Rate of Return – Must We Bother?

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Abstract

Rate of return (ROR) is a widely accepted criterion for determining the economic viability of an engineering project or other investment alternative. Similarly, incremental rate of return (IROR) is often used to choose the best alternative among several. Accordingly, most engineering economy textbooks provide appreciable instruction in ROR and IROR applications, often covering one or two chapters of text. As a result, computation of the ROR is certainly within the grasp of most engineering economy students. Even so, the underlying methodologies of ROR assessment and IROR selection are computationally more difficult than other economic methods, and results can be ambiguous, indeterminate and, unless used with care, misinterpreted. For example, students will often apply, without discernment, the oft-quoted decision rule, “If the ROR > MARR, accept the alternative …” and they are sometimes wrong.

Since our engineering economic textbooks offer such a variety of topics, it begs the question “How much ROR (and IROR) instruction is necessary and truly beneficial for the undergraduate engineering student?” This paper explores possible answers to that question and its more pointed companion, “ROR – Must We Bother?” Advantages and potential disadvantages (and disbenefits) of “staying the course” with the current ROR/IROR emphasis are considered. Alternatively, a more innovative trail is suggested that seeks a better balance between engineering economy fundamentals and (applied) economic decision analysis.

Introduction

The fundamental purpose of a course in engineering economy is to provide students with the tools to (i) make effective assessments of engineering projects and other investment alternatives, and to (ii) select the best project from a mutually exclusive set. As suggested in Figure 1, (engineering) economic decision making requires but a few basic steps. But, there are various methods for making project assessments and selection including Present Worth, Annual Worth, Benefit-Cost Ratio and Rate of Return analyses.

Provided the cash flow diagram of a project opportunity is available, its present worth may be determined by solving the following equation:

\[ \text{PW}[i] = \sum [S_t/(1+i)^t] \]

Here “i” is an appropriate interest rate, the \( S_t \) are cash vectors (some positive, some negative) at time \( t \), and the summation extends over the life of the project, i.e., for \( t = 0, 1, \ldots N \).
Annual worth of a project is the magnitude of an annuity equivalent, in an economic sense, to a project’s cash flow diagram. It is usually easier to determine its value from the project’s present worth given by eqn. (1); i.e.,

\[ \text{AW}[i] = \text{PW} \cdot \left[ (i \cdot (1+i)^N) / ((1+i)^N - 1) \right] \]  

(2)

The benefit–cost ratio of a project is defined as the ratio of the present worth of (project) benefits to the present worth of (project) costs; in equation form, this ratio can be expressed as:

\[ \text{BCR}[i] = \sum \left[ S_t^+ / (1 + i)^t \right] / \sum \left[ |S_t^-| / (1 + i)^t \right] \]  

(3)

Here, the summation in numerator is restricted to (only) positive cash vectors, and the summation in the denominator is restricted to the (absolute magnitude of only) negative cash flow vectors. Both summations extend over all values of \( t \).

Finally, a project’s rate of return, ROR, is defined as the interest rate, \( i^* \), that equates the investment’s present worth to zero. That is, one must solve the following equation for \( i^* \):

\[ \text{PW}[i^*] = \sum \left[ S_t / (1 + i^*)^t \right] = 0 \]  

(4)
It is significant that AW, BCR, and ROR calculations all relate directly to the PW equation (1), all four calculations depend on the cash flow diagram, and all are affected by an interest rate used to discount cash flows to their present-day equivalency.

Assessment of Project Alternatives

Frequently quoted decision rules for assessing the economic viability of an investment alternative (or project) are the following:

- Accept the project if… $PW[i] > 0$ ;
- Accept the project if… $AW[i] > 0$ ;
- Accept the project if… $BCR[i] > 1$ ;

and,

- Accept the project if… $ROR = i^* > MARR$. 

The MARR is often defined as the minimum attractive rate of return that an investor is willing to accept; some firms refer to it as their “hurdle rate,” i.e., the (annual) percentage return that a project must achieve before money is allocated. In principle, it is the same interest rate used in PW, AW and BCR computations.

Properly applied, each of the four decision rules (5) lead to a consistent decision, i.e., whether to accept or reject the project. However, problems can arise when the ROR decision rule is used indiscriminately. For example, when the project’s cash flow diagram suggests a borrowing condition (i.e., positive cash vectors precede negative cash vectors), simple application of the ROR rule will lead to an erroneous conclusion. And, occasionally, solution to equation (4) results in multiple rates of return that lack a clear-cut conclusion. The following example problem is suggestive of such a dilemma.

Example. A paper company anticipates leasing timberland to harvest lumber. Initial costs are $100K to establish the site. In successive years (1-5), net income will be $50K, $75K, $100K, $75K, and $50K. In the 6th year, reforestation and site improvements will cost the firm $290K. Is this a good investment if the firm’s MARR is 5%?

Soln: Using eqn. (4), one might find the ROR of this investment to be (nearly) 9.5%. Or, a second ROR may be discovered near 41%. In either case, indiscriminate use of the ROR decision rule would support the investment. Yet, the investment’s PW, if evaluated at the MARR, is negative (-$13.5K) and the PW rule suggests that the investment be rejected. (The AW and BCR rules do likewise.) One reason for the ROR inconsistency (in this case) is the multiple RORs. Further investigation will show that the investment is economically viable (PW > 0) for discount (i.e., interest) rates between the two ROR values; otherwise not.

