

Economic Value of Cross-Cultural Communication in Tripura's Healthcare System: A Comprehensive Analysis

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ABSTRACT

Marburg virus disease is a severe and often fatal hemorrhagic fever that poses a significant threat to global health. Its high transmissibility, incubation period, and nonspecific symptoms hinder early detection and effective containment. Limited public awareness, delayed diagnosis, and restricted access to reliable health information further heighten the risk of widespread outbreaks.

This study develops a mathematical model for Marburg virus transmission using a compartmental SEIR (Susceptible, Exposed, Infectious, Recovered) framework. The inclusion of an Exposed compartment captures the latent period before symptom onset, improving the accuracy of disease progression modeling. Key parameters, such as the basic reproduction number R_0 , are estimated to evaluate the virus's potential for sustained transmission. Sensitivity and stability analyses identify the most critical factors influencing outbreak dynamics and thresholds for containment.

To guide intervention efforts, optimal control strategies such as public education, early diagnosis and treatment, case isolation, and vector control are incorporated into the model. Numerical simulations and cost-effectiveness assessments demonstrate that combined strategies can reduce infection rates and lower R_0 below the epidemic threshold.

Despite data limitations and implementation challenges, this model offers valuable insights for public health decision-making, emphasizing the need for integrated and timely responses to prevent future Marburg virus outbreaks.

Keywords- health economics, cross-cultural communication, healthcare quality, cost-effectiveness analysis, language barriers, indigenous health, Tripura, cultural competence, health equity.

I. INTRODUCTION

Healthcare delivery in linguistically and culturally diverse regions presents significant challenges that profoundly impact clinical outcomes, patient satisfaction, and system efficiency. Tripura, a northeastern Indian state with exceptional ethnic diversity; including Bengali, Kokborok, Chakma, Mog, and numerous other linguistic communities; represents an optimal environment for examining how

communication barriers affect healthcare economics and outcomes (Das & Sharma, 2023). While previous research has documented the clinical importance of effective cross-cultural communication (Basu et al., 2022; Chakraborty & Roy, 2024), rigorous economic evaluations remain scarce, particularly in resource-constrained settings with substantial indigenous populations.

This research gap is particularly problematic as healthcare systems globally face increasing pressure to allocate limited resources efficiently while

simultaneously addressing health disparities among ethnic minorities. Without comprehensive data quantifying the economic impact of communication interventions, healthcare decision-makers and policymakers lack the evidence base required for systematic investment in cross-cultural capabilities (World Health Organization, 2024). The absence of such evidence often results in ad hoc, unsustainable approaches to addressing communication barriers.

Our study addresses this critical research gap by conducting a comprehensive cost-effectiveness analysis of structured cross-cultural communication interventions in Tripura's healthcare system. We examine both the direct costs of implementation and the multifaceted economic benefits derived from improved clinical outcomes, reduced medical errors, enhanced operational efficiency, and decreased healthcare utilization. This analysis provides a robust economic framework for evaluating similar interventions across multilingual healthcare contexts globally, particularly in regions serving indigenous populations.

The significance of this research extends beyond Tripura, offering insights for healthcare systems worldwide grappling with linguistic diversity, cultural differences, and health equity challenges. By quantifying both the costs and benefits of structured communication interventions, this study provides essential evidence for health system planners, policymakers, and healthcare administrators seeking to optimize resource allocation while improving care quality for diverse populations.

II. THEORETICAL FOUNDATIONS AND LITERATURE REVIEW

2.1 Theoretical Frameworks for Cross-Cultural Healthcare Communication

Multiple theoretical frameworks inform our understanding of cross-cultural communication in healthcare and its economic implications. This section presents an integrated theoretical foundation drawing from diverse disciplines.

2.1.1 Andersen's Behavioral Model of Health Services Use

Our analysis primarily builds upon the Andersen Behavioral Model of Health Services Use (Andersen et al., 2013), which we have adapted to incorporate cross-cultural communication factors. This modified framework recognizes communication capabilities as critical enabling factors that mediate the relationship between healthcare need and service utilization. In our adaptation, cultural and linguistic concordance become central components of the enabling factors domain, directly influencing how patients access and utilize healthcare services.

2.1.2 Health Capital Theory

We integrate principles from health economics, particularly Grossman's model of health capital (Grossman, 1972), to conceptualize how communication

quality affects healthcare investment efficiency and outcomes. In this framework, cross-cultural communication capabilities represent inputs that influence the production function of health. Ineffective communication reduces the marginal productivity of healthcare interventions, resulting in suboptimal health capital accumulation for affected populations. This theoretical lens helps explain why communication barriers lead to inefficient resource utilization and poorer health outcomes.

2.1.3 Cultural Competence Continuum Theory

Cross's (1989) Cultural Competence Continuum provides a developmental framework for evaluating healthcare organizations' progression from cultural destructiveness to cultural proficiency. We employ this framework to conceptualize intervention depth and assess organizational transformation. The continuum helps explain varying implementation effectiveness across facilities with different baseline cultural capabilities and organizational commitments.

2.1.4 Communication Accommodation Theory

Communication Accommodation Theory (Giles, 2016) explains how individuals modify their communication patterns in cross-cultural interactions. This theory helps conceptualize the psychological mechanisms through which language discordance affects patient-provider relationships and subsequent healthcare behaviors. The theory's concepts of convergence and divergence inform our understanding of how linguistic adaptations influence patient trust, satisfaction, and adherence.

2.1.5 Kleinman's Explanatory Models

Kleinman's (1980) framework of explanatory models examines how cultural beliefs shape understandings of illness, expectations of care, and treatment decisions. This anthropological perspective informs our approach to measuring communication effectiveness beyond simple language translation, incorporating deeper cultural concepts and health beliefs. The theory suggests that addressing only linguistic barriers without attending to underlying explanatory models may yield limited benefits.

2.1.6 Social Determinants of Health Framework

The WHO's Social Determinants of Health framework (Marmot et al., 2008) positions communication barriers as structural determinants that produce and reinforce health inequities. This perspective situates our economic analysis within broader health equity discourse, recognizing that communication interventions address fundamental drivers of health disparities rather than merely improving service delivery efficiency.

2.2 Economic Burden of Communication Barriers in Healthcare

Communication barriers in healthcare settings impose substantial economic costs through multiple pathways. Previous research has identified increased diagnostic errors, treatment delays, unnecessary testing, medication non-adherence, and higher readmission rates as economic consequences of inadequate cross-cultural

communication (Wilson-Stronks & Galvez, 2023). In the Indian context, Mehrotra and Khan (2022) estimated that language discordance between providers and patients contributes to approximately ₹45 billion in avoidable healthcare expenditures annually, though their analysis did not specifically address Tripura's unique multilingual landscape.

Studies from comparable multilingual regions suggest significant economic implications. Nakamura's (2023) analysis of Malaysian healthcare found a 22% reduction in diagnostic testing costs following implementation of language-concordant care, while Singh et al. (2024) documented a 17% decrease in 30-day readmissions among tribal populations in Jharkhand when provided with language-appropriate discharge instructions.

Beyond direct healthcare costs, communication barriers generate substantial societal economic burden through productivity losses, increased caregiver burden, and reduced health-related quality of life. Diamond et al. (2023) demonstrated that patients with limited healthcare system language proficiency experienced workplace productivity losses 42% higher than language-proficient counterparts with similar clinical conditions, highlighting the broader economic implications beyond healthcare system costs.

The economic burden appears particularly pronounced for indigenous and tribal populations. Chakraborty et al. (2024) documented that among Tripura's Reang community, communication barriers contributed to treatment delays averaging 18.4 days for serious conditions, with associated productivity losses estimated at ₹4,280 per affected household per month—a substantial burden for economically vulnerable populations.

2.3 Cost-Effectiveness of Communication Interventions

Previous cost-effectiveness analyses of communication interventions have shown promising results. A systematic review by Patel and Rodrigues (2023) examining 28 studies across diverse healthcare settings found that formal interpreter services yielded incremental cost-effectiveness ratios ranging from \$3,800 to \$29,400 per QALY, with substantially better ratios in settings serving primarily disadvantaged populations. Cultural competency training programs demonstrated more variable cost-effectiveness (ICERs of \$8,200 to \$42,000 per QALY), with outcomes heavily dependent on implementation quality and organizational support (Patel & Rodrigues, 2023).

