ISE 2014 Chapter 4

Objective: To evaluate the economic profitability and liquidity of a single proposed problem solution.

Equivalent measures of a project's profitability	Measures of liquidity
Present Worth (PW)	Simple Payback Method (∅)
Future Worth (FW)	Discounted Payback Method (∅')
Annual Worth (AW)	Investment Balance
Internal Rate of Return	

Section 4.1 What are We Measuring?

PW, AW, FW, and IRR are based on estimated cash flows and are equivalent measures of profitability.

Simple payback (∅) and discounted payback (∅') are measures of a project's liquidity and are used to supplement profitability measures.

Section 4.2 MINIMUM ATTRACTIVE RATE OF RETURN (MARR)

A proposed problem solution is profitable if it generates sufficient cash flow to pay back the initial investment and earn an interest rate greater than or equal to the MARR.

The value of the MARR will depend on:

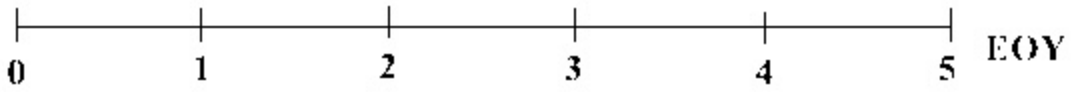
- availability of funds
- number and type (essential vs. elective) of investment opportunities
- perceived risk
- type of organization

Ch. 4 – Example Problem for PW, FW, AW and IRR

Given the following:

Cost/Revenue Estimates

Initial Investment:	$50,000
Annual Revenues:	20,000
Annual Operating Costs:	2,500
Salvage Value @ EOY 5:	10,000
Study Period:	5 years
MARR	20% per year



Draw a cash flow diagram (an important first step)

Section 4.3 Present Worth (PW) Method

1. Compute the present equivalent of the estimated cash flows using the MAR as the interest rate.

2. If PW(MARR) ≥ 0, then the project is profitable.
   If PW(MARR) < 0, then the project is not profitable.

Ch. 4 Example – PW Method

PW(20%) =

$$-50{,}000 + (20{,}000 - 2{,}500)(P|A,20\%,5) + 10{,}000(P|F,20\%,5)$$

$$= \$6{,}354.50$$

Since PW(20%) ≥ 0, the project is profitable.

PW = $6,354.50 tells us:

1. We have recovered our entire $50,000 investment,
2. We have earned our desired 20% on this investment,
3. We have made a lump sum equivalent profit of $6,354.50 beyond what was expected (required).

Section 4.4 Future Worth (FW) Method

1. Compute the future equivalent of the estimated cash flows using the MARR as the interest rate.

2. If FW(MARR) ≥0, then the project is profitable.
   If FW(MARR)<0, then the project is not profitable.

Ch. 4 Example – FW Method

FW(20%) =

$$-50{,}000(F|P,20\%,5)+(20{,}000-2{,}500)(F|A,20\%,5)+10{,}000$$

$$= \$15{,}813$$

Since FW(20%)≥0, the project is profitable.

Section 4.5 Annual Worth (AW) Method

$$AW(i\%) = R - E - CR(i\%) \qquad \text{(Eqn. 4-4)}$$

where

R = annual equivalent revenues

E = annual equivalent expenses

CR = annual equivalent capital recovery cost

CR is the equivalent uniform annual cost of capital invested. CR includes the loss in value of the asset and interest(MARR) on invested capital.

$$CR(i\%) = I\,(A/P,i\%,N) - S\,(A/F,i\%,N) \qquad \text{(Eqn. 4-5)}$$

Where I% = MARR per interest period (usually years)

Ch. 4 Example – AW Method

Calculating CR(i%)

Assume a uniform loss in asset value over the 5 yr. Study period.
(50,000 - 10,000)/5 = $8,000 loss in value each year

Year	Value of Investment at BOY	Loss in Value for Year	Interest at MARR=20% per year on BOY Investment	CR Cost for Year
1	$50,000	$8,000	$10,000	$18,000
2	42,000	8,000	8,400	16,400
3	34,000	8,000	6,800	14,800
4	26,000	8,000	5,200	13,200
5	18,000	8,000	3,600	11,600