A more complete discussion of situations in which an ROR analysis will give conflicting or erroneous results can be found in certain of the references, particularly that of Wohl1. So, what’s a student to do?
Selecting Among Project Alternatives

Due to limited resources, economic decision makers must often select among mutually exclusive alternatives. When the (economic) life of each alternative is similar, the alternative with the greater present worth (PW) or greater annual worth (AW) is preferred. There is absolute consistency between these two methods of analysis. However, greater is not necessarily better in the case of BCR and ROR comparisons. Rather, to correctly apply the BCR and ROR methods for project selection, an “incremental” approach is required.

If the incremental cash flow difference between the alternative with the higher capital investment and its competitor is “acceptable” by either the BCR or ROR decision rules (5), then the former is (usually) preferred. Otherwise, the alternative with the lower capital investment is selected (or retained.) This one-to-one comparison must be repeated until all but one alternative is eliminated. That alternative is the preferred choice. Unfortunately, incremental rate of return (IROR) analyses can suffer the same pitfalls as ROR.

In a “random” survey of nine engineering economics textbooks (see Table 1), that were available on this author’s bookshelf, each cited the basic ROR decision rule of equation (5) in one form or another. However, while the ambiguities associated with multiple rates of return were cited in seven of the nine, in two, there was no mention! Of greater concern, the inconsistency in an ROR analysis when dealing with a “borrower’s cash flow” was noted in only two of the texts; in a third, a non-descript footnote suggested that PW or AW analysis be used when dealing with a “nonconventional” cash flow diagram. Hence, I am no longer surprised if a majority of my “economics-educated” environmental engineering and design students (i.e., those having completed a basic course in engineering economy) misapply the ROR rule when presented an assessment problem with an “unconventional” cash flow, such as suggested by the earlier example.

ROR/IROR – What should we educators do?

Each of the four analysis methods addressed earlier in the paper purport to resolve the same project decisions, namely,

(1) The Assessment Decision…is a specific project opportunity worthy of investment?
and,

(2) The Selection Decision…when resources are limited, which project(s) should be pursued?

If so, must all these analysis methods (and at least four others found in different textbooks) be included in a basic engineering economy course? Perhaps. All seem to have their place in preparing students for the world beyond. Within a firm’s organization, supervisors and workers may deal with costs on a day-by-day or period-by-period basis and relate best to AW assessments. Purchasing groups within the same firm compute PW valuations of services (and equipment) to determine an appropriate price to pay (in advance) for such services. But top management seems to prefer ROR analyses when deciding to which projects the firm’s limited funds should be appropriated. Indeed, establishment of a firm’s MARR often arises out of a
### Table 1. List of Engineering Economics Texts Surveyed

<table>
<thead>
<tr>
<th>Title</th>
<th>Authors</th>
<th>Publisher</th>
<th>Year</th>
</tr>
</thead>
<tbody>
<tr>
<td>Basic Engineering Economy</td>
<td>Steiner, H.M.</td>
<td>Books Associates</td>
<td>1989</td>
</tr>
<tr>
<td>Contemporary Engineering Economics</td>
<td>Park, C.S.</td>
<td>Prentice Hall</td>
<td>2002</td>
</tr>
<tr>
<td>Engineering Economy, Applying Theory to Practice</td>
<td>Eschenbach, T.G.</td>
<td>Irwin</td>
<td>1995</td>
</tr>
</tbody>
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The company’s need to allot limited funds to a group of projects that, in total, demand a greater investment. And, finally, since public service organizations must provide services (benefits) to the public and are less focused on “the bottom line,” a BCR analysis will – at times – be most appropriate. Consequently, there is good reason to include all four methods in our courses, at least to ensure that our students can perform the necessary computations reflected in eqns. (1-4).

But, is it necessary or, even, desirable to require that students be capable of employing all methods for alternative assessments... or, for alternative selections? ...even though each method, properly applied, results in the same conclusion? And, if not, why not?

Previously, Hartman² reported of a pilot study by Needy (and others) in which 27 engineering economy educators provided information on their course content. In all, 26 different topic areas were identified. These included Present Worth, Rate of Return, and Benefit-Cost Ratios. Annual Worth and Future Worth methods were not explicitly identified but, presumably, these topics were imbedded within the Present Worth content. Other topics of special appeal to the current writer were Sensitivity Analysis, Uncertainty & Risk Analysis, (Cost) Estimation, and Multi-attribute Analysis. The study concluded that engineering educators (particularly younger ones) are well challenged to identify and sufficiently cover the topic areas that serve our clients (principally, our students) best. While such choices are opportunities, they necessitate tough, and rather subjective, decisions.

In the context of this paper, should PW, AW, BCR and ROR instruction be maintained at current levels given the multitude of opportunities to enhance our curriculum? Whereas Hartman suggests a linear programming “knapsack” approach to formulate an “optimal” syllabus, I do not claim to have employed such a logical approach to address the question. Rather, I simply share an opinion.

