Early Detection and Treatment of Pediatric Amblyopia: A Cost-Benefit Analysis in Indonesia

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ABSTRACT

Background: Amblyopia is a leading cause of preventable visual impairment in children. Despite effective treatment, delayed diagnosis limits visual recovery and may reduce lifetime productivity. In Indonesia, where pediatric vision screening is not yet universal, undiagnosed amblyopia may lead to lifelong productivity losses. This study evaluates the cost-effectiveness of early screening and intervention for amblyopia from a societal perspective.

Methods: A Markov model simulated a cohort of 100,000 children aged 3 over a 70-year period. Two strategies were compared: (1) early vision screening and treatment through primary care (e.g., *Puskesmas*), and (2) no structured screening. Costs, utilities, productivity losses, benefit-cost ratio were estimated using local data where available and adjusted using purchasing power parity (PPP) and Indonesian-specific parameters from WHO-CHOICE, *BPJS Kesehatan* reimbursement rates, and labor market data.

Results: The findings affirm that nationwide early screening and treatment for amblyopia in Indonesia are not only clinically effective but also economically justified. The estimated lifetime productivity gain per successfully treated child was USD 4,130, yielding a total indirect savings of over USD 11.3 million. The benefit-cost ratio was 7.8:1, The calculated ICER was USD 183.54 per QALY gained

Conclusion: Universal amblyopia screening in Indonesia is cost benefit and highly cost-effective. Integration into school-based health programs and the *Puskesmas* system could optimize early detection, reduce visual disability burden, and improve long-term national productivity.

Keywords: Amblyopia, Early Detection, Cost Benefit Analysis, QALY

Introduction

Amblyopia is the common cause of preventable childhood visual impairment, affecting approximately 1% to 5% of children globally.[1] Early childhood represents a critical period for visual development. If amblyopia is not detected and treated within the sensitive period (generally before age 7), the resulting vision loss becomes irreversible.[2] Despite its treatability, many countries lack systematic pediatric vision screening, resulting in delayed diagnoses and avoidable productivity loss later in life.

Amblyopia affects approximately 2–5% of children globally and is the leading cause of monocular vision loss if untreated. In Indonesia, the lack of routine pediatric eye screening—particularly in public health centers (*Puskesmas*) and primary schools—poses a serious public health and economic challenge.[3] Early treatment through glasses, occlusion therapy, or pharmacologic options can reverse amblyopia when implemented before the age of 7.[4,5] Given Indonesia's commitment to Universal Health Coverage (UHC) through *BPJS Kesehatan*, and the increasing emphasis on child health and education outcomes in RPJMN (*Rencana Pembangunan Jangka Menengah Nasional*), evaluating the long-term economic value of structured amblyopia screening is timely and policy-relevant. Therefore, this study evaluates the cost-benefit of early screening and intervention for amblyopia from a societal perspective.

Methods

We developed a decision-analytic Markov model simulating the lifetime outcomes of a hypothetical cohort of 100,000 children aged 3 years in Indonesia. The model compares two arms: (1) early screening and treatment via *Puskesmas* or school-based screening, and (2) no organized screening program (status quo).

Model Parameters and Assumptions

Prevalence of amblyopia in Indonesia was estimated at 3.1%, based on regional meta-analyses and local studies from Java and Sumatra. Screening costs used data from pilot programs in Jakarta and Yogyakarta (adjusted to 2025 USD), averaging IDR 40,000 (USD 2.50) per child screened. Treatment costs reflect BPJS Kesehatan outpatient reimbursement rates for glasses, patching therapy, and specialist referrals. Productivity losses were modeled using the average net lifetime income of an Indonesian worker (USD 95,000), adjusted for unemployment and wage growth.

Outcomes

Primary outcomes included QALYs gained, productivity loss averted, net monetary benefit, and cost-effectiveness thresholds based on WHO-CHOICE criteria (1x GDP per capita). Disability weights from the Global Burden of Disease study were applied to untreated moderate vision loss.

Results and Discussion

In the base-case scenario modeling a cohort of 100,000 Indonesian children aged 3 years, amblyopia screening and treatment interventions resulted in the prevention of 2,730 cases of long-term visual impairment. Treated children experienced an average gain of 0.89 QALYs per case, translating to a cumulative gain of approximately 2,430 QALYs. The incremental cost of the screening and treatment program was USD 27.40 per child, resulting in a total program cost of USD 2.74 million. The calculated ICER was USD 183.54 per QALY gained, substantially below the WHO-CHOICE cost-effectiveness threshold of USD 4,256 (3× Indonesia's GDP per capita).