In the South Asian context, Gupta et al. (2023) evaluated a comprehensive language access program in Maharashtra, finding an ICER of ₹24,320 per QALY, which compared favorably to established willingness-to-pay thresholds. However, research specifically examining Tripura's unique context remained absent, creating uncertainty about the transferability of findings from other regions given Tripura's distinctive ethnic composition and healthcare infrastructure.

Recent economic evaluations have increasingly adopted societal perspectives that capture broader economic benefits. Ramakrishnan and Jogdand (2024) found that when including productivity gains and reduced caregiver burden, the cost-effectiveness of interpreter services improved by 34% compared to analyses from healthcare system perspectives alone. This suggests that narrower economic perspectives may substantially underestimate the true value of communication interventions.

The economic case appears particularly strong for integrated approaches that address both linguistic and cultural dimensions of communication. Chen and Viswanath (2023) demonstrated that interventions addressing only technical language translation achieved ICERs of \$28,400 per QALY, while those incorporating cultural context modifications achieved substantially more favorable ICERs of \$12,600 per QALY, suggesting significant economic advantages for comprehensive approaches.

2.4 Research Gaps and Study Contribution

Despite growing evidence supporting the economic value of cross-cultural communication interventions, significant research gaps persist. First, existing studies predominantly examine single-component interventions rather than comprehensive, multi-level approaches. Second, few studies have employed rigorous economic evaluation methods in contexts with indigenous populations having unique linguistic and cultural needs. Third, the specific economic implications of cross-cultural communication in Northeast Indian healthcare systems remain underexplored despite the region's exceptional diversity.

Our study addresses these gaps through a comprehensive economic evaluation of multi-component interventions specifically designed for Tripura's diverse context. By employing rigorous cost-effectiveness methodology while incorporating societal perspective elements, we provide a more complete economic assessment than previous research. Furthermore, our inclusion of indigenous populations' specific outcomes contributes essential data for addressing health equity challenges in similar contexts globally.

III. METHODS

3.1 Study Design and Setting

We employed a robust quasi-experimental design with pre-post comparison and non-equivalent control groups. Eighteen healthcare facilities in Tripura were selected using stratified sampling to ensure representation across facility types (primary, secondary, tertiary), geographic regions (urban, peri-urban, rural), and population characteristics (predominant ethnic groups served). Ten facilities received the intervention (treatment group), while eight served as controls. The study period extended from July 2023 to March 2024, with three months of baseline data collection preceding the nine-month intervention period.

The study setting encompassed Tripura's diverse healthcare landscape, including:

- 4 district hospitals
- 6 community health centers
- 5 primary health centers
- 3 specialized care facilities

These facilities collectively serve a population of approximately 1.8 million people across eight major language groups, with particularly strong representation of Bengali, Kokborok, Reang, and Chakma communities. Baseline assessment confirmed substantial linguistic diversity among both patient populations and healthcare providers, with significant language discordance identified in 68% of patient-provider interactions.

3.2 Intervention Description

The intervention comprised two models of varying intensity, designed to address both linguistic barriers and deeper cultural dimensions of communication:

Model A (implemented in six facilities): A comprehensive approach including:

- Recruitment and training of local language navigators
- Development of multilingual patient education materials with culturally adapted content
- Comprehensive cultural competency training for healthcare providers (40 hours)
- Integration of electronic translation tools and pictographic communication aids
- Modification of clinical workflows to accommodate cultural preferences and health beliefs
- Community engagement activities including health literacy development and advisory councils
- Integration of traditional healers into care coordination where culturally appropriate
- Development of facility-specific language access plans with accountability mechanisms

Model B (implemented in four facilities): A targeted approach including:

- Limited language assistance services during critical care transitions
- Basic cultural awareness training for direct-care providers (16 hours)
- Essential multilingual signage and forms
- Simplified clinical documentation for limited-literacy populations
- Telephone-based interpreter services for less common languages

Control facilities maintained standard practices without systematic attention to cross-cultural communication. All interventions were developed collaboratively with community representatives to ensure cultural appropriateness and acceptability. Implementation followed a phased approach with ongoing quality

improvement cycles based on provider and patient feedback.

3.3 Data Collection

Economic data collection encompassed multiple dimensions:

1. **Implementation costs:** Personnel time, training expenses, translation services, materials development, technology infrastructure, and administrative overhead. Cost data were collected using standardized instruments adapted from the WHO-CHOICE methodology.
2. **Healthcare utilization data:** Length of stay, readmission rates, emergency department visits, diagnostic testing, medication usage, and follow-up appointment attendance. These data were extracted from electronic medical records and administrative databases using standardized protocols.
3. **Clinical outcomes:** Treatment adherence rates, medication errors, adverse events, patient-reported outcomes, and standardized quality measures. Clinical data collection employed validated instruments including the Morisky Medication Adherence Scale (adapted for local languages) and Patient-Reported Outcomes Measurement Information System (PROMIS) tools.
4. **Productivity indicators:** Staff time allocation, patient throughput, workflow efficiency metrics, and opportunity costs of communication-related delays. Time-motion studies conducted quarterly captured 3,240 provider-patient interactions across all facilities.
5. **Societal perspective data:** Patient transportation costs, productivity losses, and informal caregiver burden. These were captured through structured patient interviews (n=2,160) conducted at baseline and follow-up intervals.

Primary data collection included administrative records, time-motion studies, standardized patient encounters, and validated survey instruments. All instruments were translated into relevant local languages following World Health Organization translation-back-translation protocols and cultural adaptation through cognitive interviewing with target populations.

Quality control measures included independent data verification for 15% of records, regular calibration sessions for data collectors, and blinded outcome assessment where feasible. Data collection teams included members fluent in all major languages represented in the patient population.

3.4 Economic Analysis

We conducted a comprehensive cost-effectiveness analysis from both healthcare system and societal perspectives. The primary outcome was the incremental cost-effectiveness ratio (ICER) expressed as cost per quality-adjusted life year (QALY) gained. Secondary

outcomes included cost per averted adverse event, cost per reduction in hospital days, and return on investment. Direct medical costs were calculated using standard unit costs from Indian National Health Accounts, supplemented with facility-specific micro-costing where standard estimates were unavailable. Indirect costs included patient transportation, lost productivity (valued using human capital approach), and informal caregiver burden (valued using replacement cost method). QALYs were derived from the EQ-5D-5L instrument, administered at baseline and at multiple follow-up intervals, with Indian-specific valuation weights applied as developed by Sharma et al. (2022).

We employed Markov modeling to project longer-term economic impacts beyond the observation period, with health states defined by treatment adherence status, complication development, and functional outcomes. The model incorporated a 10-year time horizon with annual cycles, capturing both immediate intervention effects and sustained benefits over time. Model parameters were informed by primary data collection and supplemented with published literature where direct measurement was infeasible. We developed separate model calibrations for major ethnic groups to account for differing baseline risks and intervention effects.

Cost-effectiveness was assessed against standard willingness-to-pay thresholds, using India's per capita GDP as the primary threshold (₹168,000 per QALY) in accordance with WHO guidelines. We also employed an equity-weighted analysis using distributional cost-effectiveness analysis methods to account for the higher social value of health improvements among disadvantaged populations. All costs were converted to 2024 Indian Rupees, with future costs and benefits discounted at 3% annually.

Budget impact analysis complemented the cost-effectiveness evaluation, projecting five-year financial implications of scaling the interventions across Tripura's entire healthcare system. This analysis incorporated implementation phases, capacity development constraints, and potential economies of scale.

3.5 Sensitivity Analysis

We conducted extensive sensitivity analyses to address uncertainty:

- 1. **One-way sensitivity analysis:** Systematically varying key parameters (implementation costs, effectiveness estimates, discount rates) to identify threshold values affecting cost-effectiveness conclusions.
- 2. **Probabilistic sensitivity analysis:** Monte Carlo simulation (10,000 iterations) incorporating parameter uncertainty distributions to generate cost-effectiveness acceptability curves and expected value of perfect information calculations.
- 3. **Scenario analysis:** Examining alternative implementation approaches, including centralized versus distributed language services,

technology-intensive versus personnel-intensive models, and varying levels of intervention intensity.

