JAFA, 13(1), June 2026, 97-113
DOI: 10.21512/jafa.v13i1.15443

P-ISSN: 1979-6862
E-ISSN: 2746-6019

MITIGATING LINEARIZATION ERROR IN IRR ESTIMATION FOR CAPITAL INVESTMENT APPRAISAL: THE EVBAYIRO RRR-FIRST METHOD

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ABSTRACT

Capital investment appraisal requires accounting and finance professionals to explain whether a proposed expenditure clears the firm's hurdle rate, not merely to report an Internal Rate of Return (IRR) generated by software. Conventional manual IRR procedures often separate the Net Present Value (NPV) decision at the Required Rate of Return (RRR) from rate discovery and interpolate across arbitrarily selected brackets. This study develops the Evbayiro RRR-First Method as a decision-anchored appraisal procedure: it tests NPV at the RRR, forms an adjacent one-percentage-point sign-changing bracket, and applies Three-Point Curvature Closure (E3C). Its accounting and finance contribution is to integrate hurdle-rate governance, transparent decision communication, and reproducible manual computation in one workflow. The validation uses sourced conventional and non-conventional worked examples and 88,556 public-company cash-flow proxy cases constructed from SEC EDGAR/Companyfacts data and Damodaran industry WACC proxies; 76,657 cases produced applicable brackets. Iterated E3C returned an in-bracket estimate for every applicable case, met scaled zero-NPV residual thresholds of 10^-8 in 99.69% and 10^-12 in 98.80% of cases, and required a median of two closure cycles versus 33 bisection iterations. One-step E3C materially improved on two-point interpolation while retaining calculator-based feasibility. The method does not replace NPV or automated solvers; rather, it provides practitioners, accounting educators, and professional examination bodies with a traceable way to connect the hurdle-rate decision to IRR estimation and to interpret multiple-IRR cases without displacing NPV as the controlling rule.

Keywords: Capital Investment Appraisal, Internal Rate of Return, Required Rate of Return, Three-Point Curvature Closure, Accounting Education

INTRODUCTION

Capital investment appraisal is an accounting and finance process through which proposed expenditures are forecast, screened, authorized, and communicated to boards and other stakeholders (Andon et al., 2024; Hoang et al., 2025; Jandik & Salikhova, 2025). NPV and IRR therefore operate within a broader governance setting: managers must justify the cash-flow forecast, the cost-of-capital assumption, the decision rule, and the sensitivity of the recommendation (Andon et al., 2024; Gormsen & Huber, 2025; Meder et al., 2024). Although NPV and IRR are managerial appraisal tools rather than financial-statement measurement rules, their underlying forecasts and investment decisions inform internal budgeting, capital allocation, and related corporate reporting processes (Dau et al., 2024; Hoang et al., 2025; Zhang, 2026).

IRR remains important in that process because a percentage return is readily communicated and compared with a hurdle rate. Survey and review evidence shows that firms commonly use IRR alongside NPV rather than replacing one with the other (Graham & Harvey, 2001; Siziba & Hall, 2021; Sureka et al., 2022). Recent evidence also shows that knowledge and expertise influence capital-budgeting practice (Mota & Moreira, 2023). The accounting and finance problem is therefore not whether software can calculate IRR, but whether users can interpret the result and connect it correctly to the value-creation test at the firm's required return.

That connection matters because NPV and IRR answer related but distinct questions. NPV at the cost of capital is the controlling value-addition rule, whereas IRR identifies one or more zero-NPV boundaries. A mechanically reported IRR can obscure scale-related ranking conflicts and multiple-root conditions (Hazen, 2003; Weber, 2014). Research examining capital-budgeting behavior further indicates that information, incentives, organizational context, and the quality of execution matter beyond the mere adoption of particular formulas (Haka et al., 1985; Martin, 2021; Weiskirchner-Merten, 2022).

Manual computation retains a narrower but important role. In accounting and finance education, manual computation exposes the relationship among cash flows, discount rates, NPV, and IRR before spreadsheet functions are used. Research in accounting education has long examined the behavior of spreadsheet NPV and IRR functions (Louderback & McNichols, 1986), and recent case-based work integrates analytics, capital rationing, and replacement analysis into capital-budgeting instruction (Burkert et al., 2022; Daly & Walstra, 2025; De la Torre et al., 2024). This is also relevant to professional examination bodies, including ICAN and ACCA, because a transparent manual procedure can assess whether candidates understand the hurdle-rate decision rather than merely knowing a software command.

The conventional manual procedure is weak at precisely this point. It commonly begins with discretionary discount-rate guesses, searches for positive and negative NPVs, and applies linear interpolation. A wide bracket can introduce linearization error because the NPV profile is nonlinear (Gottlieb & Thompson, 2010; Press et al., 2007), while a non-conventional cash-flow stream can produce several valid IRRs (Hazen, 2003; Weber, 2014). The sequence also places the RRR at the end of the exercise, even though NPV at that rate already provides the economically controlling accept-reject test. Consequently, a calculation may be numerically correct yet poorly aligned with the decision that accountants and finance officers must explain.

