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Cost-Effectiveness of a Locally Manufactured 3D-Printed AI-Assisted Videolaryngoscope: A Model-Based Economic Evaluation

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Abstract

Background

Videolaryngoscopy improves first-pass success and reduces airway-related complications; however, high acquisition costs limit widespread adoption in resource-constrained public healthcare systems. To evaluate the cost-effectiveness of a locally manufactured 3D-printed AI-Assisted videolaryngoscope (VL-CV) compared with an imported gold-standard device, from the perspective of the Brazilian Unified Health System (SUS).

Methods

A model-based cost-effectiveness analysis was conducted following CHEERS reporting standards. An analytical decision tree simulated clinical pathways associated with orotracheal intubation. Transition probabilities were derived from a summative usability study (N = 60) and published literature. Costs were estimated using bottom-up microcosting for the VL-CV (BRL 292.00) and market pricing for the comparator (BRL 10,000.00). Parameter uncertainty was assessed through deterministic one-way sensitivity analysis and probabilistic sensitivity analysis using Monte Carlo simulation (1,000 iterations). Willingness-to-pay (WTP) thresholds were defined according to GDP per capita benchmarks.

Results

In the base-case analysis, the VL-CV demonstrated lower expected per-patient costs (BRL 145.39 vs. BRL 172.27) and greater effectiveness (100% vs. 98.3% first-pass success rate). The incremental cost-effectiveness ratio (ICER) indicated cost savings of BRL 26.87 per procedure, characterizing the intervention as a strictly dominant strategy. Probabilistic sensitivity analysis confirmed model robustness, with the probability of cost-effectiveness approaching 100% across all simulated scenarios.

Conclusion

The VL-CV represents a strictly dominant and resource-saving strategy. The integration of additive manufacturing and computer vision technologies may offer a scalable pathway for expanding access to safe airway management in public healthcare systems.

Key Points

● A locally manufactured 3D-printed AI-Assisted videolaryngoscope achieved clinical performance comparable to a gold-standard commercial device.

● A model-based economic evaluation demonstrated that the novel device is a strictly dominant and cost-saving strategy.

● Cost-effectiveness remained robust across deterministic and probabilistic sensitivity analyses.

● Additive manufacturing combined with artificial intelligence may reduce financial barriers to advanced airway management technologies.

● Frugal innovation strategies can enhance access to advanced medical technologies in resource-constrained healthcare systems.

1. Introduction

Ensuring a patent airway through orotracheal intubation (OTI) is a critical and frequently performed procedure in emergency care, intensive care, and anesthesiology. First-pass success represents the key clinical outcome, as failed attempts and multiple intubation attempts are strongly associated with increased morbidity and mortality, including severe complications such as hypoxia, airway trauma, and hemodynamic instability. Consequently, the occurrence of a difficult airway substantially increases hospital costs and length of stay in Intensive Care Units (ICUs), imposing a significant clinical and economic burden on healthcare systems [1].

In this context, videolaryngoscopy (VL) represents a transformative technological advancement over conventional direct laryngoscopy. By providing indirect, magnified visualization of the glottis, VL reduces failed intubations and minimizes complications, demonstrating clear clinical superiority, particularly in patients with anatomically or physiologically difficult airways [1,2]. However, healthcare systems face a persistent paradox: the universal and routine adoption of this technology in Brazil, particularly within the Unified Health System [Sistema Único de Saúde – SUS], is constrained by financial barriers. The high capital expenditure (CAPEX) associated with imported commercial videolaryngoscopes markedly limits their availability, compelling continued reliance on direct laryngoscopy for purely economic reasons, potentially compromising patient safety [2].

Compounding this scenario, the global literature on Health Technology Assessment (HTA) highlights a critical methodological gap. Despite rapid advances in medical device engineering, robust primary economic evaluations in this field remain scarce. The current literature addressing innovations in medical devices is still at an early stage of maturity, being predominantly composed of exploratory studies, narrative reviews, and expert opinion [3,4].

