Lee Merkhofer on Priority Systems

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PRIORITY SYSTEMS

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Priority System

A project priority system is a logical means for prioritizing projects (efforts, acquisitions, & other business investments). Because resources are limited, not every project can be undertaken immediately. A well-designed priority system will:

- Identify the value-maximizing "portfolio" of projects to conduct each budget cycle.
- Provide a defensible, explainable logic for funding choices.
- Support a more efficient and equitable decision-making process that reduces gaming, increases accountability, and "levels the playing field" for the competition for resources.
- Create a competitive business advantage.

Services

We provide education, consulting, and tools for prioritizing projects and managing project portfolios. Our collaborative Approach delivers a project priority system custom-designed to fit each need. Click Distinctions to see what makes us different.

Information

For a quick introduction to priority systems, click Tutorial. See Examples for sample priority system applications. In-depth discussion is provided in the papers:

- See Addressing the Reasons Organizations Choose the Wrong Projects
- If you're considering investing in a priority system, see Tools-Which Approach is Best?
- For math, read Mathematical Theory.
- See the System Demo to view a sample priority system.

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Priority System Tutorial

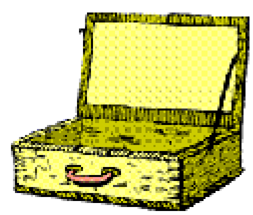
- We can't do everything. Therefore, we ***prioritize***.
- Priority should be given to things that generate the most ***value***.
- The value of something is determined by the degree to which it achieves ***objectives***.

These assumptions dictate the 3 basic steps for constructing a priority system:

1. Identify and structure your objectives. (What do you want?)
2. Define performance measures. (How will you measure the degree to which alternatives achieve objectives?)
3. Derive the aggregation equation and decision rule. (How will you combine the performance measures and use the results to make decisions?)

Example:
What to pack for vacation?

Limited Resource:
Space
(3000 cu. in.)



Alternatives:

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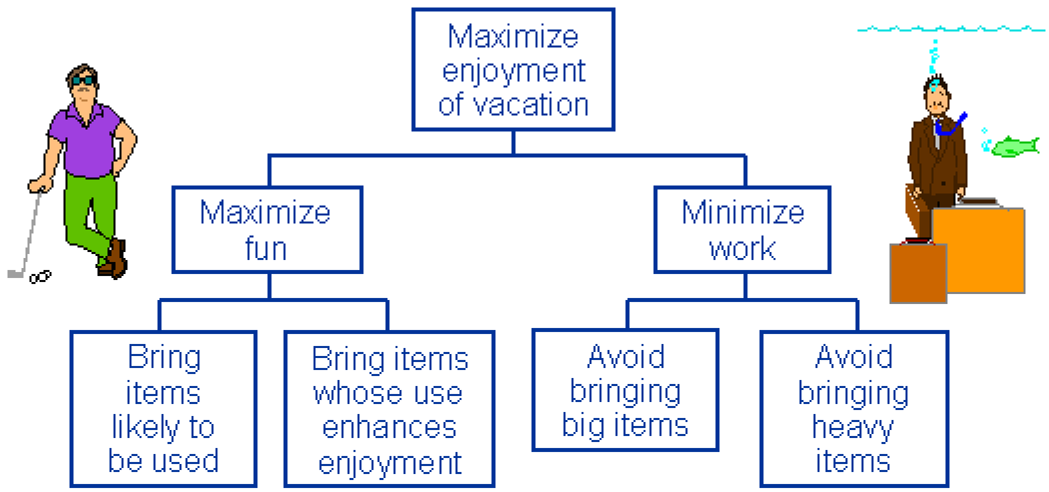
Step 1: Identify and structure objectives

Objectives must be specified by decision makers. Suppose the vacationer's top-level objective is to maximize enjoyment, which requires maximizing fun and minimizing work. Items add fun when they are used and their use enhances enjoyment. Work occurs if the items are heavy and take up too much room in the suitcase.



Structuring objectives as a hierarchy shows how achieving lower-level objectives (that are impacted by choices) enable higher-level objectives to be achieved. Objectives must be complete (to capture all significant considerations) and cannot be redundant or overlap (to avoid double counting).

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Step 2: Define performance measures

Performance measures quantify the degree to which objectives are achieved. They are typically obtained from technical specialists using a facilitated assessment process involving influence diagrams.

Objective	Selected Performance Measure	Required Estimate
Bring items likely to be used	Frequency of use	Number of times item would be used
Bring items whose use enhances enjoyment	Benefit per use	Benefit score: 4 = Major benefit added 3 = Significant benefit added 2 = Moderate benefit added (about ½ that judged "major") 1 = Minor benefit added 0 = No benefit added
Avoid bringing heavy items	Item weight	Weight in pounds
Avoid bringing big items	Item size	Volume (length x width x height, in inches)

As illustrated, performance measures can be either measurable attributes of the alternatives (like size) or constructed scoring scales.

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Step 3: Derive the aggregation equation and decision rule

The aggregation equation is derived based on characteristics of the objectives and performance measures using mathematical modeling principles. For example:

Ranking Measure = [80 x (Frequency of Use x Benefit per Use) - 20 x Weight] / Size

Why this equation?

Item	Frequency (No. times used)	Benefit per Use Score 4=major, 3=significant, 2=moderate, 1=minor, 0=none	Pounds	Cubic inches	Ranking Measure	Cumulative Space Used (3000 cu in max)	Decision
Prescription medicine	7	4	0.1	3	746	3	Pack
Swimming trunks	4	3	.2	11	97	14	Pack
Camera	4	4	0.5	25	51	39	Pack
:	:	:	:	:	:	:	:
:	:	:	:	:	:	:	:
Hawaiian shirt	2	1	0.2	26	6	3000	Pack
Tennis racket	2	2	1	100	3	3100	Don't
Bowling ball	2	3	14	800	0.3	3900	Don't

Although this priority system seems to work, it's always a good idea to test a priority system's limitations. Think of items that might be misranked. For example, this system will give bad advice for packing cash (risk of theft is ignored), tennis balls (dependencies with unpacked items are ignored), and fresh bagels (time critical items are ignored). Whether limitations need to be addressed depends on the application.

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Deriving the Aggregation Equation

For accurate recommendations, it is important to choose a logically sound aggregation equation. This equation is derived using a result from optimization theory. Suppose you have a constrained budget and want to fund the specific set of alternatives that produces the greatest possible total benefit. If the alternatives are independent (so that choosing any one doesn't affect the decision of whether to choose any other), then the choices that maximize benefit can be identified (approximately) by ranking the alternatives by their ratios of benefit to cost. Then, you simply select them from the top down until the budget is exhausted. (The result is only approximate because the alternatives selected in this way may not consume the entire budget.)

In our example, the constrained resource is luggage space, not cost, but the principle is the same. We can calculate the benefit of an item by multiplying its Benefit per Use times its Frequency of Use, and then subtracting the "disbenefit" associated with the item because of its weight:

$$\textbf{Benefit} = W_V \times (\textbf{Frequency of Use} \times \textbf{Benefit per Use}) - W_H \times \textbf{Weight}$$

The factors W_V and W_H are scaling factors (importance weights) meant to indicate how distasteful the traveler finds it to carry heavy items compared to the satisfaction derived from their use (e.g., a big person might assign different scaling factors than a smaller person). Scaling factors are set by identifying performance measure values at which the decision maker is indifferent between two choices (e.g., whether or not to carry an item). In this case, the scaling factors reflect a value judgment that it would not quite be worthwhile (implying that the item net benefit in this case is zero) to carry a 4 pound item used only once that provided only minor benefit . To see that this value judgment implies the above weights, note that an item used only once and that provided minor benefit would have a Frequency of Use equal to 1 and a Benefit per Use equal to 1. Thus, according to the above equation:

$$\textbf{Item Benefit} = W_V - W_H \times 4 = 0$$

If we require that the scaling factors sum to 100, we also have:

$$W_V + W_H = 100$$

Solving the above equations gives:

$$W_V = 80, W_H = 20$$

Plugging these values into the first equation and dividing by size then gives the ratio of benefit to item "cost":

Ranking Measure = Benefit/"Cost" = [80 x (Frequency of Use x Benefit per Use) - 20 x Weight] / Size

Thus, our equation allows the (approximate) set of benefit-maximizing set of items to be found by ranking.

Addressing the Reasons Organizations Choose the Wrong Projects

The following originally appeared as a Guest Article on Max Wideman's Project Management website.

If you've attended recent business conferences, you may have heard business leaders and management consultants speak of the "60% solution." The phrase refers to the popular belief that organizations obtain only about 60% of the value that could be derived from their businesses. The remaining 40% of available value is lost, reportedly, due to errors in decision-making and weaknesses in business systems.

I believe 60% is an accurate characterization of the way most organizations select and manage their project portfolios. As demonstrated in Part 5 of this 6-part paper, it is possible to compare, using models, the value generated by an organization's current set of project choices with the value that would be generated under a value-maximizing set of choices. My comparisons (similar results have been obtained by others) show that organizations can typically increase value by 20-40% without increasing costs, or decrease costs by 20-40% without decreasing value, each budget cycle, by making better choices.

Yes, 40% is BIG, and you may not be immediately convinced by results based on models. Therefore, this paper offers further evidence by explaining the 5 major reasons that organizations mismanage their project portfolios: 1) errors and biases in judgment, 2) failure to see the forest for the trees, 3) lack of the right metrics, 4) inattention to risk, and 5) inability to find the efficient frontier. As you will see, each of these reasons can by itself cause significant errors. It should not be surprising that the combined effect could be a 40% loss of value.

As you read about the 5 reasons, consider the degree to which each is a factor in your organization. Understanding organizational dysfunctions is useful even if your intention is not to invest in a priority system. By taking steps to mitigate the problems that affect your organization, you may be able to reduce costs while obtaining more value from your projects. Given the importance of project decisions, obtaining even small improvements will be worth the effort.

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1. Errors and Bias in Judgment

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Reason 1: Errors and Bias in Judgment

Why do we need decision aids? Can't people make good choices on their own? Like many decision analysts, I was first attracted to the science of decision making as a result of reading about the errors and biases that affect people's judgments. If you're not already familiar with the major results from this fascinating area, this introduction will help you to appreciate the value of formal decision-aiding tools. Errors and bias in judgment is the first reason that organizations choose the wrong projects.

The fact that people's intuitive decisions are often strongly and systematically biased has been firmly established over the past 30 years by literally hundreds of empirical studies. Psychologist Daniel Kahneman received this year's Nobel Prize in Economics for his work in this area. The conclusion reached by Kahneman and his colleagues is that people use unconscious shortcuts, termed heuristics, to cope with complex decisions. "In general, these heuristics are useful, but sometimes they lead to severe and systematic errors" [1].

Understanding heuristics and the errors they cause is important because it helps us find ways to counteract them. For example, when judging distance people use a heuristic that equates clarity with proximity. The clearer an object, the closer we perceive it to be. Although this heuristic is usually correct, it allows smog to trick us into thinking that objects are more distant than they are. This distortion poses dangers for airlines, so pilots are trained to rely more on instruments than on what they think they see out the cockpit window.

Some of the dozens of well-documented heuristics and related errors and biases include:

Comfort Zone Biases People tend do what's comfortable rather than what's important.	**Perception Biases** People's beliefs are distorted by faulty perceptions.	**Motivation Biases** People's motivations and incentives tend to bias their judgments.	**Errors in Reasoning** People use flawed reasoning to reach incorrect conclusions.	**Group Think** Group dynamics add additional distortions.
People: • Become attached to the status quo. • Value things more highly if they already own them. • Ignore information inconsistent with their current beliefs. • Fail to learn and correct their beliefs despite strong evidence that they should do so. • Keep doing the same things, even if they no longer work well. • Distort their views of reality in order to feel more comfortable.	People: • Anchor on information that is readily available, vivid or recent. • Make insufficient adjustments from their initial anchors. • Ascribe more credibility to data than is warranted. • Overestimate what they know. • Underestimate the effort involved to complete a difficult task. • Give different answers to the same question posed in different ways.	People: • Unconsciously distort judgments to "look good" and "get ahead." • Take actions as if concerned only with short-term consequences. • Attribute good decisions to skill, bad outcomes to others' failures or bad luck. • Escalate commitments to avoid questioning earlier decisions. • Favor actions that shield them from potentially unfavorable feedback.	People: • Simplify inappropriately. • Are persuaded by circular reasoning, false analogies, and other fallacious arguments. • Are surprised by statistically likely "coincidences." • Base the credibility of an argument on its manner of presentation. • Abhor risk but seek bigger risks to avoid a sure loss. • Cannot solve even simple probability problems in their heads.	Groups: • "Dive in" without having all of the necessary information. • Are excessively cautious in sharing data. • Avoid expressing opposing views. • Jump to conclusions prematurely or get bogged down trying to reach agreement. • Create illusions of invulnerability and ignore external views of the morality of their actions.

The following is a summary of some of the most important biases, with some ideas for reducing their impact.

Status Quo Bias

Research shows that decision makers are often biased toward alternatives that perpetuate the status quo. Psychologists call this a "comfort zone" bias based on research suggesting that breaking from the status quo is, for most people, emotionally uncomfortable. It requires increased responsibility and opening oneself up to criticism. For example, if you introduce a lower-cost/lower-quality version of an existing product to your product line, you may have to confront the trade off between increased profits and the risk of damaging your brand image. Sticking to the status quo is easier because it creates less internal tension.

There are often good reasons, of course, for leaving things unchanged. But, studies show that people assign too much value to the status quo. In one experiment, for example, each participant in a group of students was randomly given a gift consisting of either a coffee cup or a candy bar. When offered the chance to trade with each other, few wanted to exchange for the alternative gift. Apparently, "owning" what they had been given made it appear more valuable.

Institutional norms tend to reinforce preference for the status quo. For example, courts (and many organizations) view a sin of commission (doing something wrong) as more serious than a sin of omission (failing to prevent a wrong). As another example, government decision makers are often reluctant to adopt an efficiency-enhancing reform if there are "losers" as well as "gainers." Any change is seen as "unfair." The burden of proof is on the side of changing the status quo. Those who want to keep the status quo do not need arguments.