This study responds by formalizing the Evbayiro RRR-First Method. The method begins with NPV at the project-specific RRR, uses the NPV sign to direct an adjacent one-percentage-point evaluation sequence for conventional cash flows, and applies E3C to the resulting bracket. For non-conventional cash flows, it preserves NPV at the RRR as the controlling decision and treats detected IRRs as boundaries of the local NPV region. The approach is designed for manual instruction, preliminary appraisal, and transparent validation of automated outputs; it is not proposed as a replacement for project-specific cost-of-capital estimation, NPV, or production-grade numerical software.

The research gap is procedural and disciplinary. Capital-budgeting studies explain which techniques firms adopt, how uncertainty and organizational context shape appraisal, and how education can improve analytical judgment. They do not provide a manual IRR workflow that makes the RRR the initial decision anchor, creates a reproducible adjacent bracket, and closes that bracket with a curvature-sensitive formula. Addressing this gap contributes to accounting and finance knowledge by linking numerical estimation to the governance, communication, and pedagogical requirements of capital investment appraisal.

Aim and Objectives

The study aims to develop and validate a transparent IRR-estimation procedure for capital investment appraisal under manual computation constraints. Its objectives are as follows: (1) formalize RRR-first decision anchoring and adjacent bracketing; (2) evaluate E3C against wide-bracket interpolation, one-percentage-point interpolation, bisection, Newton-Raphson, and secant methods; (3) demonstrate the method with sourced conventional and non-conventional cash flows; and (4) assess its implications for practitioners, accounting education, and professional examination design.

LITERATURE REVIEW & HYPOTHESIS DEVELOPMENT

The relevant literature has four connected strands: the adoption of capital-budgeting techniques, the organizational quality of investment appraisal, the interpretation of IRR, and the teaching of computationally transparent financial analysis. Synthesizing these strands identifies the finance and accounting gap addressed by the method.

Capital-Budgeting Practice and Organizational Context

Capital-budgeting research documents a theory-practice mixture rather than a single dominant technique. Graham and Harvey (2001) establish the continued joint use of NPV and IRR in corporate practice. More recent synthesis confirms continuing variation in technique adoption and application across organizational settings (Siziba & Hall, 2021; Sureka et al., 2022), while Mota and Moreira (2023) show that practitioners' knowledge and expertise shape the methods they use.

Recent accounting and finance studies also show that capital budgeting is shaped by the institutional purpose and organizational setting of the calculation. Martin (2021) examines corporate social responsibility within capital budgeting; Leoni (2021) shows how appraisal calculations can function as advocacy devices; Kuroki (2022) tests how depreciation information affects public-sector capital budgeting; and Weiskirchner-Merten (2022) examines managerial empire building. This literature supports investigation of execution quality even where the underlying NPV decision rule remains unchanged.

Decision Quality, Uncertainty, and Appraisal Governance

Capital investment appraisal is affected by uncertainty, information quality, and internal decision processes. Haka et al. (1985) show that adopting sophisticated techniques does not by itself guarantee superior performance. More recent work links capital-budgeting judgments to risk attitude and information use (Vanini & Rieg, 2021), peer monitoring (Meder et al., 2024), and managerial incentives (Weiskirchner-Merten, 2022). Together, these studies place computational technique within a wider accounting problem of forecast credibility, control, and decision quality.

Further evidence reinforces the point that investment decisions are not produced by formulas alone. Andon et al. (2024) analyze affect and reason in uncertain accounting settings; Hoang et al. (2025) and Jandik and Salikhova (2025) show that internal capital allocation depends on organizational information and social connections; and Zhang (2026) links ownership to capital-budgeting efficiency. Discount-rate selection is itself economically consequential (Gormsen & Huber, 2025; Mielcarz et al., 2026), while annual-report readability is associated with firms' investment decisions (Dau et al., 2024). The implication for IRR estimation is practical: a traceable calculation is valuable because it allows finance officers, reviewers, and boards to see the hurdle-rate test, the local NPV profile, and the numerical basis of the reported return.

IRR Interpretation and Accounting Education

The literature distinguishes the popularity of IRR from its interpretive limitations. Hazen (2003) and Weber (2014) examine the existence and interpretation of IRR under complex cash-flow patterns. These studies justify caution: an IRR is a root of the NPV function, but in non-conventional cases it need not be a unique or decision-sufficient project return.

Accounting education research also supports combining computation with interpretation. Louderback and McNichols (1986) show that spreadsheet NPV and IRR functions themselves require careful understanding. Wouters (2006) argues for teaching capital budgeting as a broader decision process. Recent teaching cases extend that principle through analytics and automation (Daly & Walstra, 2025), capital rationing (Burkert et al., 2022), and replacement analysis (De la Torre et al., 2024). The pedagogical issue is therefore not a choice between manual work and technology; it is whether the computational sequence makes the financial decision logic visible.