In response to the urgent need to democratize access to gold-standard technologies without overburdening the public healthcare system, a locally developed AI-Assisted videolaryngoscope (VL-CV) was designed. The device was produced using additive manufacturing (3D printing) and equipped with an open-source artificial intelligence (AI) system to assist in the anatomical identification of the vocal cords. Local manufacturing aims to mitigate dependence on imported equipment and drastically reduce

acquisition costs, while the embedded AI technology has the potential to shorten the learning curve and enhance procedural safety, including for less experienced operators [5].

Although the clinical effectiveness of videolaryngoscopy is well established, economic evaluations of devices based on additive manufacturing and embedded technologies remain limited, particularly in low- and middle-income countries. Guidelines issued by the Brazilian National Committee for Health Technology Incorporation (CONITEC) and the Ministry of Health recommend that efficient resource allocation be supported by rigorous cost-effectiveness models and sensitivity analyses [6–8].

Addressing this scientific and methodological gap, and guided by the CHEERS reporting standards, the present study tests the hypothesis that anatomical optimization provided by computer vision technology improves first-pass success rates and reduces procedural duration, thereby decreasing operational costs (physician time and complication management). Accordingly, the objective of this study is to conduct a model-based cost-effectiveness analysis comparing the locally manufactured VL-CV with an imported gold-standard videolaryngoscope, from the perspective of the Brazilian Unified Health System (SUS), over a five-year time horizon.

2. Methodology

2.1 Study Design

This study constitutes a health economic evaluation using a cost-effectiveness analysis (CEA) framework, based on an analytical decision model. The study was structured and reported in accordance with the Consolidated Health Economic Evaluation Reporting Standards (CHEERS). The analysis seeks to provide evidence supporting the incorporation of innovative technologies, addressing the current scarcity of robust primary economic evaluations in the field of high-risk medical devices [3,4].

This study is a health economic evaluation conducted using a cost-effectiveness analysis (CEA) framework based on an analytical decision model. The study design, analytical methods, and reporting were developed in accordance with the Consolidated Health Economic Evaluation Reporting Standards (CHEERS) (Supplementary file 1). The analysis aims to generate evidence to support the adoption of innovative technologies in healthcare systems, addressing the current scarcity of robust primary economic evaluations in the field of high-risk medical devices [3,4].

2.2 Perspective, Time Horizon, and Target Population

The analysis was conducted from the perspective of the Brazilian Unified Health System (Sistema Único de Saúde – SUS), considering exclusively direct medical costs associated with the procedure and its immediate consequences [7]. A five-year time horizon (beginning in 2023) was adopted, deemed sufficient to capture acquisition costs, depreciation, and the estimated service life of the devices. In accordance with Brazilian methodological guidelines, an annual discount rate of 5% was applied to both costs and outcomes [6].

The model's target population comprises adult patients requiring orotracheal intubation (OTI) in intensive care and operating room settings. Two strategies were compared: Intervention Group: Locally manufactured 3D-printed videolaryngoscope with embedded artificial intelligence for computer vision assistance(VL-CV); Comparator Group: Imported commercial videolaryngoscope, considered the market gold standard, without embedded artificial intelligence.

2.3 Analytical Decision Model Structure

To simulate patient clinical pathways, a decision tree model was constructed beginning at the indication for OTI. The model assumes that, following device use (VL-CV or gold-standard VL), patients may experience either first-pass success (optimal outcome) or failure. In cases of first-pass failure, the model assumes the need for additional attempts or rescue techniques, incurring additional costs and increased risk of major complications, specifically dental trauma and severe hypoxia (SpO_2 < 90%).

2.4 Clinical Parameters and Transition Probabilities

Model efficacy parameters and transition probabilities were informed by a combination of primary empirical data [9] and secondary literature sources. Empirical data were derived from the summative phase of clinical validation of the device (N = 60). In this sample of physicians assessed within a high-fidelity simulation environment, the VL-CV demonstrated a first-pass intubation success rate of 100% (adopted as the base-case value, attributed to computer vision-assisted anatomical guidance), compared with 98.3% observed with the commercial videolaryngoscope (VL-C).