PW of CR cost =

$18,000(P|F,20%,1) + $16,400(P|F,20%,2)+...+$11,600(P|F,20%,5)
= 45,980.72

Uniform Annual Equivalent of CR Cost =

$45,980.72(A|P,20%,5) = $15,376

Ch. 4 Example – AW Method Continued

Uniform Annual Equivalent of CR Cost by Eqn. 4-5:

$$CR(i\%) = I\,(A/P,i\%,N) - S\,(A/F,i\%,N)$$

where I = investment cost and S = salvage value

$$CR(20\%) = \$50{,}000(A|P,20\%,5) - \$10{,}000(A|F,20\%,5)$$

$$= \$16{,}720 - \$1{,}344$$

$$= \$15{,}376$$

$$AW(20\%) = \underline{R} - \underline{E} - CR(20\%), \text{ or}$$

$$AW(20\%) = \$20{,}000 - \$2{,}500 - \$15{,}376 = \$2{,}124$$

Since $AW(20\%) \geq 0$, project is profitable

Equivalent Worth Methods for Ch.4 Example

Note: PW, FW, and AW are equivalent measures of profitability.

If PW ≥0, then FW ≥0 and AW ≥0.

From our example,

PW = $6,354.50 therefore,

FW = 6,354.50(F|P, 20%,5) = $15,812 and

AW = 6,354.50(A|P, 20%,5) = $2125

Section 4.6 The Effect of Compounding

Benjamin Franklin, according to the American Bankers Association, left $5,000 to the residents of Boston in 1791, with the understanding that it should be allowed to accumulate for a hundred years. By 1891 the $5,000 had grown to $322,000. A school was built, and $92,000 was set aside for a second hundred years of growth. In 1960, this second century fund had reached $1,400,000. As Franklin put it, in anticipation: "Money makes money and the money that money makes, makes more money."

Question: What average interest rate per year was earned from 1791 to 1891?

The “Ben Franklin” Problem – Solution

Given: P = \$5,000 N = 100

F = \$322,000 Find: i'% per year

$F = P(F|P, i'\%, 100)$

$\$322{,}000 = \$5000(F|P, i'\%, 100)$

therefore, $(F|P, i'\%, 100) = 64.4$

From interest tables, $(F|P, 4\%, 100) = 50.5049$
$(F|P, 5\%, 100) = 131.501$

$F = P(1+i')^N$ therefore, $322 = 5(1+i')^{100}$
$64.4 = (1+i')^{100}$
$(1+i') = 1.0425$ or $i' = 4.25\%$ per year

Section 4.6 IRR Method (Definition)

The Internal Rate of Return (IRR) method solves for the interest rate that equates the equivalent worth of a project's cash outflows (expenditures) to the equivalent worth of cash inflows (receipts or savings).

In other words, the IRR is the interest rate that makes the PW, AW, and FW of a project's estimated cash flows equal to zero. That is, PW(i') of cash inflow = PW(i') of cash outflow.

We commonly denote the IRR by *i'*.

$$PW(i'\ \%) = 0$$
$$AW(i'\ \%) = 0$$
$$FW(i'\ \%) = 0$$

In general, we must solve for *i'* by trial and error (unless we use an equation solver or computer program such as BTAX2). In this class, always use trial and error with linear interpolation unless told to do otherwise.

Evaluating Projects with the IRR

Once we know the value of the IRR for a project, we compare it to the MARR to determine whether or not the project is acceptable with respect to profitability.

IRR = $i' \geq$ MARR project is acceptable

IRR = $i' <$ MARR project is unacceptable (reject)

Difficulties with the IRR Method:

- The IRR Method assumes that recovered funds are reinvested at the IRR rather than the MARR
- Computational intractability
- Possible multiple IRRs

Why should you learn the IRR Method?

The majority of U.S. companies favor the IRR method for evaluating capital investment projects.

Ch. 4 Example Continued – IRR method

Find i'% such that the PW(i'%) = 0.

