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A CONSISTENT YIELD-BASED CAPITAL BUDGETING METHOD

David A. Volkman*

Abstract

This study develops a yield-based capital budgeting method that is consistent in maximizing shareholder wealth in six out of seven preconditioned environments. Academic studies surveying corporate management consistently conclude that corporate management prefers a yield-based capital budgeting method, such as the IRR, to a discount cash flow model, such as the NPV. This preference is strong with the NPV and EAA methods typically ranked as least favorable among corporate managment and yield-based methods ranked most favorable. However, previous yield-based methods are not consistent in maximizing shareholder wealth in many economic environments. The capital budgeting method developed in this study appeases corporate management's preference for a yield-based measure while maintaining the Fisherian assumption of wealth maximization. To maintain wealth maximization, this study demonstrates that the yield-based measure must distinguish between financing and investment cash flows, adjust to investments with differing economic lives, recognize the time disparity in the cash flow stream between mutually exclusive investments, and maintain the value additive principle.

INTRODUCTION

The internal rate of return (IRR) and the net present value (NPV) have long been the accepted capital budgeting measures preferred by corporate management and financial theorists, respectively. While corporate management prefers the relevancy of a yield-based capital budgeting method, such as the IRR, financial theorists, based on orthodox economic theory, endorse the NPV method. The debate between NPV and IRR methods dates from the inception of modern interest theory. The IRR was first proposed by Boehm-Bawerk's *Positive Theorie des Kapitals* [4] and later supported by Keynes [20]. The later introduction of the NPV in Irving Fisher's *The Rate of Interest* [13] created the impetus for conflict between the two methods. However, both methods suffer from inconsistencies when ranking potential investment projects based on the Fisherian assumption of wealth maximization. This study develops a capital budgeting method, the Rate of Return on Invested Assets (RRIA), that corrects the inconsistencies of both the IRR and NPV, is based on the assumption of wealth maximization, therefore pedagogically sound, and appeals to the relevancy of a yield-based capital budgeting method valued by corporate management.

To date, no capital budgeting method consistently selects investments such that shareholder wealth is maximized in all investment environments. Financial theorists have long stipulated conditions in which certain capital budgeting methods are superior to others. However, the violation of assumptions created in the theorist's conditions may significantly affect the consistency and superiority of the selected capital budgeting method. For example, Mao [23] shows that the IRR is consistent and may be used as a capital budgeting tool when evaluating unique normal investment projects, otherwise it is inconsistent and the NPV is a superior method. However, the NPV has been shown to be inconsistent when other environmental assumptions are violated [3], [12], [17], [25], [26], [30], [34], [37].

Miller [25] postulates that the IRR is popular among practitioners because of the confusion created by inconsistent capital budgeting methods when environmental assumptions are violated. Miller notes that corporate management frequently refer to this confusion when justifying their use of the IRR and suggests that management simply systematically ignores the method's deficiencies. Therefore, a consistent capital budgeting method must be

*University of Nebraska at Omaha

robust when correctly ranking and selecting superior investments in varying investment environments, remain theoretically sound by maintaining the Fisherian assumption of wealth maximization, and be expressed as a yield-based measure as preferred by corporate management.

Financial theorists have employed several different investment environments to demonstrate the inconsistency of some capital budgeting methods and the superiority of other methods. To test the consistency and robustness of the RRIA, this study employs seven different investment environments commonly used by previous researchers in their examination of a consistent capital budgeting method. The environments are:

1. Time disparity among mutually exclusive investments.
2. Violation of the Value Additive principle in mutually exclusive investments.
3. Investments with non-normal cash flows.
4. Mutually exclusive investments with unequal lives.
5. Investments with uncertain future cash flows.
6. The participation of capital rationing by a firm.
7. Investments with differing project scale.

A REVIEW OF PREVIOUS RESEARCH AND CAPITAL BUDGETING METHODS

While the IRR is the preferred capital budgeting method among practitioners, financial theorists are well acquainted with the objections to and limitations of using the IRR as a selection criterion among investment projects.[1] Samuelson [31] was one of the first theorists to note that an income earning investment may have multiple IRRs if some of the net cash flows are negative. Fisher's (1930) definitive statement concerning the deficiencies of the IRR became the dominant argument against yield-based capital budgeting methods. Later, Alchian [1] noted the conceptual relationships between the NPV and yield-based capital budgeting methods and delineated the inconsistencies of Keynes' IRR when two mutually exclusive investments are considered.