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PW calculations are fundamental to all others and PW analyses are convenient for both project assessments and comparisons (when lives are equal.) It seems appropriate to retain PW instruction at current levels. AW analysis is consistent with all PW conclusions and, except for definition and interpretation, seems to offer little hindrance to a solid economic education. BCR methods are necessary for public decisions and, therefore, should be retained. But, what of ROR assessments and IROR selections?

Although widely accepted, even the most ardent proponents of ROR analysis would agree that the underlying methodology is computationally more difficult than other assessment methods. And, most would agree that results can be ambiguous (in multiple-ROR scenarios) and, unless properly interpreted, can lead to erroneous conclusions. Hence, at the outset, this writer would have favored restricting ROR instruction to the basic computation of equation (4) if only to prepare students for possible client biases. However, as suggested by Eschenbach, ROR may be the most convenient approach to rank alternatives when one is not certain of the interest rate to be used for the time value of money. Indeed, evaluation of a project by PW, AW or BCR methods requires determination of a discount rate that, in a dynamic and uncertain environment, can at best be known probabilistically. In such cases, the “Net PW vs. Interest Rate” diagram, often prepared when determining a project’s ROR, provides a practical assessment tool, e.g., see Figure 2. If the diagram is overlaid with the range or, better, a probabilistic description of the discount rate, the decision maker gains an appreciation of project worthiness not available by any other assessment method.

At least one text suggests that “the IROR method is an excellent tool for analyzing” multiple alternatives when the MARR is known. Perhaps so, but this writer is of a different opinion. In fact, I can think of no compelling reason to use (or provide instruction in) IROR for alternative selection or any other purpose. It is cumbersome to apply, it suffers from the same pitfalls as ROR analyses, and it is not convenient (nor necessary) for ranking. For a known discount rate (or MARR), it provides no more useful information than other methods, e.g., present worth. And, if discount rates are uncertain, comparison of more than two alternatives by IROR will be far more perplexing than a visual parametric graph of each project’s present worth plotted against interest rate, somewhat akin to Figure 2.

!["NPW vs Interest Rate" Diagram](image-url)

**Figure 2. "NPW vs. I" Diagram for the Example Problem.**
Should we retain instruction in ROR?… yes, an appropriate focus should be retained, if only for
the additional insights it provides our students (and ourselves.) But, retain IROR?… I think not,
because there are other, better ways to compare alternatives. Why DO we bother?

Conclusion

As E^3’s (i.e., engineering economy educators), we are “blessed” with a variety of methods for
economic assessment and selection of alternative projects. And, as was suggested by Hartman,
we have a variety of topical areas to which we can expose our students. Yet, Nachtmann^5 raises a
pertinent question: “Is the engineering economy student better served by mastering a higher
fraction of fewer topics or a lesser fraction of more topics?” Opinions are sure to vary.

In most course scenarios, students are well schooled in a variety of assessment and selection
methods. And, at the very least, the various economic parameters defined by equations (1-4)
should be introduced in a basic engineering economy course if only to enable future engineers to
understand and appease the will of their prospective managers and clients. However, this writer
prefers that emphasis be placed on a single method of assessment and selection no matter
whether the intent is to deepen or broaden the learning experience. And, this writer favors
present worth methods as much for their simplicity as for the foundation that PW provides the
alternative methods.

At an earlier ASEE conference, Hartman^6 spoke of an engineering economy curriculum that is
growing stagnant. His suggestions to enhance the curriculum included teaching engineering
economy in the context of decision analysis and design processes, and also to integrate research
advances. Nachtmann^5 and others suggest that an increased emphasis be placed on case studies.
But these are more, not less. While beneficial, such integrations will increase the challenge for
educators to identify and sufficiently cover appropriate topic areas that best serve our students.

So, how should we proceed? We can begin by identifying the redundant, the unnecessary, the
somewhat ambiguous topics of instruction found in our syllabi and “prune our tree” so that new
fruits of knowledge have opportunity to grow. As suggested first by Hartman^6, this writer favors
increased emphasis on defining and assessing all practical alternatives and, also, on post-
implementation analysis. Such would include the generation of alternatives and their relevant
cash flows, ideally, from descriptive case studies. Also, instruction would focus on selection of a
best alternative(s) not only from a pre-defined static scenario but also with consideration of
uncertainties in both static and dynamic environs where project opportunities (and their cash
flows) are apt to evolve over time. Finally, since few engineering decisions are made on the
basis of economics alone, multi-attribute analysis to address intangibles such as safety, reliability
and environmental impacts should be fundamental to our instruction.

Unless convinced otherwise, I intend to begin by pruning our tree of its IROR branch. Such a
small limb, but it is a beginning.
Bibliography


Biographical sketch

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Assoc. Prof. Mayer is a past Program Director of Ocean Engineering at USNA. He teaches courses in engineering design, economic decision making, and marine-related environmental engineering. Research interests relate to the application of statistics and operations research methods to the management, engineering and construction of ocean facilities. He previously served in the Civil Engineer Corps, USN, as an ocean engineer and diving officer.