# 1.011Project Evaluation: Comparing Costs & Benefits

**Carl D. Martland**

- Basic Question:
  - Are the future benefits large enough to justify the costs of the project?
- Present, Future, and Annual Worth
- Internal & External Rates of Return

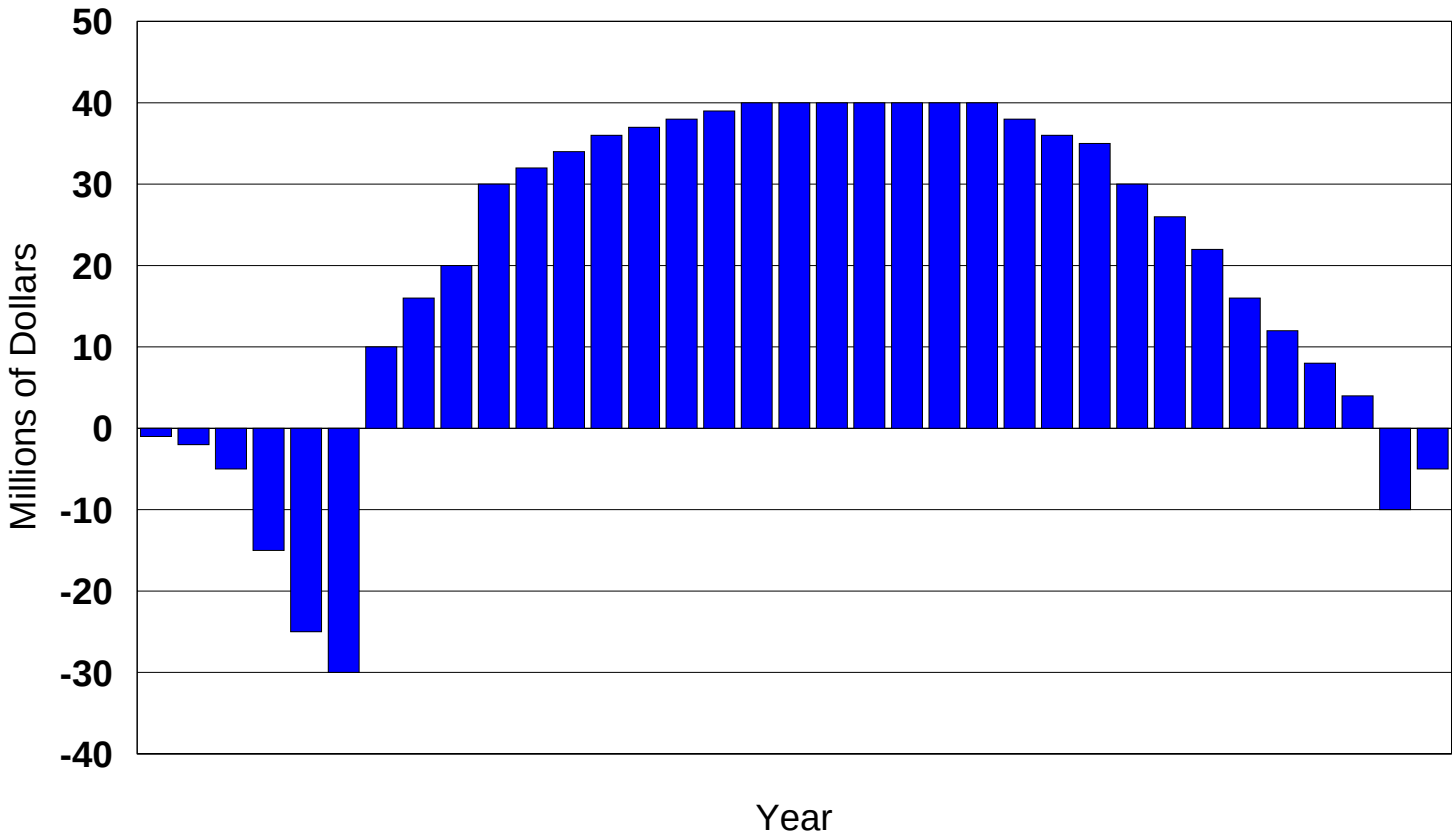
# What Is a Project?