In response to criticism of Keynes' IRR, many theorist have sought to improve the IRR by creating alternative yield-based methods [21], [23], [24], [33], [35]. Solomon [33] attempted to correct the deficiencies of the IRR by computing a terminal value based on the compounding of the investment's cash flow stream at an explicit reinvestment rate equal to the firm's cost of capital. His simplified internal rate of return, IRR*, is that rate that equates the project's terminal value to the initial cost of the investment. Clark, Hindelang, and Pritchard [10] assert that a simplified modified internal rate of return, MIRR*, similar to Solomon's measure will correct the deficiencies of the IRR. However, as demonstrated later in this research, this method is not consistent when a project's cash flows are nonnormal. Teichroew, Robichek, and Montalbano [35] and Mao [23] develop a five-step algorithm to correct the multiple root problem of the IRR. Unfortunately, their methods are not consistent when addressing the problem of time disparity among mutually exclusive investments.

Lin [21] noted that previous researchers (Arrow and Levhari [2], Flemming and Wright [14], and Teichroew, Robicheck and Montalbano [35]) identified contradictory and ambiguous results when employing the IRR due to the differences in reinvestment rate assumption. Because cash flows are assumed to be reinvested at the corporate cost of capital when employing the NPV method, Lin corrected both problems unique to the IRR by making a similar assumption in the formulation of his Modified Internal Rate of Return, MIRR. McDaniel, McCarty and Jessell [24] develop a model, termed the $MIRR^n$, that is equivalent to Lin's MIRR but adjusts the terminus period in an attempt to accommodate projects with unequal lives.[2] However, as demonstrated later in this research, both Lin's MIRR and McDaniel, McCarty and Jessell's $MIRR^n$ do not maximize shareholder wealth and are inconsistent when investments differ in their economic lives.

Since Irving Fisher's persuasive argument over 100 years ago, the NPV has become a fundamental capital budgeting method in the appraisal of corporate investment projects. Fisher's elaborate justification of the NPV method is based on the conflicts of interest between consumption today, or foregoing immediate consumption, and investing for increased utility from future consumption. Fisherian theory assumes the purpose of investing is for the possibility of increased utility from future consumption or, in other words, wealth maximization based on both present and future consumption. To maintain theoretical soundness, this research also assumes wealth maximization in the following simulations and analysis.[3]

Although the NPV does not suffer from the same deficiencies as the IRR and is professed as superior to Keynes' return method, the NPV also has deficiencies and is inconsistent in some investment environments. Specifically, the NPV has been shown to be inconsistent in selecting superior investments and ambiguous in maintaining the goal of wealth maximization in environments when investments have different economic lives [3], [12], [17], [26], [34] and when efficient market assumptions are violated [25], [30], [37]. This study demonstrates that while retaining the relevancy of a yield-based rate of return, the RRIA corrects for the inconsistencies of the NPV and maintains the goal of wealth maximization when selecting mutually exclusive projects of unequal lives and in environments of uncertainty.

DEVELOPMENT OF A CONSISTENT YIELD-BASED CAPITAL BUDGETING METHOD

The preference of a yield-based capital budgeting method by corporate management is indisputable. Several recent survey studies note that corporate management emphatically prefer a yield-based capital budgeting method such as the IRR over alternative capital budgeting methods [6], [15], [16], [18], [27], [28] [32]. In addition, these studies identified the NPV and Profitability Index as the least popular methods despite each method's theoretical advantage.

Some researchers assert that the preference of a yield-based method over a discount cash flow method, such as the NPV, is because corporate management's implicit goals and objectives are different than the Fisherian assumption of wealth maximization. Mao [23] found that corporate management did not explicitly state that the objective of the firm is to maximize shareholder wealth. In contrast, Petty, Scott, and Bird [28] note that management's stated primary goal when selecting capital expenditure investments is the "maximization of the percent return on total asset investments." Therefore, to be appealing to corporate management and theoretically sound, a capital budgeting method must be expressed as a yield-based measure, maximize the percent return on invested assets and consistent in maximizing shareholder wealth.

Given the assumption of Fisher's maximization theorem, most theorists assume the solution to corporate financing decisions involves maximizing the present value of shareholder wealth created by investment projects, thereby, solving the following maximization problem:

Equation 1

$$Max[w_0^*] = w_0 + \sum_{t=0}^{n} \frac{C_t}{(1+k)^t}$$

where:

- w_0^* is shareholder wealth after initial investment
- w_0 is shareholder wealth before initial investment
- c_t is cash flow resulting from the investment occurring in period t
- k is the corporate cost of capital

Because w_0 is given and not affected by corporate management's future budgeting decisions, the optimization of shareholder wealth can be expressed as maximizing the present value of future investment projects (I)

Equation 2

$$Max[w_0^* - w_0] = Max[I] = \sum_{t=0}^{n} \frac{C_t}{(1+K)^t}$$

Although little research has been performed on the distinction of negative and positive cash flows in yield-based capital budgeting measures, the importance of this distinction is paramount. Negative cash flows are typically termed "financing" cash flows because of the financing needs created by the cash outflows while positive cash flows are termed "investment" cash flows because of the investment opportunities of the cash inflows. As demonstrated later in this research, the root cause of many inconsistencies in yield-based capital budgeting measures, such as multiple rates of return in the IRR and some MIRR methods, stem from the inability of the yield-based measure to make distinctions between financing and investment cash flows. To determine a unique rate of return, the maximization problem of Equation 2 is segregated into financing, $C_{F,t}$, and investment, $C_{I,t}$, cash flows.