Usability assessments classified both devices as "Excellent." However, paired non-parametric analyses revealed a statistically significant intra-individual preference for the 3D-printed device ($p < 0.001$). For sensitivity analysis of the gold-standard comparator, a variation range of 65% to 99% was assumed to reflect the high failure rates documented in the literature for intensive care settings. The probabilities of complications associated with failed intubation attempts, including dental trauma (0.17%) and severe hypoxia (16.7%), were derived from targeted literature reviews [10,11]. All model input parameters are summarized in Table 1.

Table 1
Parameters of the analytical decision model and reference values for probabilistic sensitivity analysis (Monte Carlo simulation).

Parameter	Base Value	Range (Min – Max)	Distribution	Data Source
A. Efficacy and Clinical Probabilities				
First-Attempt Success Rate (VLP-CV)	100%	95% – 100%	Beta	Primary Data
First-Attempt Success Rate (Gold Standard)	98.3%	65% – 99%	Beta	Primary Data / Literature
Probability of Dental Trauma	0.17%	0.10% – 0.50%	Beta	Chanhawong et al., 2025
Probability of Severe Hypoxia (SpO2 < 90%)	16.7%	10% – 25%	Beta	Crewdson et al., 2020
B. Acquisition Costs (CAPEX)				
VLP-CV Device Cost (Unit)	BRL 292.00	BRL 233.00 – BRL 350.00	Gamma	Microcosting / Author Panel
Gold Standard Device Cost (Unit)	BRL 10,000.00	BRL 8,000.00 – BRL 12,000.00	Gamma	Pricing Panel / ComprasNet
Equipment Lifespan	5 years	3–7 years	Fixed	Institutional Estimate
Estimated number of uses per year	100 uses	50–200 uses	Fixed	Hospital Estimate
C. Event and Procedure Costs (OPEX)				
ETI Procedure (Without complication)	BRL 144.72	BRL 115.00 – BRL 173.00	Gamma	SIGTAP (03.01.10.017-9)
Dental Trauma Treatment (Replantation)	BRL 19.18	BRL 15.00 – BRL 23.00	Gamma	SIGTAP (04.14.02.007-3)
Adult ICU Daily Rate (Hypoxia Treatment)	BRL 700.00	BRL 478.00 – BRL 840.00	Gamma	SIGTAP / Market Values
D. General Parameters				
Discount Rate (Annual)	5%	0% – 10%	Fixed	CONITEC / MS Guidelines
Willingness-to-Pay (WTP) Threshold	1 GDP pc	1 to 3 GDP pc	Fixed	WHO / CONITEC Recommendation

Note: "GDP pc" stands for Gross Domestic Product per capita, representing "PIB pc".

2.5 Cost Estimation and Microcosting

Costs were categorized into capital expenditures (CAPEX) and operational expenditures (OPEX). The unit acquisition cost of the VL-CV device was estimated using a bottom-up microcosting approach, yielding a total of BRL 292.00. Direct costs associated with additive manufacturing inputs (3D printing), electronic components (sensors and microcontroller), and technical labor for assembly were considered, while the artificial intelligence software (open-source) was assigned a zero-cost value.

In accordance with CHEERS transparency principles, it is important to emphasize that the VL-CV device was manufactured in an academic laboratory environment (in-house production model). Consequently, the CAPEX attributed to the intervention group strictly reflects direct prototyping costs, excluding fixed costs associated with large-scale industrial manufacturing, corporate overhead, commercialization margins, and regulatory fees. To mitigate this limitation inherent to the current stage of technological development, potential cost increases under a commercial scalability scenario were incorporated into the Probabilistic Sensitivity Analysis ranges.

Conversely, the gold-standard device was priced at its final market value (BRL 10,000.00), based on official procurement data from the Brazilian Federal Government Pricing Panel (Painel de Preços – Comprasnet). To incorporate equipment costs into the decision tree, the Equivalent Annual Cost (EAC) was calculated using the formula:

$$EAC = CAPEX \times \frac{r}{1 - (1 + r)^{-n}}$$

where *r* represents the discount rate (5%; 0.05) and *n* denotes the estimated useful life of the equipment (5 years).

Assuming a conservative institutional volume of 100 procedures annually per device, the amortized cost per use was estimated. This value was added to the base reimbursement for the orotracheal intubation procedure (BRL 144.72; SIGTAP: 03.01.10.017-9).

