1.133 M.Eng. Concepts of Engineering Practice
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Project Evaluation

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Outline

- Motivation for Projects
- Financial & Economic Assessment
  - NPV of Cash Flows
  - Capital Budgets
  - Cost Effectiveness
  - Economic vs. Financial Assessment
- Broader Social, Economic, and Environmental Issues
- Environmental Impact Assessment (Susan Murcott)

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

Major Project Examples

Venice Gates (MOSE)

Grand Canyon Skywalk

University of Phoenix Stadium

Photo courtesy of kenyaoa on flickr. [Link to: http://www.flickr.com/photos/kenya/572992856/]

How Do We Justify a Project?

- Is this project worthwhile?
  - *Are the benefits greater than the costs?*
- Is this the best way to achieve these benefits?
  - *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?*

What Does it Take to Implement a Project?

- Financing
  - Sources of funds sufficient for design and construction
- Government Approval
  - Land use regulations
  - Environmental regulations
  - Safety regulations
- Resources
  - People, with various skills
  - Materials
  - Energy
- Social Acceptance (or manageable opposition)

What Does it Take to Implement a Project?

- Financing
- Government Approval
- Resources
- Social Acceptance or Manageable Opposition

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What Does it Take to Sustain a Project?

- Financing
  - Sufficient income to cover expenses
    - User fees, subsidies, contractual payments
- Government approvals (inspections, licensing, etc)
- Engineering
  - Sufficient maintenance and renewal to perform at an acceptable level of service
- Resources
  - People and materials as required for maintenance and operations of infrastructure
  - As required by users of the project
- Public support (or tolerable opposition and interference)

Financial & Economic Issues

- Financing
  - Where does the money come from to cover the costs that are incurred?
  - What returns are necessary to attract capital?
  - How can we reduce life cycle costs?
  - How much money can we make?
- Economic
  - How will the project affect jobs, personal income, gross regional product, ... ?
  - How can we value non-monetary costs & benefits?