Equation 3

$$\sum_{t=0}^{n}\frac{C_t}{(1+K)^t}=\sum_{t=0}^{n}\frac{C_{F,t}}{(1+K)^t}+\sum_{t=0}^{n}\frac{C_{I,t}}{(1+K)^t}$$

For the sake of parsimony, let:

$$\sum_{t=0}^{n}\frac{C_{F,t}}{(1+K)^t}+\sum_{t=0}^{n}\frac{C_{I,t}}{(1+K)^t}=(\cdot)$$

Although Equation 3 maximizes shareholder wealth based on the Fisherian maximization of Equation 1, the maximization is not consistent when evaluating investments with differing economic lives. To accommodate the analysis of investments with differing economic lives, the cash flows of Equation 3 are assumed to be replicated to a common future time period. This is accomplished by assuming an infinite stream of constant scale replications.

Equation 3.1

$$(\cdot)(n,\infty)=(\cdot)+\frac{(\cdot)}{(1+K)^n}+\frac{(\cdot)}{(1+K)^{2n}}+\ldots$$

To obtain a closed-form formula, assume:

$$\frac{1}{(1+K)^n}=\psi$$

The implementation of the closed-form formula into Equation 3.1 results in:

Equation 3.2

$$(\cdot)(n,\infty)=(\cdot)(1+\psi+\psi^2+\ldots+\psi^{n+1})$$

Multiplying both sides by ψ, Equation 3.2 becomes:

Equation 3.3

$$\psi(\cdot)(n,\infty)=(\cdot)(\psi+\psi^2+\ldots+\psi^{n+1})$$

Subtracting Equation 3.3 from 3.2 results in:

$$(\cdot)(n,\infty)-\psi(\cdot)(n,\infty)=(\cdot)(1-\psi^{n+1})$$

$$(\cdot)(n,\infty)=\frac{(\cdot)(1-\psi^{n+1})}{1-\psi}$$

To complete the analysis, taking the replications to infinity results in:

Equation 3.4

$$\lim_{n \to \infty} (\cdot)(n, \infty) = (\cdot)\left[\frac{1}{1-[1/(1+K)^n]}\right]$$

Equation 3.4 gives the maximum value of net cash flows when an *n* life project is replicated. However, not every investment is conducive to the replication process and extension of the optimization beyond the investment's economic life. Emery [12] identified four cases with distinct differences when evaluating investments with differing lives. Emery noted that some investment projects have set economic lives and are not open to replication. In Emery's first two cases the replication process is inappropriate and capital budgeting methods such the EAA and McDaniel et. al.'s [24] yield based method are inconsistent, while the last two cases require a capital budgeting method that adjusted the project's life via a replication process. To maintain consistency in all cases delineated by Emery, an exponent is added to Equation 3.4 such that the capital budgeting method is adjusted for the varying cases of investment projects with differing economic lives. Investments that are not open to replication should have an exponent value of zero while the more common case of projects with differing lives and open to replication will have an exponent value of 1. Rearranging the terms in the bracket and raising the value to the power z, Equation 3.4 is expressed as:

Equation 4

$$(\cdot)(n, \infty) = (\cdot)\left[\frac{(1+K)^n}{(1+K)^n - 1}\right]^Z$$

While Equation 4 consistently maximizes shareholder wealth in varying economic environments, the measure lacks the relevancy of a yield-based measure. To create a yield-based capital budgeting tool, the maximization problem of Equation 4 must be normalized. This study again recognizes the difference in financing and investment cash flows by normalizing the optimization problem of Equation 4 with the present value of all financing cash flows. A relevant benchmark is included in the optimization problem by adding the firm's corporate cost of capital. These adjustments create the following yield-based capital budgeting method:

Equation 5

$$RRIA = \frac{\left[\sum_{t=0}^{n} \frac{C_{F,t}}{(1+K)^t} + \sum_{t=0}^{n} \frac{C_{I,t}}{(1+K)^t}\right] \times \left[\frac{(1+K)^n}{(1+K)^n - 1}\right]^Z}{-\sum_{t=0}^{n} \frac{C_{F,t}}{(1+K)^2}} + K$$

The Rate of Return on Invested Assets (RRIA) computed in Equation 5 is theoretically sound by maintaining the Fisherian assumption of wealth maximization, is consistent in six of the seven previously identified environments, and allows corporate management to select investments based on the maximization of the percent of return of total assets.