Complication costs were defined as follows: Severe hypoxia: BRL 700.00 (additional ICU daily cost); Dental trauma: BRL 19.18 (tooth reimplantation; SIGTAP: 04.14.02.007-3).

2.6 Statistical and Sensitivity Analyses

The primary outcome measure of the model was the Incremental Cost-Effectiveness Ratio (ICER), calculated as the difference in mean costs between strategies divided by the difference in effectiveness (first-pass success rate). When an intervention demonstrated both lower costs and greater effectiveness simultaneously, it was classified as a dominant strategy.

To assess model robustness in the presence of parameter uncertainty (Table 1), two sensitivity analyses were conducted in accordance with established best practices for decision modeling in health economics [12]: Deterministic One-Way Sensitivity Analysis (OWSA): Model parameters (costs, efficacy, and complication probabilities) were varied individually across predefined minimum and maximum values. The objective was to identify variables exerting the greatest influence on the ICER. Results are

visually represented using a Tornado Diagram, the gold-standard graphical method for evaluating individual parameter uncertainty [13]; Probabilistic Sensitivity Analysis (PSA): To evaluate joint parameter uncertainty, a Monte Carlo simulation with 1,000 iterations (second-order sampling) was performed. The Monte Carlo technique enables estimation of expected outcome values through random sampling from the joint probability distributions of model parameters [12,14]. Probability and efficacy parameters (bounded between 0 and 1) were assigned Beta distributions, while cost parameters (right-skewed and non-negative) were modeled using Gamma distributions.

Finally, to determine economic viability, the willingness-to-pay (WTP) threshold was defined as one to three times the Brazilian gross domestic product (GDP) per capita, consistent with World Health Organization (WHO) and CONITEC recommendations. The probability of the VL-CV being cost-effective across varying WTP thresholds was illustrated using a Cost-Effectiveness Acceptability Curve (CEAC).

3. Results

3.1 Base-Case Analysis

The deterministic base-case analysis demonstrated that adoption of the VL-CV device resulted in an expected per-patient cost of BRL 145.39, whereas the gold-standard comparator yielded an expected cost of BRL 172.27.

In terms of effectiveness, the VL-CV achieved a first-pass success rate of 100% (1.00), compared with 98.3% (0.983) observed for the imported comparator.

Integrating these outcomes, the Incremental Cost-Effectiveness Ratio (ICER) indicated: Incremental Cost: –BRL 26.87 (cost savings per procedure); Incremental Effectiveness: +0.017 (increase in success probability)

Given that the VL-CV device was simultaneously less costly and more effective, it was classified as a strictly dominant strategy, rendering formal comparison against the willingness-to-pay threshold unnecessary for adoption justification [15].

3.2 Deterministic One-Way Sensitivity Analysis

To evaluate the mathematical robustness of the base-case findings under parameter variability reported in the literature, a Tornado Diagram was constructed (Fig. 1).

The one-way sensitivity analysis demonstrated that the variable exerting the greatest influence on the model was the *“Gold-Standard Success Rate.”* When the effectiveness of the gold-standard device was reduced to its tested lower bound (65% success), simulating catastrophic and high-complexity ICU airway scenarios as reported in the literature [16], the cost savings associated with the VL-CV device increased substantially, exceeding BRL 100.00 per procedure.

Conversely, even under the most unfavorable financial assumptions for the novel technology — increasing the VL-CV CAPEX to its upper bound (BRL 350.00) while simultaneously reducing the gold-standard CAPEX to its lower market limit (BRL 8,000.00) — the mean cost savings per patient remained approximately BRL 22.00 in favor of the intervention. Importantly, across all univariate scenarios tested, the VL-CV device retained its classification as a dominant strategy.

3.3 Probabilistic Sensitivity Analysis (Monte Carlo Simulation)

Joint parameter uncertainty was assessed through a second-order Monte Carlo simulation with 1,000 iterations, generating the cost-effectiveness plane (Fig. 2).