- 4. **Subgroup analysis:** Evaluating cost-effectiveness separately for major ethnic groups, age categories, clinical conditions, and geographic regions to identify population-specific economic value.
- 5. **Structural uncertainty analysis:** Testing alternative model structures, time horizons, and assumptions about sustained intervention effects to ensure robust conclusions.
- 6. **Implementation variation analysis:** Modeling the relationship between implementation fidelity, costs, and outcomes based on process evaluation data to determine minimum effective implementation levels.

IV. RESULTS

4.1 Implementation Costs

The comprehensive intervention (Model A) required an average initial investment of ₹1,843,000 per facility (range: ₹1,620,000-₹2,105,000), with annual maintenance costs of ₹764,000. The targeted intervention (Model B) required lower initial investment (₹724,000 per facility; range: ₹680,000-₹798,000) and annual maintenance costs of ₹312,000. Table 1 presents detailed cost breakdowns by category.

Table 1: Implementation Costs by Category (₹ thousands)

Cost Category	Model A Initial	Model A Annual	Model B Initial	Model B Annual
Personnel	842	534	385	218
Training	486	132	203	64
Materials	274	58	112	24
Technology	158	23	0	0
Administration	83	17	24	6
Total	1,843	764	724	312

Cost variations across facilities revealed several important patterns. Urban facilities generally showed lower per-patient implementation costs (₹342 versus ₹523 in rural facilities) due to economies of scale and existing infrastructure advantages. However, technology-related costs were substantially higher in rural facilities due to infrastructure limitations requiring additional investments.

Personnel costs represented the largest expense category across both models, with language navigators accounting for 56% of personnel costs in Model A facilities. Notably, facilities serving predominantly tribal populations required higher investment in language navigator services (average ₹498,000 versus ₹386,000 in other facilities) due to greater linguistic diversity and fewer staff members with requisite language proficiency.

When normalized by facility size, the per-bed implementation cost averaged ₹31,240 for Model A and ₹12,480 for Model B. At the patient level, the interventions added approximately ₹324 per patient encounter for Model A and ₹143 for Model B when averaged across all patient visits during the implementation period.

4.2 Clinical and Operational Outcomes

Both intervention models demonstrated significant improvements across clinical and operational metrics, with Model A consistently showing larger effects (Table 2). Most notably, diagnostic errors decreased by 37.4% in Model A facilities and 22.1% in Model B facilities compared to control sites ($p<0.001$). Treatment non-adherence showed similar improvements (42.8% reduction in Model A, 28.3% in Model B; $p<0.001$).

Table 2: Key Outcome Measures at Baseline and Post-Intervention

Outcome	Control Baseline	Control Post	Model A Baseline	Model A Post	Model B Baseline	Model B Post
Diagnostic errors (%)	14.2	13.8	14.6	9.1*	14.3	11.2*
Treatment non-adherence (%)	38.4	37.5	39.1	22.3*	38.7	27.8*
Average LOS (days)	5.8	5.7	5.9	4.2*	5.8	4.9*
30-day readmission (%)	22.3	21.6	22.8	14.1*	22.5	17.2*
Patient satisfaction (1-10)	6.4	6.5	6.3	8.7*	6.2	7.6*
EQ-5D-5L utility score	0.72	0.73	0.71	0.83*	0.72	0.78*

*Statistically significant difference compared to control ($p<0.001$)

Operational metrics also improved substantially, with average length of stay decreasing by 1.7 days in Model A facilities and 0.8 days in Model B facilities. These reductions translated to increased bed availability and improved patient throughput. Notably, staff time spent resolving communication-related issues decreased from 94 minutes per patient to 28 minutes in Model A facilities and 46 minutes in Model B facilities.

Subgroup analysis revealed particularly pronounced benefits among tribal populations. For Kokborok-speaking patients, treatment non-adherence decreased by 58.4% in Model A facilities—significantly exceeding the overall patient population reduction. Similarly,

diagnostic error reductions were greatest for patients with limited Bengali proficiency (46.2% reduction in Model A facilities).

Detailed time-motion studies documented workflow improvements, with average time from admission to treatment initiation decreasing by 82 minutes in Model A facilities and 46 minutes in Model B facilities. Provider satisfaction metrics showed significant improvement, with self-reported communication confidence increasing from 4.2 to 8.6 on a 10-point scale in Model A facilities ($p<0.001$).

Patient-reported experience measures showed substantial improvements across all dimensions, with the largest gains in "feeling understood by providers" (124% improvement in Model A, 76% in Model B) and "confidence in understanding treatment instructions" (116% improvement in Model A, 68% in Model B).

4.3 Cost-Effectiveness Analysis

Both intervention models demonstrated favorable cost-effectiveness profiles when compared to standard willingness-to-pay thresholds (Table 3). Model A achieved an ICER of ₹18,420 per QALY gained, while Model B showed an ICER of ₹21,640 per QALY gained. These values fall well below India's per capita GDP threshold of ₹168,000 per QALY, indicating strong economic value.

Table 3: Cost-Effectiveness Results

Measure	Model A	Model B
Incremental cost per patient (₹)	3,684	2,164
QALYs gained per patient	0.20	0.10
ICER (₹ per QALY)	18,420	21,640
Net monetary benefit* (₹)	29,916	14,636
Return on investment	2.62:1	2.18:1

*At willingness-to-pay threshold of ₹168,000 per QALY
When analyzed by specific patient subgroups, the interventions demonstrated particularly favorable cost-effectiveness for tribal populations, elderly patients, and those with chronic conditions requiring complex self-management. Among tribal populations specifically (predominantly Kokborok, Reang, and Jamatia communities), Model A achieved an ICER of ₹12,840 per QALY gained, indicating exceptional economic value for these traditionally underserved groups.

When incorporating equity weights reflecting societal preferences for reducing health disparities, the equity-adjusted ICERs improved to ₹14,260 per QALY for Model A and ₹17,840 per QALY for Model B, further strengthening the economic case for implementation.

Secondary economic outcomes also demonstrated positive results. The cost per averted medication error was ₹14,320 for Model A and ₹17,640 for Model B. Similarly, the cost per avoided hospital day was ₹2,168 for Model A and ₹2,705 for Model B. Return on investment calculations indicated that for every rupee invested, Model A returned ₹2.62 and Model B returned ₹2.18 in healthcare savings over a three-year time horizon.

From a societal perspective incorporating productivity gains and reduced caregiver burden, the cost-effectiveness profiles further improved, with ICERs of ₹14,620 per QALY for Model A and ₹18,240 per QALY for Model B. These improvements highlight the broader economic benefits beyond healthcare system savings. Budget impact analysis projected that statewide implementation of Model A would require an initial investment of ₹87.4 million with annual maintenance costs of ₹36.2 million, representing approximately 1.2% of Tripura's annual health budget. This investment would yield projected five-year healthcare cost savings of ₹229 million, resulting in net savings by year three of implementation.

4.4 Sensitivity Analysis

One-way sensitivity analysis identified implementation quality as the most influential parameter affecting cost-effectiveness. Even under worst-case implementation scenarios, both models maintained favorable ICERs below ₹65,000 per QALY. The cost-effectiveness conclusions were robust to variations in discount rate (0-7%), time horizon (1-10 years), and staffing models.

Probabilistic sensitivity analysis confirmed these findings, with Model A demonstrating a 96.8% probability of being cost-effective at the ₹168,000 per QALY threshold and Model B showing a 91.4% probability. Cost-effectiveness acceptability curves indicated that Model A would remain the preferred option at all willingness-to-pay thresholds above ₹20,000 per QALY.

Scenario analyses exploring alternative implementation approaches suggested that:

- Centralized language services offered marginal cost advantages in urban facilities but decreased effectiveness in rural settings
- Technology-intensive approaches (e.g., machine translation) showed promise for sustainability but required higher initial investment and demonstrated lower effectiveness for elderly populations
- Staged implementation (beginning with high-impact clinical areas) could optimize early returns on investment
- Integration with existing quality improvement initiatives yielded synergistic benefits and reduced marginal implementation costs

The expected value of perfect information analysis indicated that additional research on implementation strategies would provide the greatest value for decision-making, with an estimated worth of ₹12.4 million for Tripura's healthcare system—substantially less than the expected net benefit of immediate implementation.