$$0 = -\$50{,}000 + \$17{,}500(P|A, i'\%, 5) + \$10{,}000(P|F, i'\%, 5)$$

PW (20%) = 6354.50 tells us that i' > 20%

PW (25%) = 339.75 > 0, tells us that i'% > 25%

PW (30%) = -4,684.24 < 0, tells us that i'% < 30%

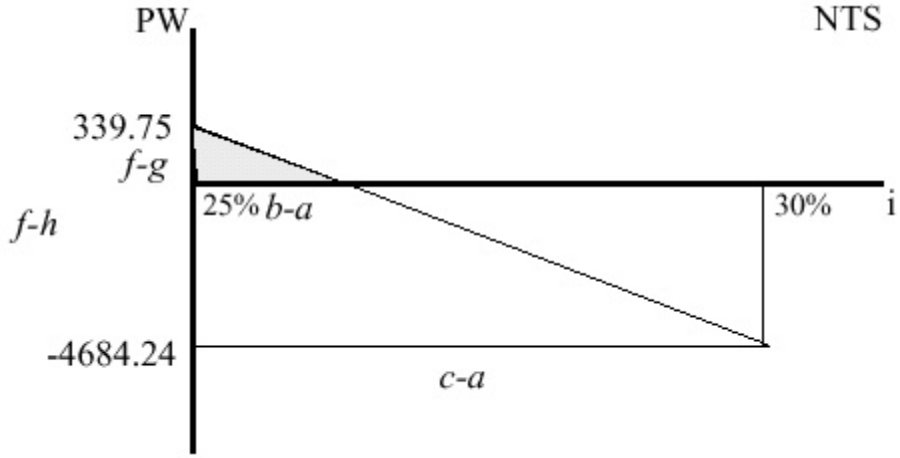
$$25\% < i' < 30\%$$

Use linear interpolation to estimate i'%.

Linear Interpolation Example

	i%	PW	
(a)	25	339.75	(f)
(b)	i'	0	(g)
(c)	30	-4684.24	(h)

$$\frac{b-a}{f-g}=\frac{c-a}{f-h} \qquad b=a+\frac{(f-g)(c-a)}{f-h}$$



$$i'=25+\frac{(339.75-0)(30-25)}{339.75-(-4684.24)}\approx 25.3\%>\text{MARR.}$$

Therefore, accept this project.

IRR – Installment Financing Example (#4-26)

An individual approaches the Loan Shark Agency for $1,000 to be repaid in 24 monthly installments. The agency advertises an interest rate of 1.5% per month. They proceed to calculate a monthly payment in the following manner:

Amount you leave with	$1,000
Credit investigation	25
Credit risk insurance	5
Total	$1,030