An overwhelming majority (approximately 100%) of the 1,000 iterations were located within the southeast quadrant of the cost-effectiveness plane, corresponding to negative incremental costs and positive incremental effectiveness. This finding indicates a high degree of statistical certainty: even when worst-case clinical failure probabilities, hypoxia risks, and capital cost variations were combined simultaneously within their respective probabilistic distributions (Gamma and Beta), the locally manufactured VL-CV device consistently remained the economically and clinically superior strategy for the Brazilian Unified Health System.

3.4 Cost-Effectiveness Acceptability Curve (CEAC)

The probabilistic sensitivity analysis evaluated willingness-to-pay (WTP) thresholds ranging from BRL 0.00 to three times the Brazilian gross domestic product (GDP) per capita (approximately BRL 150,000.00), in accordance with the methodological framework adopted for the economic evaluation [17,14]. The results reinforced the strict dominance observed in the base-case analysis. Across the entire range of WTP thresholds, including a hypothetical scenario of maximal budgetary constraint (WTP = BRL 0.00), the probability of the VL-CV device being cost-effective remained approximately 100% across the probabilistic simulations. These findings indicate that the locally manufactured VL-CV device provides greater clinical benefit at a lower expected cost than the comparator, without requiring additional financial investment by the Brazilian Unified Health System (SUS). Therefore, the intervention can be characterized as a dominant and resource-saving (cost-saving) strategy.

4. Discussion

This study proposed a comprehensive evaluation of a novel airway management technology (computer vision-assisted videolaryngoscope, VL-CV), integrating clinical usability testing with economic cost-effectiveness modeling. The findings demonstrate that the 3D-printed device not only achieved clinical performance comparable to the market gold standard but also established itself as a dominant economic strategy for the Brazilian Unified Health System (SUS), generating direct cost savings from the healthcare payer perspective.

4.1 Addressing the Methodological and Regulatory Gap

Recent literature examining the evaluation of medical devices reveals a landscape characterized by limited methodological maturity, predominantly composed of narrative reviews and expert opinion [3,4]. Tarricone and Drummond [18] and Egbosimba [19] have highlighted a critical gap: unlike pharmaceuticals, the validation of novel medical devices frequently lacks robust primary trials and structured economic analyses.

Although the introduction of more stringent European Medical Device Regulation (MDR) frameworks represents an essential advancement for patient safety, these regulatory requirements have inadvertently introduced barriers to innovation, particularly affecting accessible and frugally designed technologies. Craven et al. [20] argue that increasingly rigorous regulatory thresholds may disproportionately restrict market entry for independent and small-scale innovations.

The present study directly responds to this gap by providing a hybrid and reproducible methodological framework. By combining primary clinical testing (summative phase, N = 60) — which demonstrated statistically significant intra-individual preference for the VL-CV in usability and learnability (Wilcoxon, $p < 0.001$) — with probabilistic Monte Carlo simulation, this work enhances methodological rigor in Health Technology Assessment (HTA) for surgical devices. Furthermore, the findings corroborate recent observations emphasizing the need for evaluation strategies adapted to device-specific technological characteristics [21], demonstrating that robust economic dominance (cost-saving) evidence can be derived from academically developed, in-house technologies.

4.2 Operator Effect and Learning Curve

Beyond regulatory considerations, intrinsic methodological challenges exist in the economic evaluation of medical devices. Manca [22] and Drummond et al. [15] emphasize that device evaluations are inherently more complex than pharmaceutical assessments due to their dependence on operator skill and learning curves.

In this study, the embedded artificial intelligence (computer vision) technology directly addresses this methodological bias. By supporting real-time anatomical recognition, the system has the potential to standardize performance across operators with varying levels of experience, thereby mitigating the operator-dependent variability frequently observed in airway management procedures. This mechanism plausibly explains the high first-pass success rates observed during summative validation.

4.3 Clinical Performance and Non-Inferiority

From a clinical efficacy standpoint, the results align closely with global evidence. The absence of statistically significant differences in intubation time between the VL-CV and the commercial device (Kruskal-Wallis, $p = 0.933$) is consistent with prior investigations. Similarly, the lack of statistically significant differences in glottic visualization and tube passage times, reinforced by our meta-analytical

findings (p = 0.41), supports the clinical non-inferiority of the VL-CV, despite the high heterogeneity (I^2 = 98%) reported across comparable studies [23–25].