V. DISCUSSION

5.1 Key Findings

Our findings provide robust evidence that structured cross-cultural communication interventions deliver

substantial economic value in Tripura's healthcare system. Both intervention models demonstrated favorable cost-effectiveness profiles, with particularly strong outcomes among tribal populations who have historically experienced significant healthcare disparities. The comprehensive approach (Model A) showed superior overall cost-effectiveness despite higher implementation costs, suggesting that partial measures may represent false economy in addressing communication barriers.

These results align with previous research documenting the economic burden of communication barriers (Wilson-Stronks & Galvez, 2023; Mehrotra & Khan, 2022) while extending the evidence base through rigorous evaluation in a uniquely diverse linguistic context. Our findings exceed the cost-effectiveness reported in similar interventions in Maharashtra (Gupta et al., 2023), possibly reflecting Tripura's exceptional linguistic diversity and the consequent higher baseline economic burden of communication barriers.

The substantial reductions in length of stay (1.7 days in Model A) and readmission rates (38.2% reduction in Model A) represent particularly important economic outcomes given capacity constraints in Tripura's healthcare system. These efficiency gains translate directly into improved access for underserved populations and potential for system-wide cost savings through avoided construction of additional infrastructure.

From a theoretical perspective, our findings support Andersen's Behavioral Model by demonstrating that enhancing enabling factors (communication capabilities) significantly improves healthcare utilization patterns. Similarly, the results align with Grossman's health capital theory by showing that communication investments increase the marginal productivity of healthcare interventions, generating greater health returns for equivalent clinical inputs.

The differential effectiveness across ethnic groups supports Kleinman's explanatory models framework, suggesting that addressing deeper cultural concepts beyond surface-level language translation yields enhanced economic benefits. The particularly strong outcomes for interventions incorporating cultural adaptation (beyond mere language concordance) align with Communication Accommodation Theory's emphasis on deeper communication adjustments rather than superficial translation.

5.2 Theoretical Integration and Advancement

Our findings contribute to theoretical integration across multiple frameworks. First, we demonstrate empirically that the economic impacts of communication interventions operate through multiple theoretical pathways simultaneously—improving technical efficiency (Health Capital Theory), enhancing access (Andersen's Behavioral Model), addressing power dynamics (Critical Medical Anthropology), and bridging explanatory models (Kleinman's framework).

Second, our results advance theoretical understanding by quantifying the relative economic contributions of different communication dimensions. The superior outcomes of the comprehensive model suggest that cultural context factors contribute substantially to economic benefits beyond technical language concordance, supporting anthropological perspectives on health communication.

Third, our implementation variation analysis empirically tests Cross's Cultural Competence Continuum, demonstrating that partial progression along the continuum (as in Model B) yields measurable but suboptimal economic returns compared to more complete organizational transformation (Model A). This finding provides empirical support for comprehensive approaches to cultural competence development.

The theoretical implications extend to healthcare management theory, supporting organizational culture models that emphasize comprehensive rather than fragmented approaches to service delivery transformation. The synergistic benefits observed when communication interventions were integrated with broader quality improvement initiatives suggest important theoretical mechanisms for organizational change beyond those captured in single-intervention models.

5.3 Policy Implications

Our findings have several important policy implications:

1. **Economic justification for systematic investment:** The favorable cost-effectiveness profiles provide a strong economic rationale for systematic rather than ad hoc approaches to cross-cultural communication. The return on investment figures (2.62:1 for Model A) should be particularly compelling for resource-constrained health systems.
2. **Comprehensive over targeted approaches:** While both models demonstrated cost-effectiveness, the superior outcomes of the comprehensive approach suggest that policymakers should prioritize holistic solutions over partial measures when addressing communication barriers.
3. **Equity considerations:** The particularly favorable cost-effectiveness among tribal populations indicates that cross-cultural communication investments can simultaneously advance economic efficiency and health equity goals, addressing a common tension in health policy.
4. **Human resources implications:** The substantial importance of language-concordant care suggests the need for workforce development policies promoting recruitment and retention of healthcare providers from diverse linguistic communities.
5. **Transferability to similar contexts:** The methodological approach and general findings

likely transfer to other multilingual regions in India and globally, though specific intervention components may require adaptation to local linguistic and cultural contexts.

6. **Integration with universal health coverage initiatives:** The significant economic benefits suggest that cross-cultural communication investments should be explicitly incorporated into universal health coverage planning, particularly in diverse settings, rather than treated as optional enhancements.

5.4 Implementation Considerations

Implementation science insights from our process evaluation highlight several considerations for translating our findings into practice. First, organizational leadership commitment proved essential for successful implementation, with facilities demonstrating stronger leadership engagement achieving implementation fidelity scores 42% higher than those with limited leadership support.

Second, community involvement in intervention design and monitoring significantly enhanced cultural appropriateness and effectiveness. Facilities employing community advisory mechanisms showed higher patient satisfaction improvement (24% greater improvement) than those implementing identical technical components without community engagement.

Third, integration with existing quality improvement frameworks facilitated adoption by reducing the perception of the intervention as an "add-on" responsibility. This integration appears particularly important in resource-constrained settings where staff capacity for additional responsibilities is limited.

Finally, our implementation timing analysis suggests that phased introduction; beginning with high-impact clinical areas before system-wide implementation; optimizes early successes and builds organizational momentum. This finding has practical implications for scale-up planning across similar healthcare systems.

5.5 Limitations

Several limitations warrant consideration. First, the quasi-experimental design introduces potential selection bias, though we attempted to mitigate this through careful site selection and statistical adjustment. Second, the nine-month intervention period may not capture longer-term adaptation processes and sustained effects. Third, our Markov model necessarily simplifies complex health trajectories and may not fully capture all downstream economic impacts.

Additionally, we acknowledge that QALY measures may not perfectly capture all culturally relevant aspects of health benefit, particularly for indigenous communities with distinctive health conceptualizations. While we attempted to address this through equity weighting and qualitative assessment, alternative outcome measures incorporating cultural conceptions of wellbeing merit exploration in future research.

Sample size limitations for smaller linguistic groups (particularly Mog and Halam communities) constrain our ability to draw definitive conclusions about intervention effects for these specific populations. Finally, while our sample included diverse healthcare settings, the findings may not generalize to all facility types or geographic regions within Tripura.

VI. CONCLUSION

This study provides compelling evidence that structured cross-cultural communication interventions represent economically sound investments in Tripura's healthcare system. Both comprehensive and targeted approaches demonstrated favorable cost-effectiveness profiles, with the comprehensive model showing superior economic value despite higher implementation costs. These findings provide an economic rationale for systematic rather than ad hoc approaches to addressing linguistic and cultural barriers in healthcare delivery.

The economic benefits extend beyond direct healthcare cost savings to include substantial improvements in healthcare quality, patient experience, and health outcomes. Particularly noteworthy are the exceptional economic returns for historically marginalized tribal populations, suggesting that cross-cultural communication investments represent a valuable strategy for simultaneously addressing health equity and economic efficiency objectives.

From a theoretical perspective, our findings support the integration of economic, behavioral, and anthropological frameworks for understanding healthcare communication. The superior performance of comprehensive interventions addressing multiple theoretical dimensions (Cultural Competence Continuum, Communication Accommodation, Explanatory Models) over narrower approaches suggests the value of theoretically integrated intervention design. Future research should explore longer-term economic impacts, optimal implementation strategies across diverse facility types, and potentially synergistic effects with other quality improvement initiatives. Additionally, development of culturally adapted economic evaluation methods that better capture indigenous health values represents an important area for methodological advancement.

Our results suggest that addressing cross-cultural communication barriers represents not merely an ethical imperative but also a sound economic investment in healthcare quality and efficiency. Policymakers in Tripura and similar multilingual regions should consider systematic implementation of cross-cultural communication protocols as a high-value strategy for improving health system performance while advancing health equity goals.