Lack of complete information, uncertainty, and too many alternatives promote holding to the status quo. For example, many organizations continue to support failing projects due to lack of solid evidence that they've failed. Killing a project may be a good business decision, but it is often uncomfortable for the people involved. Many companies question why so many of their projects fail, but a better question may be, "Why don't they fail sooner?"

The best advice for countering the bias toward the status quo is to consider carefully whether status quo is the best choice or only the most comfortable one:

1. When you hear comments like "let's wait and see" or "let's meet next month to see how the project is going," question whether you're hearing status quo bias.
2. Think about what your objectives are and whether they are they best served by the status quo or a change.
3. Ask yourself whether you would choose the status quo alternative if, in fact, it were not the status quo.
4. Avoid overestimating the effort involved in switching from the status quo.
5. Note that a change becomes the status quo over time. Evaluate alternatives in terms of the future as well as the present.

Sunk Cost Bias

We know rationally that sunk costs—past investments that are now irrecoverable—are irrelevant to decision making. Only incremental costs and benefits should influence future choices. Yet, research shows that the more we invest in something (financially, emotionally, or otherwise), the harder it is to give up that investment. For example, in a telephone call, being on hold and hearing the recording, "Your call is important to us...Please stay on the line," often means that you've got a lot longer to wait. Still, it's hard to hang up and call another time. Similarly, you may have trouble terminating a project that's in trouble if you've already spent a lot on it.

The Concorde is often cited as an example of sunk cost bias. It became obvious early on that the Concorde was very costly to produce and that few orders for planes were coming in. Even though it was clear that the plane would not make money, France and England continued to invest.

Why is it so difficult to free oneself from sunk cost reasoning? Psychologists believe it is because we are unwilling, consciously or unconsciously, to admit to a mistake. For example, if you fire a poor performer you hired, you may feel you are making a public admission of earlier poor judgment.

Some of the techniques that have been suggested to counter sunk cost bias include:

1. Seek out and listen to the views of people who were uninvolved in the original choice.
2. Ask yourself whether you would choose the same course of action that you are now on if there had been no past investment.
3. Be alert to sunk cost bias in the decisions and recommendations made by others. Consider re-assigning responsibilities.
4. Remember that even smart choices (taking into account what was known at the time the decision was made) can have bad outcomes. Cutting your losses does not necessarily mean that you were foolish to make the original choice.

Supporting Evidence Bias

Supporting evidence bias is our tendency to want to confirm what we already suspect and look for facts that support it. We avoid asking tough questions and discount new information that might challenge our preconception. Suppose, for example, you are considering an investment to automate some business function. Your first inclination is to call an acquaintance who did it and got really good results. What response do you expect other than, "It's the right choice"?

Despite our inclination to look for supporting evidence, it is usually much more informative to seek out contradictory evidence. Confirming evidence often fails to discriminate among possibilities well. To illustrate, in one study students were given the initial sequence of numbers 2, 4, 6 and told to determine the rule that generated the numbers. To check hypotheses, they could choose a possible next number and ask whether that number was consistent with the rule. Most students asked whether a next number "8" would be consistent with the rule. When told it was, they expressed confidence that the rule was "the numbers increase by 2." Actually, the rule was "any increasing sequence."

Supporting evidence bias often strongly influences the way we listen to others. It causes us to pay too much attention to supporting evidence and too little to conflicting evidence. Psychologists believe the bias derives from two fundamental tendencies. The first is our nature to subconsciously decide what we want to do before figuring out why we want to do it. The second is our inclination to be more engaged by things we like than by things we dislike.

Some advice for avoiding supporting evidence bias:

1. Check to see whether you are examining all the evidence. Avoid the inclination to accept confirming evidence without question.
2. Get in the habit of looking for counter arguments. In meetings, consider appointing someone to serve as devil's advocate, to

argue against the prevailing point of view.

3. Be honest with yourself and your motives. Are you really gathering information to help you make a smart choice, or are you just looking to confirm what you already believe.
4. Don't surround yourself with "yes men."

Framing Bias

The first step in making a decision is to frame the question, but it is also where you can first go wrong. The way a problem is framed can profoundly influence the subsequent choices we make. People tend to accept the frame they are given; they seldom stop to reframe it in their own words.

As an example, whether outcomes are described as gains or losses has been found to have a big effect on people's choices. In one experiment, people were asked to express their preferences among different programs impacting community jobs. They were told that due to a factory closing 600 jobs were about to be lost. However, if program A is adopted, 200 jobs will be saved. On the other hand, if program B is adopted, there is a 1/3 probability that 600 jobs will be saved and a 2/3 probability that none of the 600 jobs will be saved. Most people preferred program A. Another group was given a rephrasing of the choice. If program C is adopted, they were told, 400 people will lose their jobs. If program D is adopted, there is a 1/3 probability that nobody will lose their job and a 2/3 probability that 600 will lose their job. This group mainly favored program D.

Similar effects occur in less-controlled, everyday circumstances. For example, it sounds more positive to say that a new product launch has a "1-in-10 chance of succeeding" compared to the mathematically equivalent statement that it has a "90% chance of failing." If people are rational, they should make the same choice in every situation in which the outcomes are identical. It shouldn't matter whether those outcomes are described as "gains" or "losses" or "successes" or "failures." But, the choice establishes very different frames, and decisions may differ because of it.

Another example, described by John Hammond and Ralph Keeney, involves automobile insurance laws voted on in New Jersey and Pennsylvania. Each state gave voters a new option: By accepting a limited right to sue they could lower their insurance premiums. New Jersey framed the initiative by automatically giving drivers the limited right to sue unless they specified otherwise. Pennsylvania framed it by giving drivers the full right to sue unless they specified otherwise. Both measures passed, and in both cases large majorities of drivers defaulted to the status quo. But, because of the way Pennsylvania framed the choice, drivers in that state failed to gain about $200 million in expected insurance savings.

Advice:

1. Ask yourself if you are working on the real problem.
2. Try posing problems in a neutral way that combines gains and losses or embraces different reference points.
3. Look at the problem from other perspectives. For example, reverse the context. If you are the seller, how would you see things if you were the buyer?
4. Choose a frame that captures all of what's important. For example, ask, "What's the total cost of ownership?" not "What's the price?"
5. Choose a high-level perspective for framing. For example, looking only at project-by-project risk may result in a portfolio of overly conservative projects.

Estimating and Forecasting Biases

People are notoriously poor at estimating and forecasting. They tend to naively extrapolate trends that they perceive in charts. They draw inferences from samples that are too small or unrepresentative. They routinely overestimate their abilities and underestimate the effort involved in completing a difficult task.

Several biases combine to cause us to make serious errors when forecasting future performance. One problem is overconfidence. We believe we are better at making forecasts or estimates than we really are. I've often repeated a well-known demonstration to illustrate what I call the "2/50 rule." People are asked to provide confidence intervals within which they are "98% sure" that various uncertain quantities lie. The quantities for the questions are selected from an Almanac, for example, "What's the elevation of the highest mountain in Texas?" When the true value is checked, up to 50% of the time it falls outside of the specified confidence intervals. If people were not overconfident, values outside their 98% confidence ranges would occur only 2% of the time. As a related observation, there are many examples of famous people expressing utter confidence about things that are subsequently proved wrong. For example, Thomas Watson, Chairman of IBM, reportedly said, "I think there is a world market for about five computers."

Another relevant bias is anchoring. Initial impressions become reference points that anchor subsequent thoughts and judgments. For example, if a salesperson attempts to forecast next year sales by looking at current year sales, the old numbers become anchors, which the salesperson then adjusts (usually insufficiently) based on other factors. When things are changing rapidly, historical anchors lead to poor forecasts and, in turn, promote to misguided choices. Dramatic or easy to recall events often become strong anchors. For example, the vividness of the horrible events of September 11 caused many to view airline travel as too risky, but many experts believe that travel has never been safer.

Various motivational biases also lead to forecasting errors. The nature of the effect can depend on the individual. For example, project managers who are anxious to be perceived as successful may pad cost and schedule estimates to reduce the likelihood that they fail to achieve expectations. On the other hand, project managers who want to be regarded (consciously or unconsciously) as high-performers may underestimate the required work and set unrealistic goals.

Forecasting errors are often attributed to the fact that most people don't get good feedback about the accuracy of their forecasts. We are all fairly good at estimating physical characteristics like volume, distance, and weight because we make such estimates frequently and get feedback about our accuracy. We are less experienced (and get less verification) when making more uncertain forecasts. Weather forecasters and bookmakers have opportunities and incentives to maintain records making more uncertain forecasts. Weather forecasters and bookmakers have opportunities and incentives to maintain records of their judgments and see when they have been inaccurate. Studies show that they do well in estimating the accuracy of their predictions.

Another problem is that people often fail to properly consider statistical information. When forecasting how long it will take to complete a project, for example, project managers may fail to consider the time taken to do previous projects. Rather, they take an "insider's view" of the current project, thinking only about the steps and scenarios leading to successful completion. This usually results in overly optimistic forecasts. Also, people tend to be insufficiently conservative (or "regressive") when making predictions based on events that are partially random. For example, shareholders expect a company that has just experienced record profits to earn as much or more the next year, even if there have been no changes in products or other elements of the business that would explain the recent, better-than-anticipated performance.

Advice for improving forecasts and estimates includes:

1. Think about the problem on your own before consulting others and getting anchored to their biases.
2. Be open-minded and receptive. Seek opinions from multiple and diverse sources. Tell them as little as possible about your own ideas beforehand.
3. Tell people you want "realistic" estimates. Ask about implicit assumptions.
4. Encourage the estimation of a range of possibilities instead of just a point estimate. Ask for low and high values first (rather than for a middle or best-guess value) so as to create extreme-valued anchors that counteract the tendency toward overconfidence around a middle value.
5. Require project proponents to identify reasons why what they propose might fail.
6. Give people who provide you with estimates knowledge of results as quickly as possible.
7. Use network diagrams and similar devices to identify and define the sequencing of component activities. A major value of such techniques is that they help reduce the likelihood that some necessary, but less visible, activities, such as procurement and training, aren't overlooked.
8. Routinely use logic to check estimates. As a simple example, if you have 2 months to complete a project estimated to require 2000 hours, verify that you have a sufficient number of FTE's available.

Garbage In, Garbage Out

Addressing biases is important even if you use formal tools and processes for evaluating and prioritizing projects. Such tools nearly always require inputs based on judgment. Poor judgments can result in GIGO (garbage-in/garbage out). Fortunately, research shows people are better at making the sort of limited, well-defined judgments that are typically required as inputs to well-designed decision models. Also, because a model breaks a problem down into individual pieces, different experts can be selected to focus on each. There is some evidence that experts are better at avoiding biases when making judgments within their specific areas of expertise. Even so, it is clear that biases are common in many of the types of judgments that are required for prioritizing projects. For example, according to one study of IT projects, only 37% of projects were completed within original schedule estimates, and only 42% were on budget.

Studies show that knowing about biases can help people reduce them. A useful technique for reducing overconfidence bias prior to obtaining judgments from people is to demonstrate the 2/50 rule described above. Show people that overconfidence is something that affects them personally, not just others. Training can also be effective. For example, studies show that formal training in statistics, in the classroom or in a 30-minute laboratory training program, improves judgments of probability. Many formal tools are available to avoid and correct for distortions in an individual's judgments, for example, techniques for "encoding" judgmental probabilities. There are also group facilitation techniques, such as Delphi and the Nominal Group Method, to minimize groupthink.

The best protection from bias comes from training, using formal techniques for obtaining important judgments, utilizing well-founded decision aids, and instituting rigorous decision processes that document the judgments and assumptions upon which choices are based. As stated by Ken Keyes, "To be successful in the business world we need to check our bright ideas against the territory. Our enthusiasm must be restrained long enough for us to analyze our ideas critically" [2].

References

1. A. Tversky and D. Kahneman, *Judgment Under Uncertainty: Heuristics and Biases*, Cambridge Press, 1987.
2. K. Keyes, Jr., *Taming your Mind*, Love Line Books, 1991.

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Reason 2: Failure to See the Forest for the Trees

Most organizations put ample effort into making individual projects successful, but not enough effort into making the entire portfolio of conducted projects as successful as it could be. The fault does not lie with project managers. Project managers are typically highly motivated. They view their value to the organization based on the successful completion of their projects. But, project managers are focused on their individual projects, not on the success of all projects. The typical project manager, for example, does not look for opportunities to redirect his or her resources toward the projects of other project managers who may need them more. Once they obtain the necessary approvals, project managers focus on achieving the costs, schedules, and performance mandates of their own specific projects.

Just because an organization may have a portfolio of mostly on-time, on-budget projects does not mean that it has the best possible project portfolio, nor that it is effectively allocating resources among the projects that it is doing. Unlike project managers, most senior executives appropriately do not judge success on a project-by-project basis. They care about the aggregate costs, risks, and value of the overall project portfolio. Likewise, the chief executive's concerns are mainly about meeting investor expectations, not whether or not individual projects succeed.

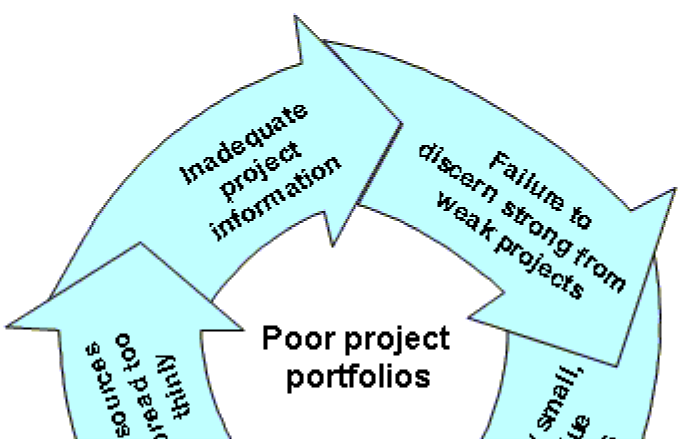
Although it should be obvious that it is the performance of the project portfolio as a whole that really matters, many organizations do not manage the aggregate cost, value and risk of their project portfolio. Either no one has responsibility for managing the project portfolio, or the efforts to do so are not as effective as they could be. Project managers tend to the individual "trees", but no one is caring for the "forest." Failure to see the forest for the trees is the second reason organizations choose the wrong projects.

