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EVALUATION METHODS FOR CONSTRUCTION PROJECTS

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Abstract. Financial evaluation methods such as Net Present Value (NPV) and Internal Rate of Return (IRR) are not fully adequate for accounting three practical aspects of construction projects: reinvestment rate, actual amount of required investment, and firm available funds. In a certain type of projects, this inadequacy often results in the inapplicability of NPV, multiple or no IRR problem, systematic bias of IRR, and inconsistent decision signal and ranking between NPV and IRR. Many modified methods have been developed, but hardly succeeded in reflecting construction market reality in an integrated manner. To address this issue, Project Present Value, Project Rate of Return, and Firm Rate of Return are proposed together with an investment decision framework. The proposed methods are designed to be free from all those problems, while incorporating market reality in them. As a result, construction practitioners would have more reliable and economically meaningful decision tools, which lead to the success of their projects.

Keywords: financial management, investments, decisionmaking.

1. Introduction

As in other business areas, the most popular financial evaluation tools for construction projects are Net Present Value (NPV) and Internal Rate of Return method (IRR) (Graham and Harvey 2002). However, NPV is unable to reflect the reality of construction market when the limitation on the use of free cashflow leads to violation of NPV's assumption that firm's opportunity cost is the same as reinvestment rate (Beaves 1988). Regarding IRR, many researchers revealed its inherent limitations such as multiple or no IRR, systematic bias, decision inconsistency with NPV, and ranking inconsistency with NPV, when cashflow is non-conventional (Lin 1976; Mc Daniel *et al.* 1988; Beaves 1988; Shull 1992; Bussey and Eschenbach *et al.* 1992). What matters here is that non-conventional cashflow is common in the construction industry due to projects sharing risks with owners, for example, by loaning initial seed capital. For this reason, using IRR is susceptible to the above-mentioned problems. However, practitioners in the construction industry rarely recognize these problems.

To address these challenging problems, significant efforts have been made, resulting in more enhanced financial evaluation tools in many aspects such as Modified Rate of Return (MIRR) (Lin 1976), Generalized Net Present Value (GNPV) and Overall Rate of Return (ORR) (Beaves 1989), and Scale Adjusted Return (SAR) (Shull 1994). However, these efforts hardly succeeded in providing the Present Value Method (PV Method) and Rate of Return method (RR Method) that overcomes all problems in a complete and integrated manner and more importantly reflects the construction market reality at the same time.

The purpose of this paper is to present construction project investment decision tools: Project Present Value (PPV), Project Rate of Return (PRR), and Firm Rate of Return (FRR). They have been developed to be free from the problems related to NPV and IRR and provide more reliable and economically meaningful investment performance indices for construction project managers. In addition, this paper also presents the evaluation procedure that helps to apply the proposed methods on a real project, based on the construction market reality. To propose new methods and their procedures, we need to exam the assumptions embedded in the existing evaluation tools, especially implicit ones.

2. Implicit assumptions revisited

Except for explicit assumptions: perfect market, no transaction cost, and no tax, there are 3 important implicit assumptions in PV and RR methods: reinvestment rate (rate at which interim cash flows are reinvested), investment base (capitals invested to undertake a project), and time horizon (the time during which a project is evaluated). The validity of final models heavily depends on the reasonableness of those assumptions. Many researchers revealed that NPV and IRR fail to control them flexibly (Bernhard 1989; Lin 1976; Beaves 1988; Shull 1992). In turn, this failure leads the problems of the existing methods. Fig. 1 describes the relationship between 3 implicit assumptions and their related problems, and the past research efforts to solve those problems.

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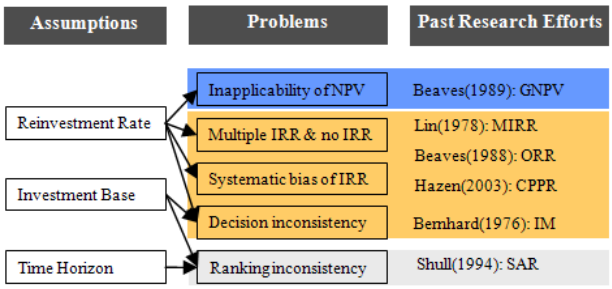

Fig. 1. Implicit Assumptions and Problems

Among the previous research efforts, Beaves (1988) revealed that NPV may be not a correct measure of the project present worth when project's reinvestment rate cannot be the same as firm's opportunity cost. Lin (1978) also gave us the insight that, if a RR method uses the same reinvestment rate as a PV method, it would provide the same decision signal with a PV method without the problems of multiple & no IRR and systematic bias of IRR. Lastly, Shull (1994) developed a new type of RR methods: SAR that provides not only the same decision signal with NPV, but also the same project rankings with NPV through assuming the same investment base and time horizon with NPV in his RR method. To get further insights on the implicit assumption issue, the past research efforts should be scrutinized closely by examining how these 3 assumptions are dealt with in GNPV, MIRR, ORR, and SAR.

3. Reinvestment

The reinvestment assumption induces 3 problems of IRR method: multiple or no IRR, systematic bias, and decision inconsistency with NPV and one problem of NPV, as mentioned in the previous section. With respect to multiple or no IRR problem, consider project 1 and project 2 in Table 1.

Table 1. Three hypothetical cases (Hazen 2003)

Proj.	Period 0	1	2	3	NPV	IRR
1	–1.00	6.00	–11.00	6.00	–0.13	0%, 100%, 200%
2	–1.00	3.00	–2.50		–0.34	no IRR
3	–1.00	4.00	–4.00		–0.67	100%

*note: firm's opportunity cost is 10%

Although a project cannot have multiple rates of return or no rate of return in reality, this happens when non-conventional cashflow is evaluated using IRR (Bussey and Eschenbach 1992). Project 1 has 3 rates of return (0%, 100%, 200%), and project 2 has no rate of return in the table. In addition, there is also the systematic bias problem that IRR generates too high or too low rates of return due to its reinvestment assumption at IRR. This can be illustrated by that the simple accounting rate of return of project 3 tells us it is not profitable, but IRR says its yield is 100%. Lastly, ranking inconsistency with NPV is illustrated by project 3. The NPV discounting at 10% is –0.67, and its IRR is 100%. While IRR is greater than 10%, which means 'Go' signal, NPV is less than 0, which means 'No Go' signal.