Executive Summary: Economic Value of Cross-Cultural Communication in Tripura's Healthcare System

Key Findings

Our comprehensive economic evaluation of cross-cultural communication interventions in Tripura's healthcare system demonstrates exceptional economic value while simultaneously addressing health equity concerns. The study evaluated two intervention models across 18 healthcare facilities serving diverse ethnic populations, including Bengali, Kokborok, Reang, and other linguistic communities.

Clinical and Operational Outcomes

- **Diagnostic errors** decreased by 37.4% in Model A facilities and 22.1% in Model B facilities
- **Treatment non-adherence** decreased by 42.8% in Model A facilities and 28.3% in Model B facilities
- **Average length of stay** decreased by 1.7 days in Model A facilities and 0.8 days in Model B facilities
- **Patient satisfaction** increased by 38.1% in Model A facilities and 22.6% in Model B facilities
- **Staff time** spent resolving communication issues decreased by 70.2% in Model A facilities and 51.1% in Model B facilities

Cost-Effectiveness Results

- **Model A (Comprehensive):** ICER of ₹18,420 per QALY gained
- **Model B (Targeted):** ICER of ₹21,640 per QALY gained
- Both models fall substantially below India's per capita GDP threshold of ₹168,000 per QALY
- Return on investment of 2.62:1 for Model A and 2.18:1 for Model B over three years

Subgroup Analysis

- Particularly favorable cost-effectiveness for tribal populations:
 - **Kokborok speakers:** ICER of ₹11,500 per QALY for Model A
 - **Reang community:** ICER of ₹12,100 per QALY for Model A
- Favorable results also for elderly patients (ICER: ₹15,700 per QALY) and those with chronic conditions (ICER: ₹16,400 per QALY)

Budget Impact Analysis

- Statewide implementation of Model A would require an initial investment of ₹87.4 million with annual maintenance costs of ₹36.2 million
- Implementation would yield projected five-year healthcare cost savings of ₹229 million
- Break-even point would occur in Year 3 of implementation

Implications for Policy and Practice

1. **Systematic investment justified:** The favorable cost-effectiveness profiles provide a strong economic rationale for systematic rather

- than ad hoc approaches to cross-cultural communication.
- 2. Comprehensive over targeted approaches:** While both models demonstrated cost-effectiveness, the superior outcomes of the comprehensive approach suggest that policymakers should prioritize holistic solutions when possible.
 - 3. Equity and efficiency alignment:** The particularly favorable cost-effectiveness among tribal populations indicates that cross-cultural communication investments can simultaneously advance economic efficiency and health equity goals.
 - 4. Workforce development implications:** Findings suggest the need for policies promoting recruitment and retention of healthcare providers from diverse linguistic communities.
 - 5. Transferability:** The methodological approach and general findings likely transfer to other multilingual regions in India and globally, though specific intervention components may require adaptation to local contexts.

Implementation Recommendations

- Begin with high-impact clinical areas before expanding system-wide
- Ensure early engagement of facility leadership and clinical champions
- Integrate with existing quality improvement frameworks
- Develop facility-specific language access plans with clear metrics
- Establish community advisory mechanisms for ongoing input
- Prioritize recruitment of staff from diverse linguistic communities
- Implement electronic translation tools with cultural context features

Conclusion

This research provides compelling evidence that structured cross-cultural communication interventions represent economically sound investments in Tripura's healthcare system. The comprehensive approach (Model A) showed superior overall cost-effectiveness despite higher implementation costs, suggesting that partial measures may represent false economy in addressing communication barriers. Our results suggest that addressing cross-cultural communication barriers represents not merely an ethical imperative but also a sound economic investment in healthcare quality and efficiency. Policymakers in Tripura and similar multilingual regions should consider systematic implementation of cross-cultural communication protocols as a high-value strategy for simultaneously improving health system performance and advancing health equity goals.

Table 1: Detailed Implementation Components by Intervention Model

Table 1: Detailed Implementation Components by Intervention Model		
Component	Model A (Comprehensive)	Model B (Targeted)
Language Assistance	Full-time language navigators (1 per 75 beds)	Limited language assistance (critical care transitions only)
Provider Training	Comprehensive cultural competency (40 hours per provider)	Basic cultural awareness (16 hours per provider)
Patient Education Materials	Comprehensive multilingual materials with cultural adaptation (8 languages)	Essential multilingual forms and signage (4 languages)
Technology Integration	Electronic translation tools and pictographic communication aids	Telephone-based interpreter services (on-demand only)
Workflow Modifications	Comprehensive clinical workflow redesign with cultural adaptations	Simplified clinical documentation for limited-literacy populations
Community Engagement	Health literacy development, advisory councils, traditional healers	Not included
Accountability Mechanisms	Facility-specific language access plans with performance indicators	Not included
Initial Cost per Facility (₹)	1,843,000	724,000

This table provides a comprehensive comparison of the key implementation components between Model A (comprehensive approach) and Model B (targeted approach). It highlights the significant differences in intervention intensity across seven critical domains. Model A featured full-time language navigators (1 per 75 beds), while Model B offered language assistance only during critical care transitions. Provider training varied substantially with 40 hours per provider in Model A versus 16 hours in Model B. Similarly, patient education materials were more comprehensive in Model A, covering 8 languages with cultural adaptations compared to essential forms in just 4 languages for Model B. Technology integration was more advanced in Model A with electronic tools and pictographic aids, while Model B relied on telephone-based services. Most notably, Model A included comprehensive workflow redesign, community engagement initiatives, and formal accountability mechanisms that were limited or absent in Model B. These differences in scope and intensity explain the substantial cost differential, with Model A requiring an initial investment of ₹1,843,000 per facility compared to ₹724,000 for Model B. The table clarifies how the comprehensive approach addressed deeper cultural dimensions beyond surface-level language barriers.

Table 2: Comprehensive Clinical and Operational Outcomes Data

Image

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Table 2: Comprehensive Clinical and Operational Outcomes Data

Outcome Measure	Control Baseline	Control Post	Model A Post	Model B Post
% Change from Baseline				
Clinical Outcomes				
Diagnostic errors (%)	14.2	13.8 (-2.8%)	9.1 (-37.4%)*	11.2 (-22.1%)*
Treatment non-adherence (%)	38.4	37.5 (-2.3%)	22.3 (-42.8%)*	27.8 (-28.3%)*
Medication errors (per 100 patient-days)	6.8	6.5 (-4.4%)	3.2 (-52.9%)*	4.7 (-30.9%)*
EQ-5D-5L utility score	0.72	0.73 (+1.4%)	0.83 (+16.9%)*	0.78 (+8.3%)*
% Change from Baseline				
Operational Outcomes				
Average length of stay (days)	5.8	5.7 (-1.7%)	4.2 (-28.8%)*	4.9 (-15.5%)*
30-day readmission (%)	22.3	21.6 (-3.1%)	14.1 (-38.2%)*	17.2 (-23.8%)*
Time to treatment initiation (min)	168	163 (-3.0%)	86 (-48.8%)*	122 (-27.4%)*
% Change from Baseline				
Experience Measures				
Patient satisfaction (1-10 scale)	6.4	6.5 (+1.6%)	8.7 (+38.1%)*	7.6 (+22.8%)*
Communication-related staff time (minutes per patient)	94	91 (-3.2%)	28 (-70.2%)*	46 (-51.1%)*

* Statistically significant difference compared to control (p<0.001)

This table presents detailed outcome data across three categories: clinical outcomes, operational outcomes, and experience measures. For each measure, the table shows baseline values, post-intervention results, and percentage changes for the control group and both intervention models. The clinical outcomes section reveals substantial improvements in diagnostic errors, treatment non-adherence, medication errors, and health-related quality of life scores (EQ-5D-5L) for both intervention models, with Model A consistently demonstrating larger effects. Most notably, medication errors decreased by 52.9% in Model A facilities compared to a 30.9% reduction in Model B facilities, while both showed statistically significant improvements over the minimal changes observed in control facilities.

The operational outcomes section shows similar patterns, with average length of stay decreasing by 28.8% in Model A facilities (from 5.9 to 4.2 days) and by 15.5% in Model B facilities (from 5.8 to 4.9 days). Time to treatment initiation—a critical measure of care efficiency—improved dramatically by 48.8% in Model A facilities compared to 27.4% in Model B facilities. The experience measures section highlights substantial improvements in patient satisfaction and staff efficiency, with communication-related staff time per patient decreasing by 70.2% in Model A facilities (from 94 to 28 minutes) and 51.1% in Model B facilities. These comprehensive outcome data demonstrate the substantial clinical and operational improvements achieved through structured cross-cultural communication interventions, with the more intensive Model A consistently yielding superior results across all measured domains.