Research Gap and Methodological Positioning

Existing accounting and finance research explains adoption, uncertainty, performance, and pedagogy, but it does not formalize the RRR as the first rate in a reproducible manual IRR search. Conventional two-point interpolation also ignores local curvature. Numerical root-finding methods address accuracy, but bisection requires repeated halving, Newton-Raphson requires derivatives, and secant behavior depends on starting values (Press et al., 2007). They were not designed around the accounting decision at the hurdle rate.

E3C is related to endpoint-midpoint-endpoint quadratic bracketing in numerical analysis, including the BDQRF approach of Gottlieb and Thompson (2010). Its contribution here is not the generic idea of fitting a quadratic through three points. It is the integration of that closure with a finance-specific sequence: NPV at the RRR, adjacent one-percentage-point bracketing, in-bracket root selection, and a scaled zero-NPV residual. The method is thus positioned as an accounting and finance appraisal framework with a defined numerical closure, rather than as a general-purpose replacement for established root solvers.

RESEARCH METHODOLOGY

This study uses methodological development and numerical validation to address a capital investment appraisal problem: how to retain the NPV decision at the RRR while producing a transparent manual IRR estimate. The design combines formal derivation, sourced worked examples, and reproducible benchmarking. The unit of analysis is an NPV sign-changing bracket generated from the stated appraisal anchor. The principal outcomes are zero-NPV residual accuracy, iteration burden, bracket preservation, and manual feasibility.

Algorithmic Framework and Decision Logic

The method separates the accounting decision from numerical closure. Phase I is economic anchoring: when a project-specific RRR is supplied, NPV at that rate determines whether the project clears the hurdle. Phase II is boundary estimation: if an IRR is required for reporting, comparison, or examination purposes, the method constructs a local sign-changing bracket and closes it with E3C. This order preserves NPV as the controlling decision rule while retaining IRR as a communicable percentage measure.

For conventional cash flows, a positive NPV at the anchor directs evaluation upward and a negative NPV directs evaluation downward. For non-conventional cash flows, that direction does not prove uniqueness; the full sign pattern and relevant NPV boundaries must be examined. The method therefore treats multiple IRRs as local boundaries around the anchor rather than allowing a single discovered root to override NPV at the RRR.

Monotone Step-Adjustment and Interval Minimization

The evaluation sequence uses a fixed one-percentage-point interval until adjacent rates produce opposite NPV signs. The interval is a manual convention, not a universal numerical optimum. It is sufficiently narrow to reduce the curvature error associated with wide interpolation chords, yet simple enough for calculator-based teaching and preliminary appraisal (Hazen, 2003).

In software, smaller steps or direct solvers remain available. The purpose of the one-percentage-point rule is to produce a transparent, reproducible bracket before closure, not to claim that every project should be evaluated manually.

Mathematical Formulation of the Evbayiro RRR-First Method

The formal procedure below defines the NPV function, decision anchor, directional evaluation rates, adjacent stopping index, and E3C closure. The sequence converts an otherwise discretionary manual search into a stated capital-appraisal protocol.

E3C uses endpoint-midpoint-endpoint quadratic information, as does BDQRF, but is applied here only after the RRR-first procedure has formed an adjacent bracket. Its unit-interval normalization, in-bracket root rule, and scaled NPV residual make it the finance-specific closure component of the method rather than a general root-finding claim (Gottlieb & Thompson, 2010).

$$f(r) = NPV(r) = \sum_{t=0}^{n} CF_t / (1 + r)^t, \qquad r > -1$$

Here, $f(r)$ is the NPV function at discount rate r; CF_t is the project cash flow at time t; $t = 0, 1, 2, ..., n$; and $r > -1$ means the discount rate must be greater than negative 100%. An IRR boundary is any rate r for which $f(r) = 0$.

Evbayiro Formula 1: Initial Anchor

$$E_0 = h, \text{ if the project-specific RRR is supplied}$$

$$E_0 = EC = 0.10, \text{ if no RRR is supplied}$$

E0 is the Evbayiro Initial Anchor. The symbol h denotes the project-specific RRR. EC is the Evbayiro Constant, equal to 10%, used only as a standardized pedagogical anchor when an exercise omits the RRR. It is not a universal cost of capital; any supplied project-specific RRR, WACC, or risk-adjusted hurdle rate takes priority.

$$D_E(h) = \text{Accept, if } f(h) \geq 0$$

$$D_E(h) = \text{Reject, if } f(h) < 0$$

This decision rule is applied only when h is supplied. It means that the accept-reject decision is made by NPV at the required return before any IRR value is interpreted.