Problems with Project-by-Project Decision Making

If project selection decisions are not made at the portfolio level, by default the project portfolio is the end result of individual project choices made one at a time with little regard for the impact that one project has on the next. Project-by-project decision making leads to too many projects with a bias toward short-duration, relatively low-value and low-risk efforts. There are several reasons for this. First, regardless of whether tools are used to formally evaluate project proposals, the basis for a "go" in project-by-project decision making is whether or not the proposed project is judged to achieve some hurdle or threshold of acceptability. For example, a company may require that larger projects be evaluated based on a financial calculation of net present value (NPV). If the NPV is positive, the acceptable hurdle is achieved and the project is deemed to pass. Many projects look good, especially in their early stages, so many projects pass the hurdles. It is only later when people are assigned to projects that it becomes clear that people are committed for more than 100% of their time.

Another problem is poor information. Surveys routinely report that management complains about insufficient information for decision-making. For example, R. G. Cooper reports that a study of product development projects at 300 firms "...revealed major weaknesses in the front-end of projects: weak preliminary market assessments, barely adequate technical assessments, dismal market studies and marketing inputs, and deficient business analyses" [1]. Poor information gives management an insufficient basis for making tough decisions. No one wants to be the one to kill a questionable project, "It's like drowning puppies!" As a result, failing projects don't get terminated soon enough.

Figure 1 illustrates the destructive cycle that relates the problems of too many projects and inadequate project information.



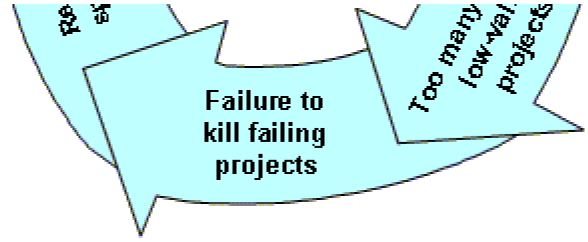


Figure 1: The downward spiral resulting in poor project portfolios.

Inadequate project information creates an inability to discriminate, leading to too many projects. Failure to kill failing projects compounds the problem. The result is resources are spread too thinly. People multi-task, which reduces efficiency. Consequently, insufficient time is devoted to developing better quality data. Quality of execution drops and project schedules slip. The portfolio is biased toward small, low-value, low-risk, short-duration projects (e.g., extensions, modification, up-dates) because large, high-value/high-risk projects aren't viewed as feasible (given the constraint on resources). Even if bigger, riskier projects are proposed, management usually isn't prepared to take the risk due to the lack of quality information. When a large project does get started, available resources get sucked into the big one. often leaving other projects high and dry.

Problems Caused by the Lack of Clear Priorities

A related problem is that the failure to establish organizational project priorities causes inefficiencies in the day-to-day allocation of project resources. Consider the following example from an article by the Product Development Institute, Inc. [2]. Imagine that you are a member of a project team in a typical organization. Like most project team members, you are working on several projects simultaneously. You are under pressure from all your project managers to make faster progress. Suppose you finish a milestone on an important project ahead of schedule. Do you use the opportunity to get an early start on your next task on this project? More likely, you turn your attention to one of your other projects. Your day-to-day priorities are based on your desire to minimize the pressures you feel from your various project managers. Although the organization may benefit more from your taking the opportunity to put your important project ahead of schedule, that project is unlikely to obtain the benefits of your early finish.

The point is that prioritization always happens. It is not a matter of whether or not to prioritize. It is only a question of who does it and how. In the absence of established priorities, people use their own prioritization methods. One common prioritization method is first in first out (FIFO). "Whatever task shows up in my in-box first, I do first." Another common prioritization method is the "squeaky wheel." Whoever complains to me the loudest gets the work done first. Another prioritization method is to do first the work for the manager that you like the best, has the most interesting projects, or writes your performance reviews. None of these methods is likely to result consistently in the best allocation of resources for the organization. Prioritization is a task for the organization's leadership. Unless management makes the effort to prioritize projects, the allocation of project resources will be left to individual project managers, and the result will not be in the best interests of the organization.

Combine Projects Into a Portfolio Database

Solving the problems created by project-by-project decision making requires shifting the focus to the project portfolio. The first step is to collect information about individual projects into a common database. A single project inventory can be constructed containing all of the organization's on going and proposed projects. Alternatively, multiple project inventories can be created representing project portfolios for different departments, programs, or businesses. Since project portfolio management can be conducted at any level, the choice of one portfolio versus many depends on the size of the organization and its structure. It might not, for example, make sense to force a centralized project portfolio on an organization that practices decentralized decision-making. The key is to group projects using common resources so as to leverage knowledge and expertise needed for execution. If multiple project portfolios are defined, the groupings should be organized so as to be as independent of one another as possible. Decisions about what projects to conduct within one portfolio should not depend in a significant way on the projects that are conducted within any other portfolio. The decision of how to allocate resources among the various project portfolios can then be made at a higher level, based on estimates of the how the value of each portfolio depends on the funding that it receives.

Since it is useful to be able to monitor and control the mix of various types of projects within the project portfolio, a project classification scheme should be established. Projects can be classified in many different ways. Examples include: size; duration; level of risk; geographic location; skills or technologies required; sponsor, client or market served; asset class addressed (e.g., infrastructure, transactions, etc.); stage of the project life cycle; type of product produced (e.g., research, software, construction); and so forth. Multiple schemes can be used so that each project is classified in several different ways. No one approach is best for every organization. The key is to choose classification schemes that will yield information useful to decision makers.

The information entered into a portfolio database should include the project name, type, and a brief description; internal and external resource requirements; number and skills of people required; estimated time to completion; and estimated cost. Importantly, the recorded information must also include some level of business justification, risk assessment, and value and urgency calculation. If project information is standardized, a template can be provided for submitting project proposals. Using a standardized project information template will encourage complete proposals and more consistent proposal evaluations.

Organizations invariably find that creating their first inventory of ongoing and proposed projects is revelational. "I didn't know

Organizations invariably find that creating their first inventory of ongoing and proposed projects is revelational, "I didn't know we had so many things going on, no wonder we can't get anything done!" Projects look less like discrete efforts and more like an interdependent suite. The initial project inventory often uncovers significant duplications and mismatches. For example, CIO Magazine [2] reports that when Schlumberger first grouped IT projects, they found that 80% overlapped. Duplicate efforts should be eliminated, obviously, and similar projects combined into a single project. Schlumberger reportedly saved $3 million by eliminating project redundancies.

Establish a Portfolio Management Office

A project portfolio manager should be appointed with accountability for the success of the entire project portfolio. The portfolio manager should be given an estimate of the total funding to be made available, but it should then be up to the portfolio manager to determine how to allocate the funds within that cost constraint. At the very least, the portfolio manager should have responsibility for recommending resource allocations for final approval by a committee of senior executives. In either case, senior executives should be enlisted to serve as a steering committee responsible for providing and updating (e.g., in response to changing strategy) the value judgments and policy decisions needed to guide portfolio management. It should be possible for the portfolio manager to suspend at any time further commitment of investment dollars due to failure to make anticipated progress, changing economic climates, or shifts in business objectives.

A portfolio management team should support the portfolio manager. This team team is responsible for evaluating project proposals, accepting or rejecting proposals, accelerating and decelerating projects, allocating resources, and otherwise continuously managing the project portfolio over time. The team should have responsibility for verifying cost, value, and risk estimates provided in support of project proposals. One member of the team should be designated as the primary contact person for each project manager.

Typical Portfolio Management Process

The main features of a typical process, illustrated in Figure 2, are as follows. On a regular basis tied to the planning and budgeting cycle (e.g., annually, biannually, or quarterly), the portfolio management team reviews all projects that are seeking funding, including ongoing projects and new project concepts. Projects are screened to determine which proposals require formal evaluation. Projects exempted from formal evaluation include obvious "non-starters," very small projects, and projects that are more appropriately funded from other budgets. Ongoing projects and "mandated" projects, projects that the organization is legally required to conduct, may or may not be exempted (see below). Screening may also be used to select a different level of analysis for different types or sizes of projects.

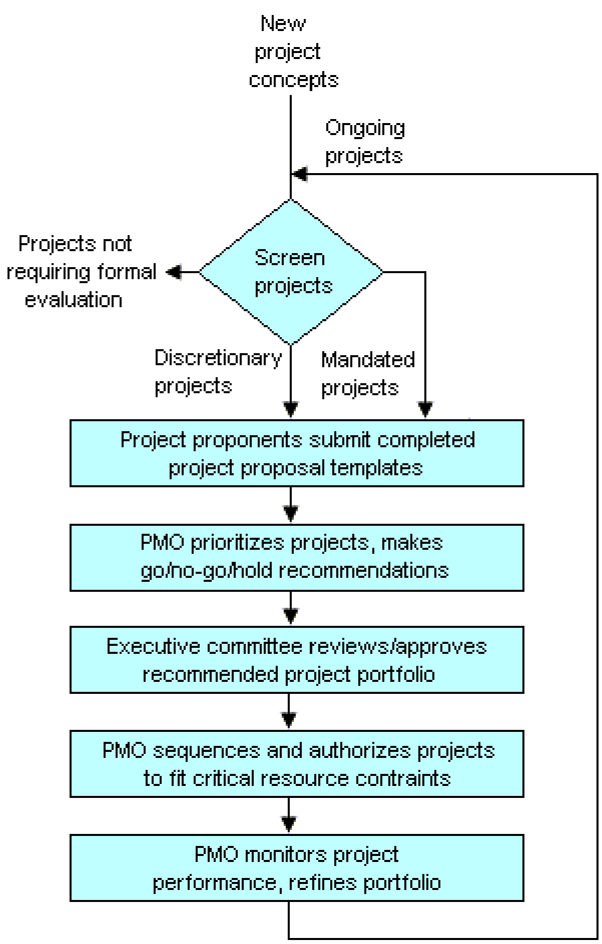


Figure 2: Typical portfolio management office (PMO) process.

Although mandated and ongoing projects may be exempted from formal evaluation, my recommendation is that both types of projects should be routinely evaluated along with new projects. In some organizations, "mandated" projects consume almost the entire budget. Very strict criteria should be provided for mandatory projects to ensure that they are defined with minimum possible scope and cost. Add-ons that go beyond what is strictly required should be defined as separate projects. Formally evaluating mandated projects promotes consistency, provides useful information, and helps the organization ensure that all of the benefits of mandated projects are, in fact, achieved.

Evaluating ongoing projects for continued funding is useful to ensure that struggling or obsolete projects do not prevent funds from being available to meet more-pressing needs. Where possible, large, long-duration initiatives should be reframed as a series of smaller projects. For example, in the case of a software project, it may be better to incrementally develop improved versions rather than trying to create one big Version 1.0 that does everything. The concept is to identify small "chunks" of work anticipated to generate some measurable benefit.

Although project managers often object to re-evaluating their projects, requiring ongoing projects to be re-evaluated is not unfair or overly burdensome to the managers of ongoing projects. Not as much effort is required to re-evaluate an ongoing project because template inputs need only to be updated rather than generated "from scratch." Estimates tend to get less uncertain as a project proceeds in its life cycle, and providing up-to-date inputs allows portfolio information to be kept current. Also, ongoing projects normally have an advantage in the competition; the relevant costs are the remaining costs needed to obtain project benefits, exclusive of costs already spent. Furthermore, the costs of terminating a project must be considered, and avoiding such costs is a legitimate benefit of continuing the project. Thus, achieving the necessary bang-for-the-buck usually isn't difficult for ongoing projects. If an ongoing project is eliminated, the decision should be regarded by all as an instance of successful resource reallocation, not as an obvious failure on the part of a project manager.

Note that the evaluation of on-going projects for the purposes of project prioritization is not meant to replace other project progress evaluations. For example, a large, multi-stage project may need to be evaluated at specified phases or "gates" to ensure that it is on track to meeting its milestones and deliverables. Project gate reviews involve in-depth evaluations based on real-time information, but they are made in relative isolation to the decisions made on other projects. Gate reviews can signal a project that is "in trouble;" which could result in immediate project termination or cause it to be flagged for re-evaluation as part of the next portfolio review.

As indicated by the example above, projects may sometimes have to be evaluated between the major budgeting cycles. This is true even in the absence of formal gate reviews. For example, a project may need to be re-evaluated if there is a major, adverse change in the project scope, a risk event occurs, an assumption is found not to hold, or there is a realization after completing a portion of the work that earlier cost or schedule estimates are too optimistic. New projects proposed between planning periods can also be evaluated mid-period. Such projects are compared against the most-recently established project priorities. A contingency fund may be established for projects added outside the normal budget cycle.

Project managers with projects that pass the initial screening are authorized to use resources to conduct additional analysis and costing to provide the data required by the proposal templates. Although it is not common to do so, requiring multiple versions of proposals for large projects can be a good idea. For example, in addition to a base-case version, some organizations require project proponents to submit enhanced, decremented, and minimum cost versions for projects larger than some specified size. By providing project alternatives, organizations can avoid "all-or-nothing" choices for important, but resource-demanding projects.

Based on the formal evaluation, projects are prioritized and project "go," "no-go," and "hold" recommendations are made with the goal of creating a value-maximizing project portfolio. Project recommendations are reviewed by the executive steering committee and project funding for approved projects is authorized. Projects are phased based on critical paths to fit people and other resource constraints, with the most urgent projects starting first. Projects designated as "hold" may be resubmitted later (oftentimes project managers redesign such projects with the goal of increasing benefits and decreasing costs). The portfolio management office monitors the status of on-going projects to ensure that projects are on tract to achieve the anticipated benefits that motivate their being included in the selected project portfolio.

In addition, the portfolio management office should:

- Define and develop the detailed, continuous process by which projects are evaluated, prioritized, selected, and managed.
- Enforce a collaborative effort that enables senior executives (the steering committee) to reach agreement on portfolio objectives.
- Provide coaching and training to project managers to help then to understand project evaluation criteria and to enable them to efficiently generate inputs for the project template.
- Communicate to project proponents which projects are approved and project priorities.
- Adjudicate resource conflicts between projects.
- Maintain visibility of key project information across the enterprise.
- Ensure that the project portfolio stays aligned with business objectives.
- Identify lessons-learned and continually refine the portfolio management process.