- For the planner (dreamer?):
  - A vision, a dream or a hope
  - A monument
  - A way to solve a problem
- For the construction company:
  - A specific task to be completed within a specific time
  - A way to make money through construction
- For the owner:
  - Potential benefits over the life of the project
  - A way to make money through operation
  - A monument
- For others:
  - Potential improvement in opportunities, environment, etc
  - Potential disruptions and degradation in environment

# How Do We Justify a Project?

- Is this project worthwhile?
  - *Are the benefits greater than the costs?*
    - ***Are MY benefits greater than MY costs?***
- Is this the best way to achieve these benefits (either engineering & institutional options)?
  - *Can similar benefits be achieved more efficiently by some other approach?*
- Is this the best place to allocate resources?
  - *Do other projects have greater payoff?*
  - *Are other types of benefits more important?*

# Cash Flow of a Typical CEE Project



# Evaluating a Time Stream of Monetary Costs & Benefits

- Key concepts:
  - Time value of money
  - Risk vs. required return
  - Present Worth (= Net Present Value)
  - Equivalence (for PW, FW, and AW)
  - Project Life

# Present Worth (Net Present Value)

The "Present Worth" of a project is commonly referred to as its "Net Present Value".

The NPV for the project is obtained by summing the discounted benefits for each year (using a discount rate i = MARR):

$$\text{NPV of Project} = PW = \Sigma[(B_t - C_t)/(1+i)_t]$$

We know that this NPV can be transformed into an equivalent annual or future worth.

# Equivalent PW, AW, and FW

- Reduce all costs and benefits to time 0
- Compute the equivalent time stream of costs and benefits over the life of the project using standard formulas or spreadsheet commands:
- Use equations, tables or spreadsheet functions to calculate equivalent annuities (AW or "Equivalent Uniform Annual Benefits") or FW
- Be careful whether cash flows occur at the beginning or the end of the period (Annuities are generally assumed to be received at the END of the period)

# Meaning of NPV

- NPV > 0, using a discount rate of i%
  - This project is better than making an investment at i% per year for the life of the project
  - This project is worth further consideration
- NPV < 0, using a discount rate of i%
  - This project does not provide enough financial benefits to justify investment, since alternative investments are available that will earn i% (that is what is meant by "Minimum Acceptable Rate of Return" )
  - The project will need additional, possibly non-cash benefits to be justified

# Importance of the Discount Rate

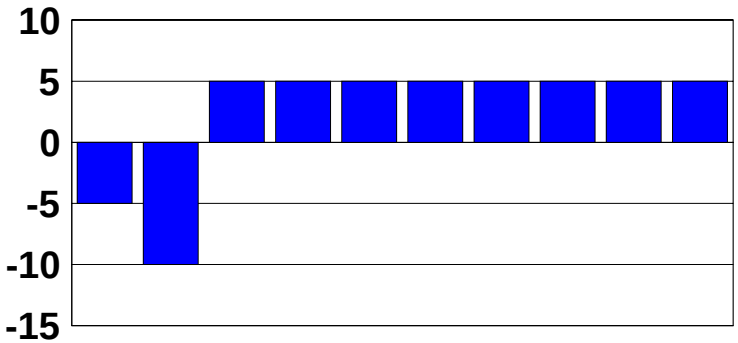
- Very low rates favor large projects with distant benefits
  - *Using very low discount rates may lead a country to undertake massive projects while ignoring current needs*
- Very high rates favor staged investments with quick payback
  - *Using very high discount rates may prevent a country from ever undertaking large infrastructure investments*

# Importance of the Project Life

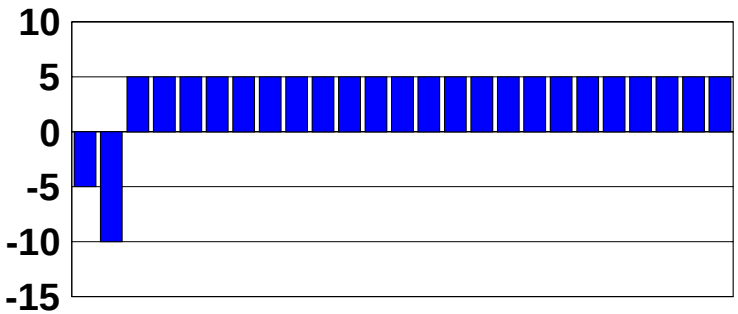
- Projects need to be evaluated over a reasonable project life (and the economic life will be shorter than physical life)
  - However, your choice of a project life should NOT determine the outcome of the analysis (if it does, you must show sensitivity of the results to project life)
- Because of discounting, the "out years" do not add much to the NPV, so a 20 to 50 year life is usually sufficient for analysis
  - The proper assumption is that the very long term effects will be positive or neutral - NOT that we can live it up now and let our children and grandchildren worry about the future!
- Risks increase with time
  - So we don't want to be dependent on long-term benefits to recover our investment.