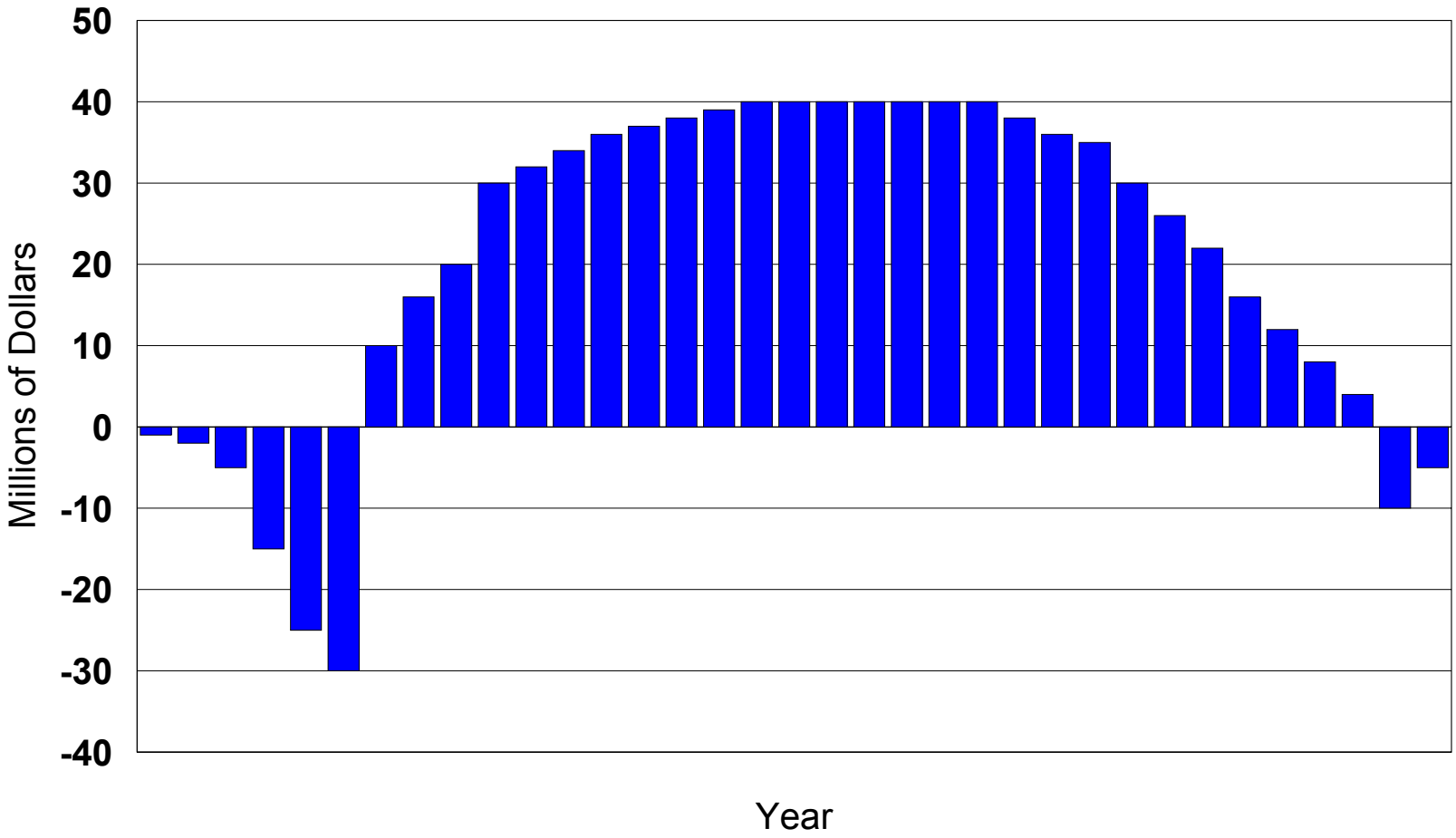
Common Steps in Project Evaluation

- Identification of problems and establishing objectives
- Identification of major options
- Design
- Financial analysis
- Economic analysis
- Environmental impact assessment
- Public hearings
- Agency approvals

Financial & Economic Analysis

- Financial — *The Wall Street Journal*
  - Sources of capital
  - Cash Flows over the life of the project
  - Comparison to financial opportunities
- Economic — *Help Wanted! For Sale!*
  - Macro-economic impact on region
  - Benefits & costs to the region

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
  - Project Life
  - Net Present Value

Time Value of Money

- $1 today is worth more than $1 next year. How much more depends upon opportunities that are available (and how much we want to "discount" future costs and benefits)

- If we invest in a government bond paying i% per year interest, then the money will grow to $(1+i) in one year and $1 * $(1+i)^t$ after t years

- Likewise, $1 at the end of t years is equivalent to having $1/$(1+i)^t$ today and investing the money in bonds paying i% interest.

Net Present Value (NPV)

The NPV (or “present worth”) is an estimate of the current value of future net benefits:

Given:

Future Value (t) = B(t) – C(t)

Discount Rate = i

Then

$NPV(t) = [B(t) - C(t)]/(1 + i)^t$ after t years

$NPV(project) = \Sigma\{[B(t) - C(t)]/(1 + i)^t\}$

Meaning of NPV

- NPV > 0
  - 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
  - This project does not provide enough financial benefits to justify investment, since alternative investments are available that will earn i% (that is the meaning of "opportunity cost")
  - The project will need additional, possibly non-cash benefits to be justified

NPV of $1 Received at Time t

	5 Yrs	10 Yrs	20 Yrs	50 Yrs	100 Yrs
1%	0.95	.91	0.82	0.61	0.37
5%	0.78	0.61	0.38	0.088	0.0076
10%	0.62	0.038	0.15	0.0085	0.000072
20%	0.40	0.16	0.026	0.00011	0.00000001