Evbayiro Formula 2: Direction Indicator

$$S_E = +1, \text{ if } f(E_0) > 0$$

$$S_E = -1, \text{ if } f(E_0) < 0$$

For conventional cash-flow patterns, S_E defines the direction of movement from the anchor. If $f(E_0)$ is positive, the conventional IRR boundary lies above the anchor; if $f(E_0)$ is negative, it lies below the anchor. If $f(E_0) = 0$, then E_0 is already an exact IRR and no bracket closure is required.

$$\text{If } f(E_0) = 0, \text{ then } IRR_E = E_0$$

Evbayiro Formula 3: Evaluation Rate

$$E_m = E_0 + S_E(m\Delta), \qquad m = 1, 2, 3, ...$$

E_m is the m-th Evbayiro Evaluation Rate. The symbol Δ is the fixed 100-basis-point interval, so $\Delta = 0.01$. For example, if $E_0 = 12\%$ and $S_E = +1$, then $E_1 = 13\%$, $E_2 = 14\%$, and $E_3 = 15\%$. If $S_E = -1$, the same formula generates 11%, 10%, and 9%.

Evbayiro Formula 4: Evaluation NPV

$$NPV_{Em} = f(E_m) = \sum_{t=0}^{n} CF_t / (1 + E_m)^t$$

This formula means that every generated evaluation rate is passed back into the NPV function. The analyst therefore does not guess; instead, the next rate and its NPV are generated systematically.

Evbayiro Formula 5: Adjacent Stopping Index

$$m^* = \min\{m \geq 1 : f(E_{m-1}) \times f(E_m) \leq 0\}$$

$$B_E = [E_{m^* - 1}, E_{m^*}]$$

The stopping index m^* is the first adjacent step at which the NPV sign changes or becomes zero. This adjacent rule is safer than comparing every evaluation rate only with the initial anchor because it traps the IRR between two neighboring rates. The bracket width is therefore exactly $\Delta = 0.01$, or 100 basis points.

$$r_L = \min(E_{m^* - 1}, E_{m^*}), \qquad r_U = \max(E_{m^* - 1}, E_{m^*})$$

The symbols r_L and r_U are the lower and upper rates of the Evbayiro bracket. The NPVs at the two endpoints must satisfy $f(r_L) \times f(r_U) \leq 0$.

Evbayiro Closure Step 6: Three-Point Curvature Closure (E3C)

$$r_M = (r_L + r_U) / 2$$

$$N_L = f(r_L), \qquad N_M = f(r_M), \qquad N_U = f(r_U)$$

E3C closes the bracket by adding the midpoint to the lower and upper endpoints. These three local NPV points allow the local curvature of the NPV function to be approximated rather than ignored.

$$x = (r - r_L) / (r_U - r_L)$$

The transformation x converts the rate interval into a unit interval. When $x = 0$, the rate is r_L. When $x = 0.5$, the rate is r_M. When $x = 1$, the rate is r_U.

$$Q_E(x) = Ax^2 + Bx + C$$

$$A = 2(N_L + N_U - 2N_M)$$

$$B = 4N_M - 3N_L - N_U$$

$$C = N_L$$

$Q_E(x)$ is the Evbayiro local quadratic closure function. It is constructed so that $Q_E(0) = N_L$, $Q_E(0.5) = N_M$, and $Q_E(1) = N_U$. The E3C estimate is found by solving $Q_E(x) = 0$.

If $N_L = 0$, r_L is reported directly as the IRR. If $N_U = 0$, r_U is reported directly as the IRR. Otherwise:

$$x_E = \frac{-B \pm \sqrt{B^2 - 4AC}}{2A}, A \neq 0$$

$$x_E = -\frac{C}{B}, A = 0, B \neq 0$$

In either case, select the unique real solution satisfying $0 < x_E < 1$.

The second case is the linear limiting form of E3C when the local quadratic coefficient is exactly zero.

$$r_k = r_L + x_E(r_U - r_L)$$

The value r_k is the E3C closure estimate for the current bracket. In a manual classroom setting, one E3C closure may be reported as the Evbayiro estimated IRR. Where higher precision is required, the closure can be iterated.

Evbayiro Formula 7: Iterated E3C Precision Rule

$$R(r_k) = |f(r_k)| / \sum_{t=0}^{n} |CF_t|$$
$$\text{Stop when } R(r_k) \leq \varepsilon$$

$R(r_k)$ is the scaled NPV residual. It measures how close the E3C estimate comes to the zero-NPV condition after allowing for the size of the cash-flow stream. The tolerance ε is the declared precision standard. For classroom use, one E3C closure or a practical tolerance such as 10^{-4} or 10^{-6} may be sufficient. For software benchmarking, stricter levels such as 10^{-8}, 10^{-10}, 10^{-12}, or 10^{-14} may be disclosed.

$$\text{If } f(r_L) \times f(r_k) \leq 0, \text{ set the next bracket to } [r_L, r_k]$$

$$\text{If } f(r_k) \times f(r_U) \leq 0, \text{ set the next bracket to } [r_k, r_U]$$

The iteration preserves the sign-changing bracket. It therefore refines the IRR estimate without abandoning the Evbayiro bracket discipline.