# Choice of a Project Life Should NOT Determine the Outcome of Your Analysis!

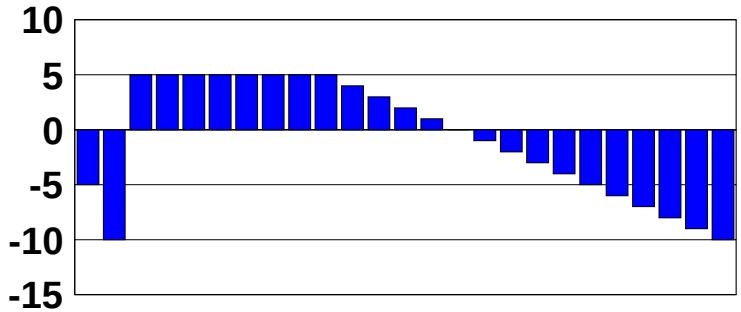
**A. Net Cash Flows Over a 10-Year Life**



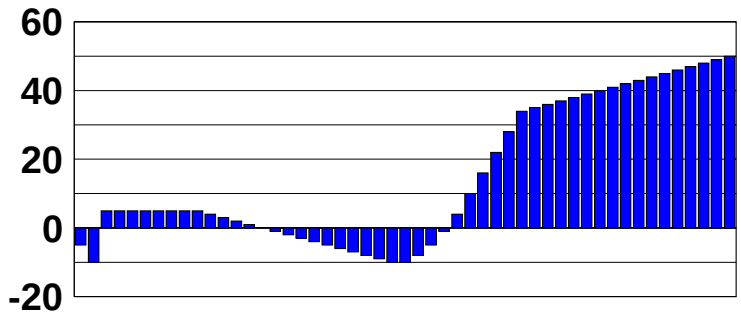

**B. Net Cash Flows Over 25 Years (Assuming Steady State After Year 10)**




**C. Cash Flows Over 25 Years (Increasing Competition & Maintenance)**



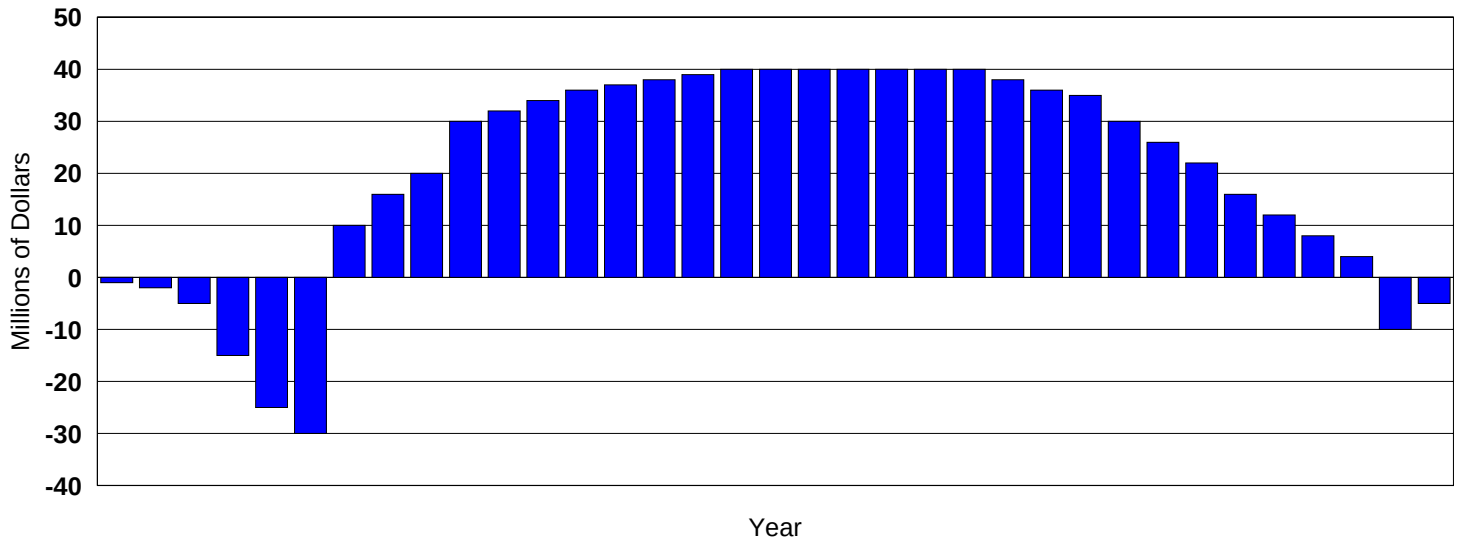

**D. Net Cash Flows Over 50 Years (Rehab and Expansion in Prime Location)**

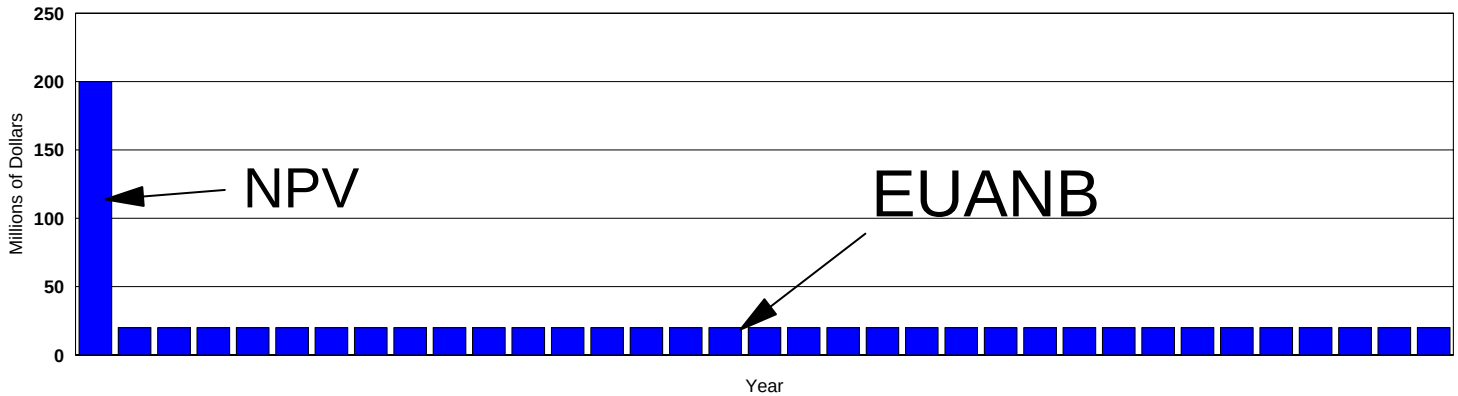


# Other Ways to Evaluate Cash Flows

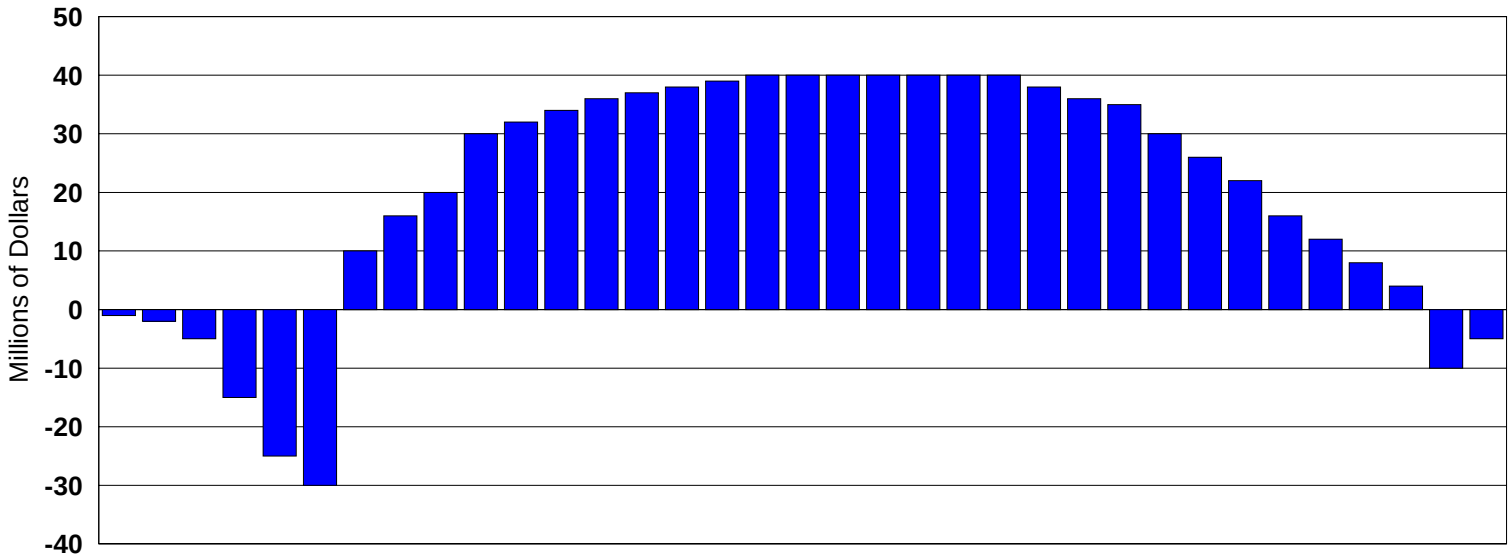
- Benefit/Cost Ratios
  - NPV(Benefits)/NPV(Costs)
  - Commonly used in public policy analyses
    - Required in order to ensure that benefits (by SOME measue at least!) are greater than costs
    - A political, not a methodological statement!
- Internal and External Rates of Return (IRR and ERR)
  - Very common in private sector, but there may be problems with IRR (which can be fixed by using ERR)
- Payback Period
  - How many years to recoup my investment?  (A rather unsatisfactory approach that may be useful for quick assessment of some projects)