Improving the Prioritization Process

The weak link in the above description of the portfolio management office is the prioritization of projects. For most organizations, prioritization involves the forced-ranking of projects. Then, to select the project portfolio, considerations that apply at the portfolio level, such as project interdependencies, portfolio risk, and balance, should be used as final modifiers to the ranking. Needless to say, forced ranking as well as the final choice of which projects to conduct are difficult decisions, and politics often plays a major role. Although creating a portfolio management office and a project inventory helps, the key to reaping the true benefits of portfolio management is following through and evaluating alternative projects and project portfolios based on value and risk.

Many organizations use scoring models as aids to project prioritization. Middle scores are common for most projects, especially when numerous scoring criteria are used. High scores on some criteria cancel out low scores on others. Most scoring models aren't sufficiently precise to trust small differences in total scores. Furthermore, ranking projects by their project scores is generally incorrect anyway. Typical scoring systems ignore project cost and, therefore, fail to represent "bang for the buck." (Additional problems with scoring models are described in the next section.)

Prioritizing projects requires being able to estimate the costs, value, and risks of alternative project portfolios. But, both sides of the equation are difficult. Project costs include not just the funding request, but also any funding provided from other sources plus the opportunity costs of using equipment, personnel, raw material and any other "non-costed" resources that will be employed by the project. Also, all future costs necessary to obtain project benefits must be identified, estimated, and included in the calculation. Some companies still do not track costs at the project level, relying instead on the general ledger system to impute approximate project costs. Tracking project costs is necessary to encourage accurate estimating and provide budget data needed to make, monitor, and update project decisions.

Estimating value is even more difficult than estimating costs. Systems must be in place to help managers measure the benefits of projects as well as to determine the value of alternative project portfolios. This leads to the hard part—developing the metrics for measuring project and portfolio value.

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1. Errors and Bias in Judgment **3. Lack of the Right Metrics**

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Reason 3: Lack of the Right Metrics

The metrics that an organization uses have a big impact not only on the projects that get chosen but also on the projects that get proposed. "Tell me how you will measure me, and I will tell you how I will behave" [1]. Even if the metrics aren't used to create incentives, managers interpret them as indicating what the organization regards as important. Lack of the right metrics is the third reason organizations choose the wrong projects.

Inadequacy of Financial Metrics

Most organizations use financial metrics, for example, return on investment (ROI), return on assets (ROA), internal rate of return (IRR), net present value (NPV), pay-back period, etc. Using these metrics to evaluate candidate projects requires forecasting all of the ways that a project can impact cash flows, which is often difficult to do. The biggest limitation of using such metrics for project prioritization, however, is that they provide, at best, only a partial representation of what is relevant.

Financial metrics, quite simply, don't capture all of the organization's true objectives. For public-sector organizations, this limitation is obvious. Public-sector organizations have non-financial objectives such as protecting public health and the environment, as well as mission-specific objectives. For example, a water utility has a mission that includes serving community water needs. A public school has a mission that includes educating its students. Financial metrics fail to measure the full value of projects that achieve non-financial objectives.

Likewise, the standard financial metrics do not represent the true objectives of private-sector organizations. Management scientists and U.S. business leaders are nearly unanimous in the opinion that the fundamental objective of investor-owned organizations is to maximize shareholder value. With this view, the appropriate metrics for evaluating projects in the private sector are those relevant to forecasting impacts on the market value of the business.

Shareholder Value

For publicly held companies, the value assigned by markets is the ultimate measure of the degree to which the company is meeting its business goals. Market valuations are objective and applied consistently across all publicly held companies and markets. If they were not there would be opportunities for arbitrage; that is, one could buy shares of a company at a lower price in one market and simultaneously sell it at a higher price in another market. Seeking higher stock value is clearly important to senior management. A company whose stock is depressed because it is not effectively managing for shareholder value is a candidate for investor takeover.

It is important to understand that managing for shareholder value and managing for profitable cash flows are two very different things. As shown by the figure below, the market value of a company does not equal the risk-adjusted discounted value (NPV) of its projected future earnings. In the literature on real options, the difference is referred to as "option value."

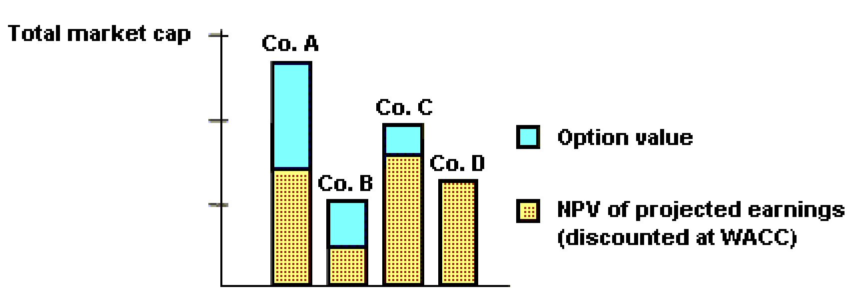


Figure 3: Company value depends on market perception of "real option value" as well as projected earnings (data for 4 companies in same industry).

As illustrated, it is not uncommon to find two companies in the same industry such that one has a higher NPV of projected returns but the other has a higher total market value. Market value depends not only on projected future cash flows, but also the how buyers and sellers in the marketplace perceive, among other things, the ability of the business to respond to future opportunities and avoid future threats. Option value does eventually translate into increased earnings. However, because it is difficult or impossible to forecast the exact mechanisms by which this will occur, option value and other indirect sources of value will not be represented in accounting forecasts of cash flows. Companies that evaluate projects by estimating impacts on profits alone ignore a significant component of market value.

Stakeholder Value

An alternative view, more popular outside the U.S., is that firms should create value for all stakeholders, not just shareholders. Stakeholder value includes value for employees, suppliers, customers, and the local community. Proponents of more narrow shareholder value argue that organizations that pursue self-interest and economic efficiency will, in fact, be socially responsible and serve all stakeholders. However, this argument carries the implicit assumption that the markets within which the firm operates are "perfect," with the result that stakeholders other than shareholders are unaffected by the firm's actions. For example, if people are hired, they are merely paid market wages, and if they are laid off, they can immediately get equivalent jobs elsewhere. Similarly, suppliers and consumers can switch to other firms, and taxes to all layers of government will be the same regardless of the firm's operations.

The U.S. economy is well diversified, which makes the "perfect market assumption" a pretty good approximation. However, the recent well-publicized accounting scandals have caused politicians and some U.S. business leaders to question absolute reliance on shareholder value. It may be reasonable, therefore, for even a private sector company to want to explicitly consider impacts on all stakeholders when making company decisions. Including stakeholder value further weakens the argument for using financial metrics as the sole basis for evaluating projects.

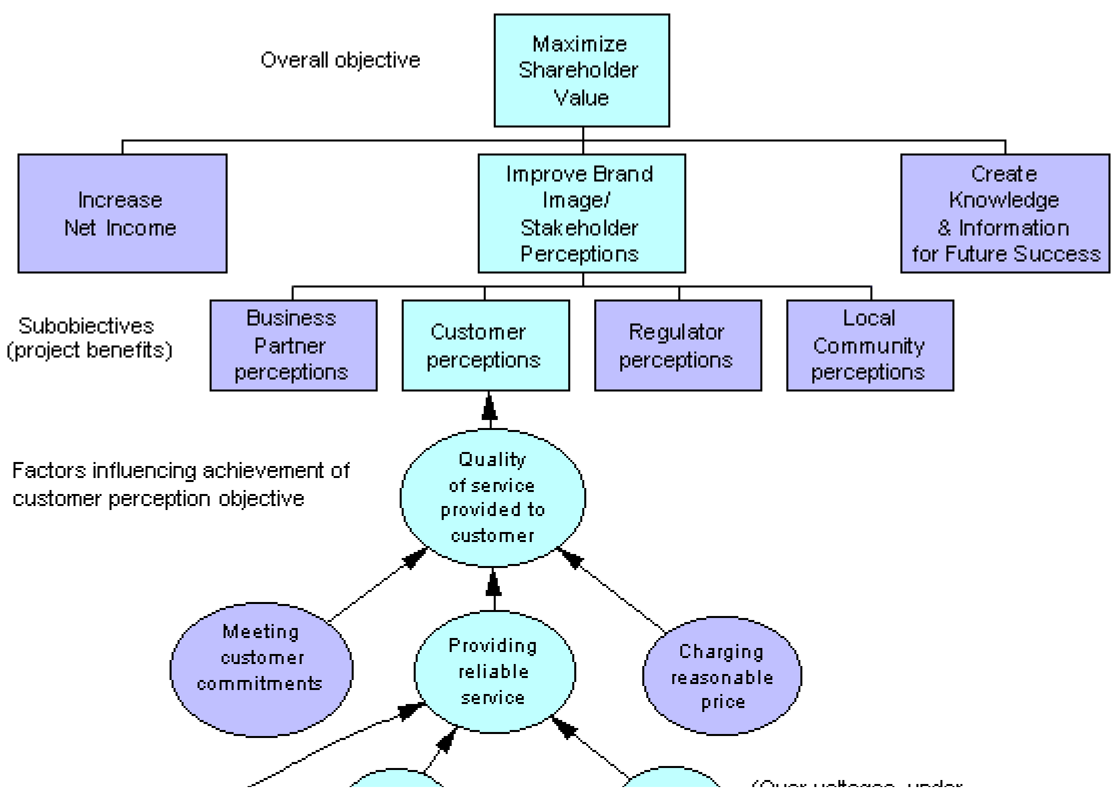
Finding the Right Metrics

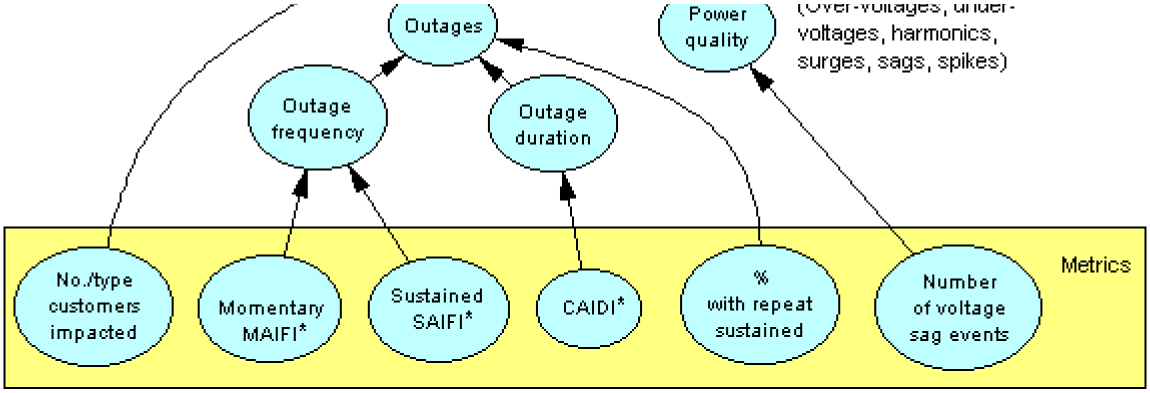
What kinds of metrics reflect impacts on value? Many organizations have trouble answering this question. Organizations tend to measure what is easy to measure, not necessarily what is important. Most organizations use a bottom-up approach. They define interesting metrics, but then can't come up with the algorithms for computing value based on those metrics. Unless there is a way to combine the metrics to determine the value added by projects, the metrics will not be of much help in identifying value-maximizing project portfolios. How can you determine the value added by projects?

Create a Value Model

The answer is—You need to reverse the process, use a top-down approach and create a value model [2]. The value model describes the various ways that projects create value (e.g., shareholder value, stakeholder value, or mission value). Identifying the ways that a project creates value requires judgment, (in the case of shareholder value, judgments similar to those made by careful investors and Wall Street analysts). Since the model is based on judgment, the model's assumptions must be clear so that they can be discussed, debated, and set to reflect best-organizational understanding of how what the organization does determines the value it creates.

Building a value model is not as difficult as it may sound. Even a fairly sophisticated value model can be constructed in a 2-3 day framing workshop (using techniques based on multi-attribute utility analysis, influence diagramming, and causal modeling). The model captures the understanding of the organization's experts in relevant areas such as R&D, engineering, manufacturing, marketing, sales, customer relations, legal counsel, regulatory affairs, etc. The value model establishes an explicit connection between the characteristics of the business that may be impacted by proposed projects and the value ultimately derived. Figure 4 provides an example.





* Measures of electric power distribution system reliability commonly tracked by utilities:
MAIFI = Momentary average interruption frequency index
SAIFI = System average interruption frequency index
CAIDI = Customer average interruption duration index

Figure 4: Portion of value model linking characteristics and impacts of proposed projects to value creation (electric power delivery company) [3].

Having a value model is critical to making intelligent project decisions. Project value determines whether the project should be done at all, and whether, after it has been started, it should be continued. But, the value model has other uses as well. For example, a value model provides a way to estimate the value of a day of schedule, the value of a project feature, or the value of a dollar of project cost. The project team or portfolio manager can use the value model to illustrate how a marginal change in resources, say plus or minus 10%, might affect the overall value to be generated. A value model is a means for explaining and justifying the resources required for doing projects.

Once you have a value model, it is relatively easy to define the right project metrics. The desired metrics are "observables" (see below) that influence the model's value drivers; that is, those project characteristics and impacts (model parameters) that have the greatest influence on value. These typically include forward-looking financial metrics, like NPV, but also factors and considerations on value paths that don't directly impact cash flows. The latter can include indicators of the contribution of the project to the organization's capability and knowledge, customer satisfaction, and even political and regulatory impacts. Metrics for these other sources of project value must be included along with the financial metrics, otherwise the value of projects will be underestimated and there will be a bias against doing projects whose benefits cannot readily be expressed as cost savings or revenue increases. Note that metrics need to represent timing (when the project benefits are likely to occur) and risks (e.g., the likelihood that the project will actually produce its anticipated benefits). When all such metrics are specified, the model defines the aggregation equation that allows the value of a project to be expressed in dollar terms (that, in the case of a privately-owned company, for example, represent the estimated impact of the project on shareholder value).

Metrics Should Be "Observables"

To the extent possible, metrics should be observables; that is, characteristics of projects or project outcomes that can be observed and measured in the real world. Since estimating project value requires forecasting the future, metrics don't, obviously, all have to be things we can observe today. Metrics can, for example, include a projected future state of some observable, for example, an improvement in a reliability-of-service statistic important to customer satisfaction.

