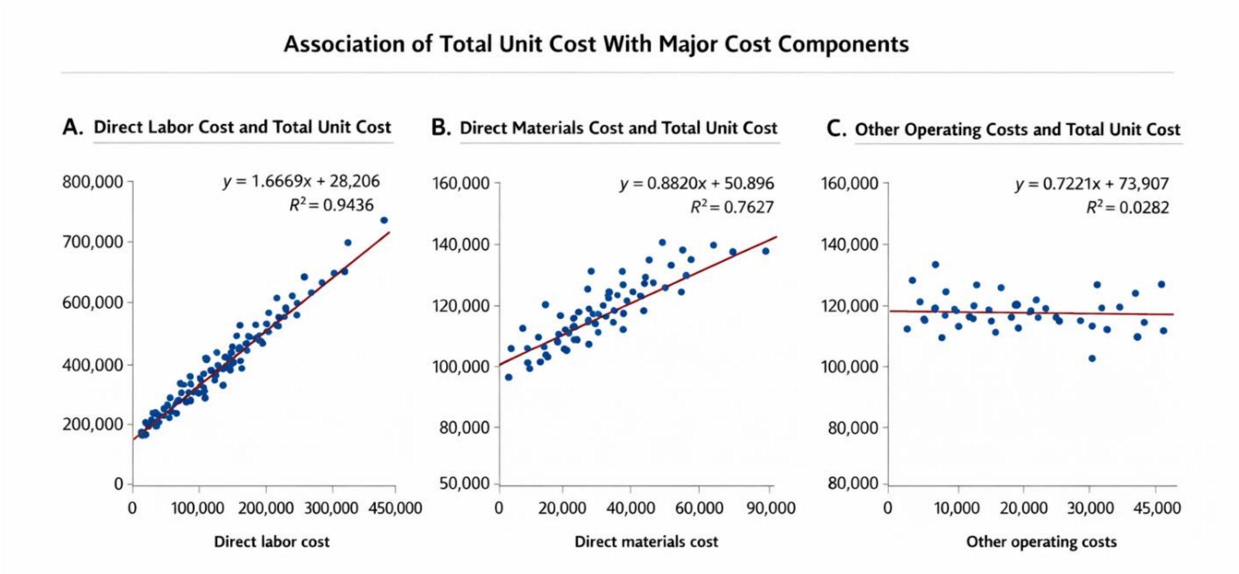

Figure 2. **Association of total unit cost with major cost components.** Three scatter plots illustrate the relationship between total unit cost and individual cost components. Panel A shows the association between direct labor cost and total unit cost, demonstrating a strong positive linear relationship (y = 1.6669x + 28,206; R^2 = 0.9436). Panel B shows the association between direct materials cost and total unit cost, indicating a moderate positive linear relationship (y = 0.8820x + 50,896; R^2 = 0.7627). Panel C shows the association between other operating costs and total unit cost, demonstrating a negligible linear relationship (y = 0.7221x + 73,907; R^2 = 0.0282). Solid lines represent fitted simple linear regression lines, and each point represents an individual observation.

3.5 Comparison with Current Tariffs

Comparison of ABC-derived unit costs with current reimbursement tariffs (where available) revealed significant discrepancies. For example, the current DRG-based tariff for surgical pathology (included within broader procedure payments) substantially underestimates the true resource consumption for complex cases while potentially overcompensating for simple biopsies. This misalignment creates cross-subsidization and distorts incentives for efficient resource allocation.

4 DISCUSSIONS

4.1 Principal Findings

This study provides one of the first systematic Activity-Based Costing estimates for pathology services in Mongolia. The analysis demonstrated four main findings. First, unit costs varied substantially across pathology services, indicating that broad average costing is insufficient for tariff design. Second, direct labor and direct materials were the major contributors to total unit cost, while overhead contributed less to cost variation across most services. Third, cost structures differed by service type: molecular diagnostics and immunohistochemistry were material-intensive, consultative and quality-control services were labor-intensive, and autopsy services

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required a high absolute level of both labor and materials. Fourth, sensitivity analysis showed that reagent price fluctuations and service-volume changes can meaningfully affect unit costs, especially for low-volume or material-intensive services. These findings are consistent with the theoretical premise of ABC, which argues that accurate costing requires tracing resources to activities and then to final services based on actual consumption patterns (Cooper, 1988; Kaplan & Anderson, 2007). In pathology, where workflow complexity and material intensity vary substantially across services, this approach is more appropriate than traditional costing systems that rely on broad allocation bases (Blocher, 2019; Mogyorosy & Smith, 2005).

4.2 Comparison with International Evidence

The findings are consistent with international evidence showing that ABC and related costing approaches provide more transparent estimates than traditional allocation-based costing methods in healthcare. Process-based costing is particularly useful when services differ in complexity, professional time, and material consumption (Kaplan, 2007; Mogyorosy & Smith, 2005). In pathology, such differences are substantial. Routine surgical pathology, frozen section, immunohistochemistry, molecular diagnostics, cytology, and autopsy services involve different workflows and resource requirements. Therefore, a single tariff or broad bundled reimbursement rate may not reflect actual resource use. Than et al. (2017) demonstrated that unit cost estimation in public hospitals can generate valuable evidence for health financing, pricing, and resource allocation. Similarly, hospital costing studies have shown that cost estimates become more informative when labor, material, equipment, and overhead components are separated rather than combined into broad averages (Sodani et al., 2011; Zhang et al., 2021). The present study extends this logic to the Mongolian pathology sector by demonstrating how service-level costing can identify high-cost, material-intensive, and labor-intensive diagnostic services.