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*

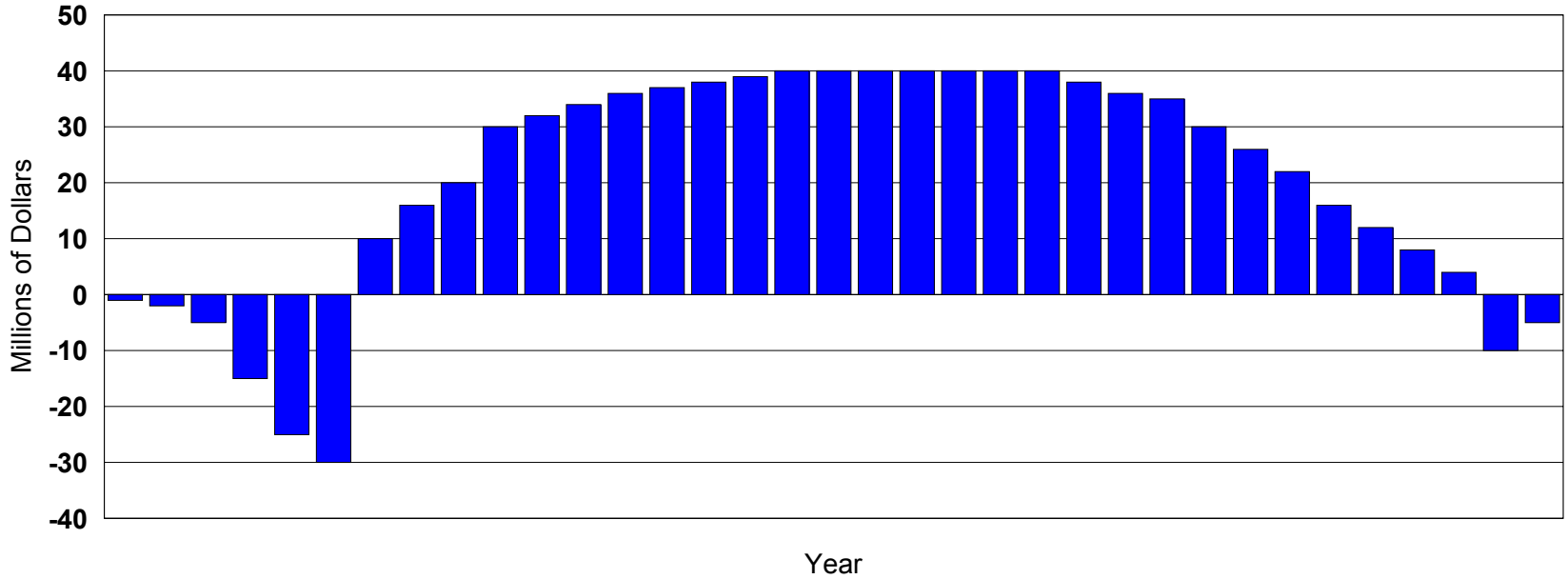
Other Ways to Evaluate Cash Flows

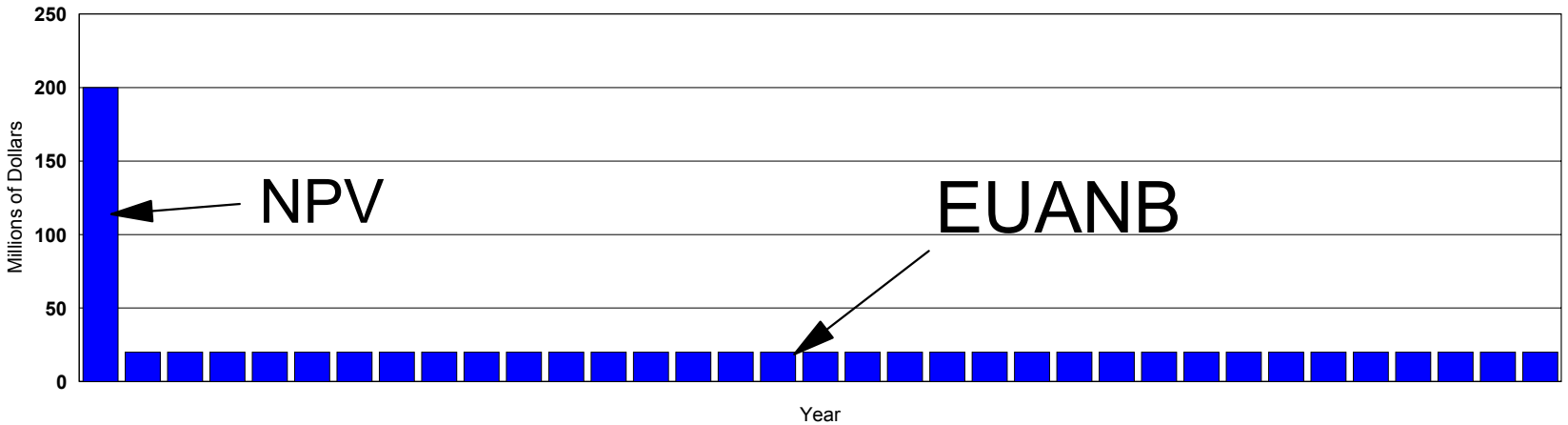
- Benefit/Cost Ratios
  - NPV(Benefits)/NPV(Costs)
  - Commonly used in public policy analyses
- Equivalent Uniform Annual Benefits, Costs, or Net Benefits
  - Useful when considering annual performance
- Internal Rate of Return (IRR)
  - Very common in private sector
- Payback Period
  - How many years to recoup my investment? (A rather unsatisfactory approach that may be useful for quick assessment of some projects)