A useful device for checking whether a metric is observable is the so-called "clairvoyant test" devised by my college mentor, Professor Ron Howard. Before accepting what appears to be a good metric, consider whether a clairvoyant could give an unequivocal value for that metric given that a project decision is made in a specific way. Oftentimes, the clairvoyant test points out inexactness of what initially appears to be a well-defined metric. For example, "customer satisfaction" doesn't pass the clairvoyant test. However, "percent reduction in recorded customer complaints" and "company ranking in the next industry customer satisfaction survey" are metrics that do pass the test.

Metrics that don't pass the clairvoyant test are vague. They create inconsistency and imprecision when used for estimating. More importantly, if the metrics are not observables, they cannot be monitored so that actual values can be compared against estimates. Observable metrics allow project proponents to be held accountable for achieving estimates submitted as part of project proposals, which is essential for minimizing biases and gaming in project forecasts.

Don't Forget Financial Metrics

The traditional financial metrics should be used to determine the direct financial (or "hard") components of project value. Project investment cost is, of course, an important financial metric for any project. Projects that impact operations (e.g., projects that create new products or cut costs) produce additional financial impacts that should also be evaluated. Thus, any significant, incremental, period-by-period cash flows that are anticipated to result from such projects should be estimated (either directly as an average or in the form of alternative scenarios). The organization's standard accounting model may then be used to determine the after tax ("free") cash flows, which may be used to compute a project's financial NPV. Some important principles for estimating financial value in support of project prioritization include:

- Ignore previously paid, sunk costs.
- Include opportunity costs (the opportunity cost of a resource is the value of the net cash flow that could be derived from it if it were put to its best alternative use).
- Include overhead expenses (e.g., administrative expenses, managerial salaries, legal expenses, rent) that are directly related to a project. Indirect overhead can, if necessary, be prorated across proposed projects.
- Include "spill over" effects. For example, if a project introduces a new product or service that draws sales from existing products, include such lost revenue in cash flow estimates.
- Interpret expected project cash flows submitted in support of a project proposal as commitments to be achieved by the project manager. If there are cash flow components that are more speculative or for which the project manager cannot be held accountable (e.g., because they are contingent on events beyond the control of the project manager), specify such cash flows separately and assign probabilities.
- Identify and include any terminal cash flows, for example, cash flows expected from the disposal of assets when the project is terminated.
- Be consistent in accounting for inflation. For example, using an inflation-adjusted discount rate while ignoring inflation in estimating cash flows would result in a bias against accepting projects.
- For the purposes of prioritizing projects, remember that the project's financial benefit is its NPV exclusive of its current-period costs.

Be suspicious of long-term, positive NPV's. Keep in mind the economic axiom that excess profits (the source of positive NPV) are zero in a competitive market. For a project to have a positive NPV, it must have some competitive edge—be first, be best, be the only.

Be Careful Using Balanced Scorecards

The majority of currently available, project prioritization and portfolio management software tools provide the capability for defining both financial and non-financial metrics. The tools are often based on the balanced scorecard approach. Balanced scorecards can be effective, but there are problems with the way they are often implemented. First, the scorecards are typically defined so as to trade off achievement of objectives in some arbitrary or subjective way intended to imply balance: “The measures represent a balance between external measures for shareholders and customers and internal measures of critical business processes, innovation, and learning for growth” [4]. But, maximizing value requires efficient business processes, innovation and learning, and customer satisfaction. Why would an organization want to accept less value (e.g., lower shareholder value), in order to obtain a higher score (i.e., better "balance") on some internal business process? Maximization is the goal, not balance.

The second problem is that, contrary to typical scorecard mathematics, it is generally not correct to weight objectives that represent means for achieving more fundamental objectives. For example, suppose we include scorecards for both costs and business processes. But, improving business processes is a means for achieving the more fundamental objective of reducing costs. Thus, a project might get a favorable score on process improvement, but zero weight should be assigned to this score if the value of that process improvement is completely reflected in a favorable score assigned to cost reduction. If the weight is not zero, there will be double counting.

Failure to account for the hierarchical nature of objectives and the consequent overlap is a serious error being made by many who are designing tools for project portfolio management. For example, a project portfolio management white paper provided on another website advises: "There are four goals for portfolio management, value maximization, balance, strategic direction and the right number of projects." There is only one goal, value maximization. The proper balance, strategic direction and number of projects are whatever is required to maximize value.

A third problem is that it is generally not correct to add different types of value. This statement, which is well established by value measurement theories such as multi-attribute utility analysis, often comes as a surprise to people accustomed to adding and subtracting money values. In fact, being able to weight and add sources of values is an exception. It requires the condition in which the value of achieving any level of performance on any one objective does not depend on the degree to which any other objective is achieved. Scoring methods are being advocated that involve weighting and adding scores for criteria such as project risk, internal rate of return, time-to-complete, urgency, and many other criteria that fail to pass this test. It makes no sense, for example, to weight and add a project's score for time-to-complete to weighted scores for other criteria that indicate the value added once the project is completed. Being quick is much more valuable if the project adds a lot of value than if the project adds little or no value. Weight-and-add could only make sense, in this case, if the weights are not constants; that is, if the weight assigned to time-to-complete is a function of the ultimate value of the project.

A sound value model addresses these issues by specifying a logically correct way of quantifying value. Prioritizing projects using a balanced scorecard approach will distort project decisions unless the weights and mathematical form of the aggregation equation are derived consistent with the model of value.

Each Organization Needs Its Own Metrics

Different organizations conduct different types of projects. The metrics for evaluating new product investments by a software vendor, for example, will be different than the metrics needed to evaluate process improvements for a company operating an oil pipeline. Also, different organizations create value in different ways. An electric utility, for example, creates value differently than does a ballet school. Some organizations will seek to maximize shareholder value, while others will want to value impacts to other stakeholders as well. Thus, each organization will have a different model for how its projects create value and, therefore, will want to use different metrics. There is no one set of project metrics that works for every organization. However, in all cases, good metrics provide a means for computing the value added by projects. Good metrics are observables. And

In all cases, good metrics provide a means for computing the value added by projects. Good metrics are observables. And, they are sensitive to project decisions so that they may be used to differentiate the value of alternative project portfolios.

One of the most under-appreciated benefits of having good metrics linked to a defensible value model is improved justification. Author Anthony O'Donnell quotes a portfolio manager at an insurance company that implemented a portfolio management tool: "People would come to me and ask me to do a particular project...I would tell them I couldn't fit it in, but had a hard time articulating why." Metrics now allow him to give concrete reasons for turning away projects. "Their satisfaction immediately went up, and I still didn't do their projects!"[5].

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2. Failure to See the Forest for the Trees | **4. Inattention to Risk**

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Reason 4: Inattention to Risk

Risk management is receiving greater attention since September 11 and the stock market losses that occurred shortly thereafter. Yet, while nearly all organizations are focusing more on security, assurance, and liquidity, when it comes to selecting projects many still don't adequately address risk. Inattention to risk is the fourth reason organizations choose the wrong projects.

There are important reasons why more attention to project risk is needed. The increasingly competitive economic environment is putting tremendous pressure on managers to produce results quickly. Meanwhile, projects are becoming more complex due, for example, to new technologies, more regulatory requirements, increased product liability, and the greater interdependency organizations have with multiple business partners. Organizations are being held to higher standards by shareholders, customers, regulators, and the public. Executives are much less tolerant of budget overruns and inferior project outcomes. A serious project mishap can seriously damage the reputation and profitability of the organization. Coming in on time, on budget, and to project specifications is no longer good enough.

What is Risk?

The first step toward better addressing project risk is to understand it. Risk, according to Webster, is "a possibility of loss." Risks arise from uncertainty, our inability to foresee the future. If an uncertainty creates the potential for loss, we refer to it as a risk. The opportunity to quantify risk is provided by the language of probability. A probability distribution (sometimes called a risk profile) characterizes a risk by describing the range of possible consequences and their probabilities of occurrence (Figure 5).

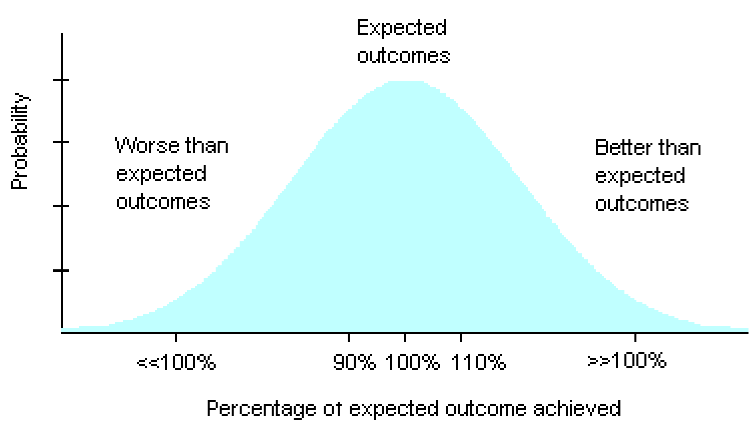

Figure 5: Risk is quantified by providing a probability distribution over possible consequences.

Types of Risk

There are many different kinds of risks of concern to projects. For example:

- Governance risk relates to board and management performance with regard to ethics, community stewardship, and company reputation.
- Strategic risks result from errors in strategy, such as choosing a technology that can't be made to work.
- Operational risk includes risks from poor implementation and process problems such as production and distribution.
- Market risks include competition, foreign exchange, commodity markets, and interest rate risk, as well as liquidity and credit risks.
- Legal risks arise from legal and regulatory obligations, including contract risks and litigation brought against the organization.

As indicated by these examples, project risks include both internal risks associated with successfully completing each stage of the project plus risks that are beyond the control of the project team. These latter types include external risks that arise from the project plus risks that are beyond the control of the project team. These latter types include external risks that arise from outside the organization but affect the ultimate value to be derived from the project. In all cases, the seriousness of the risk depends on the nature and magnitude of the possible end consequences and their probabilities.

Project Risk Management

Project risk management, as defined by Max Wideman, is "an organized assessment and control of project risks." The level of risk management that is required depends on the level of risk. Riskier projects, such as new product launches, global initiatives, projects involving new technology, major regulatory-driven projects, and so forth, tend to have complex interacting elements and involve high stakes. A poor track record on similar projects is an indicator or risk. While risk management is most needed for the most risky projects, some level of project risk management must be provided in all cases.

An organization can practice risk management in several different contexts. Projects are proposed throughout the organization in response to perceived needs and opportunities. Sometimes, the identified need is reducing a risk. For example, an organization operating a hazardous facility may invest in projects to reduce health, safety, and environmental risks. In such cases, the project is itself an investment in risk management. Regardless of the need or opportunity the project is intended to address, there are three main contexts for project risk management. As shown in Figure 6, these are project planning, project selection, and project execution.

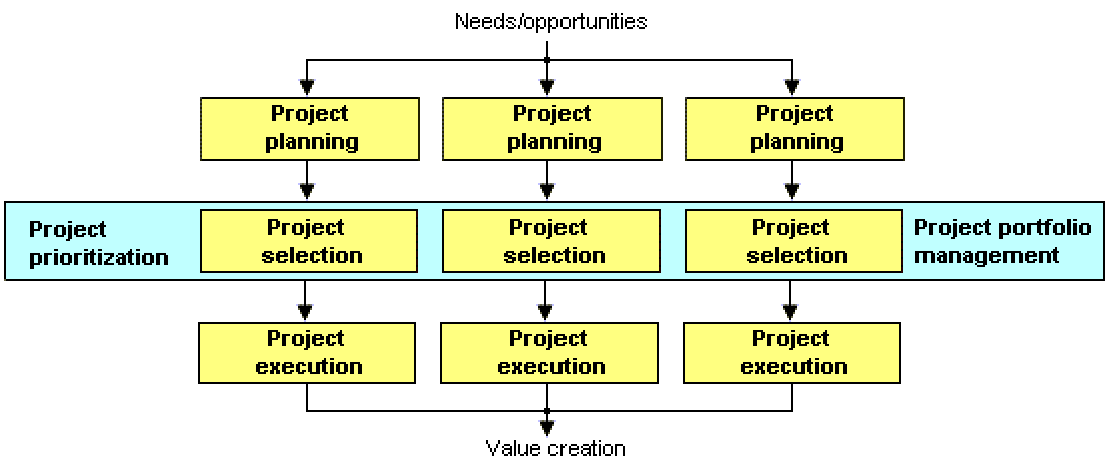

Figure 6: Project planning, project selection, and project execution are all opportunities for risk management.

Although many organizations have instituted risk management processes within project planning and project execution, risk management in project selection is often little more than a yes/no answer to "Should we accept the project risk?" This limited view coupled with project-by-project decision-making creates problems for risk management.

The Need for Project Selection Risk Management

Important types of project risk are best addressed by project selection because they are outside the scope of project managers. A paper by the accounting firm Ernst & Young provides this example [1]. A company conducted a project to install new equipment to increase capacity. However, the project planning team failed to evaluate whether there was a market for the increased supply made available by the added capacity. Narrowly defined, the project was a success because the new equipment was installed successfully, on time and on budget. However, because there was insufficient demand, the company could not sell its extra output at its prevailing price. It ultimately had to shut down some of its production lines. As illustrated, risk management within project planning and project execution often fails to address external project risks. Project portfolio management provides an opportunity to account for external risks and to get senior executives to take some ownership of project risks before the project commences.

Risky Projects May Be Good Projects

For many organizations project risk is simply something to be avoided. But, as Alan Greenspan stated, "Risk-taking is indeed a necessary condition for the creation of wealth" [2]. Successful organizations deliberately take risks when it is to their advantage. According to Suzanne Labarge, Vice Chairman of the Royal Bank of Canada, "Risk in itself is not bad. What is bad is risk that is mismanaged, misunderstood, mis-priced, or unintended" [3]. Failure to recognize, understand and accept risk leads to project portfolios skewed toward low-risk projects with little upside potential. It can also lead to an occasional, unrecognized, high-risk project that endangers the enterprise.

