Chapter

9

Economic Analysis Basics

Motivation

The majority of GE 494 projects are specified such that the economic analysis is a crucial part, if not the most important part of the report for determining the final recommendations to the sponsor, and the plan for their implementation. This is because the sponsoring companies, in the broadest sense, are investment firms whose goal is to maximize profits for the company owners and shareholders. The sponsor chooses to invest in its own processes, product development, and production capability, because it can reliably achieve a far greater return on investment than any other outside investment such as stocks, bonds, real estate, etc. Because of this, economics will determine the ultimate decisions the sponsor will make with respect to the project. The engineering component of the project provides the possible technical solutions to the problem. The economic analysis (generally) will be used to choose the best solution(s) and the order and timing of their implementation.

Cost Data, Savings, and Verification with Sponsor

Your economic analysis will typically rely on costing and financial data provided by the sponsor for scrap rates, material costs, labor rates, overhead or burden, warranty claims, increased sales, and other types of appropriate costs and revenues. Start early in your project to make the proper contacts with your sponsor to get the types of information you will need for your economic analysis. Often, this data must be estimated by the sponsor or retrieved from sources that may take many weeks to access and compile.

As mentioned earlier in this handbook, a valid path to find the best solution in many projects is to “follow the money.” Gain a full and accurate understanding of how costs, savings and revenues are recognized by your sponsor. Do this as early as possible. This will give valuable insights to your economic analysis and help guide your project. Establish guidelines for the upper bound to the amount of savings and/or additional profits possible if the full goal of your project is achieved. This will give you early direction about feasibility of possible solutions. Some projects may generate savings of several hundred thousand dollars per year, which support very ambitious and costly solutions. Other projects may result in savings of only a few tens of thousands of dollars per year. This may immediately eliminate many costly solutions from consideration by the project team and save precious time.

Typically your results will show a savings to the sponsor after your recommended capital expenses are made by the sponsor. Make sure your costing data is accurate and takes into account labor, overhead, maintenance, materials, scrap, training, testing, calibrations, and any other costs that may affect the analysis. In some cases, savings can be directly calculated by the project team for verification by the sponsor. In other cases, reasonable estimates for savings are made by the project team and must receive the sponsor's endorsement before being used in the final reports.

In ALL cases, ALL calculations for costs, savings, etc. must be endorsed by your company sponsor for use in your economic analysis.

Projects often result in several alternative solutions, as well as many different optional solutions. In these cases, present your solutions in a table listing capital cost along with payback period, ROI, and NPV as shown later in this chapter. It is often best to present a stepwise implementation of recommendations that begin with the lowest cost or greatest ROI investments first. The sponsor will use the early savings to fund the later implementations. Recommendations should also be made in a manner that is minimally disruptive to current production processes and cash flows.

See previous GE 494 reports available in 104 TB and on the GE 494 web site for examples of economic analyses.

For more detail, reference your materials from GE 188/288 as well as the help information provided with MS Excel.

Calculation Techniques

The mathematics of economic analysis is based on simple time value of money calculations. Although these are not complex, note that Albert Einstein called them "*the greatest mathematical discovery of all time*", and "*the most powerful force in the universe.*"

Compound interest can be demonstrated by a single deposit placed into an interest bearing account. If the interest (*i*) is compounded annually, the final value of the account is determined by the number of years that the interest is compounded:

$$F = P(1+i)^n$$

F = future value
P = initial deposit
i = interest rate
n = number of compounding periods

As an example if $1000 is deposited for 6 years at 10% compounded annually, the future value is found to be $1,771.56.

Similarly, to find the present value (P) of a future payment (F) made after (n) compounding periods at interest rate (i) the equation is simply:

$$P = \frac{F}{(1+i)^n}$$

The term $(1+i)^n$ is a key term in just about all time value of money calculations. This should be a review of earlier course material you had in your undergraduate courses GE 188/288.