Equivalent Uniform Annual Benefits, Costs, or Net Benefits

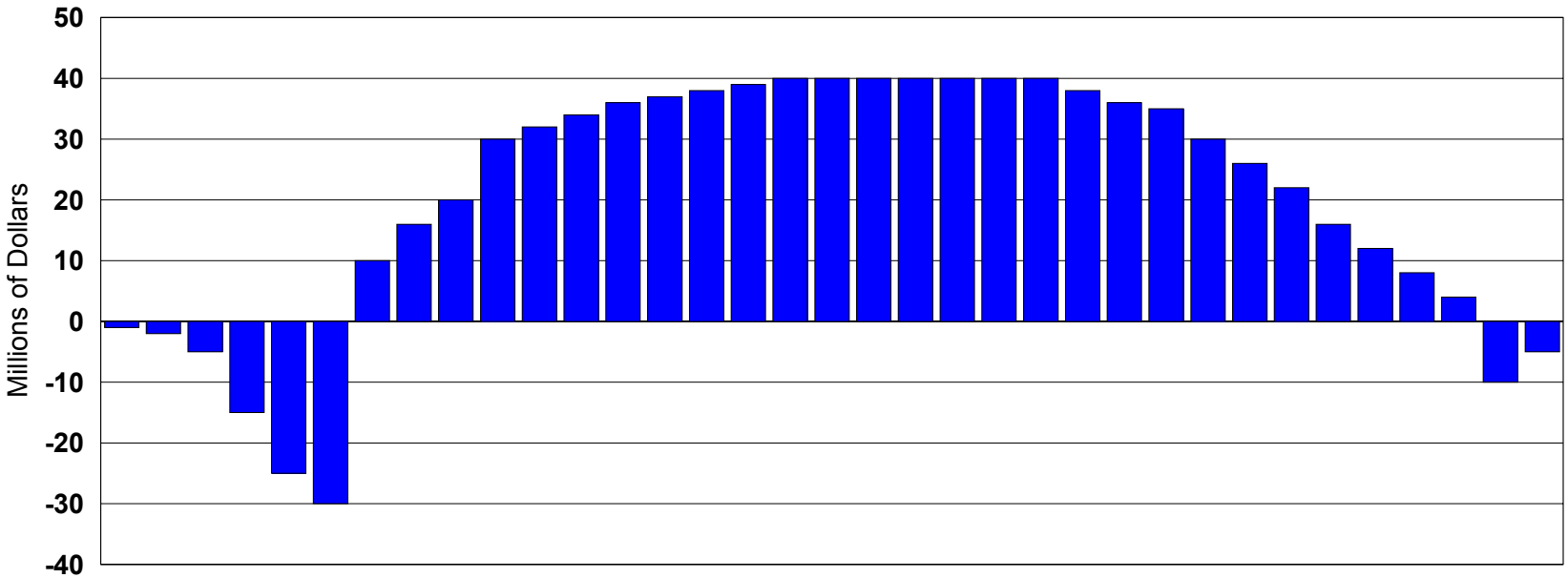
- Reduce all costs and benefits to time 0
- Compute the equivalent time stream of costs and benefits over the life of the project using standard formulas or spreadsheet commands:
- PMT(NPV, interest, # periods)
- Be careful whether cash flows occur at the beginning or the end of the period