With respect to reinvestment assumption, many researchers (Mao 1969; Lin 1978; Beaves 1988; Bernhard 1989; McDaniel *et al.* 1988) assert that the problems related to it can be easily overcome by using the same reinvestment rate in a RR method. The reason why the problems in IRR exist is that IRR assumes reinvestment rate at IRR, and NPV assumes reinvestment rate at firm's opportunity cost. It is the very discrepancy in reinvestment rate that generates the above-mentioned 3 problems. Meanwhile, inapplicability of NPV arises when reinvestment rate is not the same as firm opportunity cost. NPV does not allow a different reinvestment rate from a firm opportunity cost due to its core explicit assumption that lending and borrowing rate is the same. This implies that NPV may be not a correct method to use when reinvestment rate is the same.

The meaningful attempt to solve the reinvestment problem in both NPV and IRR has been established by Beaves' GNPV and ORR (Beaves 1988). Beaves argues that NPV may be not a correct return measure since it assumes firm opportunity rate as reinvestment rate and discount rate at the same time. To avoid this problem in NPV, Beaves suggest GNPV, equation (1).

$$GNPV = \sum_{t=t^*+1}^{n} \frac{a_t(1+r_{t,n})^{n-t}}{(1+r_{0,n})^{n}} + \sum_{t=0}^{t^*} \frac{a_t}{(1+r_{0,n})^{n}}, \quad (1)$$

a_t is net cash flow and $r_{0,t}$ is firm opportunity cost at each period. Interim cash flow is reinvested at $r_{t,n}$ to the end of a project from t^* transition point, when no more outside capital is required. This approach is called by Beaves as incremental wealth approach, since GNPV converts all cashflows to two cashflows investment base $\sum_{t=0}^{t^*} a_t(1+r_{0,t})^{-t}$ and terminal value $\sum_{t=t^*+1}^{n} a_t(1+r_{t,n})^{n-t}$. GNPV differentiate reinvestment rate $r_{t,n}$ from discount rate or firm opportunity rate $r_{0,n}$. In this way it achieves a more general assumption on the reinvestment rate. If the incremental approach is applied to a RR method, it would produce Beaves' ORR, equation (2).

$$ORR = \left[\frac{\sum_{t=t^*+1}^{n} a_t(1+r_{t,n})^{n-t}}{\sum_{t=0}^{t^*} \frac{a_t}{(1+r_{0,t})^{t}}} \right]^{1/n} - 1. \quad (2)$$

Beaves' ORR also includes a flexible reinvestment assumption at $r_{t,n}$, and it is the same reinvestment assumption with GNPV. Thus, these two provide the same decision signals. For example, Project 3's ORR at 10% discount rate and the same reinvestment rate is –23.94%, which provides the same decision signal with GNPV at the same rates – 0.13, which is 'No Go' signal.

Another way of dealing with reinvestment assumption is Lin's MIRR (Lin 1976). The equation is

$$MIRR = \left[\frac{\sum_{t=0}^{n} R_t (1 + r_{t,n})^{n-t}}{\sum_{t=0}^{n} \frac{I_t}{(1 + r_{0,t})^t}} \right]^{1/n} - 1, \quad (3)$$

where R_t and I_t are positive cashflow and negative cashflow respectively. Difference between MIRR and ORR is the investment base that each method assumes. ORR investment base is the minimum required funds, but MIRR investment base is the negative cashflow. Generally these two yield different numbers due to the different assumption on investment base. This implies that there still remains an unsettled issue in investment base assumption, which will be examined thoroughly in the later section.

However, ORR and MIRR provide NPV-consistent decision signal and are free from multiple or no IRR problem and systematic bias because those tools assume the same reinvestment rate with NPV or GNPV.

4. Investment base and time horizon assumption

ORR provides NPV consistent decisions and NPV consistent rankings as well when evaluating equal size projects over the common time horizon. However, when evaluating unequal size projects over the common time horizon or evaluating equal size projects over the uncommon time horizon ranking, inconsistency with NPV occurs. In short, the ranking problem is attributed to the unequal investment base and the uncommon time horizon of RR methods with NPV (Shull 1992). Table 2 illustrates how rates of return such IRR and ORR provides different rankings with NPV.

Table 2. Shull's 3 hypothetical projects

Proj.	Period				NPV	IRR	ORR
	0	1	2	3			
A	–16	1.1	–2.42	20	–1.97	5.28%	5.57%
B	–2500	14000	–10000		1962.81	–15.96%	46.97%
C	–10	20			8.18	100.00%	100.00%

* note: firm opportunity cost and reinvestment rate are the same at 10%

Applying NPV, IRR, and ORR to the above 3 projects, each method yields different rankings. NPV, IRR and ORR yields the rankings of B>C>A, C>A>B, and C>B>A respectively. This inconsistency in rankings is attributed to difference in investment base assumptions where the size of project C is only \$10. The same goes with ORR.

This issue of investment base can be solved by introducing the same investment base and time horizon as Shull (1992) suggested. To this end, Shull introduced a new assumption that the common investment base is the largest one among investment bases required to undertake available projects, and the unused capitals are invested at firm opportunity rate. Based on this assumption, Shull's Scale Adjusted Return on A (SAR) is

$$SAR_A = \left[(RB_A + (IB_c - IB_A)(1+k)^n) / IB_c \right]^{(1/n)} - 1, \quad (4)$$

where

RB$_A$ (Terminal Value) = $\sum_{t=t^*+1}^{n} a_t (1 + r_{t,n})^{n-t}$;

IB$_A$ (Investment Base)= $\sum_{t=0}^{t^*} a_t (1 + r_{0,t})^{-t}$;

IB$_C$ (The largest investment base) = $\sum_{t=0}^{t^{**}} a_t (1 + r_{0,t})^{-t}$;

n = the common time period, t^* = project A's transition point, t^{**}= The largest project B's transition point, a_t = project A' net cashflow.

As shown in Table 3, SAR provides not only NPV consistent decision signals but also NPV consistent rankings regardless of the investment base and time period. This is due to the fact that the equal size and the common time horizon are assumed. For instance, project C has IRR 100%, but SAR 10.12%. Since SAR assumes the same investment base for all projects, so the big return on the small investment C does not have a significant effect on the overall performance. The rate of return on project B is also changed 46.97% into 33.44% due to the common time horizon of all projects, which is one year longer than project B' time horizon.