Because the RRIA is expressed as a rate of return, it is intuitively appealing but does not suffer from deficiencies of other yield-based capital budgeting methods. The RRIA expresses the annualized rate of return per total invested assets over the life of the investment. The first term in the numerator maintains the goal of wealth of maximization and identifies and separates financing from investment cash flows. The second term in the numerator adjusts for investments of differing economic lives. The denominator again maintains the difference between financing and investment cash flows and, in combination with the cost of capital, gives the method the relevancy of a yield-based method preferred by corporate management. Employing the RRIA is similar to the IRR where an investment is deemed profitable if the RRIA is greater than the firm's cost of capital and the ranking of investments occurs from the highest to lowest marginal rate of return.

INCONSISTENCIES AND CONSISTENCIES IN CAPITAL BUDGETING METHODS

To demonstrate the RRIA's consistency and robustness of ranking superior investments in varying environments, the RRIA measure and other capital budgeting measures are computed in the seven environments previously delineated in this study.

Environment 1: Inconsistency In Ranking And Time Disparity Of Mutually Exclusive Investments

Although preferred by practitioners, the IRR suffers from several conflicts and inconsistencies when ranking investments. One well documented conflict occurs when selecting mutually exclusive investments with differences in the timing of cash flows. For example, assume projects A and B both cost $100,000 but differ in the timing of future cash flows. Project A's cash benefits occur later in the project's life, while Project B's cash benefits occur early in the project's life. Table 1 details the cash flows for each project and the resulting capital budgeting measures.[4]

TABLE 1
Inconsistencies Of The IRR And The Consistency Of The RRIA When A Disparity In The Timing Of Cash Flows Between Mutually Exclusive Projects Exists

	C_0	C_1	C_2	C_3	NPV	IRR	RRIA
A	$-100,000	0	$60,000	$80,000	$9,692	14.07%	15.58%
B	$-100,000	$70,000	$52,000	0	$6,612	15.15%	13.81%

As Table 1 illustrates, a firm employing the IRR to select and rank investment projects will select the least profitable investment, Project B, although maximizing the rate of return. This conflict occurs because of the differing values assigned to generating cash flows earlier rather than later in the investment's life. When the NPV is greater than zero, the IRR method will assign a higher value for earlier cash flows as opposed to the NPV or RRIA methods and vice versa when the NPV is less than zero.

In contrast, a firm employing the RRIA to rank and select investments based on management's preference of maximizing the rate of return, will also maximize shareholder wealth. Because of similar assumptions concerning the reinvestment rate of cash flows, both the RRIA and the NPV methods maximize shareholder wealth by ranking Project A over Project B.

Environment 2: Inconsistency In Ranking And The Violation Of The Value Additive Principle

Weston and Copeland [36] note that an optimal capital budgeting method must allow management to select independent investments separate from other investments or as a combined package without inconsistency in the investments selected. To demonstrate the inconsistency of the IRR and the measure's violation of the value additive principle, assume a firm is considering three investment proposals. Projects A and B are mutually exclusive and project C is independent. Table 2 details the projects' cash flows and accompanying capital budgeting measures.

The value additive principle demands that firms be able to select one project independent of all others. A capital budgeting method that does not violate the value additive principle will allow a firm to select one of the mutually exclusive investments, projects A or B, without considering the third investment, project C. Note, firm attempting to rank investments based on the IRR will select projects A and C. However, a firm attempting to maximize the rate of return on total invested assets by employing the IRR will select projects B and C. The implication of the inconsistency of the IRR is that every combination of possible projects must be considered by the firm. For example, if a firm were considering five investments, 32 different combinations of projects would have to be considered.

TABLE 2
Importance Of The Value Additive Principle In A Capital Budgeting Method

	C_0	C_1	C_2	NPV	IRR	RRIA
A	$-200	0	$363	$100	34.7%	38.8%
B	$-200	$264	0	$40	32.0%	21.5%
C	$-200	$350	0	$118	75.0%	44.0%
A+C	$-400	$350	$363	$218	48.6%	41.4%
B+C	$-400	$614	0	$158	53.5%	32.5%

In contrast, both the NPV and RRIA do not violate the value additive principle. A firm employing the RRIA to maximize the rate of return on total assets would select projects A and C independent of each other. When the projects are combined, a firm using the RRIA to rank investments based on maximum rate of return would again select projects A and C. Because the RRIA method does not violate the value additive principle, the method can be employed to rank investments by the maximum rate of return without considering a multiplicative number of different project combinations.