Cash Flows, NPV, and Equivalent Uniform Annual Net Benefits

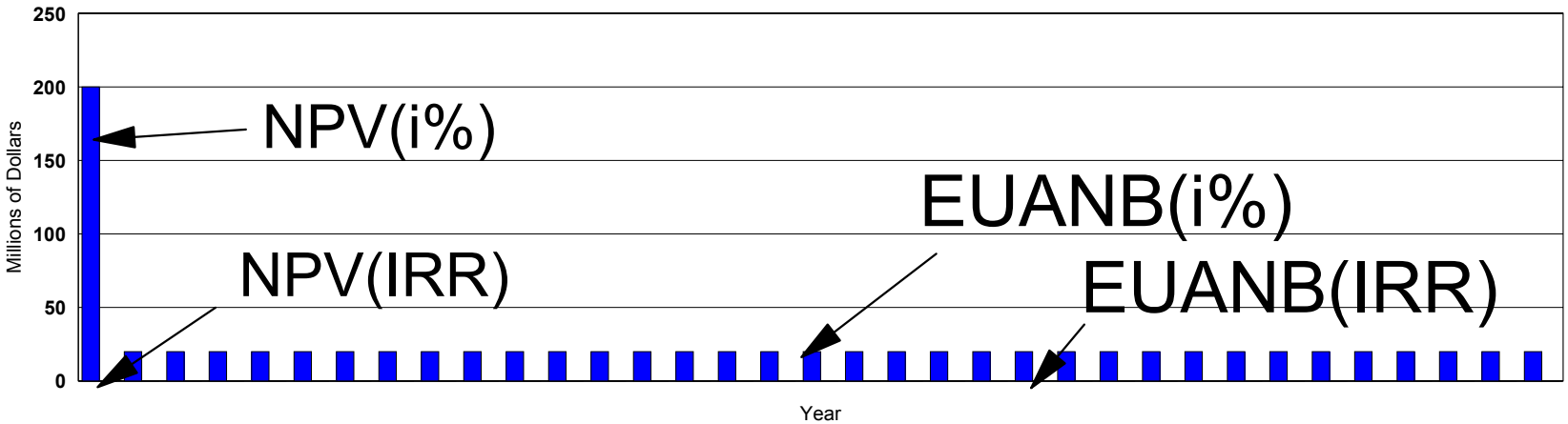




Calculating the Internal Rate of Return