Table 3. Comparison among IRR, ORR, and SAR

Proj.	NPV	IRR	ORR	SAR
A	(1.97)	5.28%	5.57%	9.97%
B	1962.81	–15.96%	46.97%	33.44%
C	8.18	100.00%	100.00%	10.12%

* note: firm's opportunity cost and reinvestment rate are the same at 10%, and IBc = –2.500

Another aspect of SAR is that SAR can be considered as a firm rate of return. Assuming the same investment base and time horizon as firm available funds and firm time horizon, the rate of return calculated by SAR becomes firm specific. In contrast, the rate of return calculated by ORR is project specific due to the same reason. This interpretation would entail the important implications for practitioners, which will be visited again in the later section.

5. Toward market reality

The research efforts extending from Lin (1976) to Hartman and Schafrick (2004) have contributed to the development of better investment decision tools and have brought about a great understanding of existing investment decision tools as briefly discussed in the preceding sections. However, as discussed earlier, they are not fully adequate for construction projects, especially risk-sharing ones with owners. To be useful for construction projects, the following aspects regarding construction market reality into their tools should be incorporated in an integrated manner.

1. Investment stream should be determined not by tools but decided by a investment decision-maker.

2. The amount of available funds is firm specific, not project specific.

3. Reinvestment rate and firm opportunity cost are not equal in some construction cases.

Regarding the statement 2, when calculating SAR or a firm rate of return, we need the common investment base. However, no reasonable suggestion is made until now. For instance, Shull just used the largest one among investment bases of available projects. Hajdasinski (1996) have only shown that firm available capital can be from $Max\{0,-NPV\}$ to $+\infty$ without the loss of PV consistency, but he did not suggest, how investment base should be set. This paper suggests that investment base for a firm rate of return should be the actual amount of available funds. This way, the actual firm rate of return can be generated in a project.

In respect of the statement 3, the existing methods fail to reflect construction market reality, when there is the limitation on the use of operating cash flows. For example, the market convention on the use of interim cash flows in risk-sharing projects such as co-investment partner is that interim cash flows from development projects should be kept on the low-risk money market until projects are completed. This implies that reinvestment rate may be significantly lower than firm opportunity rate. In this case, NPV is not an appropriate measure for evaluating those development projects. To this end, this paper takes the modified incremental wealth approach.

Despite incorporating the above two conditions, there is still a more fundamental question left. It is related to the statement 1, investment base or stream should be determined not by tools, but by a firm decision maker. In other words, how much to invest is up to a firm, not to a theoretician or a tool as McDaniel *et al.* (1998) suggested. By separating investment stream from return stream, an investment decision-maker can measure the actual investment base. Doing so, the rate of return and present value calculated based on those, can be more reliable and accurate investment performance measures. It is because existing RR methods and PV methods make arbitrary assumptions on investment base such that MIRR assumes the present value of negative net cash flows as investment base and ORR assumes the minimum required funds as investment base. This difference among the tools in assuming investment base is illustrated in Table 4.

Table 4. Comparison of the investment bases between MIRR, ORR, and actual case

Period	NCF	MIRR case		ORR case		Actual case	
		IS	RS	IS	RS	IS	RS
0	(16.00)	(16.00)	0.00	(16.00)	0.00	(16.00)	0.00
1	1.10	0.00	1.10	0.00	0.00	(3.90)	5.00
2	(2.42)	(2.42)	0.00	(1.21)	0.00	(7.42)	5.00
3	20.00	0.00	20.00	0.00	20.00	0.00	20.00

* note: IS: Investment Stream, RS: Return Stream, NCF: Net Cash Flow

Suppose that in the case of Actual Case minimum operating cash flows are kept in the project. The investment stream of MIRR is {–16, 0, –2.42, 0}, which is a negative net cash flow by its definition, and the investment stream of ORR is {–16, 0, –1.21, 0}, which is minimum required funds by its definition. Although their investment streams are different from each other, their net cash flows are the same since the sum of investment stream and return stream is the net cash flow. However, these 2 investment streams are not the actual investment base: {–16, –3.9, –7.42, 0}. How can we assert that MIRR and ORR based on the hypothetical investment bases provide the correct return measure? This is the pitfall of net cash flow approach. The investment stream are included in the net cash flow but may not be extracted from the net cash flow without a proper procedure. It is critical to consider the actual investment base and streams in the investment decision tools since we measure returns based on investment. As discussed in the preceding paragraphs, 3 aspects regarding construction market reality, especially the actual investment base, call for a new method, which shall reflect the real market practices, not hypothetical ones.

6. Project present value

NPV has the limitation in incorporating reinvestment practices in a certain industry. GNPV (Beaves 1993) reflects these practices by taking the incremental wealth approach. However, GNPV still does not incorporate the actual amount of investment, since it assumes the investment base as the minimum required fund. In other words, GNPV may be not a reliable measure when an investment base is incorrect. To resolve this issue, we need separate the actual investment stream from the return stream. Fig. 2 describes intertemporal NPV model, which will help deriving a new PV method.

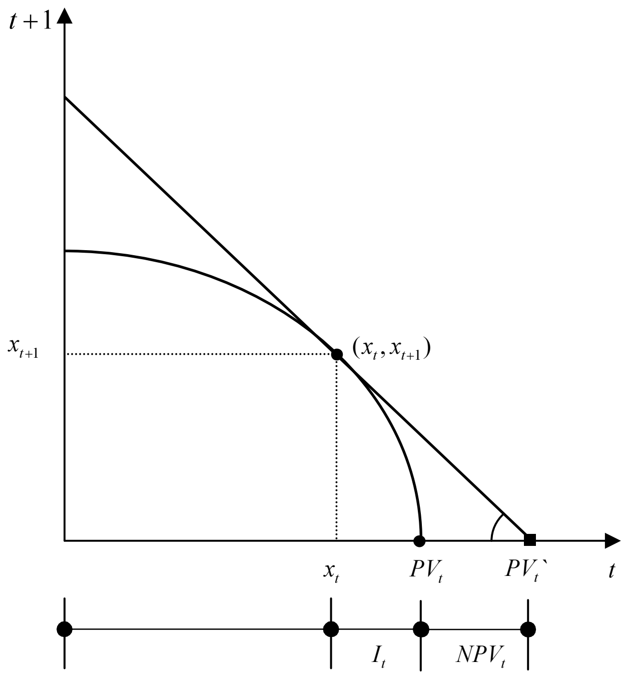

Fig. 2. NPV at t period

First, consider the present value of firm's wealth at t when undertaking a project.

$$PV'_t = x_t + \frac{x_{t+1}}{(1+r_{t+1})^t}.$$

Second, consider the present value of firm wealth at t, when not undertaking a project, which is PV_t on x-axis (Fig. 2).