Compared with international experience, the Mongolian pathology cost structure appears strongly influenced by labor intensity, imported reagents, and service-volume constraints. Material-intensive diagnostics such as FISH, CISH, RT-PCR, immunohistochemistry, and liquid-based cytology are vulnerable to reagent price changes because many inputs are imported and purchased in relatively small volumes. Low-volume specialized services may also have higher unit costs because fixed equipment and overhead costs are distributed across fewer cases. These findings are important for Mongolia because reimbursement reform without accurate costing may unintentionally disadvantage specialized diagnostic services..

4.3 Policy Implications

The results have direct implications for Mongolia's health financing and provider payment reform. First, ABC-derived costs can support more evidence-based tariff setting. Current payment mechanisms may not adequately distinguish simple, routine, complex, urgent, and highly specialized pathology services. This creates a risk of under-reimbursing complex diagnostic services while over-reimbursing simpler services. Cost-reflective tariffs are therefore necessary to reduce payment distortion and support financial sustainability.

https://doi.org/10.69588/mjer.v30i19.5124

Second, ABC can help reduce cross-subsidization. When high-cost services are reimbursed below actual cost, institutions may rely on revenue from other services to compensate. This reduces transparency and weakens incentives for efficiency. Cost-reflective tariffs would allow purchasers and providers to identify which services require targeted subsidy, strategic procurement, or volume consolidation. Third, the findings support better investment planning. For material-intensive services, cost containment should focus on reagent procurement, supplier competition, stock management, and test-volume planning. For labor-intensive services, efficiency improvement should focus on workflow redesign, task distribution, digital reporting, and appropriate use of telepathology. For services with high fixed overhead, regional consolidation or referral networks may be more efficient than duplicating low-volume capacity across many institutions. Fourth, ABC provides a foundation for performance-based financing. Standard cost estimates can be used to compare expected and actual resource use, monitor efficiency variance, and identify opportunities for process improvement. However, performance indicators should not focus only on cost reduction. Pathology services are quality-sensitive; therefore, future payment models should incorporate turnaround time, diagnostic accuracy, quality-control performance, and clinician satisfaction. This is consistent with healthcare costing guidance, which emphasizes that cost estimates should support decision-making but should not be interpreted separately from service quality and outcomes (Mogyorosy & Smith, 2005; World Health Organization, 2020).

4.4 Methodological Considerations and Limitations

This study improves on traditional costing by tracing costs through activities and cost drivers rather than assigning all overhead through a single volume-based rule. The use of financial records, procurement data, salary information, operational statistics, and time logs increased the credibility of the estimates. The inclusion of sensitivity analysis also strengthened interpretation by showing how unit costs may change under plausible economic and operational scenarios.

Nevertheless, several methodological issues should be considered. First, the study was conducted at a single national reference institution. The results are highly relevant for national pathology policy but may not be directly generalizable to smaller hospitals or regional laboratories with different case mixes and staffing structures. Second, some allocation decisions required assumptions where direct measurement was not feasible. Third, retrospective financial data may not fully capture real-time workflow variation. Fourth, inflation and exchange-rate effects may influence year-to-year cost comparability, especially for imported reagents. Fifth, the correlation analysis is descriptive and should not be interpreted causally because total unit cost is mathematically derived from component costs. Sixth, the study did not link cost estimates with diagnostic quality, turnaround time, or patient outcomes.

These limitations are common in institutional costing studies, particularly in settings where detailed cost accounting systems are still developing (Mogyorosy & Smith, 2005; World Health Organization, 2020). However, transparent documentation of cost pools, allocation bases, and sensitivity assumptions can improve the usefulness and replicability of the findings.

4.5 Future Research Directions

https://doi.org/10.69588/mjer.v30i19.5124

Future studies should expand ABC implementation to multiple hospitals and regional diagnostic laboratories. A multi-center design would allow benchmarking across institutions and identification of scale effects. Time-Driven Activity-Based Costing could also be tested as a simpler and more scalable method for routine use (Kaplan & Anderson, 2007). Future research should integrate cost data with quality indicators, including turnaround time, diagnostic concordance, repeat testing, specimen adequacy, and external quality-assurance results. Such evidence would support value-based diagnostic financing rather than cost-based reimbursement alone.

5 CONCLUSION

This study demonstrates that Activity-Based Costing can generate transparent and service-specific unit cost estimates for pathology services in Mongolia. Unit costs varied substantially across services, mainly because of differences in labor intensity, material consumption, and fixed-overhead requirements. Molecular diagnostics, immunohistochemistry, and liquid-based cytology were particularly sensitive to reagent prices, whereas consultative and quality-control services were more sensitive to labor cost. These findings support cost-reflective tariff revision, improved procurement planning, better workload management, and evidence-based resource allocation. Scaling ABC or Time-Driven Activity-Based Costing across pathology and other diagnostic services could strengthen Mongolia's health financing reform and improve the financial sustainability of essential diagnostic care.

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