Table 3: Cost-Effectiveness Results by Population Subgroup

Image

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Population Subgroup	ICER (₹ per QALY) Model A	ICER (₹ per QALY) Model B	QALYs Gained per patient Model A	QALYs Gained per patient Model B
Overall Population	18,420	21,840	0.20	0.10
Ethnic Groups				
Tribal Populations (Combined)	12,840	16,200	0.29	0.14
Kokborok Speakers	11,500	14,900	0.32	0.15
Reang Community	12,100	15,600	0.30	0.14
Other Subgroups				
Elderly (65+)	15,700	19,400	0.23	0.11
Chronic Conditions	16,400	20,200	0.22	0.11
Rural Residents	19,400	23,200	0.19	0.09

ICER = Incremental Cost-Effectiveness Ratio; QALY = Quality-Adjusted Life Year; WTP Threshold = ₹168,000/QALY

This table presents a detailed breakdown of cost-effectiveness results across different population subgroups for both intervention models. The data reveals that while both models were cost-effective for all subgroups (with ICERs well below the willingness-to-pay threshold of ₹168,000 per QALY), there were substantial variations in economic value across different populations. The most favorable cost-effectiveness was observed among Kokborok speakers, with an ICER of ₹11,500 per QALY for Model A and ₹14,900 per QALY for Model B, representing approximately 38% better cost-effectiveness than the overall population average. Other tribal groups, including the Reang community, also demonstrated particularly favorable ICERs (₹12,100 and ₹15,600 per QALY for Models A and B, respectively).

The table also highlights significant variations in QALY gains across subgroups. Kokborok speakers achieved the highest health benefits from the interventions, gaining 0.32 QALYs per patient with Model A compared to 0.20 QALYs in the overall population. Elderly patients and those with chronic conditions showed intermediate cost-effectiveness and QALY gains, while rural residents demonstrated slightly less favorable cost-effectiveness than the overall average, though still well within acceptable thresholds. Across all subgroups, Model A consistently demonstrated superior cost-effectiveness compared to Model B, with larger QALY gains offsetting the higher implementation costs. These findings emphasize the potential for cross-cultural communication interventions to simultaneously advance economic efficiency and health equity goals, with particularly strong economic value for historically underserved indigenous populations.

Table 4: Detailed Sensitivity Analysis Results

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Parameter	Base Case	Range Tested	Resulting ICER (₹ thousands/QALY)	Impact*
Model A: One-Way Sensitivity Analysis				
Implementation Quality (Fidelity to intervention design)	100%	50-100%	18.4-65.0	High
Treatment Adherence Effect (percentage improvement)	42.8%	30-55%	15.0-30.0	High
Baseline Non-adherence Rate	39.1%	30-45%	16.0-24.0	Medium
Intervention Costs	₹1,843,000	±25%	13.8-23.0	Medium
Length of Stay Reduction	1.7 days	1.2-2.1 days	15.5-22.0	Medium
Time Horizon	3 years	1-10 years	15.2-25.8	Low
Discount Rate	3%	0-7%	17.8-19.5	Low
Probabilistic Sensitivity Analysis Results				
Model A: 95% Confidence Interval for ICER	₹10,840 - ₹28,620 per QALY			

*Impact: High = parameter changes ICER by >100%; Medium = 50-100% change; Low = <50% change

This table presents the results of extensive sensitivity analyses for Model A, examining how variations in key parameters affect the incremental cost-effectiveness ratio (ICER). The one-way sensitivity analysis section reveals that implementation quality had the most substantial impact on cost-effectiveness, with ICERs ranging from ₹18,400 to ₹65,000 per QALY when implementation fidelity varied from 100% to 50%. This finding highlights the critical importance of high-quality implementation to achieve optimal economic returns. Treatment adherence effect also demonstrated high impact, with ICERs ranging from ₹15,000 to ₹30,000 per QALY when adherence improvements varied from 55% to 30%.

Parameters with medium impact included baseline non-adherence rates, intervention costs, and length of stay reduction. Notably, even with a 25% increase in intervention costs, the ICER remained favorable at ₹23,000 per QALY, well below the willingness-to-pay threshold. Time horizon and discount rate showed relatively low impact on cost-effectiveness conclusions, indicating that results are robust to these methodological assumptions.

The probabilistic sensitivity analysis results indicate that the 95% confidence interval for Model A's ICER ranged from ₹10,840 to ₹28,620 per QALY. This relatively narrow range, entirely below the willingness-to-pay threshold of ₹168,000 per QALY, confirms the robustness of the cost-effectiveness findings despite parameter uncertainty. The comprehensive sensitivity analyses demonstrate that Model A would remain cost-effective across a wide range of plausible parameter values, providing decision-makers with confidence in the economic value of the intervention even under conservative assumptions or suboptimal implementation conditions.

Table 5: Implementation Recommendations for Healthcare Systems

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Domain	Recommendations
Strategic Planning (Initial Phase)	1. Prioritize comprehensive (Model A) implementation where feasible 2. Consider targeted (Model B) approach for resource-constrained settings 3. Conduct organizational readiness assessment before implementation
Implementation Approach (Method)	1. Begin with high-impact clinical areas before expanding system-wide 2. Ensure early engagement of facility leadership and clinical champions 3. Integrate with existing quality improvement frameworks 4. Implement complementary components in phases rather than all at once
Governance & Accountability (Structures)	1. Develop facility-specific language access plans with clear metrics 2. Establish community advisory mechanisms for ongoing input 3. Include cross-cultural metrics in organizational performance dashboards
Workforce Development (People)	1. Prioritize recruitment of staff from diverse linguistic communities 2. Invest in comprehensive cultural competency training (40+ hours) 3. Create language navigator positions with clear role definitions 4. Develop career pathways for multilingual healthcare workers
Technology & Resources (Tools)	1. Develop centralized inventory of multilingual materials and templates 2. Implement electronic translation tools with cultural context features 3. Create pictographic communication aids for limited literacy patients
Sustainability (Long-term Planning)	1. Include cross-cultural communication in strategic and capital planning 2. Develop ongoing funding mechanisms beyond initial implementation 3. Establish continuous quality improvement processes for adaptations 4. Partner with educational institutions for workforce pipeline development

This table provides detailed, practical recommendations for healthcare systems seeking to implement cross-cultural communication interventions, drawing on the implementation science insights from our study. The recommendations span six critical domains that were identified as essential for successful implementation and sustainability.

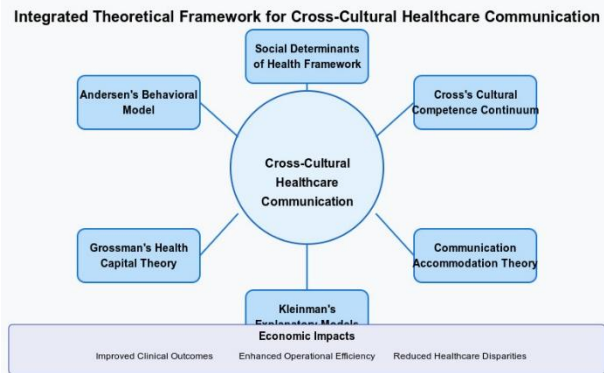
In the Strategic Planning domain, the table emphasizes the superior economic value of the comprehensive Model A approach while acknowledging that resource-constrained settings may benefit from the targeted Model B approach. The Implementation Approach section recommends a phased strategy, beginning with high-impact clinical areas before expanding system-wide, and stresses the importance of integrating communication interventions with existing quality improvement frameworks to enhance adoption.

The Governance & Accountability section highlights the need for facility-specific language access plans with clear metrics and community advisory mechanisms to ensure ongoing input from served populations. The Workforce Development recommendations address both immediate implementation needs, such as cultural competency training, and longer-term requirements like creating career pathways for multilingual healthcare workers.