# Cash Flows, NPV, and Equivalent Uniform Annual Net Benefits

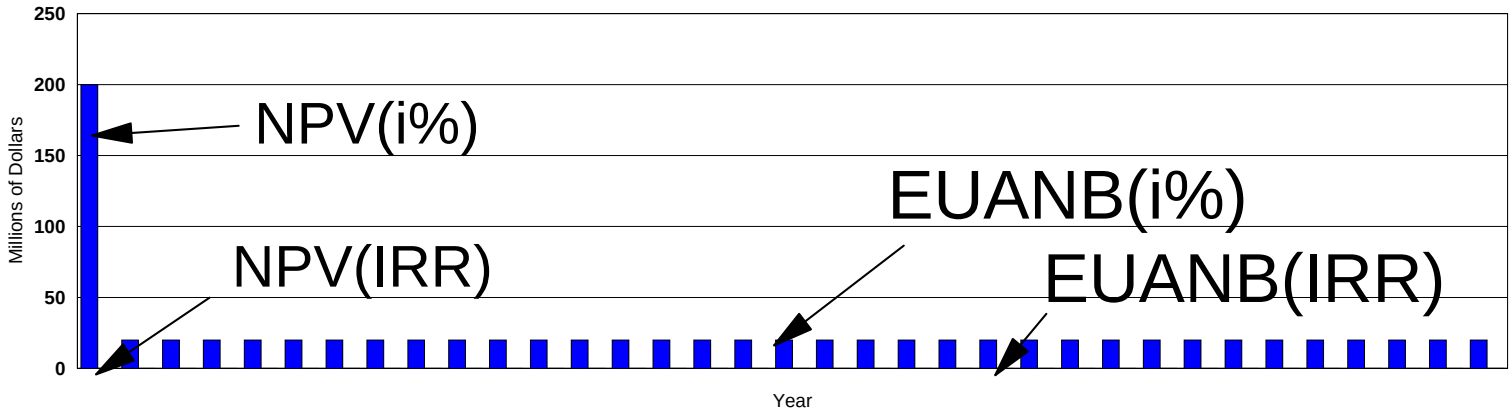


# Calculating the Internal Rate of Return




## Choose discount rate such that the NPV = 0



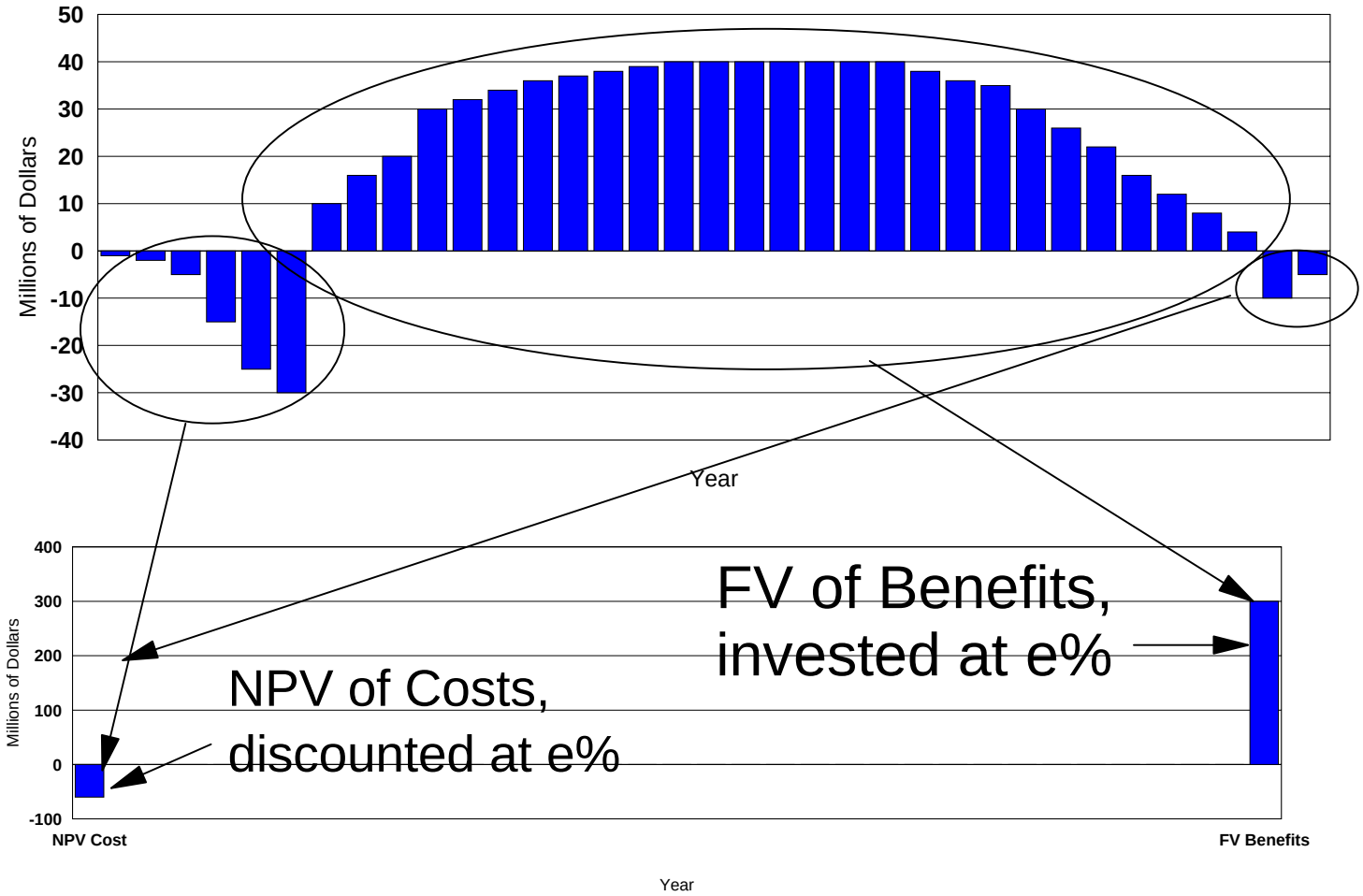
# Problems With the Internal Rate of Return

- If the cash flows switch signs more than once, there could be two or more IRR for which NPV(IRR) = 0
- This method assumes that all intermediate cash flows can be discounted/reinvested at the IRR
  - This is unrealistic when the IRR is very high
- The private sector uses this method very commonly despite these problems

# A Better Approach: The External Rate of Return

- Use a different discount rate (called the "External Rate of Return") to
  - Discount all expenses to time 0
  - Reinvest all benefits for the remaining time in the project life
- Then compare the NPV of the costs and the Future Value of the benefits
  - The external rate of return is the discount rate s.t. the NPV of the costs is equivalent to the FV of the benefits