The present value (P) of a series of (n) future payments (A) with a prevailing interest rate (i) per compounding period is given by:

$$P = \sum_{j=1}^{n} \frac{A_j}{(1+i)^j}$$

If all payments (A) are equal, the present value (P) simplifies to:

$$P = A\sum_{j=1}^{n} \frac{1}{(1+i)^j}$$

And the term $\sum_{j=1}^{n} \frac{1}{(1+i)^j}$ can be used to find the amount of a loan payment:

$$P\sum_{j=1}^{n}(1+i)^j = A$$

Where:

P = loan amount
n = months of the loan
i = interest rate per month = annual rate/12
A = loan payment

For a 30 year loan of $100,000 borrowed at an annual rate of 10%, the monthly payment would be:

$$A = 100{,}000 \sum_{j=1}^{360} (1 + (.10/12))^{j} = \$877.57$$

From the bank's perspective, which borrows money at an annual interest rate of 6%, the net present value (NPV) of a series of 360 loan payments of $877.57, which initially cost the bank $100,000, is given by:

$$NPV = -100{,}000 + \sum_{j=1}^{360} \frac{1}{(1 + (.06/12))^{j}} * 877.57 = \$46{,}371.32$$

Note that **NPV** includes subtracting the initial cost of the loan, as seen from the bank's perspective.

So, the net present value to the bank for making this loan is $46,371.32.

The simple **Payback Period** for the loan is the amount of time needed to recover the initial $100,000 cost of the loan. This is simple cash recovery and does not take into account any interest rate.

Payback Period = 100,000/877.57 = 113.95 months = 9.496 years

The **Return On Investment (ROI)** is defined as the interest rate which makes NPV = 0. This is also called the Internal Rate of Return.

In the above example, ROI = 10% simple annual interest.

Note that interest rates used in the formulas are the simple interest rate per compounding period. If 10% simple annual interest is compounded annually, the effective interest rate is exactly 10%. If 10% simple annual interest is compounded monthly, the effective annual interest rate becomes:

Effective Interest Rate = $(1 + (.10/12))^{12} - 1$ = .1047 = 10.47%

Project Economic Analysis Example

Likewise, any business looks at its investments into new products, process improvements, etc., from the same standpoint.

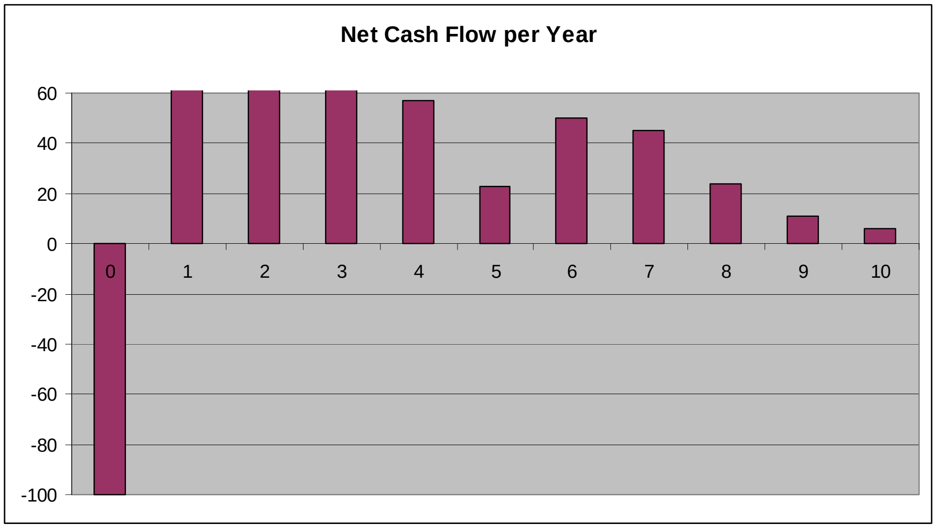
To analyze investments and their returns, construct a cash flow chart and apply time value of money calculations. The example shown below is for a manufacturing process improvement project that reduces the scrap rate of the process from 5% to 1%. The prevailing annual interest rate for the duration of this example is 10%. All numbers are in thousands of dollars.