Lastly, subtract $PV`_t$ from PV_t to measure incremental amounts of the present value of firm wealth. Then, NPV formula for q project would be

$$NPV_q = \sum_{t=0}^{n} \frac{(PV'_{t,q} - PV_{t,q})}{(1+r_{0,t})} = \sum_{t=0}^{n} \frac{x_t + \frac{x_{t+1}}{(1+r_{t+1})^t} - PV_{t,q}}{(1+r_{0,t})},$$

since $PV_{t,q} - x_t$ is considered as the investment at t (I_t), which is the amount of money transferred to the next period, and $x_{t+1}/(1+r_{t+1})^t$ can be defined as return in next period (R_t).

$$NPV_q = \sum_{t=0}^{n} \frac{R_{t,q} - I_{t,q}}{(1+r_{0,t})^t} = \sum_{t=0}^{n} \frac{R_{t,q}}{(1+r_{0,t})^t} - \sum_{t=0}^{n} \frac{I_{t,q}}{(1+r_{0,t})^t},$$

where I_t – investment amount at t period, R_t – return at t period $R_{0,t}$ – lending or borrowing rate between 0 and t period

After separating investment stream and return stream, we need to define investment base as $IB_q = \sum_{t=0}^{n} I_{t,q}(1+r_{0,t,})^{-t}$ and return base as $RB_q = \sum_{t=0}^{n} R_{t,q}(1+r_{t,n})^{n-t}$. The above equation can be restated into

$$NPV_q = -\sum_{t=0}^{n} \frac{I_{t,q}}{(1+r_{0,t})^t} + \sum_{t=0}^{n} \frac{R_{t,q}(1+r_{t,n})^{n-t}}{(1+r_{0,n})^n} =$$

$$-IB_q + RB_q(1+r_{0,n})^{-n}.$$

If firm opportunity cost and reinvestment rate are different, no PV method, including NPV, holds. As Beaves (1989) argues, that even if $(1+k)^n = (1+r_{t,n})^{n-t}(1+r_{0,t})^t$ does not hold, a decision based on NPV does not necessarily maximize the firm value (Beaves 1988). In this circumstance the incremental wealth approach would be more appealing to practitioners since at least it correctly considers reinvestment rate. In GNPV, Beaves assumes $r_{0,t}$ and $r_{t,n}$ as reinvestment rate and $r_{0,n}$ as firm opportunity cost. However, it is not clear why investment base should be discounted at reinvestment rate. Instead, this paper suggests that only the return stream is compounded at reinvestment rate, and investment stream and return base (not return stream) are discounted at firm opportunity cost. In this way, PPV is be more incremental since the incremental wealth approach regards n numbers of cash flows as 2 cash flows: investment base and return base. The final form of PPV is

$$PPV_q = -IB_q + RB_q(1+k)^{-n}, \quad (5)$$

where $IB_q = \sum_{t=0}^{n} I_{t,q}(1+k)^{-t}$, $RB_q = \sum_{t=0}^{n} R_{t,q}(1+r)^{n-t}$, k – firm's opportunity cost, r – project reinvestment rate.

If reinvestment rate and firm opportunity cost are the same, NPV, GNPV, and PPV would generate the same value because all 3 methods are equivalent. However, NPV, GNPV, and PPV would produce different values, when these 2 rates are different, as illustrated in Table 5. Interpreting the results, the actual case is the least profitable because it requires more capital investment than the other 2 methods assume.

Here, it is required to go over how market reality is dealt with in line with the 3 statements. In connection with the statement 1, separating investment stream allows PPV to measure the actual investment base. Regarding the statement 2, PPV assumes that the amount of money less investment base is invested or raised at firm opportunity cost, if firm's available funds are more or less than investment base. In this way, PPV of the remaining capitals would be zero. Thus, the available funds concept and the property of NPV for the virtue of separation theorem, independence from investment base and time horizon, still are reflected in the proposed method. Pertaining to the statement 3, the proposed method opens the possibility of the difference between reinvestment rate from firm opportunity cost by taking the increment wealth approach.

Table 5. Comparison between NPV, GNPV, and PPV

Period	Base case	NPV case		GNPV case		PPV case (Actual)	
		IS	RS	IS	RS	IS	RS
0	(16.00)	(16.00)	0.00	(16.00)	0.00	(16.00)	0.00
1	1.10	0.00	1.10	0.00	0.00	(3.90)	5.00
2	(2.42)	(2.42)	0.00	(1.25)	0.00	(7.42)	5.00
3	20.00	0.00	20.00	0.00	20.00	0.00	20.00
Investment base		(18.00)		(17.04)		(25.68)	
Return base		21.33		20.00		30.92	
Return measure		(1.97)		(2.01)		(2.45)	

* note: firm opportunity cost is 10%, reinvestment rate is 6%

Table 6. Comparison among MIRR, ORR, and PRR

Period	Base case	MIRR case		ORR case		PRR case (Actual)	
		IS	RS	IS	RS	IS	RS
0	(16.00)	(16.00)	0.00	(16.00)	0.00	(16.00)	0.00
1	1.10	0.00	1.10	0.00	0.00	(3.90)	5.00
2	(2.42)	(2.42)	0.00	(1.21)	0.00	(7.42)	5.00
3	20.00	0.00	20.00	0.00	20.00	0.00	20.00
Investment base		(18.00)		(17.00)		(25.68)	
Return base		21.33		20.00		31.55	
Return measure		5.82%		5.57%		7.11%	

* note: firm opportunity cost and reinvestment rate are the same at 10%

7. Project rate of return

Developing PRR is relatively simple since we already derived PPV. In the course of deriving PPV, how investment and return stream and reinvestment rate should be dealt with it has already been discussed in detail in the preceding section. Similarly to PPV, investment stream should be separated from return flow and discounted at firm opportunity cost, and return stream should be compounded at reinvestment rate to consequently generate the investment base and return base. The investment efficiency measure of a project that has 'm' period of life would be

$$PRR_q = \left[\frac{RB_q}{IB_q}\right]^{1/m} - 1, \qquad (6)$$

where $IB_q = \sum_{t=0}^{m} I_{t,q}(1+k)^{-t}$ and $RB_q = \sum_{t=0}^{m} R_{t,q}(1+r)^{m-t}$

t: cash flow timing, q: project number, r: reinvestment rate, m: project time horizon.