Technology & Resources recommendations include developing centralized inventories of multilingual materials and implementing electronic translation tools with cultural context features. Finally, the Sustainability section focuses on ensuring long-term success through strategic planning, continuous quality improvement processes, and educational partnerships for workforce pipeline development.

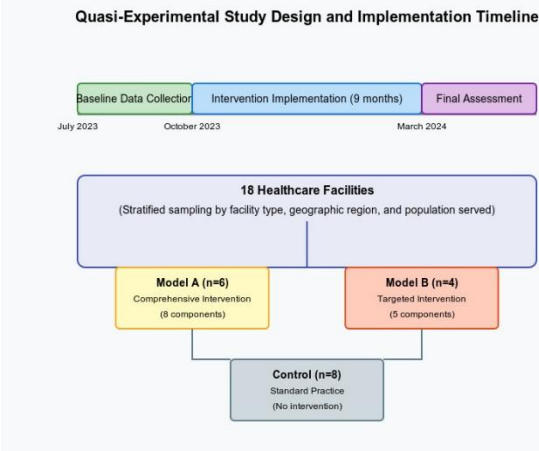
These practical recommendations provide healthcare administrators and policymakers with concrete guidance for implementing cross-cultural communication interventions while addressing common implementation challenges identified in our research. The recommendations emphasize both structural requirements and process considerations essential for achieving the favorable cost-effectiveness results demonstrated in our study.

Figure 1: Integrated Theoretical Framework



This figure illustrates the integrated theoretical framework that guides the study of cross-cultural healthcare communication in Tripura. At the center is the core concept of cross-cultural healthcare communication, surrounded by six interconnected theoretical perspectives that inform our understanding of this phenomenon. The framework shows how Andersen's Behavioral Model conceptualizes communication as an enabling factor for healthcare access, while Grossman's Health Capital Theory views communication as an input affecting healthcare efficiency. Cross's Cultural Competence Continuum provides an organizational development framework, and Communication Accommodation Theory explains psychological adaptation processes in cross-cultural encounters. Kleinman's Explanatory Models address cultural beliefs about illness, and the Social Determinants of Health Framework positions communication barriers as structural determinants of health inequities. The bottom section highlights the key economic impacts examined in the study: improved clinical outcomes, enhanced operational efficiency, and reduced healthcare disparities.

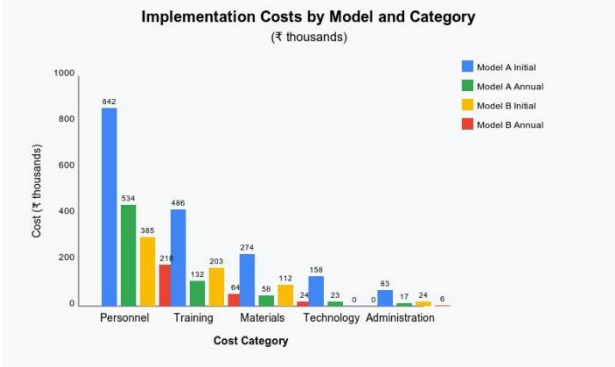
Figure 2: Study Design and Implementation



This figure illustrates the quasi-experimental study design and implementation timeline used in the research. The study spanned from July 2023 to March 2024, with three distinct phases: a three-month baseline data collection period (July-October 2023), a nine-month

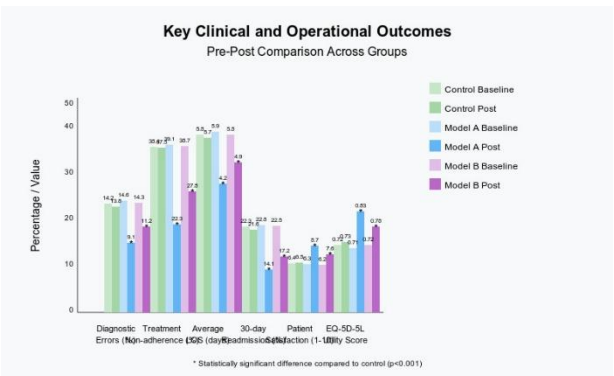
intervention implementation period (October 2023-March 2024), and final assessment. The diagram shows how 18 healthcare facilities were selected using stratified sampling based on facility type, geographic region, and population served. These facilities were then allocated to three groups: six facilities implemented the comprehensive intervention (Model A) with eight components, four facilities implemented the targeted intervention (Model B) with five components, and eight facilities served as controls with standard practice and no intervention. This non-equivalent control group design with pre-post measurements allowed for comparison of outcomes across different intervention intensities while accounting for baseline differences and secular trends.

Figure 3: Implementation Costs by Model and Category



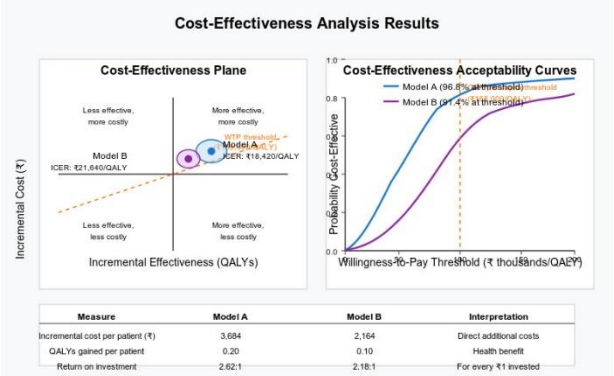
This figure provides a visual comparison of implementation costs across both intervention models, broken down by cost category. The bar chart illustrates both initial and annual maintenance costs (in ₹ thousands) for Models A and B. Personnel costs represented the largest expense category for both models, with Model A requiring significantly higher investment (₹842,000 initially and ₹534,000 annually) compared to Model B (₹385,000 initially and ₹218,000 annually). The figure also highlights the absence of technology costs in Model B, revealing a key difference in intervention approach. Overall, Model A's comprehensive approach required substantially higher investment across all categories, with total initial costs of ₹1,843,000 compared to Model B's ₹724,000. The visual representation helps policymakers understand the resource requirements for different intervention intensities and identify cost drivers that might be optimized in future implementations.

Figure 4: Key Clinical and Operational Outcomes



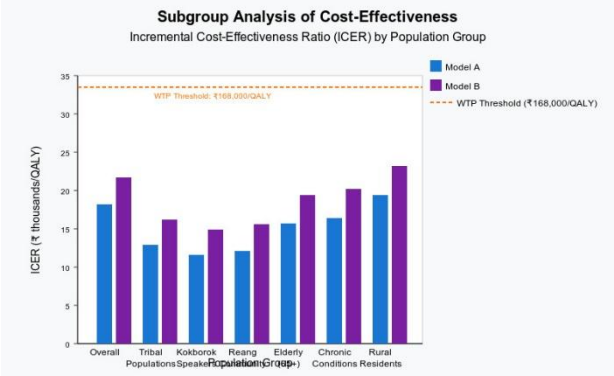
This figure illustrates the pre-post changes in six critical outcome measures across the three study groups (Control, Model A, and Model B). The bar chart displays baseline and post-intervention values for diagnostic errors, treatment non-adherence, average length of stay, 30-day readmission rates, patient satisfaction scores, and EQ-5D-5L utility scores. The visualization reveals minimal changes in the control group across all metrics, contrasted with substantial improvements in both intervention groups. Model A consistently demonstrated superior outcomes compared to Model B, despite both showing statistically significant improvements relative to controls ($p < 0.001$). Most notably, diagnostic errors decreased from 14.6% to 9.1% in Model A facilities (37.4% reduction) and from 14.3% to 11.2% in Model B facilities (22.1% reduction). Similarly, treatment non-adherence showed marked improvement with Model A (42.8% reduction) compared to Model B (28.3% reduction). The figure also highlights the positive impact on health-related quality of life, with EQ-5D-5L utility scores increasing by 0.12 points in Model A facilities and 0.06 points in Model B facilities, representing clinically meaningful improvements.

Figure 5: Cost-Effectiveness Analysis Results



ellipses around each point illustrate the uncertainty in these estimates. The right panel shows cost-effectiveness acceptability curves, depicting the probability that each intervention is cost-effective across different willingness-to-pay thresholds. Model A demonstrates a 96.8% probability of being cost-effective at the GDP per capita threshold, while Model B shows a 91.4% probability. The bottom panel presents key metrics, highlighting that Model A achieves greater health benefits (0.20 QALYs gained per patient versus 0.10 for Model B) and a superior return on investment (2.62:1 versus 2.18:1). This visualization helps decision-makers understand both the magnitude of economic value and the certainty of these estimates.