Year	Capitalization	Production	Scrap Savings	Maintenance	Salvage	Cash Flow	NPV	ROI (IRR)
0	100	0	0	0	0	-100	-100.00	
1	0	1800	72	10	0	62	-43.64	-38.0%
2	0	1900	76	10	0	66	10.91	18.0%
3	0	1850	74	12	0	62	57.49	40.4%
4	0	1800	72	15	0	57	96.42	50.2%
5	30	1700	68	15	0	23	110.70	52.4%
6	0	1600	64	14	0	50	138.93	55.1%
7	0	1500	60	15	0	45	162.02	56.5%
8	0	1100	44	20	0	24	173.22	57.0%
9	0	900	36	25	0	11	177.88	57.1%
10	0	400	16	25	15	6	180.19	57.2%

Key points:

1. Capital cost of the scrap reduction equipment is $100K. This is purchased at the beginning of the first year or at time zero.
2. Production for the first year is $1800K and varies with product demand over the 10 years of the project.
3. Savings from scrap is 4% of total production.
4. Maintenance increases with the age of the equipment.
5. Partial recapitalization of $30K is done in year 5 to reduce maintenance costs.
6. By year 10, the product market is dwindling, and the process is discontinued. The sale of the production equipment for $15K is listed in the salvage column.

The first step in the analysis is to construct a **Net Cash Flow Diagram** for the life of the project. Note that this is <u>net</u> cash flow, taking into account the savings as well as the costs. Savings are shown as positive and costs are shown as negative.



Cash Flow diagram for above example

The simple **Payback Period** for the above example is the amount of time to recover the capital cost of the initial investment. This is done using the net cash flow per year for the first few years:

payback period = (capital cost)/(cash flow/year)

payback period = 100/60 = 1.67 years

Net Present Value (NPV) is calculated by finding the value of each cash flow (A) when it is brought back to the present by use of the interest or discount rate, along with subtracting the capital cost. This calculation is accurate with the assumption that the cash flow comes at the end of the interest period.

$$NPV = \sum_{j=1}^{n} \frac{A_j}{(1+i)^j} - capital\ cost$$

A = periodic cash flows

NPV = $180,194

Note that when the NPV() function in MS Excel is used for this calculation, the initial capital cost at time zero is not considered, and must be included manually.

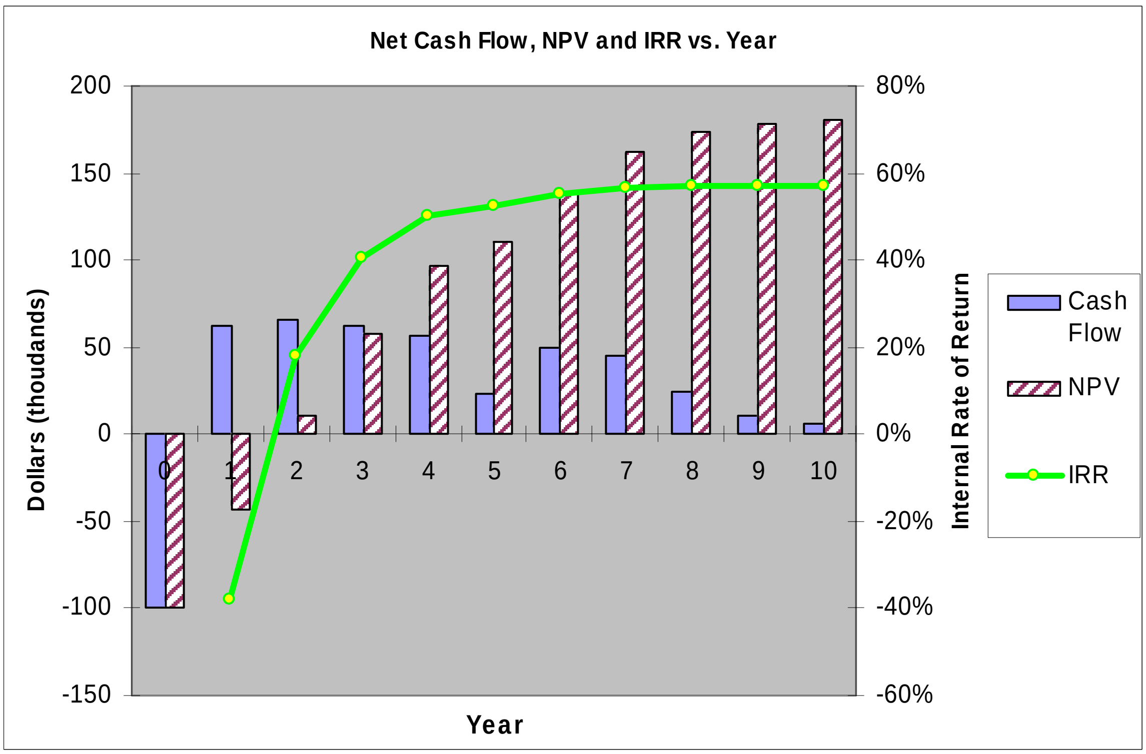
Return On Investment (ROI) is defined as the interest rate at which the NPV is zero. Note that this sets NPV to zero and solves for (i). It is clear that this calculation does not have a closed form solution. It is solved iteratively by successively testing interest rate values and checking for a NPV of zero.