Treating Risk as an "Intangible"

When evaluating projects to support project selection decisions, many organizations view risk as an "intangible." To describe risk, they use qualitative terms such as "likely" versus "unlikely" and "significant" versus "insignificant." Such words are insufficiently precise and mean different things to different people. For example, a lower-level manager might have a very different notion of what qualifies as a significant risk compared to that of the CEO. The fact that most organizations do not have a clear policy on risk-taking is a major reason project portfolios tend to be biased toward low-risk projects. Unless risk is measured, it is difficult to use it as a consideration for project selection.

measured, it is difficult to use it as a consideration for project selection.

Hurdle Rates

Most organizations that account for risks when selecting projects do so using hurdle rates. The hurdle rate is a risk-adjusted cost of capital used to discount future project costs and benefits. Increased hurdle rates are applied to projects considered to be risky.

Using hurdle rates is preferable to ignoring risk or treating it as an intangible. However, hurdle rates have limitations. For one thing, organizations are frequently unclear about what hurdle rate should be applied. Studies have shown that the rates used by firms vary considerably. According to finance theory, the "correct" hurdle rate is the "opportunity cost" of the investment, which is the return available from investing in securities equivalent to the risk of the project being evaluated. Most companies don't adjust the hurdle rate for risk nearly enough.

A more fundamental problem is reflected in research on real options showing that the discount rate needs to vary with the project management strategy (e.g., an irreversible project investment would call for a higher hurdle rate) as well as with time (the discount rate is not a constant, but changes depending on when the discounted future outcomes will occur). Using a constant hurtle rate for a project implicitly assumes that uncertainty increases over time in a specific way (i.e., geometrically). Hurdle rates tend to create a bias toward short-term, quick-payoff projects because they severely penalize project benefits that occur in the more distant future.

Characterizing Risks with Probabilities

The best way to understand project risk is to characterize it by describing the range of possible outcomes, estimating when they will occur (risk timing), and assessing probabilities. If relevant data are available (e.g., as might be the case for system failure probabilities for evaluating reliability maintenance projects), probabilities for characterizing risks can be derived using statistical analysis. In the absence of such data, probabilities must still be assigned, and it makes sense to do so directly based on expert judgment.

Although quantifying risks requires more inputs to describe proposed projects, note that the additional inputs need not be very complex. If some aspect of a project's performance is uncertain, instead of obtaining only a middle-value, point estimate, get a range of possible values (e.g., a 90% confidence interval) as well as a mean or most-likely value. (As indicated in the section of this paper on errors and biases, techniques should be used to guard against overly narrow ranges caused by overconfidence.) With practice, it takes no more time to specify a range than it does to generate a single point estimate. The necessary probabilities can be roughly estimated from the range and a mean or most-likely value.

Once probabilities have been assigned to important risks, those probabilities can be propagated through the value model (described in the previous section) to derive the uncertainty over the various benefits and total value of the project. This can be done using Monte Carlo analysis or event trees. The probabilities can be displayed graphically to show how uncertainty evolves over time (Figure 7). The amount of uncertainty caused by project risks and the specific project benefits that are impacted may be used to better estimate what hurdle rates should be used and the types of benefits to which they should be applied.

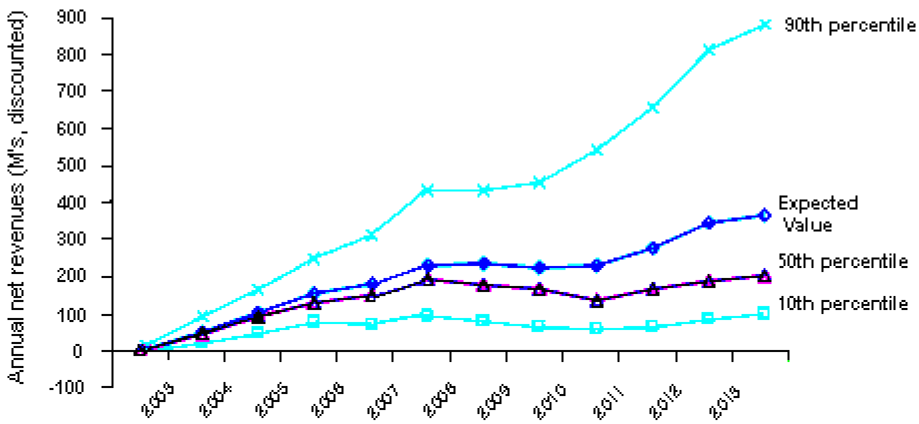

Figure 7: Characterizing risks shows how uncertainties evolve over time.

Project Managers Benefit from Characterizing Project Risks

Although project managers may initially feel uncomfortable with probabilities, my experience is that this group can benefit significantly from moving away from using artificial point estimates. The following is a summary of an example devised by Mark Durrenberger of Oak Associates making this point [4].

Imagine that a project manager is asked to complete a project in 3 weeks. Suppose the project manager feels that this estimate is unrealistically optimistic; that everything would have to go just right to make the deadline. The project manager may feel apprehensive about going to the project sponsor to address the problem. It may not be easy to explain why an may feel apprehensive about going to the project sponsor to address the problem. It may not be easy to explain why an optimistic, aggressive project schedule isn't a good one.

Suppose, instead, that the project manager estimates as a range the time required to complete each project step. Those ranges can be combined (by adding the means and variances) to determine the probability of completing the effort within any specified time. Rather than feeling "at the mercy" of the sponsor, the project manager can now say, "I understand your desire to complete the project within three weeks. However, my calculations suggest that we have less than a 5% chance of meeting that deadline." The sponsor will want to know more, including how the probability estimate was obtained. This gives the project manager the opportunity to discuss the realities of the job and to negotiate tradeoffs (like reducing project scope or deliverables so as to increase the likelihood of meeting the desired schedule).

Note that specifying ranges is not a license for the project manager to make baseless claims. Over time, performance can be compared with range estimates. A project manager whose performance routinely beats the means of his specified uncertainty ranges, for example, will be exposed as one who pads estimates.

Risks of the Project Portfolio

Another important reason to consider quantifying project risks is it that the overall risk of the project portfolio can then be determined. Conducting a portfolio of projects reduces risks through risk diversification (hedging) in the same way that an individual can reduce financial investment risks by investing in a portfolio of stocks. In a stock portfolio there is a limit to how much diversification can reduce risk. This limit is determined by the degree to which stock prices tend to move together; that is, the degree to which the prices of the stocks in the portfolio are statistically correlated with overall market movements. To understand the risks of a stock portfolio, it is necessary to measure these correlations (this is typically done using a correlation statistic called "beta").

In a project portfolio there are risks that impact multiple projects simultaneously. So, in exactly the same way as with stocks, a project portfolio is not as effective at reducing correlated risks. The only way to estimate accurately the risks of alternative project portfolios, and thereby choose projects that collectively produce maximum value at minimum risk, is to quantify these project risks, including distinguishing risks that impact single projects from those that impact multiple projects.

Fully characterizing project risks shows whether the assumptions required for using hurdle rates are satisfied and supports the selection of project-specific hurdle rates. It also allows the use of another approach involving the concept of risk tolerance.

Organizational Risk Tolerance

The degree of aversion to risk taking can be measured and expressed as a number called the risk tolerance. Risk tolerance also goes by terms such as exponential utility, risk preference, risk aversion, risk attitude, risk premium, and risk discounting. The risk tolerance is not the maximum amount that the decision maker can afford to lose, although decision makers and organizations with greater wealth generally have larger risk tolerances. Like hurdle rates, risk tolerance involves applying an adjustment that penalizes the value of a risky project.

The concept works as follows. If decision makers did not care about risk, they would want to "go with the odds;" that is, they would want to make decisions so as to maximize expected value. The expected value is defined as the probability-weighted sum of the possible uncertain outcomes. Decision makers unconcerned about risk would want to maximize expected value because the expected value is the amount that they would obtain on average each time the uncertainty is faced. As an example, the expected value of a coin flip that pays $1 on "heads" and zero on "tails" is 50 cents.

For substantial risks, organizations (and individuals) are risk averse, meaning that they value uncertainties at less than their expected values. The "certain equivalent" is defined as the amount of money for which a decision maker would be indifferent between receiving that amount for certain and receiving the uncertain outcomes of the gamble. For example, a risk-averse decision maker might assign a certain equivalent of $500,000 to a risky project with equal chances of yielding $0 and $2,000,000, even though the expected value for this alternative is $1,000,000.

One way to approximate the risk tolerance is to have senior decision makers (ideally, the CEO) answer the following hypothetical question. Suppose you have an opportunity to make a risky, but potentially profitable investment. The required investment is an amount R that, for the moment, is unspecified. The investment has a 50-50 chance of success. If it succeeds, it will generate the full amount invested, including the cost of capital, plus that amount again. In other words, the return will be R if the investment is successful. If the investment fails, half the investment will be lost, so the return is minus R/2. Figure 8 illustrates the opportunity. Note that the expected value of the investment is R/4.

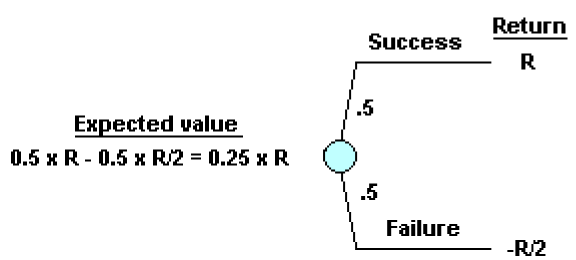

Figure 8: What is the maximum amount R you would invest in this gamble?

If R were very low, most CEOs would want to make the investment. If R were very large, for example, close to the market value of the enterprise, most CEOs would not take the investment. The risk tolerance is the amount R for which decision makers would just be indifferent between making and not making the investment. In other words, the risk tolerance is the value of R for which the certain equivalent of the investment is zero.

Various studies have been conducted to measure organizational risk tolerances. The results show that risk tolerances obtained from different executives within the same organization vary tremendously. Gnerally, those lower in the organization have lower risk tolerances. As a rough rule of thumb, for publicly traded firms, typical risk tolerances at the CEO or Board level are equal to about 20% of the organization's market value.

Once risk tolerance has been established, the certain equivalent for any project can be obtained by subtracting a risk adjustment factor from the expected value of the uncertain future value to be derived from the project (see Figure 9). The risk adjustment factor depends on the risk tolerance and the amount of project risk. An important advantage of this approach is that a single risk tolerance can be established for the organization. Use of the common risk tolerance ensures that risks are treated consistently, thus avoiding the common bias in which greater levels of risk aversion tend to be applied by lower-level managers.

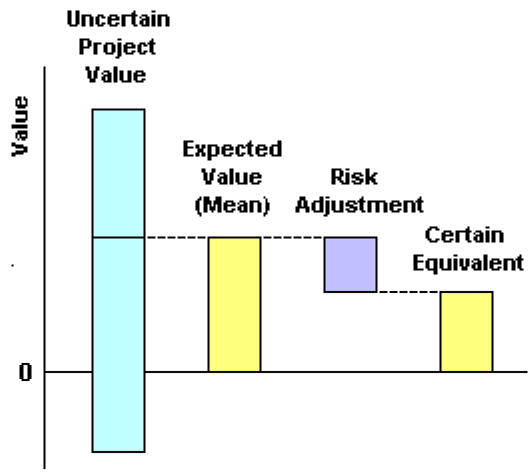

Figure 9: Adjusting project value for risk

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3. Lack of the Right Metrics

5. Inability to Find the Efficient Frontier

Reason 5: Inability to Find the Efficient Frontier

The goal for selecting projects is to pick project portfolios that create the greatest possible risk-adjusted value without exceeding the applicable constraint on available resources. Economists call the set of investments that create the greatest possible value at the least possible cost the "efficient frontier." Most organizations fail to find the best project portfolios and, therefore, do not create all of the value available. Inability to find the efficient frontier is the fifth reason organizations choose the wrong projects.

If the problems discussed in the previous sections of this paper are addressed, value-maximizing project portfolios can be found. Specifically, if the organization has the right metrics and models in place, including the ability to value risk, and it has taken steps to minimize errors and biases in inputs provided to those models, the capability exists to estimate the value that would be added by doing any proposed project portfolio. It is a relatively easy last step, then, to find the best combination of projects. The concept of efficient frontier is highly useful in this regard.

Definition of the Efficient Frontier

Suppose that an organization is currently conducting a set of projects represented by the point labeled Portfolio A in Figure 10. Economists would describe Portfolio A as inefficient because there is another project portfolio, Portfolio B, that produces more value for the same cost. Similarly, there is also a Portfolio C that produces the same value for less cost. Furthermore, there is a Portfolio D with a combination of these two characteristics.

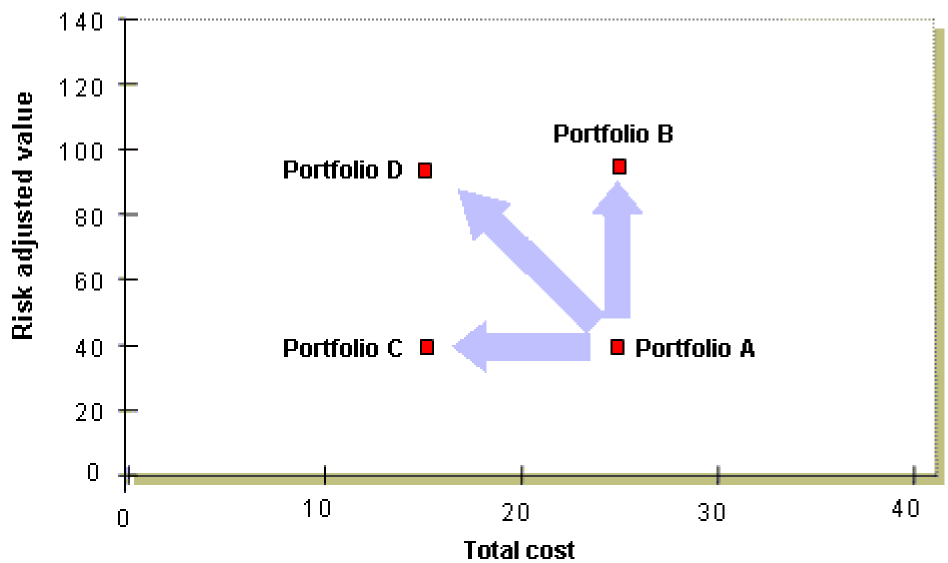

Figure 10: Different project portfolios have different costs and values.