Environment 3: Nonnormal Projects And Capital Budgeting Inconsistencies

The inconsistency of the IRR to select profitable investments and maximize shareholder wealth also occurs when a project's cash flows are nonnormal. Brigham and Gapenski [8] define a nonnormal project as having "a large outflow of cash either sometime during or at the end of the project's life." Employing the IRR as a capital budgeting tool with a nonnormal project can create three unique inconsistencies: (1) If the investments are mutually exclusive, the IRR may select an unprofitable investment and simultaneously reject the profitable investment; (2) A nonnormal project may not have an IRR; and (3) A nonnormal project may have multiple IRRs.

TABLE 3
Inconsistencies Of The IRR And MIRR* And The Consistencies Of The RRIA When Investment Cash Flows Are Nonnormal

	C_0	C_1	C_2	NPV	IRR	MIRR*	RRIA
A	$-250,000	$160,000	$160,000	$27,686	18.2%	15.9%	16.3%
B	$90,000	$90,000	$-250,000	-$34,793	24.0%	29.5%	-0.3%
C	$100,000	$-200,000	$230,000	$108,264	–	–	44.3%
D	$-16,000	$100,000	$-115,000	$-20,132	51.9% or 373.1%	–	-0.4%

Table 3 details the inconsistency of the IRR and the consistency of the RRIA when an investment has nonnormal cash flows. Assume a mining firm must decide between updating a mining facility to meet EPA standards, costing the firm $250,000, and receiving economic rents from the mine in one year, $360,000, or, leasing the mine today for $160,000 and meeting the EPA standards in one year. Projects A and B are mutually exclusive. Although Project B is obviously unprofitable, a firm attempting to maximize return by employing the

IRR to select and rank mutually exclusive investments will choose Project B. However, the RRIA and the NPV both maximize shareholder wealth by selecting Project A. Again, the RRIA allows a firm to meet the goal of maximizing the rate of return on invested assets while not violating the Fisherian assumption of wealth maximization.

To illustrate other conflicts created by nonnormal cash flows, assume the mining firm is considering two independent investments, projects C and D. Project C is impossible to evaluate and rank when employing the IRR because the investment's IRR does not exist. However, the investment does have a rate of return when employing the RRIA. Concurrent with the NPV, the investment's RRIA is greater than the firm's cost of capital and implies that a firm should accept the profitable project.

The more familiar inconsistency created by nonnormal cash flows is illustrated with project D. Project D has an initial cash outflow at t=0 and a later large cash outflow at t=3. The variance in cash flow from negative to positive and back to negative results in two IRRs. Firms employing the IRR based on the goal of maximizing the rate of return, are faced with the confusing decision of which IRR to use and how to use it. However, a firm using the RRIA to select investments based on maximizing the rate of return will not have the confusion of multiple rate of returns. A firm will obviously reject project D because the RRIA of -0.4 percent is significantly below the corporate cost of capital.

Financial theorists have long asserted that the inconsistencies of the IRR is because employment of the method may result in multiple root solutions when an investment's cash flows are nonnormal. This assertion has lead many researchers into the erroneous belief that simply correcting the multiple root problem will correct the inconsistencies of the IRR. Solomon [33] and Clark, Hindelang, and Pritchard [10] proposed that a yield-based capital budgeting method with a single root, such as the MIRR*, will correct the deficiencies of the IRR when cash flows are nonnormal. The researchers forced the MIRR* to have a single root by compounding all initial cash flows to a terminal value and finding the rate of return that equates the terminus to the initial cash flows. However, as Table 2 demonstrates this assertion is not correct. Similar to the IRR, the MIRR* selects the least profitable investment when comparing mutually exclusive projects A and B. In addition, a firm cannot use the MIRR* when evaluating projects C and D because the MIRR* does not exist.

The deficiency of the IRR is not because the method may result in multiple roots when cash flows are nonnormal. The multiple root problem is systemic of an implicit assumption within both the IRR and MIRR*. The deficiency of the IRR and MIRR* to correctly evaluate nonnormal cash flow investments results from the methods' inability to distinguish between financing and investment cash flows. Interestingly, little research has focused on this cause of multiple rates of return. The MIRR* also suffers from the similar deficiency because the method explicitly forces the equivalent manipulation of all noninitial cash flows. The method compounds both positive as well as negative cash flows when calculating the project's terminal value. Therefore, because both the IRR and MIRR* do not distinguish between investment and financing cash flows, both methods suffer significant deficiencies and inconsistencies when evaluating nonnormal cash flow projects.