Choose discount rate such that the NPV = 0



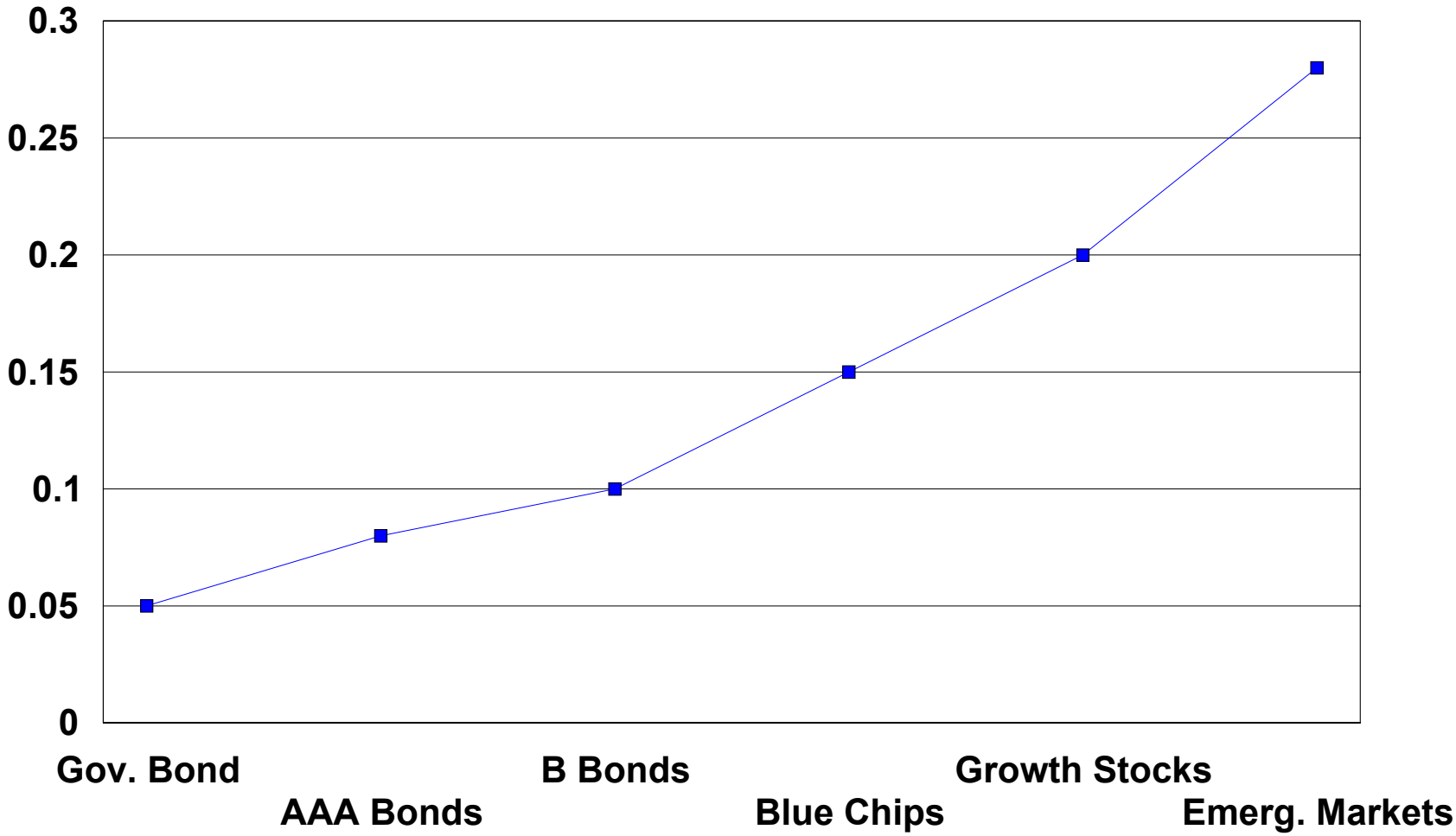
Problems With the Internal Rate of Return