Interest: ($1,030)(24)(0.015) = $371

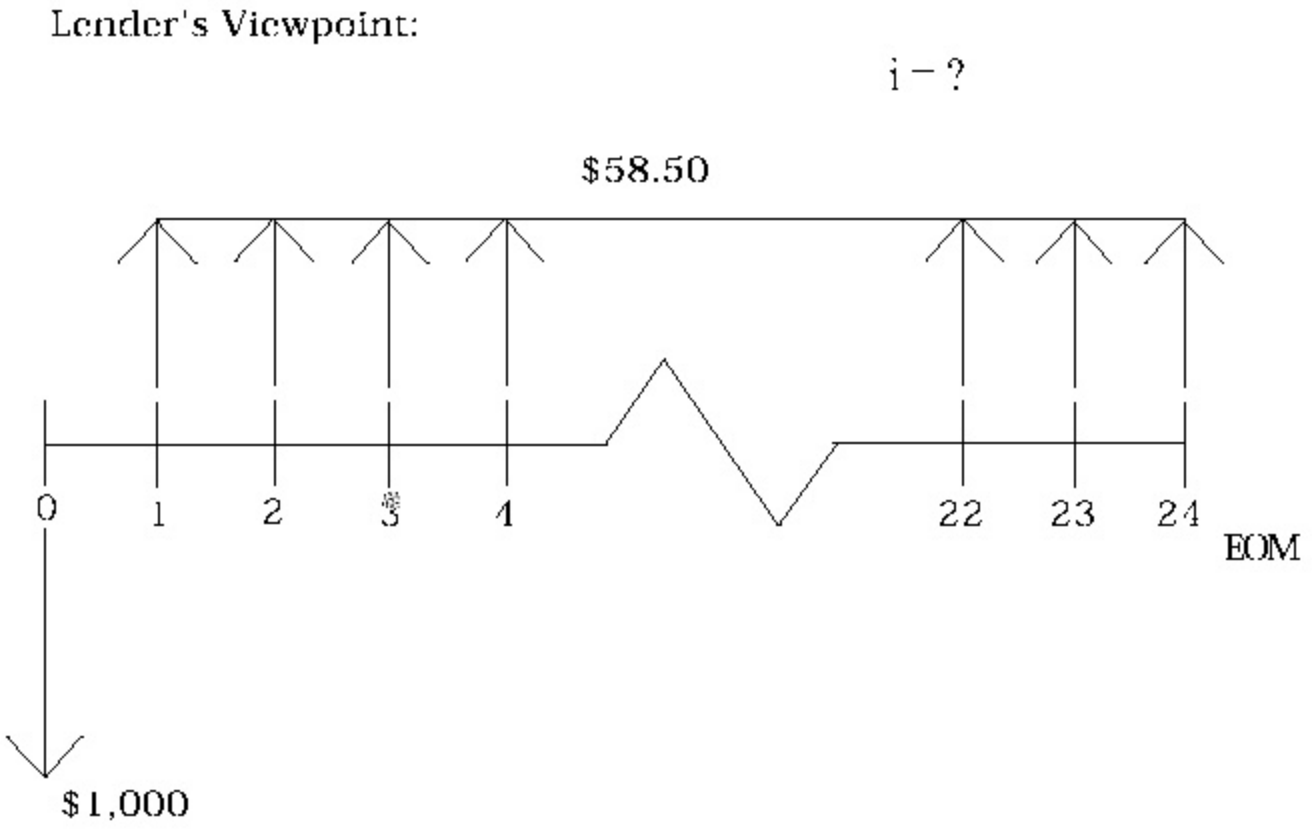
Total owed: $1,030 + $371 = $1,401

Payment: $1,401/24 = $58.50 per month

What effective annual interest rate is the individual paying?

Another way of approaching this is to ask “what is the IRR from the lender’s perspective?”

<u>Step 1</u> – Draw a cash flow diagram.



Step 2 – Solve for i'

$$\text{PW(inflows @ } i'\% \text{)} - \text{PW(outflows @ } i'\% \text{)} = 0$$

$$\$58.50\,(P/A,i'\%,24) - \$1{,}000 = 0$$

$$(P/A,i'\%,24) = 17.0940$$

From Appendix C,

$(P/A,2\%,24) = 18.9139$

$(P/A,3\%,24) = 16.9355$

$2\% < i' < 3\%$

Using linear interpolation, we find that i' = 2.92% per month.

From equation 3-3 with r/M = 0.022, the effective annual interest rate being charged is

$$(1.0292)^{12} - 1 = 0.4125 \text{ or } 41.25\% \text{ per year}$$

Section 4.6 Installment Financing

In 1555 King Henry VIII borrowed money from his bankers on the condition that he pay 5% of the loan every 3 months, until a total of 40 payments were made. Then the loan would be considered repaid. What effective annual interest did King Henry pay?

Solution:

$P = 0.05P\ (P/A,i'\%,40)$; therefore, $(P/A,i'\%,40) = 20$

$(P/A,4\%,40) = 19.7928$

$(P/A,3\%,40) = 23.1148$

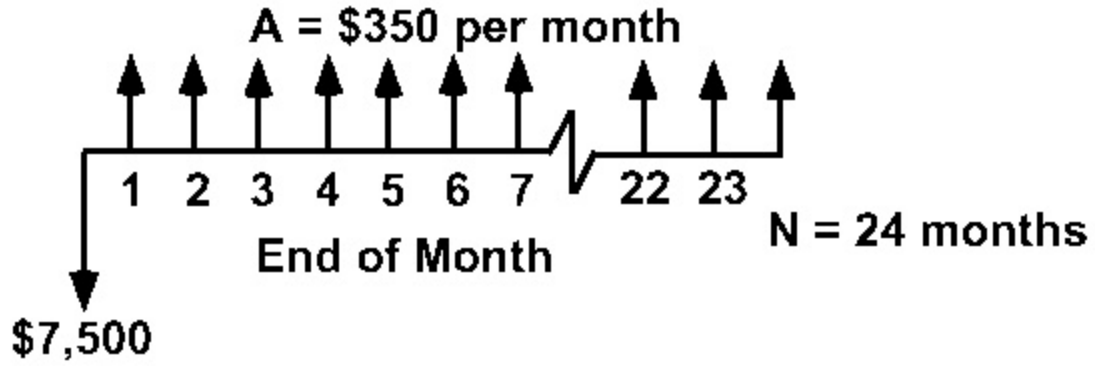
$i' = 3.94\%$ per quarter

$i/yr. = (1.0394)^4 - 1 \approx 0.1672\ (16.72\%)$

Section 4.6 Installment Financing

Example: $7,500 loan repaid in 24 monthly payments of $350 each.