The previous example demonstrated the inconsistencies of yield-based capital budgeting methods that do not distinguish between a project's financing and investment cash flows. Specifically both the IRR and MIRR* may select unprofitable investments, have multiple roots, or not exist when a project's cash flows are nonnormal. In contrast, methods that do distinguish between investment and financing cash flows, such as Lin's MIRR and this study's RRIA, are consistent when evaluating nonnormal cash flow investments. However, Lin's MIRR and other modified rate methods have other deficiencies and, similar to the NPV method, suffer from inconsistencies when evaluating investments with differing economic lives as demonstrated in the following section.

Environment 4: Inconsistency In Ranking Investments With Differing Economic Lives

In their original form, both the NPV and MIRR are computed from cash flows generated from an original investment, without allowance for the possibility of replacement of the investment upon termination. However, the more common and realistic project is one in which the project continues after termination of the investment's economic life with the ability to purchase another investment. This lack of consideration for future investments can create conflicting and ambiguous accept/reject decisions and fail to consistently maximize shareholder wealth when mutually exclusive investments have differing economic lives. Several researchers have noted this conflict in selecting investments of unequal lives when employing the NPV method [3], [12], [17], [26], [34].

Previous researchers have proposed varying adjustments to the NPV to correct for this inconsistency. Two proposed modifications to the NPV are the "common life multiple" and "equivalent annual annuity" methods. While both the common life multiple and equivalent annual annuity consistently maximize shareholder wealth when comparing investments with unequal lives, unfortunately, both methods have computational difficulties. The common life method assumes each investment is replaced by a similar method at its termination. This replacement process is continued until a common life between the mutually exclusive investments is found. Although correcting the inconsistencies of the NPV by forcing a shared common life on each investment, the common life method may result in an unfeasibly long evaluation period. For example, because the common life between investments is based on the lowest common multiple of prime numbers of each investment's life, a common life for three mutually exclusive investments with lives of 7, 11, and 13 years is 1,001 years (1 x 7 x 11 x 13 = 1,001 years).

The equivalent annual annuity (EAA) method circumvents the difficulty of discounting cash flows over an unrealistically long evaluation period, as in the common life method, by assuming the investments are expressed as a perpetuity. While not open to the criticism of an unacceptably long project life as with the common life method, the EAA method is obtuse and lacks the relevancy of a yield-based method preferred by corporate management.

In an attempt to correct the deficiencies created by mutually exclusive investments with unequal lives and remain relevant to corporate management, several researchers have erroneously claimed that the MIRR will correct the inconsistencies in the NPV method and select wealth maximizing investments with unequal lives [21] [24]. Lin [21] postulates that because the MIRR is expressed as a yield and is not a function of the life of the project, the measure is not affected by investments with differing lives. However, this assertion is not correct, in that the MIRR does not consistently select superior investments in all investment scenarios.

McDaniel et. al. [24] assert that by adjusting the terminal period of the MIRR to equal the life of the longest lived investment, a variant of the MIRR, distinguished in this research by $MIRR^n$, will correctly select investments with differing economic lives. The researchers note that while the numerical estimate of the $MIRR^n$ will differ with different terminal periods, the measure is not affected by investments with different lives. However, similar to Lin's MIRR, McDaniel et al.'s proof occurs within a specific environment of selected unequaled life projects. Their $MIRR^n$ is not consistent when evaluating investments of different economic lives.

To demonstrate the inconsistency of the NPV, the MIRR, and the $MIRR^n$ methods and the consistency in the RRIA method in maximizing shareholder wealth when selecting investments with unequal lives, assume corporate management is faced with deciding between three replicatable mutually exclusive investments with differing economic lives. Table 4 details the cash flows for each $100,000 investment and the corresponding capital budgeting measures.

TABLE 4
Inconsistency Of The NPV And MIRR And The Consistency Of The RRIA When Ranking Investments With Unequal Lives

	C_0	C_1	C_2	C_3	C_4	C_5	C_6
A	($100,000)	$143,000					
B	($100,000)	$1,000	$1,000	$251,000			
C	($100,000)	$217,000	$1,000	$1,000	$1,000	$1,000	$1,000

	NPV	Common Life	EAA	MIRR	$MIRR^n$	RTIA
A	$30,000	$143,724	$330,000	43.00%	14.92%	43.00%
B	$90,316	$158,171	$363,172	36.32%	22.45%	46.32%
C	$100,719	$100,719	$231,258	23.54%	23.54%	33.13%

Ignoring the ability of corporate management to replicate each investment, project C is the most profitable based on its NPV.[5] However, the NPV method is biased to long life projects and does not maximize shareholder wealth when the projects are replicable. This illustrated in the common life and equivalent annuity methods. If projects A and B are replicated to the commonal period of six years, project B is the most profitable with a common life NPV of $158,171. If projects A, B, and C were extended to infinity, the EAA method concurs with the common life NPV and maximizes shareholder wealth by selecting project B with an EAA of $363,172.