Even if reinvestment rate and opportunity costs are assumed to be the same, the results from MIRR, ORR, and PRR are different, as shown in Table 6. This is due to the differences in the investment base of each method. The assumed investment base in MIRR case is 18, which is the present value of negative net cash flow. The assumed investment base in ORR case is 17, which is the present value of minimum required funds. However, those 2 cases are not the actual investment base that PRR takes. Thus, PRR produces a more reliable rate of return than other methods because the better measure of investment base means the better measure of return rate of.

It may be argued that PRR overestimates the rate of return of the unprofitable project compared to MIRR and ORR. It seems plausible considering that PPV on this project yields the least value of 3 methods discussed. However, the reason why PRR produces the highest is that the more money invested in the project than the other two, are reinvested at 10% higher rate than its yield, 7.11%. If a profitable project is examined instead, PRR will produce the least value of MIRR, ORR, and PRR.

8. Firm rate of return

Before developing a RR method of PV consistent ranking, it should be noted why PV methods are the better measures of rankings than RR methods even under unequal-sized and uncommon time horizon. In the size issue, NPV is independent of investment base because NPV of raising funds and investing funds are assumed to be zero. In addition, the time issue is simply irrelevant to NPV since NPV value does not change no matter how many years of a project time period are extended as long as reinvestment rate and opportunity cost are the same. As discussed in the PPV section, PPV has also the property of NPV, independence from investment base and time horizon, if it are assumed as PPV = 0 to raise and invest funds that is more or less than the amount of money required investing available projects.

In contrast, the investment base and time of PRR are project specific since PRR evaluates investment efficiency at the project level, not the firm level. When the ranking comparison among projects is needed, the equal size and time horizon need to be assumed as PPV does. As mentioned earlier, there are 2 ways to overcome the ranking problem in a RR method: Incremental Method (Bernhard 1989) and Scale Adjusted Return Method (Shull 1992). Since Bernhard method requires ${}_nC_2 = n!/2!(n-2)!$ comparisons to rank n projects, SAR approach is more efficient way of ranking projects. By incorporating the equal size and the equal time horizon assumptions into PRR method, we can produce a modified SAR method, which will be called as Firm Rate of Return hereunder.

Suppose that the life of 'q' project is m-period, and the common time horizon is n-period, where $n>m$. Investment performance at the firm level would be

$$FRR_q = \left[(RB_q(1+k)^{n-m} + (IB_c - IB_q)(1+k)^n)/IB_c\right]^{(1/n)} - 1, (7)$$

where $IB_q = \sum_{t=0}^{m} I_{t,q}(1+k)^{-t}$, $RB_q = \sum_{t=0}^{m} R_{t,q}(1+r)^{m-t}$,

and $IB_c \in (Max\{0, -PPV_q\}, +\infty)$

In the formula, IB_c is the firm available funds. If the firm level of investment efficiency needs to be calculated, IB_c should be the denominator instead of project q's investment base. Since the project has m periods, the return base of it is the sum of interim cashflows reinvested to the m period. FRR, however, assumes the period of return as n periods for the purpose of comparison. Thus, R_B should be assumed to be reinvested at k for the difference period (*n-m*), and IB_c less IB_q also should be assumed to be invested at k for n periods. Consequently, the return base compounded at k for n-m plus the firm available funds less project's investment base (IB_c–IB_q) compounded at k for n should be the nominator. In this way, we can measure the firm rate of return based on the common investment base and common time horizon. In addition, FRR includes Miroslaw's work (1996) on the feasible range of firm available funds to allow for a more flexible capital assumption. Since this paper considers only investment projects, the feasible range of firm available funds would be between $\text{Max}\{0,-PPV_q\}$ and $+\infty$.

FRR generates different values from SAR, when investment base is different. The most significant difference arises when reinvestment rate and firm opportunity cost are different as in Table 7. For instance, Project A's FRR is 9.96%. In contrast, Project A's SAR is 9.97%. This difference arises from the reinvestment rate of 6%. Since SAR does not consider reinvestment rate, RB of SAR and RB of FRR are different as much as the sum of future values of interim cashflow reinvested at 10% less than that at 6%.

Table 7. Comparisons among PPV, PRR, and FRR (IBc = 2,500)

Proj.	PPV	PRR	FRR	SAR
A	–2.45	6.39%	9.96%	9.97%
B	1417.36	15.83%	27.76%	28.66%
C	8.18	71.88%	10.12%	10.12%

* note: Opportunity cost is 10% and reinvestment rate is 6%

Regarding the ranking problem, FRR provides not only PPV consistent decision signal but also PPV consistent rankings. As shown in Table 7, the ranking by the money measure PPV is B>C>A, but the ranking by PRR is C>B>A. This is because PRR is the investment efficiency measure of a project, that is, more precisely, one of the investment base of it. However, FRR generates the same ranking as PPV: B>C>A. The fact that FRR ranking is better than PRR can be explained by the rationale that we are interested in the amount of money earned by taking projects, not the efficiency itself of investment. Suppose that there are 2 options: project S in which the return on the investment of $1 is $11, which means the rate of return is 1000%, while project R in which the return on the investment $10 is $30, which means the rate of return 200%. If we have enough money to invest in both projects but should choose only one of 2 options, which one would we choose? The answer should be Project R.

9. Verifying the proposed tools

The proposed tools: PPV, PRR, and FRR are to be verified according to the following 5 criteria.

1. Is market reality appropriately dealt with?
2. Does the proposed RR method yield a unique rate of return?
3. Does the proposed RR method generate the consistent decision with a proposed PV method?
4. Does the proposed RR method provide the same rankings with a proposed PV method?