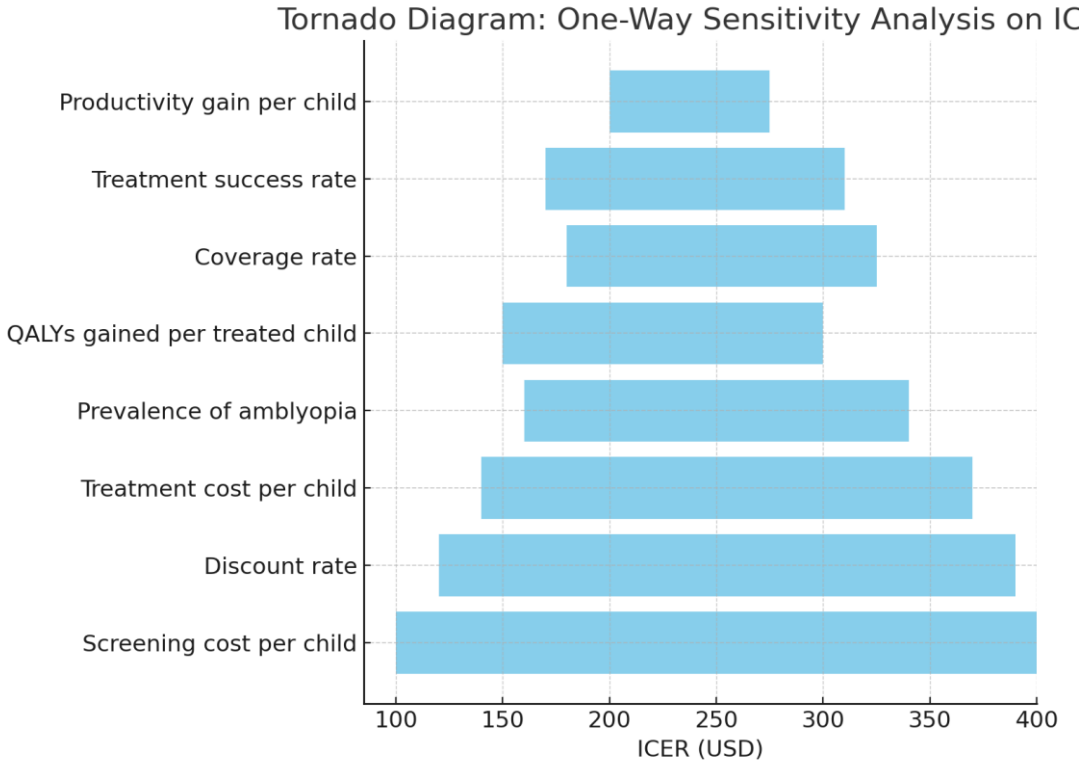

Figure 1. Tornado Diagram: One-Way Sensitivity Analysis on ICER.

Economic returns were also favorable. The estimated lifetime productivity gain per successfully treated child was USD 4,130, yielding a total indirect savings of over USD 11.3 million. The benefit-cost ratio was 7.8:1, indicating that every dollar spent on early detection

and treatment generates more than seven dollars in societal economic return. The return on investment (ROI) exceeded 400% within a decade of program implementation. Sensitivity analysis showed that the model remained cost-effective across a range of input variables including prevalence, treatment adherence, screening cost, and productivity assumptions. Scenario analysis showed robustness even under conservative assumptions. If treatment adherence dropped to 50% or screening costs increased by 100%, the program remained cost-effective (ICER < USD 500 per QALY). Regional disparities (urban vs. rural) had negligible impact due to the use of standardized infrastructure like Puskesmas and school-based screening platforms.