Step 1: Draw a CFD (here viewpoint is lender's).



Step 2: Find i'/month that establishes equivalence between cash outflows and cash inflows.

$$0 = -\$7{,}500 + \$350\,(P/A,i',24 \text{ months})$$

$$i' \approx 0.93\% \text{ per month}$$

Step 3: Find i' per year.

$$i'/\text{year} = (1.0093)^{12} - 1\ 12\%$$

Section 4.8 Measures of Liquidity

Simple Payback Period (Ø) - how many years it takes to recover the investment (ignoring the time value of money).

Discounted Payback Period (**Ø**') - how many years it takes to recover the investment (including the time value of money).

Measures of Liquidity – Chapter 4 Example

EOY	Simple Payback Cumulative PW (i = 0%)	Discounted Payback Cumulative PW (i = MARR = 20%)
0	-$50,000	-$50,000
1	-32,500	-35,417
2	-15,000	-23,264
3	+2,500	-13,137
4	+20,000	-4,697
5	+47,500	+6,354.50
	Ø = 3 years	**Ø'** = 5 years

Discounted Payback:

@k=1, PW = -50,000 + 17,500(P|F, 20%, 1) = -35,417

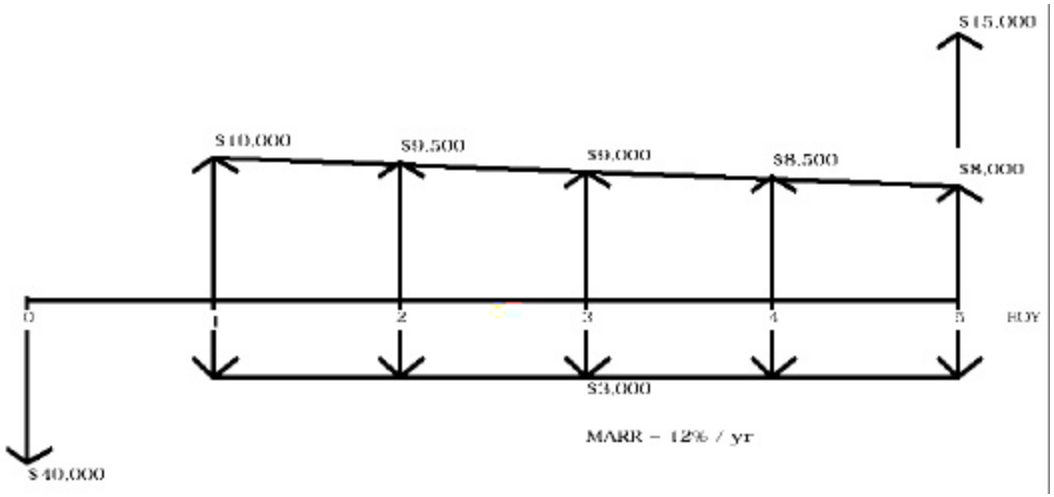
Continue for k=3, 4, …, Ø' at which time the cumulative PW becomes positive.

Example: Problem 4-5 (page 178)

Investment	$40,000
Annual Expenses	$3,000
Annual Revenues (next year) decreasing by $500/year thereafter to Yr. 10	$10,000
Study Period	5 years
Market Value @ Yr. 5	$15,000
MARR	12% per year

Use the PW method to evaluate this investment.

Problem 4-5 Continued



PW(12%)=

= -$40,000 + $7,000 (P/A,12%,5) - $500 (P/G,12%,5) - 15,000 (P/F,12%,5)

= -$9455 < 0 Reject

FW(12%)

= -$40,000 (F/P,12%,5) + $7,000 (F/A,12%,5) - $500 (A/G,12%,5)(F/A,12%,5)
+ $15,000

= -$16,660 < 0 Reject

Problem 4-5 Continued

$$AW(i\%) = \underline{R} - \underline{E} - CR(i\%)$$

where

$\underline{R}$ = annual equivalent revenues

$\underline{E}$ = annual equivalent expenses

CR= annual equivalent capital recovery cost

CR is the equivalent uniform annual cost of capital invested. CR includes the loss in value of the assets and interest on invested capital.