Extension to Non-Conventional Cash Flows

$$V(CF) = \text{number of sign changes in the cash-flow sequence}$$

If V(CF) > 1, the cash-flow stream is non-conventional and multiple IRRs may exist. In such cases, the NPV-at-RRR decision remains the first test when h is supplied, but the IRR search must be interpreted as a form of boundary detection rather than as proof of a single project return.

$$U_m = E_0 + m\Delta, \quad L_m = E_0 - m\Delta$$

$$m_U^* = \min\{m \geq 1 : f(U_{m-1}) \times f(U_m) \leq 0\}$$

$$m_L^* = \min\{m \geq 1 : f(L_{m-1}) \times f(L_m) \leq 0\}$$

U_m evaluates rates above the anchor, while L_m evaluates rates below the anchor. The upper and lower stopping indexes identify adjacent sign-changing boundaries around the anchor. Each detected boundary is then closed with the same E3C formula.

$$IRR_E,upper = E3C(B_U), \quad IRR_E,lower = E3C(B_L)$$

$$C_E(E_0) = [IRR_E,lower, IRR_E,upper], \text{ if both boundaries exist}$$

$C_E(E_0)$ is the anchor-contiguous NPV corridor. If E_0 = h, the corridor is decision-relevant because it is built around the actual required return. If E_0 = EC, it is only pedagogical. The method does not claim to eliminate the multiple-IRR problem; it reduces the risk of selecting a decision-irrelevant root by making NPV at the RRR the first and controlling test.

For reference, the complete method may be summarized by the following compact signature. It combines the RRR decision anchor, adjacent one-percentage-point sign-change bracket, and E3C closure without repeating the derivation above.

$$\mathrm{IRR}_E = \mathrm{E3C}(B_E)$$
$$E_{m^*-1} = E_0 + S_E(m^* - 1)\Delta, E_{m^*} = E_0 + S_E m^* \Delta$$
$$B_E = [r_L, r_U]$$
$$\mathrm{E3C}(B_E) = r_L + x_E(r_U - r_L)$$
$$A{x_E}^2 + Bx_E + C = 0; 0 < x_E < 1$$

Here, BE is the adjacent sign-changing bracket generated from E0, SE, m*, and the one-percentage-point interval; rL and rU are its ordered endpoints; and xE is the unique in-bracket solution of the E3C quadratic. Endpoint-zero and linear-limiting cases remain governed by Closure Step 6. One-step E3C is the manual form, while repeated E3C is the higher-precision extension.

RESULT

Source-Based Worked Example 1: Conventional Cash Flow

The first worked example uses the public OpenStax Principles of Finance embroidery-machine example (Dahlquist & Knight, 2022). The source reports an initial investment of \$16,000, followed by inflows of \$2,000 in year 1, \$4,000 in year 2, and \$5,000 in each of years 3 to 6. The source reports an IRR of approximately 14.09%. Because no project-specific RRR is supplied, the Evbayiro Constant is used only as a standardized pedagogical anchor.

Table 1. Cash-Flow Pattern for the OpenStax Embroidery-Machine Example

Year	Cash flow
0	-16,000
1	+2,000
2	+4,000
3	+5,000
4	+5,000
5	+5,000
6	+5,000

Source: Dahlquist and Knight (2022)

Step-by-step application

$$E_0 = EC = 10\%$$

$$f(10\%) = +2{,}222.58$$

Since $f(E_0) > 0$, the conventional search direction is upward, so $S_E = +1$ and $E_m = E_0 + m\Delta$.

Table 2 Evbayiro Evaluation Rates and NPVs for the Conventional Example

m	E_m	$NPV(E_m)$	Interpretation
0	10%	+2,222.58	Anchor NPV is positive
1	11%	+1,638.36	Continue upward
2	12%	+1,081.27	Continue upward
3	13%	+549.74	Continue upward
4	14%	+42.29	Lower endpoint of nearest bracket
5	15%	-442.43	Upper endpoint of nearest bracket

Source: Author (2026), Dahlquist and Knight (2022)

$$B_E = [14\%, 15\%], \quad r_L = 14\%, \quad r_U = 15\%$$

$$r_M = 14.5\%$$

$$N_L = +42.29, \quad N_M = -202.83, \quad N_U = -442.43$$

$$A = 11.04, \quad B = -495.75, \quad C = 42.29$$

$$x_E = 0.085469$$

$$r_k = 14\% + 0.085469(1\%) = 14.085469\%$$

Thus, the one-step E3C estimate is 14.085469%, which rounds to 14.09%, the same percentage reported by OpenStax. If the E3C closure is iterated, the estimate becomes approximately 14.085455%. This example shows how the method moves from a non-discretionary anchor to a 1% bracket and then uses E3C to close the bracket without relying on wide, arbitrary guessing.

Source-Based Worked Example 2: Non-Conventional Cash Flow

The second worked example uses the public mining-project example from Introduction to Financial Management: A Contemporary Approach (University of Queensland, 2024). The source gives the cash-flow sequence below and explains that the project has two IRRs, approximately 6.4% and 37.6%, because the cash-flow signs change more than once.