# Calculating the External Rate of Return



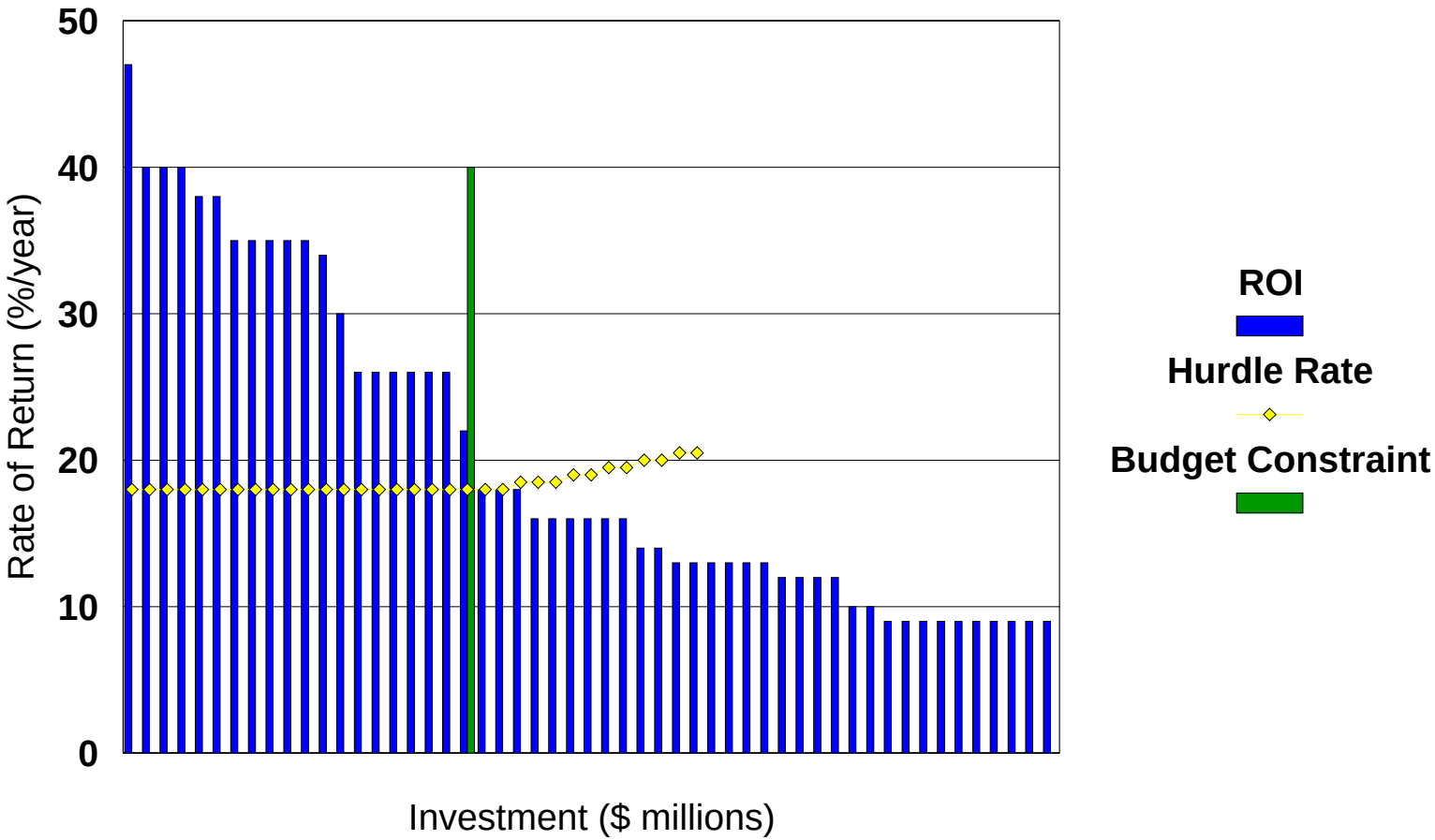
# Are There Alternatives For Achieving the Objectives of this Project?