10. Market reality

Under the delivery system with risk-sharing structure with construction companies, normally developers cannot withdraw project net cash from the project during the construction period. This is because the contract convention under this structure tends to lay the limit on developer's withdrawing money from the project except for construction progress payement until the construction project completes. The implication from this business practice in this type of setting is that the reinvestment of positive net cash flow from the project is inherently limited for reinvesting other projects. In other words, the reinvestment of net cash flow is much lower than the firm's opportunity cost because operating cash in the project is allowed to keep usually in the safe instrument such as saving account or the money market fund. Regarding investment base, PPV, PRR, and FRR represent the actual investment stream. There is no arbitrary assumption on investment stream, which is found in MIRR and ORR. In addition, when calculating FRR, we use the actual available funds, not the largest amount as SAR assumes.

Three aspects of market reality are all reflected in the proposed methods, so the tools can capitalize more actual situation. For this reason, the proposed tools provide the actual measure of incremented money, rate of return for the project, and rate of return for the firm.

11. Unique rate of return

Unlike IRR, PRR and FRR provide a unique rate of return. Not being the high degree equation as seen in Eqs (6) and (7), PRR and FRR take only one value between –1 and $+\infty$.

12. PPV consistent decision signal

Both PRR and FRR signal the same decision with PPV. Suppose that project time horizon is m and firm's planning horizon is n.

First, consider PRR. If $PPV_q > 0$, then this inequality becomes

$$-IB_q + RB_q(1+k)^{-m} > 0 \Leftrightarrow \left[\frac{RB_q}{IB_q}\right]^{1/m} - 1 > k \Leftrightarrow PRR_q > k. \tag{8}$$

This inequality implies that PRR is greater than firm opportunity cost when PPV is greater than zero, which means PRR signals the same decision with PPV.

Second, consider FRR. If (1+*k*) is separated from the 1/*n* squared term, the formula would be

$$FRR_q = \left[(RB_q(1+k)^{n-m} + (IB_C - IB_q)(1+k)^n)/IB_c\right]^{(1/n)} - 1 =$$
$$(1+k)\times\left[(RB_q(1+k)^{-m} + IB_C - IB_q)/IB_c\right]^{(1/n)} - 1.$$

If $PPV_q > 0$, then

$$-IB_q + RB_q(1+k)^{-m} > 0 \Leftrightarrow RB_q(1+k)^{-m} > IB_q,$$

and Inequality (9) holds.

$$FRR_q > (1+k)\times\left[(IB_q + IB_C - IB_q)/IB_c\right]^{(1/n)} - 1 \Leftrightarrow FRR_q > k, \quad (9)$$

which means that FRR is greater than firm's opportunity cost, when PPV is greater than zero. Thus, FRR also provides the same decision signal with PPV.

13. PPV consistent rankings

Suppose that the life of Project A and B m, *n*-periods respectively, where *n* is greater than m. The FRR formula can be modified as

$$-IB_C(1+FRR_A)^n + RB_A(1+k)^{n-m} + (IB_C - IB_A)(1+k)^n = 0.$$

Now, think of modifying PPV_A as

$$-IB_C(1+k)^n + RB_A(1+k)^{n-m} + (IB_C - IB_A)(1+k)^n = PPV_A(1+k)^n$$

and subtracting the former from the latter. It produces

$$PPV_A(1+k)^n = IB_C\left[(1+FRR_A)^n - (1+k)^n\right].$$

If we develop $PPV_B(1+k)^n$ in the same manner, and subtract $PPV_B(1+k)^n$ from $PPV_A(1+k)^n$, then we get

$$(1+k)^n\left[PPV_A - PPV_B\right] = IB_C\left[(1+FRR_A)^n - (1+FRR_B)^n\right].$$

Since the interest is in the ranking, we need to exam the sign of $PPV_A - PPV_B$. The sign of the left term $\left((1+k)^n[PPV_A - PPV_B]\right)$ would be the same as the sign of $(PPV_A - PPV_B)$ because the term $(1+k)^n$ is positive. Also, the sign of the right term $IB_C\left[(1+FRR_A)^n - (1+FRR_B)^n\right]$ is the same as the sign of $(FRR_A - FRR_B)$, since IB_c is assumed to be positive. Thus, the sign of $PPV_A - PPV_B$ would be the same as that of $FRR_A - FRR_B$, which means that PPV and FRR provide the same ranking as shown in Eq (10).

$$\text{sgn}\left[PPV_A - PPV_B\right] = \text{sgn}\left[FRR_A - FRR_B\right]. \quad (10)$$

14. Fewer assumptions

Table 8 compares the proposed tools with the existing ones. As illustrated, the proposed tools have fewer assumptions so that they can reflect reality of market, and at the same time they are free from the problems that are found in NPV and IRR. For example, NPV assumes reinvestment rate as firm opportunity rate, but, as discussed, in the construction market it is impossible due to its reinvestment practice. In contrast, PPV does not make any assumption on reinvestment. In connection with investment base, ORR and SAR assume investment base as

Table 8. Comparison among various tools

		NPV	IRR	GNPV	ORR	SAR	PPV	PRR	FRR
Assumptions	Reinvestment Rate	Firm's Opportunity Cost	IRR	Not Assumed	Not Assumed	Firm's Opportunity Cost	Not Assumed	Not Assumed	Not Assumed
	Investment Base	Not Assumed	Unspecified	Minimum Required Funds	Minimum Required Funds	The Largest MRF	Not Assumed	Not Assumed	Not Assumed
	Time Horizon	Not Assumed	Project Horizon	Project Horizon	Project Horizon	Not Assumed	Not Assumed	Project Horizon	Not Assumed
PV consistency & Unique rate	PV-Consistent Decision	…	No	..	Yes	Yes	…	Yes	Yes
	PV-Consistent Ranking	…	No	…	NO	Yes	…	NO	Yes
	Unique Rate of Return	…	No	…	Yes	Yes	…	Yes	Yes
Market Reality	Actual Reinvestment Rate	No	No	Yes	Yes	No	Yes	Yes	Yes
	Actual Investment Base	Yes	No	No	No	No	Yes	Yes	Yes
	Actual Available Funds	Yes	No	No	No	Yes	Yes	No	Yes

* note: MRF: Minimum Required Funds

minimum required funds and the largest minimum required funds for projects respectively. However, PRR and FRR do not make any assumption on investment base. In this way the proposed method can reflect actual reinvestment rate, actual investment base, and actual available funds without assumptions. More importantly, the proposed methods are integrated with each other since PPV because these 3 tools are based on the same assumption set illustrated Table 8 and the same approach: modified incremental wealth approach. For instance, the proposed methods do not assume any of 3 important assumptions except for PRR time horizon. Furthermore, the proposed PV method and RR methods provide the same decision signal and ranking, as discussed earlier, but PV-consistent ranking can be only applied to FRR. PRR does not provide PV-consistent rankings since its investment base and time horizon are project specific. However, PRR is also important since a project specific rate of return may be required when a firm only looks into rate of return due to unlimited access to outside funds. Regarding the difference among PPV, PRR, and FRR, it should be noted that PPV is a scale and time independent money measure. FRR has the same qualities of independence with PPV. For this reason, FRR are firm's rate of return on funds available from a firm, and it can be used in the same way as PPV. However, FRR shows us the rate of return, which is more intuitively clear than money measure.