Now suppose we consider all of the alternative project portfolios that can be constructed from a set of project proposals. Typically there are many, and Figure 11 illustrates a real example. In this case the organization had 30 project proposals under consideration in one budget cycle. Four of those projects were considered mandatory (3 process fixes and a new initiative required by regulators), leaving 26 discretionary projects. In general, if there are N potential projects, there are 2^N possible project portfolios. (This is because there are a total of 2^N subsets within a set of N items; see Mathematics: Methods for Solving the Capital Allocation Problem for more explanation). Thus, this application required evaluating 2^{26} or approximately 67 million portfolios, far more than shown in the Figure 11! The best portfolios define the efficient frontier.

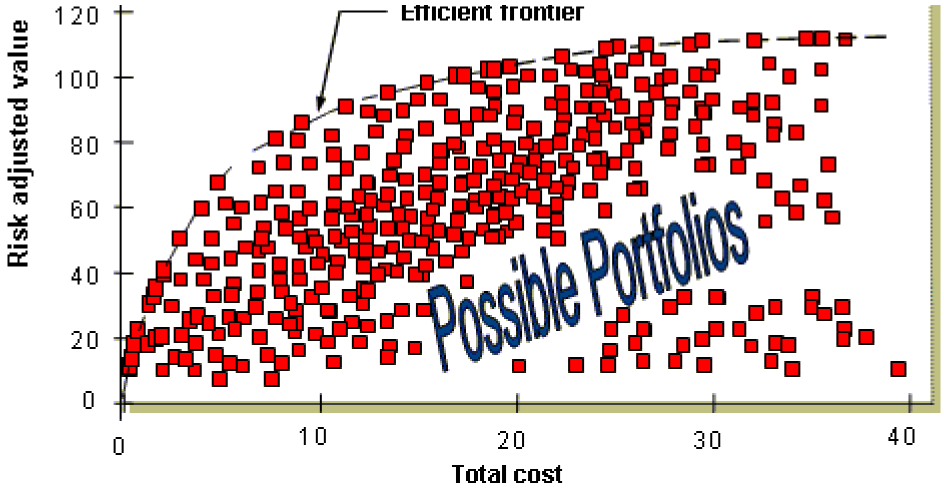

Figure 11: The best project portfolios define the efficient frontier.

Notice how the efficient frontier is curved, not straight. This is because the efficient frontier is constructed such that the best projects are included in the least-cost portfolios, i.e., those portfolios that show up first on the left side of the curve. Such portfolios create the greatest "bang-for-the-buck," and, therefore, the slope of the curve is steepest here. As the cost constraint is relaxed and more projects can be added, the new projects are not quite as good as those included earlier. The slope of the curve encompassing these projects is flatter because their bang-for-the-buck is not quite as high. Thus, there is a declining return in the value obtained with each additional increment of cost. This is what causes the curve to bend as shown in Figure 11.

Finding the Frontier

It is relatively easy for a computer (with an efficient optimization engine) to try various combinations and locate the efficient frontier, provided the right algorithms are in place for determining how the costs and benefits of individual projects combine to determine the costs and benefits of the project portfolio as a whole. In simple situations where projects are independent and risks are independent or do not matter, the costs and value of the project portfolio are basically just sums, respectively, of the costs and value of the individual projects. However, if there are interdependencies or a need to adjust for risks, more sophisticated models are required.

Evidence that Finding the Efficient Frontier Adds Considerable Value

If we locate the efficient frontier, then for any specified total portfolio cost, we can pick out the specific project portfolio that produces the greatest possible value. Figure 12, derived again from an actual application, shows that an alternative portfolio was found that increased value by over 30% without increasing costs. Similarly, an alternative portfolio was found that reduced costs by 40% without decreasing value. This result is typical. Locating the efficient frontier shows that current project portfolios often perform well below the potential.

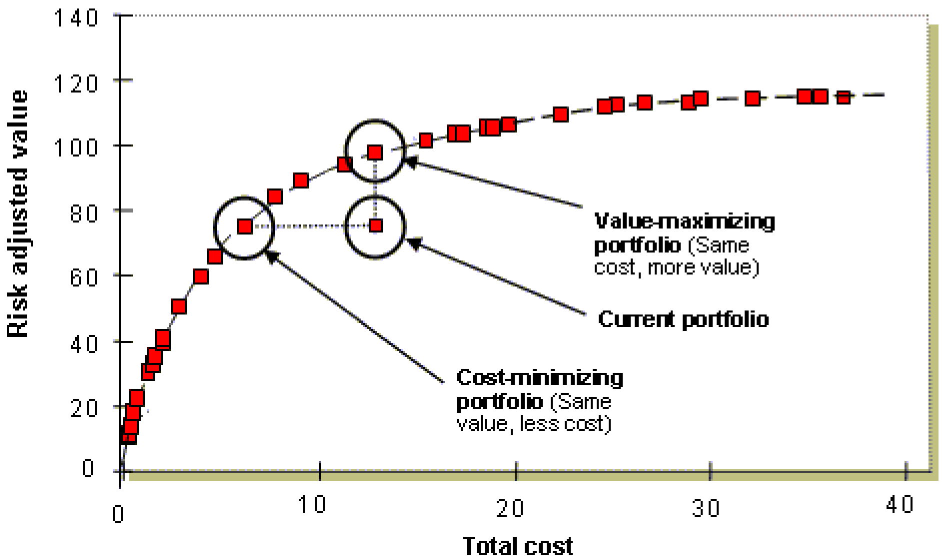

Figure 12: The project portfolios selected by organizations can typically be improved significantly.

The Efficient Frontier Moves Over Time

It should be noted that the efficient frontier is not static. Organizations face the challenge of finding project alternatives that advance the frontier. As project managers better understand the link between their project designs and the value derived by the organization, they create better project proposals. Also, better technology creates new opportunities that create more value for less cost. This causes the efficient frontier to move up over time. The fundamental goal, though, remains the same—Create as much value as possible using as little capital as possible. To do this, you must find the efficient frontier.

4. Inattention to Risk

Summary and Conclusions

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Summary and Conclusions

Project portfolio management is a way to organize and manage a multi-project environment. It is a dynamic process whereby projects and project proposals are regularly evaluated, prioritized, and selected based on the goal of obtaining the greatest possible value from the organization's limited resources. Selecting the right projects is the core of project portfolio management, but project selection includes deciding how to allocate and apply resources to projects, project timing, and when to accelerate, slow, or kill projects.

Almost any project selection process will separate "must-do" projects from clear "losers." How far organizations go beyond this depends on the effort they put into it. In order to get much beyond a "60% solution," however, organizations need to address the fundamental reasons that project selection decisions are prone to error.

In summary, organizations need to:

✓ Address the Errors and Biases that Affect Human Judgment

- Increase awareness of prevalent errors and biases, including comfort zone, perception, and motivation biases, as well as errors in reasoning, and "group think." As Daniel Kahneman advises, use the knowledge to create "human error detectors" within your organization.
- Consider incentives and the effects of framing when evaluating your and other people's judgments. Remember that an estimate from a disinterested but knowledgeable party may be more reliable than that of a better-informed but involved expert.
- Provide feedback to people on the accuracy of their forecasts. Require that forecasts of project performance be expressed in terms of observables that pass the clairvoyant test. Then, collect data from funded projects to help calibrate people and keep their estimates honest.

✓ Get Control of the Project Selection Process

- See the forest as well as the trees. Collect projects and project proposals into a common database. Look for duplications and interdependencies. Establish common format and content requirements for project proposals.
- Move from project-by-project decision-making to decision-making aimed at producing optimal project portfolios. Create a project portfolio management office with responsibility for managing the organization's portfolio of projects.
- Understand the options that are created and destroyed by project choices. When choosing projects, consider project urgency as well as project value.

✓ Develop an Enterprise View of Project Value

- Create a value model for your business that documents best-organizational understanding about how projects create value.
- Use the value model to develop metrics and to estimate the impacts of doing projects.
- Engage senior executives in the process of establishing objectives, defining how value tradeoffs should be made, sharing ownership of project decisions, and co-developing project expectations.

✓ Be Proactive in Addressing Risk

- Establish processes for identifying internal and external project risks, communicating those risks, and implementing risk-mitigation action plans.
- Avoid the bias toward doing too many, mostly low-risk, low-return projects. Remember that risky projects often create learning and increased capability, values that aren't readily captured in financial metrics.
- For "big bet" investments, quantify risks and consider establishing an organizational risk tolerance to guide decision-making.

✓ Get to the Efficient Frontier by Institutionalizing Decision Making Competencies

- Promote and attend training workshops on the logical principles of decision analysis, project prioritization, and capital budgeting.
- Learn the best techniques for articulating objectives, expressing value tradeoffs, assessing probabilities, and establishing risk tolerance.
- Recognize and reward people based on the quality of their decisions, not just based on the quality of their outcomes

- Recognize and reward people based on the quality of their decisions, not just based on the quality of their outcomes.
- Identify and utilize the best-available tools.

Five Levels of Project Portfolio Management

Figure 13 summarizes five levels of portfolio management. Each level represents the adoption of one of the major solutions discussed in this paper for addressing the reasons that organizations choose the wrong projects.

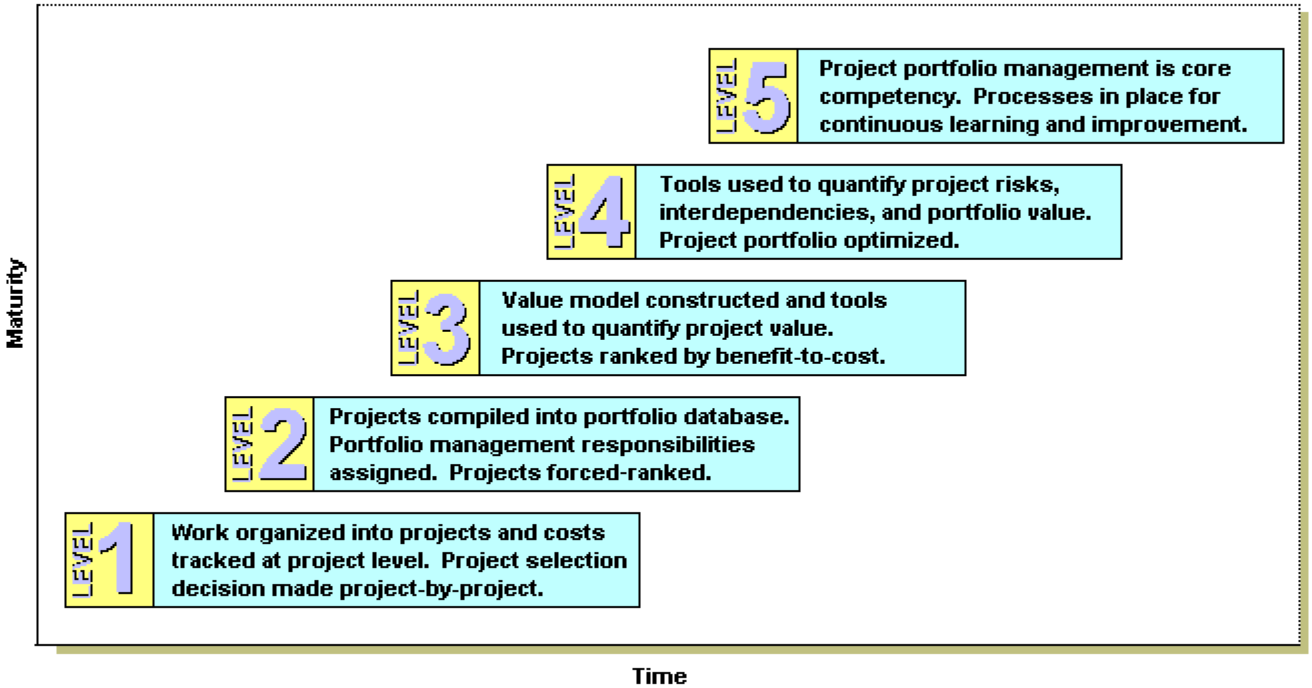

Figure 13: Five levels of project portfolio management.

As shown in the figure:

- Level 1 organizes the work into discrete projects and tracks costs and other resource usage at the project level.
- Level 2 replaces project-by-project decision making with the goal of identifying the best collection of projects to be conducted within the resources available. At a minimum this requires aggregating project data into a central database, assigning responsibilities for project portfolio management, and force-ranking projects.
- Level 3, perhaps the most difficult for most organizations, requires developing metrics, models, and tools for estimating the value to be derived from projects. Although interdependencies are still ignored, this allows projects to be accurately ranked by "bang-for-the-buck" and provides a good approximation of the value-maximizing project portfolio.
- Level 4 improves the tools to correctly account for project risks and interdependencies, which allows the project portfolio to be optimized.
- Level 5 occurs when the organization has made project portfolio management a core competency and has put processes in place for continuous learning and improvement.

Why Isn't Everyone Doing This Already?

As this paper has described, methods are available for addressing all of the reasons organizations choose the wrong projects, including quantitative methods for identifying the efficient frontier. Some organizations that regularly make high-stakes, project selection decisions (e.g., some financial institutions, oil and gas exploration companies, pharmaceutical companies, the military and some other government agencies) are already using many of these methods. But, most organizations are not. A fair question is, "If these methods are so great, why isn't everyone using them?"

In my experience, there are two pitfalls explaining why these methods aren't being used as much as they could be: fear of complexity and a belief that there may be too much uncertainty to justify sophisticated methods.

Fear of Complexity

For some organizations, trying to select optimal project portfolios is just too complicated to tackle. Psychologists identify fear of complexity as one of the key pitfalls that prevent people from overcoming important problems. They point out that the perception of complexity is reduced, however, when people use information processing structures (i.e., description languages) that provide a good fit to the complexities they encounter.

Systems modeling,the foundation for the methods described in this paper, is a language for describing and understanding complex problems. Models break a complex problem down into its individual pieces. The critical components are sorted out complex problems. Models break a complex problem down into its individual pieces. The critical components are sorted out, identified, and analyzed separately. Computers perform the required synthesis at the end. Thus, systems modeling is the means for breaking down and overcoming complexity. As long as the concepts are understood, the fact that the math may be difficult is not really an issue; computers can handle the math.