$$CR(i\%) = I\,(A/P,i\%,N) - S\,(A/F,i\%,N) \qquad (4\text{-}5)$$

For our problem,

CR(12%) = \$40,000 (A/P,12%,5) - \$15,000 (A/F,12%,5) = \$8,735

AW(12%) = \$10,000 - \$500(A/G,12%,5) - \$3,000 - \$8,735

= -\$2,620 < 0 Reject

Problem 4-5 Continued

EOY	Cumulative PW(i=0%)	Cumulative PW(i=12%)
0	-$40,000	-$40,000
1	-33,000	-33,750
2	-26,500	-28,568
3	-20,500	-24,297
4	-15,000	-20,802
5	+5,000	-9,454

Simple Payback Period:

Ø = 5 years

Discounted Payback Period:

Ø' => 5 years

ISE 2014 Your Uncle's Retirement – Can You Help Chapter 4

At a July 4 family reunion last summer, your Uncle Sidney learned that you will be taking a course in engineering economy. Uncle Sidney has been working as a skilled machinist for Ford Motor Company since 1965. At the picnic he was curious about a couple of things, so he asked you these questions pertaining to the engineering economy course:

(a) What is engineering economy? (Please explain this in terms your uncle can understand.)

(b) Your uncle is thinking about "early" retirement at age 62 (he's now 54 years old), at which time he will being receiving a monthly Social Security check for $800. Alternatively, he can wait until age 65 to start receiving monthly Social Security checks for $1,000. If you conclude his personal MARR is about 1/2% per month (conservative), how old will your uncle be when both Social Security plans are equally desirable to him? What advice would you give him?

(c) Referring to part (b), what's the answer when your uncle's MARR is 1.5% per month? (In this case he's a fairly aggressive investor!) What can you generalize from your answer to parts (b) and (c)?

I. Capitalized Cost

* Gross capitalized cost $16,149.50
* Capitalized cost reduction $ 2,339.00
* Adjusted capitalized cost $13,810.50

J. Allowable and Excess Mileage

* Monthly lease allowance 833 miles
* Full term lease allowance 40,000 miles
* Odometer mileage reading at delivery 83 miles
* Maximum use allowed at lease expiration 40,083 miles
* Mileage penalty for miles over maximum use allowance is $0.10 per mile

K. Termination Value

You have no equity or other ownership rights in the Vehicle or in accessories or replacement parts other than the right to exercise the Purchase Option. The termination value of this Vehicle will be $7,134.60 at the end of the 48 month term.

L. Required Insurance

* Public liability: $100,000 per person and $300,000 for each accident
* Property damage $50,000
* Comprehensive (max. deductible of $500)
* Uninsured motorist
* Name of insurance company; policy number

Recall the handout from Chapter 2 that discussed the cost of quality resulting from product variability. In this scenario, a company is producing a high-volume item that sells for $0.75 per unit. The variable production cost is $0.30 per unit. The company is able to produce and sell 10,000,000 items per year when operating at full capacity.

The critical attribute for this product is weight. The target value for weight is 1000 grams and the specification limits are set at ±50 grams. The filling machine used to dispense the product is capable of weights following a normal distribution with an average (μ) of 1000 grams and a standard deviation (σ) of 40 grams. Because of the large standard deviation (with respect to the specification limits), 21.12% of all units produced are not within the specification limits (they either weigh less than 950 grams or more than 1050 grams). This means that 2,112,000 out of 10,000,000 units produced are non-conforming and cannot be sold without being reworked.

Assume that non-conforming units can be reworded to specification at an additional fixed cost of $0.10 per unit. Reworked units can be sold for $0.75 per unit. It has been estimated that the demand for this product will remain at 10,000,000 units per year for the next five years.

To improve the quality of this product, the company is considering the purchase of a new filling machine. The new machine will be capable of dispensing the product with weights following a normal distribution with μ = 1000 grams and σ = 20 grams. As a result, the percent of non-conforming units will be reduced to 1.24% of production. The new machine will cost $710,000 and will last for at least five years. At the end of five years, this machine can be sold for $100,000.

(a) If the company's MARR is 15%, is the purchase of the new machine to improve quality (reduce variability) economically attractive? Use the AW method to make your recommendation.

(b) Compute the IRR, simple payback period, and discounted payback period of the proposed investment.

(c) What other factors, in addition to reduced total reword costs, may influence the company's decision about quality improvement? Feel free to include both monetary and non-monetary factors.

(d) How would your answers to parts (a) and (b) change if reworked units could only be sold for $0.65?