Table 3 Cash-Flow Pattern for the Non-Conventional Mining Example

Year	Cash flow
0	-1,000,000
1	+800,000
2	+1,000,000
3	+1,350,000
4	-2,250,000

Source: University of Queensland (2024)

Step-by-step application

$$V(CF) = 2$$

Because $V(CF) > 1$, the project is non-conventional and multiple IRRs may exist. The source reports NPV(15%) = +52,997.95, so the NPV in the RRR-region is positive at 15%. The method therefore interprets IRRs as boundaries around the positive-NPV region, rather than treating a single discovered IRR as the whole decision.

Table 4 E3C Boundary Estimates for the Non-Conventional Mining Example

Boundary	Adjacent bracket	Endpoint NPVs	One-step E3C	Iterated E3C
Lower	6%-7%	NPV(6%)=-4,011.29; NPV(7%)=+6,590.19	6.364143%	6.364095%
Upper	37%-38%	NPV(37%)=+3,045.57; NPV(38%)=-1,897.51	37.618679%	37.618669%

Source: Author (2026), University of Queensland (2024)

For the lower boundary, r_L = 6%, r_U = 7%, and r_M = 6.5%. The corresponding NPVs are N_L = -4,011.29, N_M = +1,452.31, and N_U = +6,590.19. E3C gives A = -651.45, B = 11,252.93, C = -4,011.29, x_E = 0.364143, and r_k = 6.364143%. Iterating E3C refines the lower boundary to approximately 6.364095%.

For the upper boundary, r_L = 37%, r_U = 38%, and r_M = 37.5%. The corresponding NPVs are N_L = +3,045.57, N_M = +587.39, and N_U = -1,897.51. E3C gives A = -53.44, B = -4,889.64, C = 3,045.57, x_E = 0.618679, and r_k = 37.618679%. Iterating E3C refines the upper boundary to approximately 37.618669%.

This example illustrates why the RRR-first order matters in non-conventional cases. A lower IRR boundary may be mathematically valid, but it is not sufficient by itself to reject a project when NPV at the required return is positive. The method first evaluates the NPV at the RRR region, then treats the multiple IRRs as boundaries of the NPV profile.

Comparative Benchmarking of Closure Methods

Table 5 compares final IRR estimates, closure counts, scaled zero-NPV residuals, and manual feasibility for representative conventional and non-conventional cash flows. Table 6 reports the aggregate benchmark data deposited on Zenodo (Evbayiro, 2026). The 88,556 public-company proxy cases were constructed from SEC EDGAR/Companyfacts cash-flow data and Damodaran industry WACC proxies; they are not confidential project files or company-disclosed hurdle rates (U.S. Securities and Exchange Commission, 2025; Damodaran, 2026a, 2026b).

Accuracy is measured by the scaled zero-NPV residual R(r) = |NPV(r)| / sum|CFt|. The representative cases use a practical 10^-6 threshold; the aggregate benchmark reports thresholds from 10^-4 through 10^-14. Non-iterative methods are assessed after their single closure calculation.

Table 5 Representative Comparison of IRR Closure Methods

Case	Method	IRR estimate	n	R(r)	P	Manual feasibility
OpenStax conventional	Wide interpolation	14.640556%	1	6.446e-3	N	High; low precision
OpenStax conventional	Evbayiro 1% interpolation	14.087249%	1	2.109e-5	N	High; improved bracket
OpenStax conventional	One-step E3C	14.085469%	1	1.649e-7	Y	High; one formula
OpenStax conventional	Iterated E3C	14.085455%	2	2.668e-13	Y	Moderate/high; repeat formula
OpenStax conventional	Bisection	14.085455%	19	4.274e-9	Y	Low; many halvings
OpenStax conventional	Newton-Raphson	14.085455%	3	4.187e-9	Y	Low; derivative required
OpenStax conventional	Secant	14.085455%	3	1.818e-11	Y	Moderate; start-sensitive
UQ non-conv. lower	Wide interpolation	7.315075%	1	1.510e-3	N	High; low precision

Case	Method	IRR estimate	n	R(r)	P	Manual feasibility
UQ non-conv. lower	Evbayiro 1% interpolation	6.378371%	1	2.401e-5	N	High; improved bracket
UQ non-conv. lower	One-step E3C	6.364143%	1	7.966e-8	Y	High; one formula
UQ non-conv. lower	Iterated E3C	6.364095%	2	8.086e-12	Y	Moderate/high; repeat formula
UQ non-conv. lower	Bisection	6.364090%	16	9.228e-9	Y	Low; many halvings
UQ non-conv. lower	Newton-Raphson	6.364095%	3	1.334e-10	Y	Low; derivative required
UQ non-conv. lower	Secant	6.364096%	3	8.336e-10	Y	Moderate; start-sensitive
UQ non-conv. upper	Wide interpolation	37.366590%	1	1.947e-4	N	High; larger residual
UQ non-conv. upper	Evbayiro 1% interpolation	37.616128%	1	1.967e-6	N	High; improved bracket
UQ non-conv. upper	One-step E3C	37.618679%	1	7.892e-9	Y	High; one formula
UQ non-conv. upper	Iterated E3C	37.618679%	1	7.892e-9	Y	Moderate/high; repeat formula
UQ non-conv. upper	Bisection	37.618668%	16	8.798e-10	Y	Low; many halvings
UQ non-conv. upper	Newton-Raphson	37.618669%	3	1.895e-13	Y	Low; derivative required
UQ non-conv. upper	Secant	37.618659%	2	7.857e-9	Y	Moderate; start-sensitive