15. Investment decision through PPV, PRR, and FRR

As discussed in the previous section, the proposed methods release 3 assumptions of reinvestment rate, available fund, and investment base. Releasing three assumptions in PPV, PRR, and FRR differentiate investment decision procedure from the existing one.

Fig. 3 describes these 3 points in the investment decision procedure of construction projects. The first point in the procedure is that the proposed methods consider how reinvestment practice in a certain project is conducted. This is mainly related to the limitation on the use of cashflow, which is mostly determined by the type of a business and the position in the business. For instance, contract and sole type of construction business usually do not carry the limitation on the use of cashflow. In contrast, partnership and corporation type of construction business usually have the limitation. If reinvestment practice requires setting a different rate from firm opportunity cost, estimating reinvestment rate is required. When construction company and development company do a business together, the construction company delegates a part of risks by borrowing money from banks to fund its development project in some cases. For this reason, constructors usually lay the limit on the use of cashflow during construction for the safe of the project, and the cashflow from this project is invested in the money market, which is relatively a low risk, until the project ends. In this case, the reinvestment rate during construction period should be the yield of money market. The overall reinvestment rate for the project duration can be the averaged money market yield and firm opportunity cost.

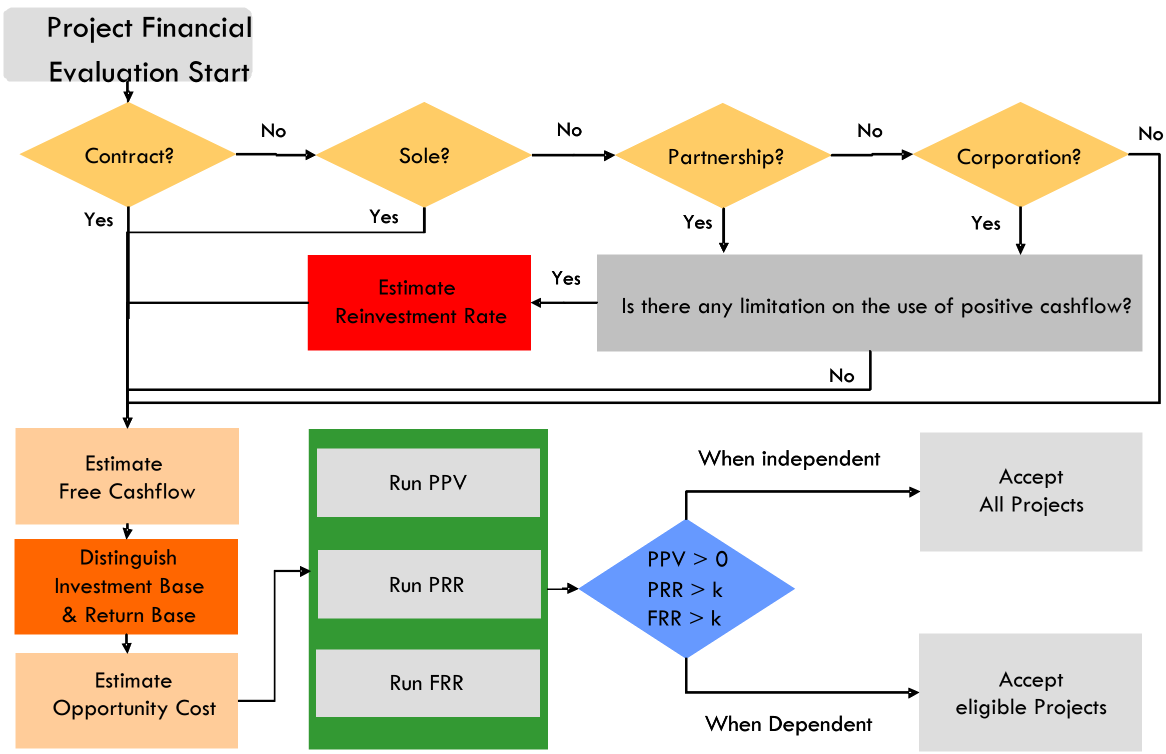

Fig. 3. Investment Decision Procedure using PPV, PRR, and FRR

At the second point, the actual amount of firm's available funds should be estimated for calculating more accurate investment base at the firm level. In this stage a firm should decide how much available funds for projects are there and how much funds should be raised. This procedure is required regardless of types of construction businesses. The funds need not be all available money of a firm, but need to be the funds available for projects in the selection frame. It is because we want to measure the firm level of investment efficiency within the project in questions.

Lastly, the proposed methods require separating investment stream from return stream in the first place, which is also necessary for all projects regardless of situations. The criteria in distinguishing investment from cost should be carefully prepared according to firm policy because funding by the return from the project may reduce the actual amount of funds contributed by the firm. The one good solution can be the source of spent cost. For example, if cash out is from the return from projects, it is a cost. However, if it is from firm treasury or firm other projects, it should be an investment. In this way, practitioners can measure the actual investment amount and calculate more economically meaningful return measure. With the exception of 3 described points, the rest of the procedure is the same.

16. Further study

PPV, PRR, and FRR assume the use of unlimited other resources such as human resource. As long as PPV > 0, PRR and FRR > k, the project in question is accepted. However, reality is more complicated. However, other resources required for a project may be limited. In this circumstance, decision-makers encounter the situation that profitable projects should be rejected based on the limited resource. The proposed method and the investment decision procedure for these tools should reflect these kinds of complex situations involved in investment decision by considering resource constraints other than monetary values. In addition, construction projects carry more risks than other industries in average, so risk factors such as uncertainty of cashflow (Hazen 2009, Ye and Tiong 2000) also need to be considered. Another extension of further study will be the option evaluation, which is currently discussed by De Reyck *et al*. (2008) and Keswani and Mark (2006).