- 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

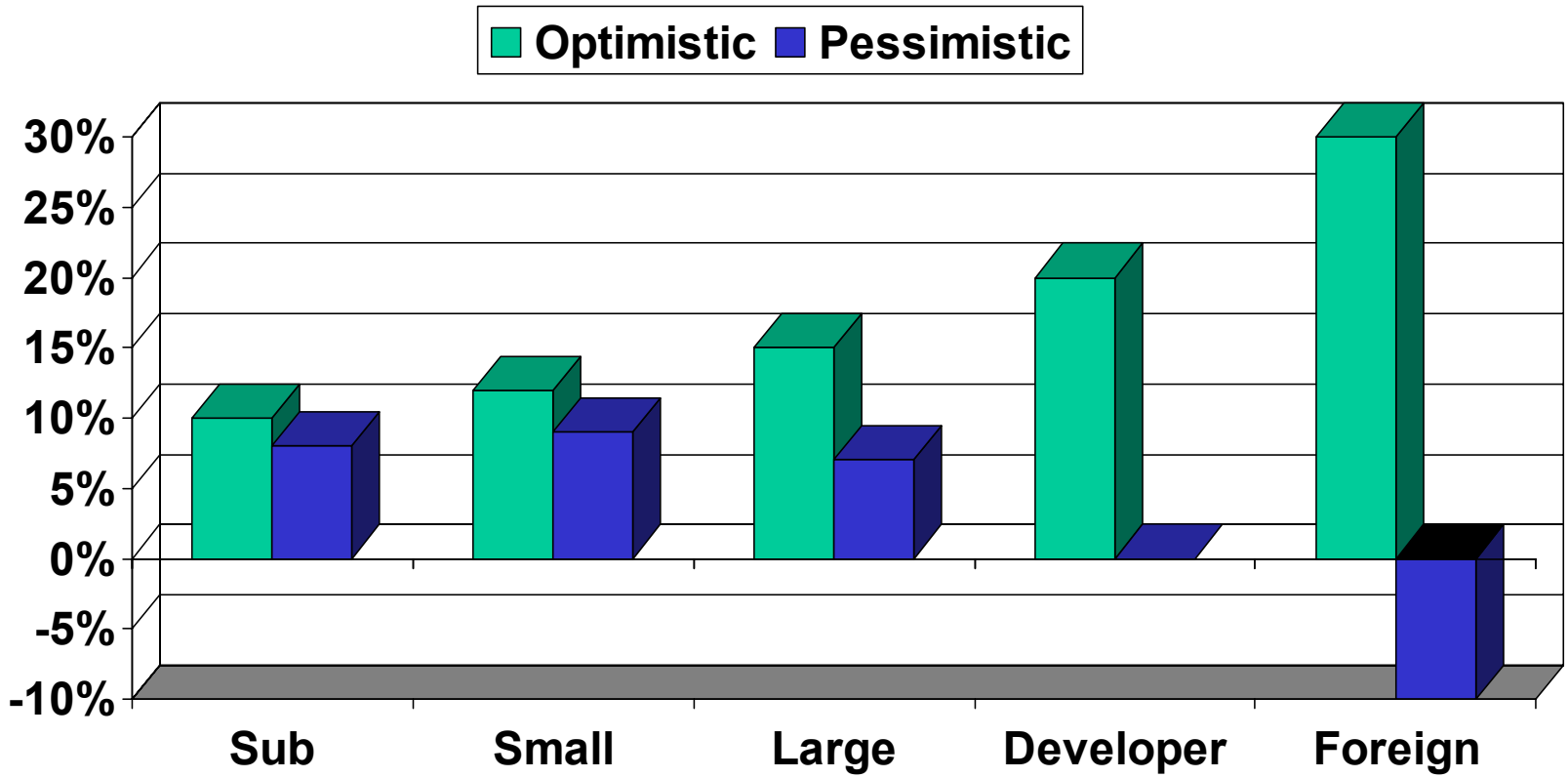
Choosing A Discount Rate

- The discount rate reflects the opportunity cost for the person or organization that will receive the cash flows (e.g. the federal government specifies a rate to be used)
- The analysis can be done with real or nominal discount rates
  - Real rates are used in constant-dollar analyses
  - Nominal rates reflect expected inflation (market interest rates are therefore "nominal" interest rates)
- The discount rate is not the same as the interest rate obtained to finance the project
- Higher risks will require a higher discount rate
  - Project risks (e.g. can we build this on budget and on schedule?)
  - Market risks (e.g. will the market for real estate remain strong?)
  - Economy risks (e.g. will there be a recession?)
  - Country risks (e.g. will the government remain stable and supportive of new infrastructure projects?)

What is an Appropriate Discount Rate?
Risk vs. Expected Return



What is an Appropriate Discount Rate?
Risk % Returns of YOUR Opportunities



WHOSE Discount Rate?

- Investors
  - Compare risks and returns of investing in your project to their other options (*THEIR* perceptions of risks & opportunities)
  - WHO gets paid HOW MUCH and WHEN and HOW do they get paid?
- Developers
  - Compare risks and returns of YOUR options (YOUR perceptions of risks & opportunities)
  - How to reduce actual and perceived risks; how to share risks and potential rewards among participants and investors

What is an Appropriate Project Life?

- Projects need to be evaluated over a reasonable project life (and the economic life will be shorter than physical life)
- Because of discounting, the "out years" do not add much to the NPV
  - Using a 10% discount rate, $100 in 25 years is worth less than $10 today
- Risks increase with time
  - Competing or supplementary facilities or services (e.g. highways reduce demand for railways)
  - Changes in demand (e.g. suburbanization)
  - Changes in factor prices (e.g. fuel)