Note: n = iterations; P = pass at $R(r) \leq 10^{-6}$.
Source: Author (2026)

The representative cases show that one-percentage-point interpolation reduces wide-bracket error but remains a two-point chord. One-step E3C uses one additional midpoint NPV and reaches the practical 10^-6 threshold in each representative case. Repeated E3C is used only when a stricter declared residual is required.

Table 6 Aggregate Benchmark Pass Rates (%) across 76,657 Applicable Evbayiro Sign-Changing Brackets

Method	Returned	10^{-4}	10^{-8}	10^{-12}	10^{-14}	Median iters	P95 iters
Evbayiro 1% linear interpolation	76,657 / 76,657	86.31	20.18	0.03	0.00	1	1
One-step E3C	76,657 / 76,657	94.98	71.40	14.53	2.30	1	1
Iterated E3C	76,657 / 76,657	99.92	99.69	98.80	97.39	2	3

Method	Returned	10^{-4}	10^{-8}	10^{-12}	10^{-14}	Median iters	P95 iters
Bisection	76,657 / 76,657	99.91	99.67	98.72	97.41	33	43
Newton-Raphson	76,639 / 76,657	99.90	99.69	98.81	97.37	4	5
Secant	74,652 / 76,657	97.38	97.38	97.38	97.38	3	5

Source: Author (2026)

Across all 76,657 applicable brackets, one-step E3C increased the 10^-8 pass rate from 20.18% for one-percentage-point linear interpolation to 71.40%. Iterated E3C reached 99.69% at 10^-8, 98.80% at 10^-12, and 97.39% at 10^-14 while returning an in-bracket estimate in every applicable case. Bisection reached a similar strict-threshold rate but required a median of 33 iterations, compared with two E3C cycles.

Among the 74,660 cases reaching 10^-14, 49,674 required two E3C cycles and 22,582 required three; only 641 required four to six. This distribution supports advanced manual verification because the same bracket-preserving calculation is repeated a small number of times rather than replaced by a different procedure.

Lower pass percentages at stricter thresholds do not represent lost financial return or a changed project decision. They indicate only that fewer estimates satisfy a smaller residual. Manual teaching and reporting normally round IRR to basis points or two decimals, whereas 10^-12 and 10^-14 are software stress tests. The 1,997 E3C cases reaching the 100-cycle cap still returned in-bracket estimates; near-flat profiles, cancellation, and finite-precision arithmetic can make additional cycles numerically uninformative.

DISCUSSION

The findings contribute to capital-budgeting research at the level of method execution. Prior surveys explain why firms use NPV and IRR and how practice varies across organizations (Graham & Harvey, 2001; Siziba & Hall, 2021; Sureka et al., 2022). The present study addresses a different question: how a manually reported IRR can be produced without separating the calculation from the hurdle-rate decision. By making NPV at the RRR the first step, the method turns the IRR search into an extension of the investment decision rather than an isolated percentage calculation.

From an accounting-governance perspective, the main benefit is traceability. A finance officer can show the RRR, the NPV at that rate, the adjacent rates that contain the boundary, and the closure used to report IRR. This sequence creates an audit trail that is easier to review than undisclosed spreadsheet starting values. It also supports communication to boards and investment committees because the accept-reject conclusion is stated before the supplementary yield measure. That emphasis is consistent with research showing that capital allocation depends on information quality, organizational interpretation, and internal governance (Andon et al., 2024; Hoang et al., 2025; Jandik & Salikhova, 2025; Meder et al., 2024).

For practitioners, the method is most useful in preliminary screening, review, and validation. It does not imply that corporate systems should abandon spreadsheet or software IRR. Rather, one-step E3C provides a calculator-based estimate with less local linearization error, while iterated E3C provides a reproducible check where a declared residual is required. In non-conventional cases, the RRR-first sequence is especially important because it prevents a mathematically valid lower root from being treated as a sufficient rejection signal when NPV at the required return is positive.

For accounting and finance education, the method links three topics often taught separately: cost of capital, NPV decision-making, and IRR estimation. This responds to education research that calls for computational tools to be taught with interpretation rather than as black-box functions (Louderback & McNichols, 1986; Wouters, 2006; Burkert et al., 2022; Daly & Walstra, 2025). One-step E3C is appropriate when a course or professional examination requires manual calculation; repeated E3C can be demonstrated in advanced spreadsheet or analytics work.