$$NPV = 0 = \sum_{j=1}^{n} \frac{A_j}{(1+i)^j} - capital\ cost$$

MS Excel uses the function IRR(), which takes as its arguments all of the periodic cash flows, including the initial capital investment, and requires a guess to begin the iteration process.

For the example above ROI = 57.16% for a 10-year project life span.

The following graph shows Cash Flow, NPV and ROI or IRR together. Note that both NPV and IRR are time functions from the standpoint of how far into the future the analyst desires to consider these values for purposes of comparison of present investment decisions.

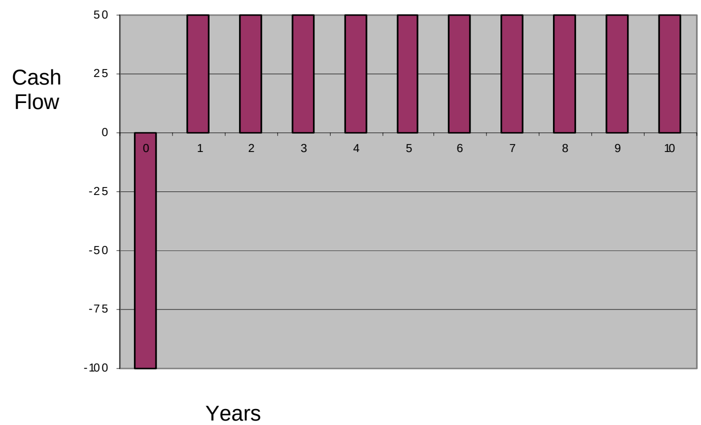


Comparison of the Three Methods

The three methods shown above are not interchangeable. Each method gives a different view of the cash flow pattern of the project being analyzed. Note this carefully. This is why all three methods (Payback Period, NPV, ROI) must be included in your project report along with the cash flow diagram.

The payback period or simple cash recovery period ignores the interest rate and is therefore easiest to calculate. In fact, it can typically be done on the back of a napkin. But, results can be very misleading. Take for example a company that requires a 2-year payback for all capital projects. The implicit assumption in this payback requirement is that the net cash flow model will be similar to the "perfect 2-year payback" shown below:

Year	Cash Flow
0	-100
1	50
2	50
3	50
4	50
5	50
6	50
7	50
8	50
9	50
10	50

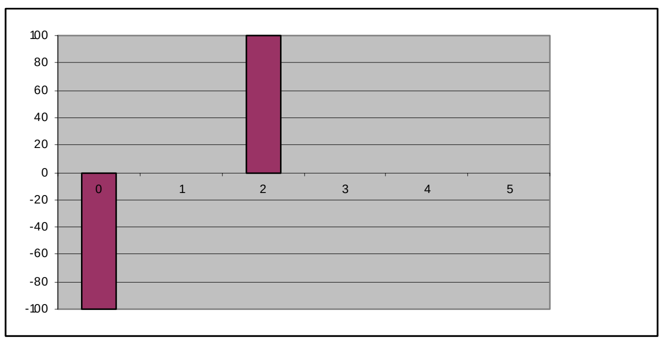


This model has the following characteristics:

Payback period	2 years
NPV	$207.23
ROI	49.08%

The following model has the same payback period but a clearly different cash flow pattern:

Year	Cash Flow
0	-100
1	0
2	100
3	0
4	0
5	0



This model has the following characteristics:

Payback period	2 years
NPV	-$17.36
ROI	0%

Although this cash flow model passes the payback period test, NPV and ROI show it to be a terrible investment. Again, this example demonstrates why all three methods should be used to get a more complete picture for decision making.

Decision Making

When choosing among mutually exclusive projects or features of the same project, NPV, ROI, and payback period should be calculated for each alternative in order to make the best economic choice.

If the mutually exclusive options have different life spans, NPV is typically the best metric for comparison because all savings are brought to the present.

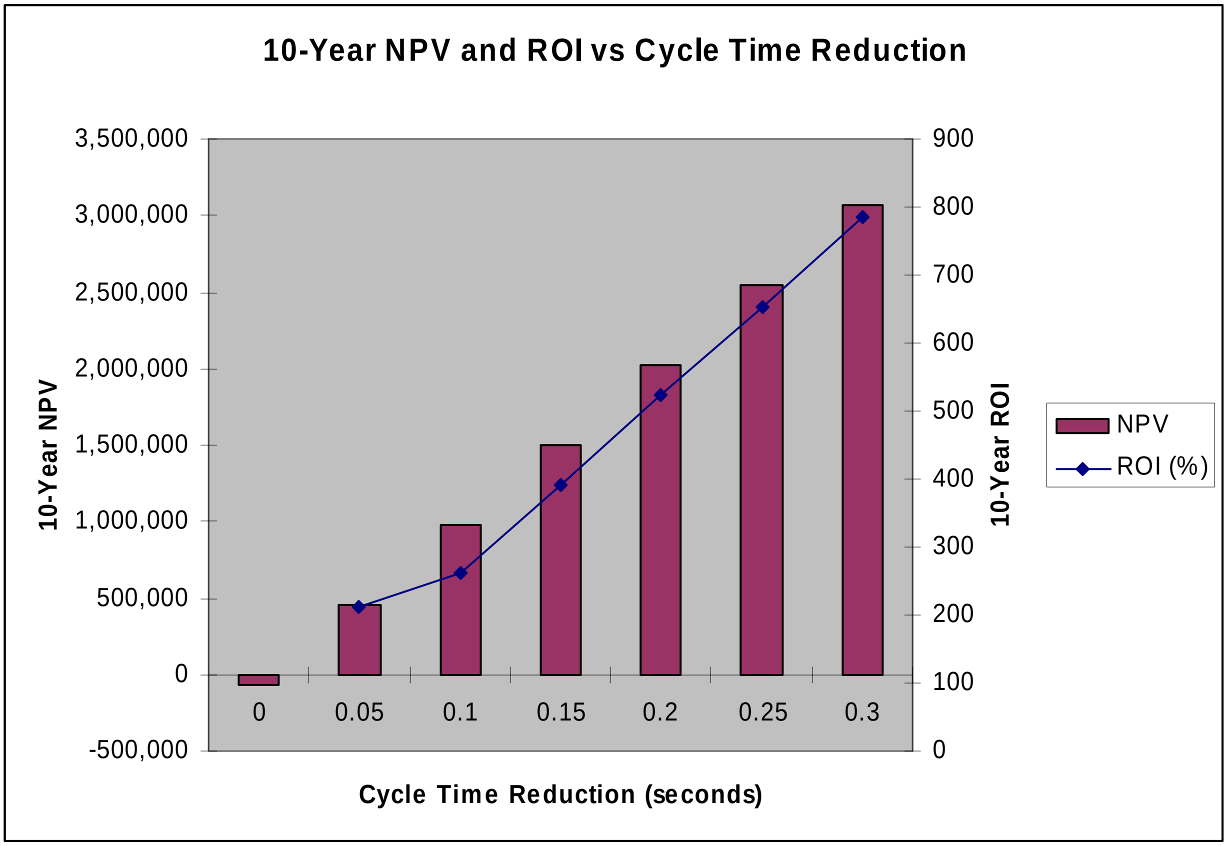
When deciding whether or not to fund non-mutually exclusive options in a project, a table can be made to show the cash flow characteristics of each option. Typically the company will choose to fund the options with the highest profitability first, and then use the savings to fund the options with lower rates of profitability.