- The NPV analysis only shows that a project can be justified relative to the discount rate that is used
- There may be other projects that are even better for achieving the same objectives:
  - Better materials & technologies to build the same facility
  - Different design for a structure to serve the same purpose
  - Different location for a similar structure
  - Different scale (larger or smaller)
- In general, you cannot prove that your design is the best, you can only defend and refine (or abandon) your design in response to other options

# Can We Justify this Project Against Competing Projects?

- In principle, any project with NPV > 0 is worth pursuing.
- In practice, capital budgets are limited, so that choices must be made:
  - *What set of projects gives the greatest benefits from using the available resources?*
- Common approach in private sector: Hurdle rate of return:
  - Rank independent projects by rate of return (typically IRR, but should be ERR):
  - Choose projects (or sets of projects) with highest return subject to a budget constraint

# Selecting Projects Based Upon a Hurdle Rate of Return



# Broader Economic Issues

- Prices of resources may not reflect their true costs
  - Local rather than world rates for energy costs
  - Natural resources priced at extraction cost rather than at market cost
  - Opportunity cost of land may be omitted (build the highway through the park)
  - Government may require use of excess labor as a public policy
- Generational equity
  - Discounting of future costs and benefits may lead to long-term decline in the environment
  - "Worry about today and the future will take care of itself"

# Broader Economic Issues (Continued)

- Distributional Equity
  - Costs and benefits will be unevenly distributed
  - If total benefits exceed total costs, there is at least a possibility of compensating the losers
  - Pareto optimality - some are better off and none are worse off (after compensation)
  - "No one is hurt" (a very strong constraint on development)\
- Regional Economic Impact
  - Multiplier effect of project expenditures on the local economy
  - Use of local labor & resources
- Non-financial Externalities
  - Many impacts - both positive and negative - may be left out of the cash flow analysis
  - Environmental impacts & need for remediation

# Broader Economic Issues - Conclusions

- For any large project, there will be additional costs & benefits that must be considered in addition to the cash flows directly related to the project
- Some of these costs and benefits cannot readily be reduced to monetary measures
- Distribution of costs & benefits will be a concern
- In some cases, the non-quantifiable items will be the most important items to consider

# Dealing with Multiple Attributes

| | NPV | Capacity Increase | New Jobs | Decline in Air Quality | Land Required | Effects on Congestion |
|---|---|---|---|---|---|---|
| Project 1 | **$100** | **80%** | -15% | High | 500 acres | Much more |
| Project 2 | $50 | 75% | 20% | Medium | 200 acres | **Lower** |
| Project 3 | $20 | 40% | **30%** | Medium | 250 acres | Moderate |
| Project 4 | $15 | 20% | 20% | **Low** | **100 acres** | None |

# Dealing with Multiple Attributes

- There may be a clear winner, but unless one option is the best in all categories, it is impossible to say it is the best overall
- Weighting schemes may help, but the weights themselves are inherently a value judgement
- Selection of the best project in complicated cases will be a political issue rather than an economic issues

# Dealing with Multiple Attributes: What Can An Engineer Do to Help?

- Clarify and quantify costs and benefits
  - Highly vocal objections may be based upon false assumptions - analysis can reduce these objections
  - Some objections may be perfectly true - but minor in the overall context of the project
- Conduct an incremental assessment of costs and benefits
  - The best project may be a larger or smaller version of the project under consideration
  - Staging may help to reduce initial costs and allow some benefits to be achieved earlier
- Consider options for ameliorating negative impacts
  - Minor additional investment
  - Somewhat broader scope for the project
- If there are major concerns, structure a political process for reviewing options, costs, benefits, and major decisions

# Cost Effectiveness

- If the objective can be quantified, but not in monetary terms, we can calculate the cost effectiveness of various options
  - What is the cost per unit improvement in the objective for each alternative?
  - Even if we cannot put a value on the improvement, we know that it is good to
    - Minimize the cost per unit of improvement
    - Maximize the improvement per unit of cost
- How much to spend per unit of improvement becomes a political issue

# Financing a Project

- The investor provides money for the project in return for a share of the benefits
  - Debt:  low interest rate if cash flows are believed to be very secure
    - Comparison of debt payments to expected net cash flow
    - Could be based upon the credit of the owner rather than the quality of the project
  - Equity
    - Depends upon the expected cash flows after debt payments (including subsidies)
    - The higher the debt payments, the greater the risk
- Who bears the risks is a key concern for the owner, the contractor & sub-contractors, and the investors

# Financial Feasibility vs. Project Desirability

- These two concepts are very different
  - Can we get money from someone to build the project?
  - Should we build the project?
- Financing restrictions may preclude certain highly desirable projects, yet encourage other clearly undesirable projects
- Engineers have some responsibility for pursuing desirable projects that can be financed
  - Proper presentation of estimated costs and benefits
  - Consideration and presentation of alternatives to the proposed project