The trade-off is explicit. If the relevant boundary is far from the RRR, a one-percentage-point evaluation sequence may require more NPV calculations than a favorable wide initial guess. The method chooses reproducibility and local accuracy over discretionary speed. This is appropriate where the purpose is explanation, assessment, or review; direct numerical solvers remain preferable when high-volume production computation is the only objective.

CONCLUSION

This study contributes to accounting and finance knowledge by formalizing a capital investment appraisal sequence in which the hurdle-rate decision governs IRR estimation. The contribution is distinct from the numerical fact that a quadratic closure can approximate a root. It is the integration of NPV-at-RRR decision anchoring, reproducible adjacent bracketing, E3C closure, and multiple-root interpretation into a traceable workflow for reporting and teaching IRR.

Viewed against research documenting the continued joint use of NPV and IRR in practice (Graham & Harvey, 2001; Siziba & Hall, 2021; Sureka et al., 2022) and accounting-education research emphasizing interpretable capital-budgeting computation (Louderback & McNichols, 1986; Wouters, 2006; Daly & Walstra, 2025), the method contributes an execution framework that connects technique selection to decision communication and review.

The empirical benchmark supports that contribution. Iterated E3C returned an in-bracket estimate for all 76,657 applicable cases, reached 99.69% at the 10^-8 residual threshold, and 98.80% at 10^-12, and required a median of two cycles. One-step E3C remained materially more accurate than two-point interpolation while retaining practical calculator use. These results show that a decision-centered manual method can substantially reduce linearization error without adopting the iteration burden of bisection or the derivative requirement of Newton-Raphson.

For accounting practitioners and corporate finance officers, the method provides a reviewable bridge between the approved hurdle rate and the percentage return communicated to decision makers. For professional examination bodies such as ICAN and ACCA, it offers a way to test whether candidates understand why a project passes or fails before calculating its IRR. For accounting and finance curricula, it provides a structured progression from manual reasoning to spreadsheet validation and data analytics.

The method should therefore be understood as a disciplined appraisal and pedagogical framework, not as a substitute for NPV, professional judgment, or automated financial systems. Its value lies in making the financial logic visible: the RRR determines the decision, the bracket locates the relevant boundary, and E3C improves the reported IRR estimate.

Recommendations

1. Accounting and finance programs and professional examination bodies should teach RRR-first anchoring alongside conventional IRR interpolation so that students state the NPV decision before estimating the return and can explain multiple-IRR cases.

2. Finance teams should use the method for preliminary screening and independent validation, with the project-specific RRR documented, the NPV-at-RRR decision retained as controlling, and the reported residual or rounding standard disclosed.

3. Educational software and spreadsheet templates should expose the anchor, adjacent bracket, midpoint NPV, E3C estimate, and stopping tolerance as a show-your-work audit trail rather than returning only a final IRR.

Limitations and Future Research

The benchmark uses public-company free-cash-flow proxies derived from SEC EDGAR/Companyfacts and Damodaran industry WACC proxies, not confidential internal projects or company-disclosed hurdle rates. The sourced examples and benchmark establish reproducibility and numerical behavior, but they do not represent every project structure, tax regime, managerial constraint, or industry-specific forecasting process.

Future research should test the method with confidential project files, country-specific capital-budgeting data, alternative hurdle-rate policies, longer and more irregular cash-flow streams, and controlled accounting-education or professional-examination studies. Comparisons with spreadsheet IRR, MIRR, and production numerical engines should evaluate both numerical accuracy and whether the method improves users' understanding and communication of the investment decision.

The present benchmark is not specific to Indonesian. Application to Indonesian firms should use local project cash flows and risk-adjusted discount rates before contextual generalization. This is a validation priority rather than a limitation of the underlying NPV-IRR-RRR relationship.

Acknowledgement

The authors gratefully acknowledge Dr. Akwoba Joseph Ogugua, whose lectures in Veterinary Econometrics inspired the first author to identify the problem addressed in this study and helped shape the intellectual foundation from which the present solution was developed. Special appreciation is also extended to Prof. Francis Egbokhare and the academic staff of the Faculty of Veterinary Medicine, University of Benin, for their guidance, encouragement, and contributions to the authors' academic development. The authors further acknowledge Evbayiro Ali, Evbayiro O. Isabella, and Evbayiro A. Israel for their unwavering support, encouragement, and confidence throughout the development of this research.

Funding: This research received no external funding.

Conflict of interest: The authors declare no conflict of interest.

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The closure-benchmark package, representative-case comparison table, aggregate publication summary, reproducibility script, and SHA-256 hash manifest are publicly available on Zenodo (Evbayiro, 2026): https://doi.org/10.5281/zenodo.20633917. The benchmark cases in that package were constructed from public SEC EDGAR/Companyfacts data and Damodaran industry WACC and company-industry classification files (U.S. Securities and Exchange Commission, 2025; Damodaran, 2026a, 2026b).

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