This equivalence in procedural duration represents a critical finding. Within health economics, establishing clinical non-inferiority is a prerequisite for cost-minimization considerations. Although participants reported tactile differences attributable to material properties inherent to fused deposition modeling (FDM) and reduced blade rigidity, the observed 100% first-pass success rate effectively mitigates risks associated with adverse outcomes. Given that complications such as severe hypoxia and dental trauma impose substantial economic burdens, achieving equivalent clinical performance at markedly lower acquisition costs substantiates the classification of the VL-CV as a dominant strategy.

4.4 Supply Chain Resilience and Frugal Innovation

Dependence on imported medical technologies generates not only elevated acquisition costs but also structural vulnerabilities related to global market fluctuations. Contemporary analyses highlight the importance of incorporating supply chain resilience into economic evaluations of modern medical devices [26].

The additive manufacturing approach adopted in this study eliminates importation bottlenecks, enabling rapid local production and deployment, particularly in high-demand scenarios. This framework reflects broader global shifts toward frugal innovation strategies tailored to emerging healthcare markets, facilitating sustainable democratization of access to gold-standard technologies [27].

4.5 Dominance Under Uncertainty and Study Limitations

The principal contribution of this study lies in its economic projections. While existing literature consistently identifies capital cost as the primary barrier to videolaryngoscope adoption in public healthcare systems, the present decision model demonstrated that the VL-CV constitutes a strictly dominant strategy.

Importantly, even under extreme one-way sensitivity scenarios — including maximal VL-CV CAPEX and minimal gold-standard efficacy — economic superiority was preserved. Additionally, the inability of logistic regression models to predict intubation failure, attributable to the minimal number of observed failures, further underscores the high safety profile achieved during validation.

Certain limitations warrant consideration. Acquisition costs for the VL-CV reflect in-house prototyping and do not incorporate indirect industrial manufacturing expenses, corporate overhead, or regulatory compliance costs associated with large-scale commercialization. Nevertheless, the magnitude of the cost differential between the VL-CV (BRL 292.00) and the market gold standard (BRL 10,000.00) is sufficiently large that even substantial adjustments for industrial scaling would be unlikely to alter the dominance outcome.

Finally, clinical validation was conducted within a high-fidelity simulation environment. Although simulation represents an established and methodologically robust approach for device assessment,

multicenter randomized controlled trials conducted in real-world emergency and intensive care settings remain necessary to confirm complication rates and externally validate model parameters.

5. Conclusion

This study demonstrates that the computer vision-assisted 3D-printed videolaryngoscope (VL-CV) constitutes a strictly dominant economic strategy compared with the imported commercial gold-standard device. By integrating additive manufacturing with open-source artificial intelligence algorithms, the proposed technology achieved clinically non-inferior performance — evidenced by a 100% first-pass success rate and mitigation of operator-dependent variability — while simultaneously enabling a substantial reduction in acquisition costs.

Analytical modeling and probabilistic simulation confirmed an approximately 100% probability of the VL-CV being the most cost-effective alternative for the Brazilian Unified Health System, even under highly conservative economic assumptions. Characterized as a resource-saving intervention, this frugal innovation has the potential to overcome the financial barriers currently limiting universal videolaryngoscopy adoption in public healthcare systems.

Moreover, this study addresses a critical gap in the medical device evaluation literature, demonstrating that robust clinical and economic evidence can be generated for academically developed technologies supported by resilient local supply chains. Future multicenter randomized clinical trials conducted in real-world emergency and intensive care environments are recommended to definitively validate these findings and support large-scale policy implementation.

Declarations

Conflict of Interest

The authors declare that they have no conflicts of interest.

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Availability of Data and Materials

All data generated or analyzed during this study are included in this published article and its supplementary materials. Model input parameters were derived from primary usability validation data and publicly available literature sources cited in the manuscript. Additional analytical details may be obtained from the corresponding author upon reasonable request.