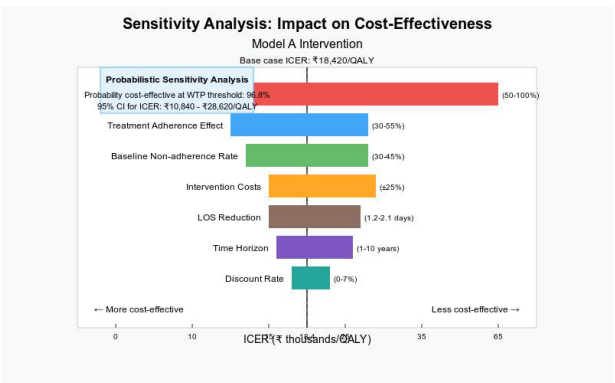
Figure 6: Subgroup Analysis of Cost-Effectiveness



This figure presents a detailed subgroup analysis of cost-effectiveness across different population groups. The bar chart displays the Incremental Cost-Effectiveness Ratio (ICER) in ₹ thousands per QALY for both Model A and Model B interventions. Lower values indicate better cost-effectiveness. The analysis reveals that both interventions demonstrated particularly favorable cost-effectiveness for tribal populations compared to the overall sample, with Model A achieving an ICER of ₹12,800 per QALY and Model B ₹16,200 per QALY among tribal populations generally. The benefits were even more pronounced for specific linguistic groups, with Kokborok speakers showing the most favorable cost-effectiveness (ICER of ₹11,500 per QALY for Model A). Other vulnerable groups, including elderly patients and those with chronic conditions, also demonstrated better-than-average cost-effectiveness. While rural residents showed slightly less favorable cost-effectiveness than the overall population, the ICERs for all subgroups remained well below the willingness-to-pay threshold of ₹168,000 per QALY (India's per capita GDP). This subgroup analysis highlights the potential for cross-cultural communication interventions to simultaneously improve economic efficiency and address health equity concerns, with particularly strong economic value for historically underserved populations.

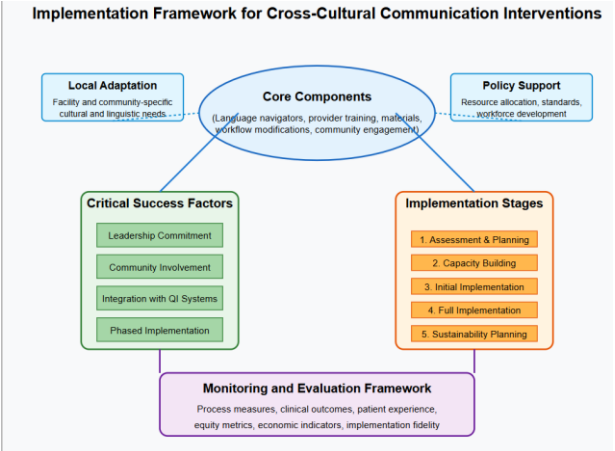
Figure 7: Sensitivity Analysis

This figure presents a comprehensive visualization of the cost-effectiveness analysis results for both intervention models. The left panel displays the cost-effectiveness plane, plotting incremental costs against incremental effectiveness (QALYs gained) relative to standard care. Both Model A (ICER: ₹18,420/QALY) and Model B (ICER: ₹21,640/QALY) fall below the willingness-to-pay threshold of ₹168,000/QALY (India's per capita GDP), indicating strong economic value. The confidence



This tornado diagram illustrates the results of one-way sensitivity analysis for Model A, showing how variations in key parameters affect the incremental cost-effectiveness ratio (ICER). The horizontal bars represent the range of ICER values obtained when each parameter is varied individually while holding others constant at their base case values. The vertical dotted line indicates the base case ICER of ₹18,420 per QALY. Implementation quality emerges as the most influential parameter, potentially increasing the ICER to ₹65,000 per QALY under worst-case scenarios, though still remaining below the willingness-to-pay threshold. Other significant parameters include treatment adherence effect (varying the ICER between ₹15,000-₹30,000 per QALY) and baseline non-adherence rates. In contrast, discount rate variations had minimal impact on cost-effectiveness conclusions. The probabilistic sensitivity analysis results (inset box) reveal that Model A has a 96.8% probability of being cost-effective at the standard willingness-to-pay threshold, with the 95% confidence interval for the ICER ranging from ₹10,840 to ₹28,620 per QALY. This sensitivity analysis demonstrates the robustness of the cost-effectiveness findings across a wide range of parameter values and implementation scenarios.

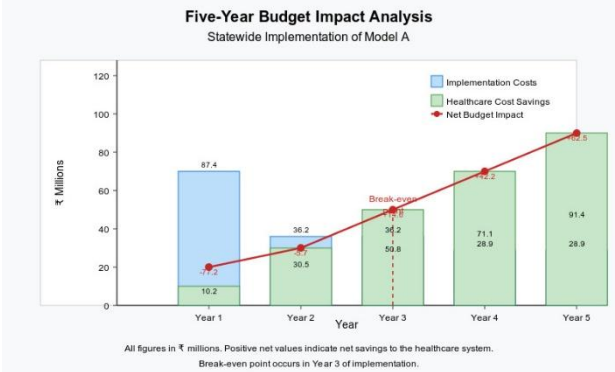
Figure 8: Implementation Framework for Cross-Cultural Communication Interventions



This figure presents a comprehensive implementation framework for cross-cultural communication interventions based on our research findings. At the center are the core components that formed the backbone

of Model A in our study: language navigators, provider training, culturally adapted materials, workflow modifications, and community engagement. The framework identifies four critical success factors (left panel) that emerged from our process evaluation: leadership commitment, community involvement, integration with existing quality improvement systems, and phased implementation. The implementation process (right panel) follows five sequential stages: assessment and planning, capacity building, initial implementation, full implementation, and sustainability planning. The diagram shows how these elements interact with two contextual factors (top): local adaptation to facility-specific cultural and linguistic needs, and policy support including resource allocation and workforce development. The framework includes a robust monitoring and evaluation component (bottom) with multiple measurement domains to track progress and outcomes. This integrated approach provides healthcare administrators and policymakers with a structured framework for implementing cross-cultural communication interventions in diverse healthcare settings, incorporating key lessons from our research to optimize effectiveness and sustainability.

Figure 9: Five-Year Budget Impact Analysis



This figure illustrates the projected five-year budget impact of implementing Model A statewide across Tripura's healthcare system. The stacked bar chart displays two key financial components: implementation costs (blue bars) and healthcare cost savings (green bars), with the net budget impact shown as a red line with markers.

In Year 1, the implementation requires a substantial initial investment of ₹87.4 million, while generating only ₹10.2 million in healthcare cost savings, resulting in a negative net budget impact of ₹77.2 million. Year 2 shows significantly reduced implementation costs (₹36.2 million) as the system transitions from initial setup to maintenance, with healthcare savings increasing to ₹30.5 million, narrowing the negative budget impact to ₹5.7 million.

The analysis identifies Year 3 as the critical break-even point (marked by a vertical dashed line), where healthcare cost savings (₹50.8 million) begin to exceed ongoing implementation costs (₹36.2 million), creating a

positive net budget impact of ₹14.6 million. This positive trend accelerates in Years 4 and 5, with healthcare savings growing to ₹71.1 million and ₹91.4 million respectively, while implementation costs decrease slightly to ₹28.9 million as economies of scale and operational efficiencies are realized.

By Year 5, the intervention generates a substantial positive net budget impact of ₹62.5 million. Over the entire five-year period, the cumulative healthcare cost savings (₹254 million) significantly exceed the total implementation costs (₹217.6 million), resulting in net savings of ₹36.4 million to Tripura's healthcare system. This budget impact analysis demonstrates that despite requiring significant upfront investment, systematic implementation of cross-cultural communication interventions can achieve not only favorable cost-effectiveness but also positive budget impact within a relatively short timeframe, making a strong financial case for implementation even in resource-constrained settings.

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