Options	Cost	Payback (months)	NPV	ROI (%)
Quick change fasteners	400	1.1	26,409	1,090
Tool shadow board	450	1.5	21,670	800
Cross training personnel	2,200	3	51,872	400
Adjustment jigs	4,200	14	25,908	117
Automated conveyor rails	80,000	22	188,124	54

Often the economic results of a project may not be directly measurable, but may be a function of a key parameter of the project results, whose direct measurement is beyond the scope of the project. One such project was an analysis of airflow efficiency in a thermoforming process in an effort to increase airflow rates and reduce overall cycle times for the thermoforming process. The project resulted in a 40% increase of airflow efficiency, however, direct measurement of cycle time reduction was impossible during the project due to the high cost of production prototyping. The economic analysis was presented as a function of cycle time reduction as follows. (NPV and ROI are calculated for a 10 year project life.)

Cycle time reduction (seconds)	Cap Cost	Annual Savings	Payback (years)	NPV	ROI (%)
0	65,000	0	n/a	-65,000	n/a
0.05	65,000	85,000	0.76	457,000	212
0.1	65,000	170,000	0.38	979,000	261
0.15	65,000	255,000	0.25	1,502,000	392
0.2	65,000	340,000	0.19	2,024,000	523
0.25	65,000	425,000	0.15	2,546,000	653
0.3	65,000	510,000	0.13	3,068,000	784

This table can be graphed with annual savings, payback period, NPV, and ROI all as a function of the eventual cycle time reduction.



Methods for Product Development and New Technologies

Occasionally a project does not readily conform to types of analyses that are discussed above. Note that the methods above are all analyses of cash flows in one form or another. Cash flows may be in the form of a reduced cost in an existing product, a totally redesigned product, a new product in an existing market, or a new product in a totally new market. In these cases, the future cash flows, market shares, price point and profit margin for the product, etc., may be uncertain. It is important to get reasonably good estimates for these cash flows from your company sponsors in order to do the required analyses. If you have questions about this, see your Advisor, or the Course Chairman.

Break Even Analysis

New product costs typically involve tooling, manufacturing, shipping, marketing, distribution, sales, warranty, etc. Estimates for these costs should be accessible by the company sponsor. The company sponsor should also have an idea of the price point for the new product in the market they are addressing. In order to meet a payback requirement, the analysis can be “reverse engineered”. Calculations for the startup costs and the fixed and variable costs listed above can be made. With the price point of the product, the profit margin can then be determined. It is then possible to determine how many units of the new product must be sold to give the desired payback on the investment in the new product development and manufacture. Once this sales target is determined, the marketing department of the company sponsor has a clear sales target to meet the company’s requirements for investments. This entire determination is iterative in nature and involves risk, but is a simple and effective way to evaluate new product economic potential.

New Product Development – Direct Value Method

The Direct Value Method is used to determine the price point for new and modified products. It is a simple method of marketing research in which the target demographic is asked to fill out a simple questionnaire to directly value the product modifications. From this analysis, the company sponsor can get a very good idea of the target price point that will be successful. It will also give estimates of the profit margin for the new product. For more information, see Prof. Brian Lilly, or the course Chairman.