Code Availability

The decision-analytic model was developed in Microsoft Excel. The model structure, assumptions, and input parameters are fully described in the manuscript. The analytical model may be made available by the corresponding author upon reasonable request.

Ethics Approval and Consent to Participate

The usability validation phase was conducted in a high-fidelity simulation environment and did not involve patients or identifiable personal data. According to national regulations, formal ethics committee approval was not required. All participating professionals provided informed consent.

Consent for Publication

Not applicable.

Declaration of generative AI and AI-assisted technologies in the manuscript preparation process

During the preparation of this manuscript, the authors used ChatGPT (OpenAI, San Francisco, CA, USA) to assist with English language refinement, translation, and improvement of text clarity and structure. The AI tool also supported the organization and articulation of methodological content. All outputs were critically reviewed, verified, and edited by the authors, who take full responsibility for the integrity and accuracy of the final manuscript.

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Author's contributions

All authors contributed to the study conception. ACBKM was responsible for the study design, methodological development, and drafting of the original manuscript. IMH and LODV contributed to data curation, investigation, data analysis, and critical revision of the manuscript. MVR contributed to the literature review, formal analysis, and visualization of results. ASB contributed to formal analysis, visualization, and critical revision of the manuscript. RGL supervised the project, contributed to data interpretation, secured funding, and critically revised the manuscript. All authors read and approved the final manuscript.

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Figures

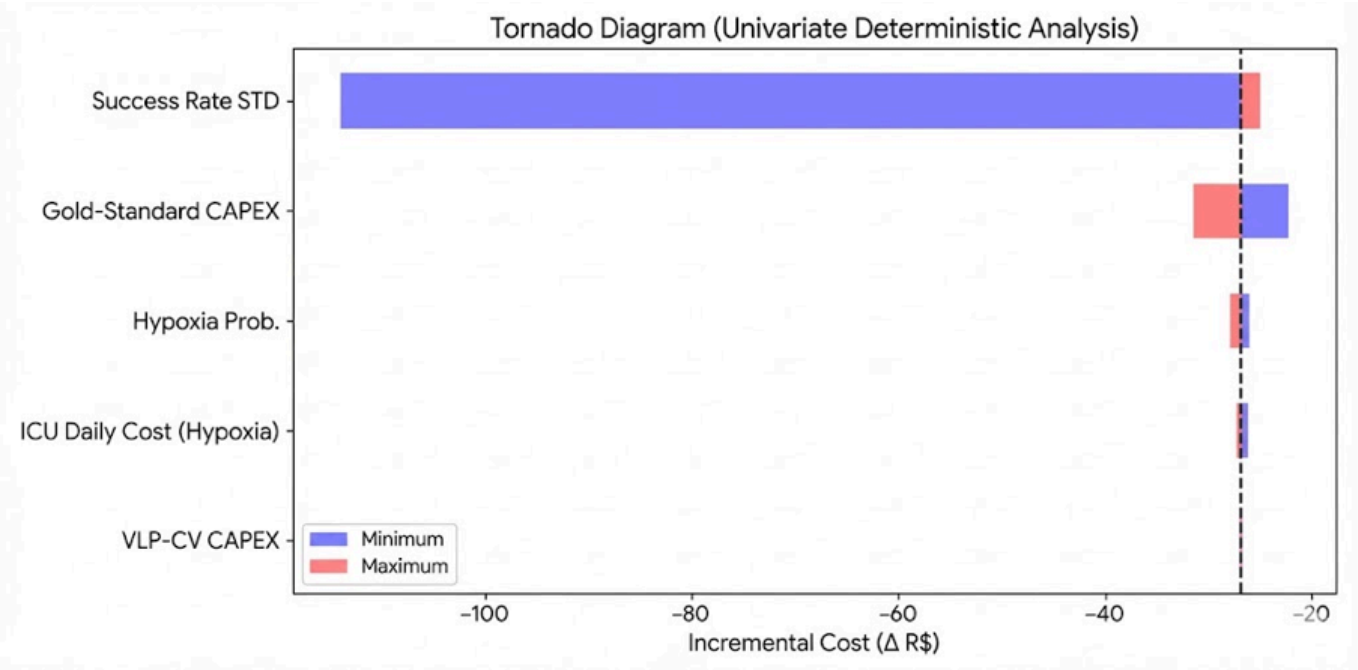


Figure 1

Tornado Diagram [13].