Counter to assertions in previous research, the MIRR and the $MIRR^n$ do not maximize shareholder wealth by selecting the most profitable investment. In contrast to the NPV, Lin's MIRR is biased towards short lived projects when evaluating investments of unequal lives and erroneously selects project A as the most profitable. Similar to the NPV, McDaniel et al.'s $MIRR^n$ is biased towards long life projects and erroneously selects project C as the most profitable. Although expressed as yield-based method, both methods are inconsistent with maximizing wealth when evaluating projects of differing lives.

In contrast to the MIRR and $MIRR^n$, the RRIA maintains the Fisherian assumption of wealth maximization. The RRIA concurs with both the common life NPV and the EAA methods and identifies project B as the most profitable with a six year annualized rate of return of 110.7 percent. However, because the RRIA is yield-based, the method is not as obtuse and is more tenable to corporate management than the EAA and common life methods. In addition to wealth maximization, the RRIA allows corporate management to achieve the goal of maximizing the rate of return.

Environments 5 And 6: Inconsistencies In Imperfect Markets, Economic Uncertainty And Capital Rationing

The attractiveness to practitioners of employing a capital budgeting measure based on a rate of return, such as the RRIA, may extend beyond the measure's ability to rank consistently projects with differing economic lives. Most yield-based capital budgeting measures contain information beyond the accept/reject recommendation of proposed investments. This additional information allows corporate management to evaluate investments in the presence of imperfect markets.

Methods such as the NPV and EAA may not consistently maximize shareholder wealth in the presence of imperfect markets. The NPV and EAA methods are limited by the assumptions that future investment cash flows are known with certainty and that the firms do not participate in capital rationing. Hirschleifer [19] noted the consequences of violating this assumption. He asserts that the pattern of future cash flows is significant and that in the presence of imperfect markets and uncertain cash flows the NPV is an incomplete criterion for an investment appraisal.

Table 5 illustrates the deficiencies of the NPV and EAA methods when future cash flows are uncertain. Assume a firm is considering two mutually exclusive investments, projects A and B costing $20,000 and $200,000 respectively.

TABLE 5

Benefits Of The RRIA In An Environment Of Uncertain Cash Flows

	C_0	C_1	NPV	EAA	RRIA
A	$-20,000	$33,000	$10,000	$11,000	65.0%
B	$-200,000	$232,000	$10,909	$11,999	16.0%

While the NPV and EAA methods give a direct measure of profitability, yield-based capital budgeting methods, such as the RRIA, contain information about a project's safety margin that is not contained in the NPV or EAA methods. Based on the NPV and EAA, a firm should select project B and reject project A. However, in a world of uncertain future cash flows, although project B has a higher NPV, project A offers a larger margin for cash flow error. A firm can error in estimating Project A's cash flows by 35 percent before the project becomes unprofitable. In contrast, Project B's cash flows can decline by only 5 percent before the project becomes unprofitable. Note that a firm employing the RRIA to select investments will select the investment with the highest "safety margin."[6]

Another form of inefficient markets occurs when a firm participates in capital rationing. Although capital rationing violates the theoretical world of efficient markets, the participation of restricting capital expenditures by corporations is commonplace. In a survey by Gitman and Forrester [16], the researchers found that the amount of funds available for investment in a specific period is relatively fixed and independent of the capital markets. Rao [29] delineates several rational reasons for corporate capital rationing.

While the majority of firms participate in capital rationing, capital budgeting methods such as the NPV and EAA are inconsistent in selecting investments that maximize shareholder wealth. For example, assume a firm is constrained by a $20 million capital budget and is considering three independent projects; project A costing $10 million, project B costing $20 million, and project C costing $10 million. Based on the capital rationing constraint of $20 million, the firm could select either project A, projects B and C, or none of the investments. Table 6 details each investment's cash flows and corresponding capital budgeting values.

TABLE 6
Inconsistency Of The NPV And The Consistency Of The RRIA To Rank And Select Investments When A Firm Practices Capital Rationing

	C_0	C_1	C_2	NPV	EAA	RRIA
A	$-20	$20	$10	$6.45	$3.72	28.6%
B	$-10	$5	$12	$4.46	$2.57	35.7%
C	$-10	$6	$11	$4.55	$2.62	36.2%

A firm employing the NPV or EAA method would rank project A as the most profitable followed by project C and then project B. Based on this ranking and the capital rationing constraint of $20 million, the firm would select project B and reject projects A and C. However, if investments were ranked by the RRIA, project C is selected first followed by project B and then project A. Based on the RRIA ranking and capital rationing of $20 million, the firm should select projects C and B. Note that when ranked by the NPV method, shareholder wealth is not maximized. Based on the NPV ranking, total increase in shareholder wealth is $6.45 million, while ranking by the investment's RRIA, total shareholder wealth increases by $9.01 million. Again, the RRIA method allowed the firm to maximize the rate of return on invested assets while maximizing shareholder wealth.