17. Conclusion

The efforts to develop more reliable investment decision tools have led to GNPV, MIRR, ORR, and SAR, all of them produce more meaningful return measure than NPV and IRR in many aspects. However, these tools are not designed to work in an integrated way. To be integrated, PV methods and RR methods should be based on the same assumption set and follow the same approach. The proposed method: IPPV, PRR, and FRR take the modified incremental wealth approach, which works well on the construction market where the reinvestment rate in most projects are lower than firm's opportunity cost, and cashflow is non-conventional. Concerning the same assumption set, PRR corresponds with PPV because the same reinvestment rate is assumed, and FRR is in concord with PPV in every aspect because the same investment base and time horizon are assumed. This explains why the proposed method is capable of being free from inconsistency problems and multiple or no IRR problem.

More importantly, distinguishing investment and return streams allow reflecting the actual investment amount which is not possible in GNPV, ORR, and SAR where arbitrary assumptions are made on investment base as a minimum required fund and MIRR as the present value of negative cashflow. a rate of return based on an arbitrary investment base may be consistent with NPV in deciding between 'Go' and 'No Go' only if the reinvestment rate assumption of the PV method and RR method is the same. However, it is difficult to say that the result generated shows a correct value due to the incorrect investment base. Eliminating this arbitrary assumption through distinguishing investment stream and return stream, the proposed method can generate more economically meaningful indices for investment decision.

In sum, integrating PV and RR method by a modified incremental wealth approach and distinguishing investment stream and return stream render the proposed method to work as more accurate and meaningful indices for the project financial valuation. In addition, proposing this method and procedure will provide more discretion for investment decision-makers to control some variable that is before assumed to be fixed in the existing tools and more opportunities for investment decision-makers' choosing various methods.

Reference

Beaves, R. G. 1988. Net present value and rate of return: implicit and explicit reinvestment assumptions, *The Engineering Economist* 33(4): 275–302. doi:10.1080/00137918808966958

Beaves, R. G. 1993. The case for a generalized net present value formula, *The Engineering Economist* 38(2): 119–133. doi:10.1080/00137919308903091

Bernhard, R. H. 1989. Base selection for modified rates of return and its irrelevance for optimal project choice, *The Engineering Economist* 35(1): 55–65. doi:10.1080/00137918908903003

Bussey, L. E. and Eschenbach, T. G. 1992. *The economic analysis of industrial projects.* 2nd Ed., Prentice-Hall, New Jersey.

De Reyck, B.; Degraeve, Z., and Vandenborre, R. 2008. Project options valuation with net present value and decision tree analysis, *European Journal of Operational Research* 184(1): 341–355. doi:10.1016/j.ejor.2006.07.047

Graham, J. and Harvey, C. 2002. How do CFOs make capital budgeting and capital structure decisions? *Journal of Applied Corporate Finance* 15(1): 8–22. doi:10.1111/j.1745-6622.2002.tb00337.x

Hajdasinski, M. M. 1996. Adjusting the modified internal rates of return, *The Engineering Economist* 41(2): 173–186. doi:10.1080/00137919608967484

Hartman, J. C. and Schafrick, I. C. 2004. The relevant internal rate of return, *The Engineering Economist* 49(2): 139–158. doi:10.1080/00137910490453419

Hazen, G. B. 2003. A new perspective on multiple internal rates of return, *The Engineering Economist* 48(1): 31–51. doi:10.1080/00137910308965050

Hazen, G. B. 2009. An extension of the internal rate of return to stochastic cash flows, *Management Science* 55(6): 1030–1034. doi:10.1287/mnsc.1080.0989

Keswani, A., and Mark, B. S. 2006. How real option disinvestment flexibility augments project NPV, *European Journal of Operational Research* 168(1): 240–252. doi:10.1016/j.ejor.2004.02.028

Lin, S. A. Y. 1976. The modified rate of return and investment criterion, *The Engineering Economist* 21(4): 237–247. doi:10.1080/00137917608902796

Mc Daniel, W. R.; McCarty, D. E., and Jessell, K. A. 1988. Discounted cash flow with explicit reinvestment rates: Tutorial and extension, *The Financial Review* 23(3): 369–385. doi:10.1111/j.1540-6288.1988.tb01276.x

Shull, D. M. 1992. Efficient capital project selection through a yield-based capital budgeting technique, *The Engineering Economist* 38(1): 1–18. doi:10.1080/00137919208903083

Shull, D. M. 1994. Overall rates of return: investment base, reinvestment rates, and time horizon, *The Engineering Economist* 39(2): 139–163. doi:10.1080/00137919408903118

Ye, S. and Tiong, R. L. K. 2000. NPV-at-risk method in infrastructure project investment evaluation, *Journal of Construction Engineering and Management* 126(3): 227–233. doi:10.1061/(ASCE)0733-9364(2000)126:3(227)

STATYBOS PROJEKTŲ ĮVERTINIMO METODAI

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Santrauka

Finansiniai įvertinimo metodai, kaip dabartinės vertės (DV) arba vidinės grąžos (VG), neadekvačiai vertina tris praktinius statybos projektų aspektus: reinvestavimo greitį, tikrąjį investicijų ir kapitalo poreikį. Dėl to neadekvatumo tam tikrai projektų rūšiai minėtųjų metodų iš viso neįmanoma pritaikyti. Sukurta daug modifikuotų metodų, tačiau jie sunkiai atspindi statybos rinkos tikrovę integruota forma. Tam pasiūlyta investicinių sprendimų sistema, į kurią integruoti trys metodai: dabartinės projekto vertės, projekto vidinės grąžos ir įmonės apyvartumo. Pasiūlytieji metodai gali įvertinti rinkos realybę. Dabar statybos gamybininkai turės patikimesnes ekonomiškai reikšmingas priemones sprendimams priimti ir galės sėkmingiau įgyvendinti savo projektus.

Reikšminiai žodžiai: finansų valdymas, investicijos, sprendimų priėmimas.

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