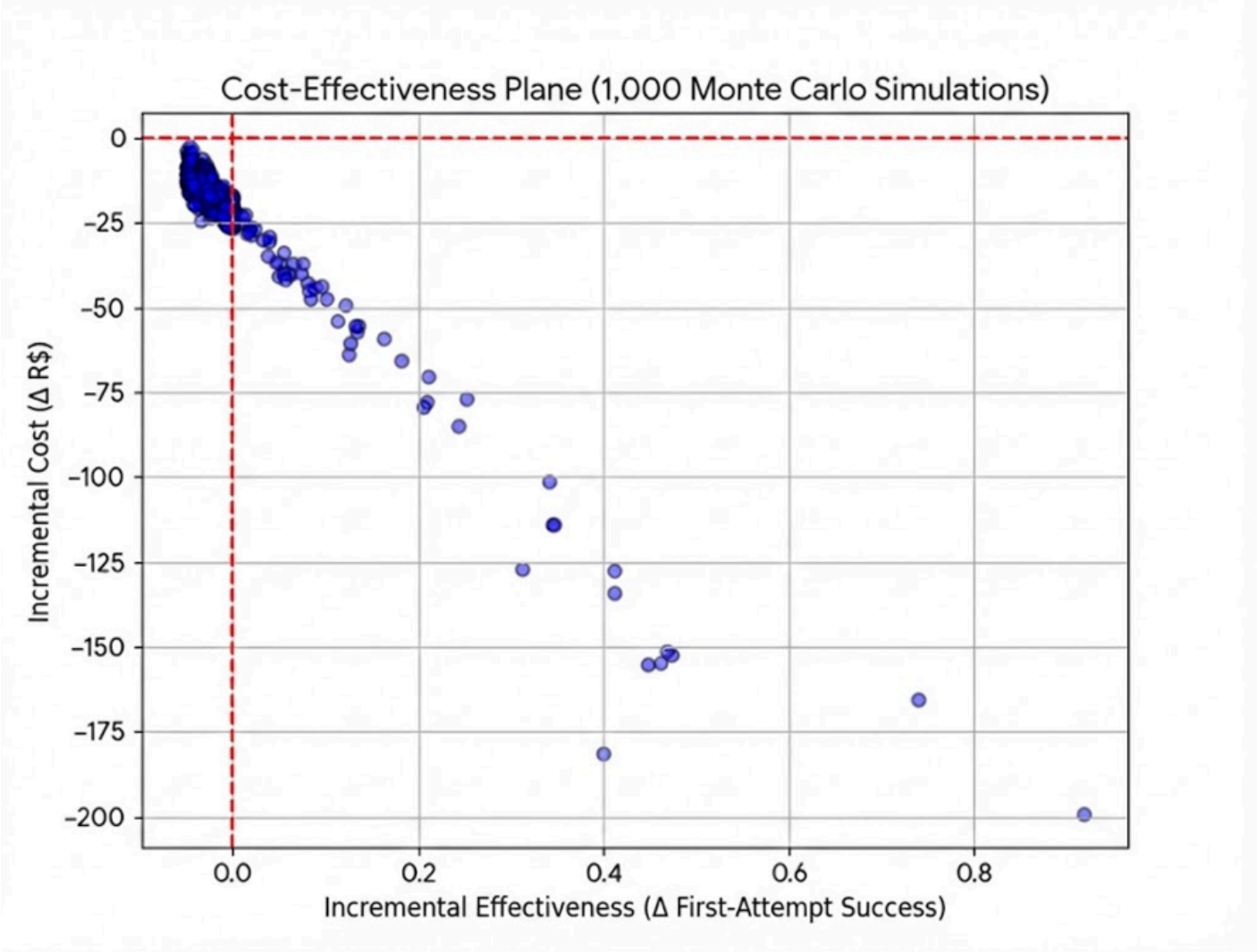


Figure 2

Monte Carlo Simulations [12,14].