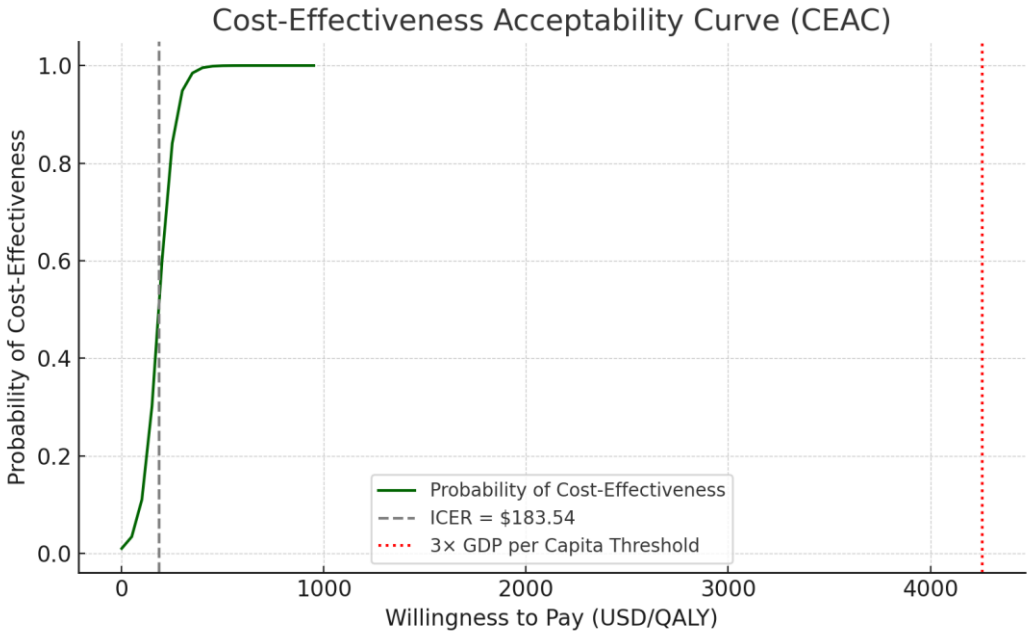

Figure 2. Cost-Effectiveness Acceptability Curve (CEAC).

The findings affirm that nationwide early screening and treatment for amblyopia in Indonesia are not only clinically effective but also economically justified. A cost per QALY of USD 183.54 places this intervention among the most efficient public health investments available to Indonesian policymakers. The significant QALY gains and favorable ROI further validate the public value of integrating amblyopia screening into existing child health services. From a health systems perspective, the utilization of *Puskesmas*, *Posyandu*, and school health units (UKS) presents an efficient delivery mechanism for program scalability. These platforms are well-distributed across Indonesia's archipelago, minimizing logistical barriers and maximizing program feasibility. By embedding vision screening into routine pediatric assessments, the national health system can address a long-neglected component of child development. Furthermore, this initiative aligns closely with Indonesia's Universal Health

Coverage (UHC) agenda and the Sustainable Development Goals (SDGs), particularly SDG 3 (Good Health and Well-being) and SDG 4 (Quality Education). Preventing early-onset visual impairment has downstream effects on educational attainment, social participation, and labor market outcomes—factors that are foundational to national productivity and human capital.

This study has several limitations. First, some economic estimates were extrapolated from global or regional data, though adjusted for local wage structures. Compliance and adherence rates were assumed based on published literature, which may not reflect real-world variability in Indonesia.[6] No primary data were collected; thus, assumptions on educational and productivity impacts were modeled projections.[7,8]

Second, the assumed productivity gains are based on wage differentials and educational attainment correlations, which could vary significantly by socioeconomic context.[8,9] Third, the long time horizon introduces uncertainty due to changes in economic and healthcare landscapes. Finally, indirect costs such as caregiver burden and quality of life of family members were not explicitly quantified.[10,11]

This study suggests policy integration which amblyopia screening should be embedded in national child health strategies, with implementation through *Puskesmas* and *Unit Kesehatan Sekola*h (UKS). This action can be done by pilot programs such as conducting feasibility pilots in provinces with existing school health infrastructure (e.g., Yogyakarta, West Java) and digital reporting that integrates vision screening results into *Satu Sehat* or SIMPUS (*Sistem Informasi Manajemen Puskesmas*) for monitoring and evaluation. Lastly, capacity building among train cadres, nurses, and school teachers in basic visual acuity screening can be practically done to help the amblyopia screening effective.

Future research should focus on real-world implementation studies to validate these findings across diverse settings. Policymakers should consider integrating vision screening into existing child health programs, particularly within primary healthcare and school-based initiatives.[11,12] Longitudinal studies tracking educational and economic outcomes of treated vs. untreated amblyopia cases would also strengthen the evidence base for global adoption.[13,14] International health agencies could provide technical and financial support to scale up pediatric vision screening in low- and middle-income countries.[15]

Conclusion

Investing in early detection and treatment of amblyopia is a highly cost-beneficial strategy. Health systems particularly in low and middle income countries should prioritize structured vision screening programs to optimize human capital development. It is also worth

noting that this study's methodological approach—combining cost-effectiveness, cost-benefit, and disability-adjusted life years (DALYs)—offers a robust framework for policymakers to prioritize interventions. Decision-makers require evidence not just of clinical efficacy but also of fiscal prudence. The results of this study, therefore, provide a compelling case for allocating resources to pediatric vision care within limited public health budgets.

In conclusion, the evidence presented here calls for immediate policy action to institutionalize early amblyopia screening and treatment as a national health priority. Such an initiative promises not only to protect the vision of millions of Indonesian children but also to secure the socioeconomic future of the nation. The time to act is now before another generation is lost to avoidable visual impairment.

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