Environment 7: The Lumpiness Of Projects And The Inconsistency Of The RRIA

Although the RRIA is consistent in a variety of environments, because the method is yield-based, the measure does not consistently select investments of differing initial costs. McDaniel et. al. [24] notes that all yield-based methods are inconsistent when size disparity, commonly termed lumpiness, exists among mutually exclusive investments. Unfortunately, the ability of the RRIA to incorporate the safety margin of a project in measure, also impedes the measure when lumpiness exists.

Despite the fact that the RRIA developed in this study is a significant addition to the current pedagogy of capital budgeting methods and that the method corrects for inconsistencies in the IRR, MIRR, MIRR*, $MIRR^n$, NPV, and EAA, the inconsistency of the RRIA when investments have significant differences in initial costs detracts from its efficacy. However, the RRIA can be adjusted to accommodate the lumpiness problem. Observing that the RRIA is the rate of return on total invested assets, a set remuneration based on total invested assets can be calculated by multiplying a project's initial costs by its RRIA. While this adjustment will create a consistent capital budgeting tool when evaluating investment projects with different initial costs, it unfortunately loses the relevancy of a yield-based method desired by corporate management.

CONCLUSION

Historically, corporate management has strongly expressed a preference for yield-based capital budgeting measures, such the IRR, MIRR and $MIRR^n$, despite the theoretical inconsistencies of these methods. In contrast, financial theorists have adamantly supported cash discount models, such as the NPV and EAA, despite corporate management's obvious aversion to such methods. This study developed a yield-based capital budgeting method, the RRIA, that maintains the Fisherian assumption of wealth maximization. To test the robustness and consistency of the RRIA, this study employed seven different preconditioned investment environments. While maintaining the desirability of a yield-based model, the RRIA consistently ranked investments based on the assumption of wealth maximization in six of the seven preconditioned environments. The RRIA was not consistent when exposed to the lumpiness of investments.

In addition, this study has made a significant contribution to the research of capital budgeting methods by delineating several factors that are paramount to the development of a consistent yield-based method. Previous research analyzing the deficiencies of the IRR asserted that simply correcting the multiple root problem by compounding the investment's cash flows at a rate of return equal to the corporate cost of capital will correct the IRR's deficiencies. However, counter to previous research, this research demonstrated that compounding an investement's cash flows at the corporate cost of capital is not sufficient to correct the deficiencies of the IRR but rather several factors are important when developing a consistent yield-based capital budgeting measure. Specifically, to maintain wealth maximization in a yield-based method, this study demonstrates that the method must distinguish between financing and investment cash flows, adjust to investments with differing economic lives, recognize the time disparity in the cash flow stream between mutually exclusive investments, and maintain the value additive principle. While the RRIA developed in this study is a significant addition to the current pedagogy of capital budgeting methods and corrects for inconsistencies in the IRR, MIRR, MIRR*, $MIRR^n$, NPV, and EAA, the method is open to future research when analyzing investments of differing size.

ENDNOTES

1. For an excellent review of yield-based capital budgeting methods see McDaniel, McCarty and Jessell [24].

2. McDaniel et al. [24] termed their yield-based measure the marginal return on invested capital, MRIC. Because their method is very similar to Lin's MIRR and only differs by adjusting the terminal period, to decrease confusion this research uses $MIRR^n$ to symbolize their yield-based measure.

3. Dorfman [11] notes that corporate financial literature suggests that frequently other goals of the corporation take precedence over wealth maximization such as market dominance or sales volume. He demonstrates that a yield-based capital budgeting can identify superior projects when a firm's goal is other than wealth maximization.

4. For simplicity and brevity of exposition, the corporate cost of capital is assumed to be 10 percent for all examples in this study. This assumption does not significantly affect the implied conclusions of each example. The consistency of the RRIA is not a function nor affected by varying the corporate cost of capital.

5. Note that if the projects were not replicable, the RRIA would concur with the NPV method and select project C as the most profitable. In an environment of nonreplicable projects, the RRIA for projects A, B, and C would be 40.0, 100.3, and 110.7 percent respectively.

6. Miller [25] and other research suggests employing the Profitability Index, PI, in the presence of uncertain cash flows. While the PI will identify the projects with the highest safety margin, the method is inconsistent in selecting investments with varying economic lives and is not expressed in the desirable format of a yield-based method.

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