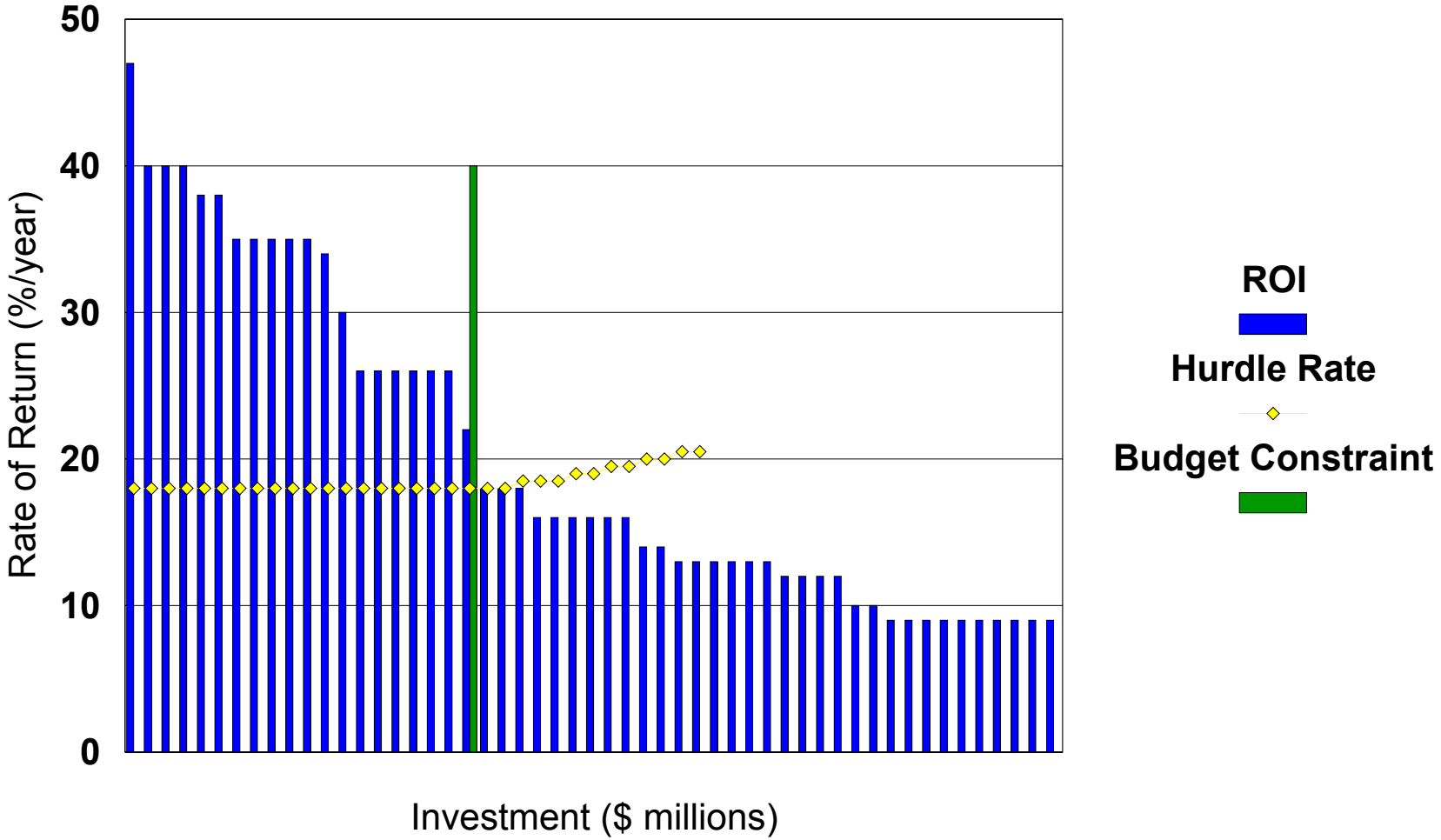
Are There Alternatives For Achieving the Objectives of this Project?

- 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 :
  - 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, Social, and Environmental 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"

What Route? What Technology? Where to Place Stations? Noise Abatement?

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Broader Economic, Social, and Environmental 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, Social and Environmental 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 issue

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

Finances Are Important, but They Aren't Everything

- Environmental Impact Assessment
  - Understand the expected impacts of the major alternatives on the environment
- Sustainability
  - Can (or should?) this project (or this program) be sustained indefinitely?
  - Three sets of concerns
    - Financial/economic
    - Social
    - Environmental

What Does it Take to Implement a Project?

Thames River Recycling Center, using Barges for Transportation Waste Materials. Photo courtesy of den99 on flickr. [Link to: http://www.flickr.com/photos/10260831@N02/2741219485/]

- Financing
- Government Approval
- Resources
- Social Acceptance or Manageable Opposition