Admittedly, systems modeling and the related methods described in this paper can themselves seem complex. Remember, though, that the most sophisticated tools need not be applied in all situations. If projects do not involve significant risks there is no need for probabilities and concepts like risk tolerance. More critical decisions require more sophisticated methods. Follow the often quoted advice of Albert Einstein, "Seek the simplest possible solution, but no simpler." With learning and familiarity that come from experience, the appropriate methods will no longer seem complex. In any case, the real issue is not whether the methods seem complex, but rather whether the costs and effort required to apply the methods are justified in terms of increased value from better and more defensible decisions.

As sophisticated methods gain use, hard evidence of their value is beginning to surface. For example, an article in the journal Oilfield Review reported a study of 20 oil exploration companies that "established a strong positive correlation between the degree of sophistication in the companies' use of decision and risk analysis and the success of their project decisions." The same article also described another oil company study that found that, "Companies that integrated workflow and used decision and risk analysis saw their performance improve shortly after the introduction of this methodology" [1].

Discomfort with Uncertainty

The second pitfall is discomfort with uncertainty. People ask, "Doesn't the great uncertainty in the costs and benefits of projects invalidate the application of sophisticated mathematics to project selection?" My experience in discussions of this sort is that skeptics will quickly agree that sophisticated methods based on probability can work. Roughly 40 years, ago, for example, probabilistic analysis was used to "beat" the game of blackjack. The sticking point is whether the same methods have merit when probabilities must be based on subjective judgment rather than on "objective data."

The following checklist of questions helps me decide whether I need to quantify subjective uncertainty:

1. Is the uncertainty significant? If so, assessing a range of values will make more sense, and be easier, than specifying a single-number, best guess.
2. Does the uncertainty make a difference? Try varying the uncertain quantity across the range of possibilities. The uncertainty only matters if you would want to make decisions differently depending on the actual value.
3. Do the experts know anything that leads them to believe some possibilities are more likely than others? I've never encountered a situation where the experts didn't have relevant beliefs, but if I did, there would be good reason to choose a uniform probability distribution, where one assumes that all possibilities are equally likely.

Once the beliefs about the uncertainty have been expressed in a probability distribution, a probabilistic analysis is usually not much harder than the corresponding analysis without probabilities. (It only becomes more difficult if the experts know a great deal that can be represented in models and that can be used to improve the quantification of uncertainty.)

"But," people say, "the probabilities are subjective!" Actually, everything associated with decision-making is subjective, but in the interest of space I won't get into those arguments! The importance of subjective probabilities is that they provide a way to encode what may be the most important knowledge held within a company.

Consider the concept known as the "knowledge-based theory of the firm." The theory argues that knowledge is the only strategically important firm resource. Other resources, like electric power and raw materials, are available at essentially the same prices to all competitors. Knowledge is the only resource that can provide a real advantage. According to the theory, fundamentally what firms do is "apply knowledge to the production of goods and services."

Since knowledge is held by individuals and not the organization, "the central role of the enterprise and its management is to integrate distributed knowledge and make it usable" [2]. Probabilities provide the best-known means for capturing precisely and in a useful fashion what the company's experts believe about the inherently uncertain business environment. Probabilities encode the information in a way that can be understood and used throughout the organization. Thus, characterizing uncertainties with probabilities would appear to be critical to an organization making best use of the knowledge held by its specialists.

Although judgmental probabilities are indeed subjective, it is important to appreciate that they are not arbitrary. If a project manager says there is a 25% chance that the project will go over budget, that manager is saying that the degree of confidence in achieving the budget is the same as randomly selecting a red ball from an urn containing one red ball and three white balls. Thus, subjective probability is related to an objective reality. Expressing uncertainty as a probability gives a much more precise and useful statement than saying "it's uncertain." Furthermore, judgmental probabilities can be calibrated to experience. If there is ample evidence that only one-fourth of projects come in on budget, then, presumably, others will have more confidence in the 25% probability judgment.

The existence of uncertainty doesn't undermine the usefulness of probabilistic methods. To the contrary, it enhances their usefulness. When significant uncertainties are present, only a systematic and rigorous approach can produce an accurate understanding of risk and support a sound logic for making risky decisions.

Beat the 60% Solution!

The 60% solution can be beaten. It may not be easy, but it can definitely be done. The fact that optimizing project decisions is hard to do (but doable) is why organizations that successfully address the problems identified in this paper can create for themselves a significant competitive business advantage.

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5. Inability to Find the Efficient Frontier

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Challenge

According to polls, managers say prioritizing projects is their number-one investment challenge. Increasing competition and the need to do more with less make choosing the best projects more important than ever. Given tens or hundreds of potential projects, it is easy to make the wrong choices. The prioritization processes used by many organizations:

- Provide insufficient understanding of the costs, risks, and benefits of proposed projects.
- Encourage biased estimates from project proponents.
- Under-value spending by failing to account adequately for the “soft benefits” of projects, such as new capability and knowledge.
- Result in unjustified project portfolios that are unaligned with strategy.
- Lose up to 40% of the value potentially available from their project portfolios.

Quantitative Methods

Quantitative methods (see Mathematical Theory) may be used to prioritize projects. However, properly applying the methods requires understanding and the ability to value project benefits.

Software

Software vendors are offering tools for prioritizing projects and managing project portfolios (see Tools-Which Approach is Best?). But, most commercially-available tools use simplistic “rate-and-weight” methods that the National Academy of Sciences has called “unsatisfactory, inadequate, undocumented, and biased.” Better methods are needed to account for project interdependencies, project urgency, option value, and risk.

A useful tool must reflect the organization's unique strategy and means for creating value. Yet, even well-tailored software may not achieve organizational “buy in.” Unless all parties have confidence that using the priority system will help them and the organization to succeed, insufficient effort will be devoted to inputs, and outputs will not impact funding decisions.

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Mathematical Theory for Prioritizing Projects and Optimally Allocating Capital

Introduction

Nearly every organization faces the problem of allocating limited capital (and other scarce resources) across projects or other types of investments. Organizations address the capital allocation problem by specifying a (more or less) fixed budget for funding projects within a specified time period (e.g., the upcoming year). Project proponents (individuals or organizational units) propose projects and request corresponding portions of the budget. The budget is typically insufficient to fund all projects. The goal is to select the particular subset (or "portfolio") of projects which can be funded within the budget constraint that creates the greatest possible value for the organization.

To support the decision of which projects to fund, most organizations (formally or informally) prioritize proposed projects. Projects determined to have highest priority are selected for funding. Unfunded projects are eliminated or reconsidered for funding in subsequent time periods. The process is frequently contentious and time consuming and results in less than optimal choices.

Prioritizing projects is difficult for many reasons. Evaluating a project often requires detailed technical knowledge. Decision makers may have to rely on the project proponent for information about the need the project addresses and to assess the degree to which the project will satisfy that need. Project proponents may "pad" their budget requests or exaggerate claims in order to increase the likelihood that they receive adequate funding. Different projects have different costs and benefits, so choosing among them requires difficult "apples versus oranges" comparisons. It may be possible to delay some projects, while delaying others would significantly increase their costs or reduce their effectiveness. Some projects may be more risky than others, potentially making them less attractive. Finally, there may be interdependencies among projects that make strict priorities difficult or impossible to establish. If there are hundreds or even tens of proposed projects, identifying the right project portfolio can be an unmanageable problem.

Fortunately, there are numerous techniques for aiding capital allocation. These techniques fall into several categories, including methods for quantifying project value and risk, methods for motivating unbiased estimates and for holding project proponents accountable, and methods for optimizing the portfolio of selected projects. Provided here is an introduction to some of the tools in the last category — mathematical methods for optimally allocating capital resources across projects. We begin on the next page by describing a mathematical model of the capital allocation problem.

A Mathematical Model of the Capital Allocation Problem

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A Mathematical Model of the Capital Allocation Problem

The standard, mathematical model of the capital allocation problem is constructed as follows. Let **P** denote the set of available projects. For now, assume that the projects are independent; that is, it is reasonable to select any combination of projects and the cost and benefit of any project do not depend on what other projects are selected. Define, for each project i in the available set **P** (denoted $i \in$**P**), the zero-one variable x_i. The variable x_i is one if the project is accepted and zero if it is rejected. Let b_i be the benefit of the i'th project and c_i be its cost. Let **C** be the total available budget. The goal is to select from the available project set **P** a subset of projects with a total cost less than or equal to **C** that produces the greatest possible total benefit. The problem may be expressed mathematically as:

$$\textbf{Maximize } \sum_{[i \in P]} b_i x_i$$

$$\textbf{Subject to: } \sum_{[i \in P]} c_i x_i <= C \textbf{ and } x_i = 0 \textbf{ or } 1, \textbf{ for } i \in P.$$

where the notation $\sum_{[i \in P]}$ denotes summing over all projects i in **P**. As a concrete example, suppose we have $10,000 to spend on four possible projects:

Project ID	Cost	Benefit
1	$3571	$5714
2	$2857	$4286
3	$5000	$7857
4	$2143	$2857

The optimal allocation is the solution to:

$$\textbf{Maximize } [5.714x_1 + 4.286x_2 + 7.857x_3 + 2.857x_4]$$

$$\textbf{Subject to: } 3.5714x_1 + 2.857x_2 + 5x_3 + 2.143x_4 <= 10$$

$$x_i = 0 \textbf{ or } 1, \textbf{ for } i = 1,2,3,4.$$

Mathematical optimization problems that are constrained to have only integer values (i.e. whole numbers such as -1, 0, 1, 2, etc.) at the optimal solution are known as integer (or pure integer) programming problems. The above formulation is a special case called a zero-one integer programming problem. As illustrated, zero-one variables are useful for capital budgeting because they can be used to represent yes/no decisions, specifically, whether to include a particular project in a selected project portfolio. Methods for solving the zero-one integer programming problem are described later below. First, though, some useful extensions to the basic model are indicated.

Extensions to the Basic Model

Although the basic capital allocation model is simplistic, it can be extended to handle many complexities that must be addressed in the real world. For example, the model can be extended to deal with projects whose benefits are spread over time, the "costs" of not doing projects, interdependencies among projects, soft budget constraints, multi-period budget constraints, and differences in the degree to which projects can be delayed.

Benefits Spread Over Time

Although the above formulation assumes benefits are paid in the current period, the model can be applied to the case of projects that provide benefits spread out over future periods by simply defining the current benefit of each projects to be the present value of its future benefits.

"Costs" of Not Doing Projects

Oftentimes, projects are not done so much to make things better as to prevent things from getting worse. This can be handled by simply defining the benefit of a project as the difference between what happens if the project is done compared to what happens if the project is not done. In other words, project benefit is the incremental benefit relative to what would happen if the project is not conducted.

Mutually Exclusive and Sequential Projects

By adding constraints to the basic model, mutually exclusive projects can be handled. Suppose **S** denotes a subset of the projects that represent different ways of doing the same thing (e.g., choosing competing technologies or alternative vendors for achieving the same goal). Then, the constraint

$$\sum_{[i \in S]} x_i <= 1$$

ensures that no more than one project is selected from the set **S**.

Oftentimes, mutually exclusive projects represent different ways of addressing the same need, and the project choice affects the benefits obtained. This can be handled by changing the objective function so that benefit b_{ij} is obtained if the ***i***'th need is addressed via the ***j***'th project. Expressed mathematically, the problem is then:

$$\text{Maximize } \sum_{[i \in P]} \sum_{[j \in J_i]} b_{ij} x_{ij}$$

$$\text{Subject to: } \sum_{[i \in P]} \sum_{[j \in J_i]} c_{ij} x_{ij} <= C$$

$$\sum_{[j \in J_i]} x_{ij} <= 1 \text{ for all } i \in P,$$

$$x_{ij} = 0 \text{ or } 1, \text{ for all } i \text{ and } j.$$

In these equations,

- J_i is the set of mutually exclusive projects for addressing need i,
- x_{ij} equals 1 if the need i is achieved through project j; otherwise it is zero [for $i \in P$, $j \in J_i$],
- c_{ij} is the cost of achieving the ***i***'th need with the ***j***'th project,
- b_{ij} is the benefit obtained if the ***i***'th need is achieved with the ***j***"th project.

Adding constraints also works in situations where precedence relationships apply; that is where one project cannot be chosen unless another is also chosen. For example, suppose there are contingent projects (e.g., a software project) that can be selected only if another project (e.g., the necessary hardware) is also funded. Suppose project i is contingent on project k. The constraint

$$x_i - x_k <= 0$$

ensures that i cannot be selected (x_i cannot be 1) without k being selected (without x_k being 1).

As a concrete example, suppose that, instead of being independent, the four projects from the previous example are dependent as follows:

- Project 4 requires Project 2
- Project 3 can't be conducted if Project 1 is conducted

The constraints that must be added to the previous formulation are:

$$x_4 - x_2 <= 0$$

(If x_4 is 1, then x_2 must be 1.)

$$x_1 + x_3 <= 1$$

(If x_1 is 1, then x_3 must not be 1.)

Inter-Dependent Projects and Optimal Project Portfolios

The most common type of project interdependency is that described above; unless another project is conducted, the benefits of the project won't be realized. However, sometimes the interdependencies among projects is partial; doing another project will enhance the attractiveness of a project, but it may still be worthwhile to do the project even if the projects that would enhance its value are not conducted. For example, combining multiple projects in strategic ways can produce economies of scale and resource sharing that can lower the total costs of the related projects. Similarly, there may be synergies among projects such that total benefits increase if they are all conducted together.

One type of benefit synergy is diversification of risks. Portfolio theory is a mathematical theory for understanding diversification and the relation between risk and return as it applies to portfolios of stocks and other financial investments. Just as a portfolio of stocks can lower risks through diversification, a portfolio of well-chosen projects can be more attractive because it creates a more desirable balance between near-term versus long-term payoffs, "sure things" versus "gambles," and risk versus return.

Project interdependencies can be handled within the model by changing the decision unit from individual projects to alternative sets of projects. The approach involves defining clusters of inter-dependent projects such that each cluster is independent of every other cluster. A project cluster is independent of other project clusters if no project in the cluster depends on any project outside the cluster. The costs and benefits of conducting each possible subset from each cluster are determined, taking into account synergies and other interdependencies. The optimal portfolio is then obtained by choosing the subset from each cluster (a subset containing no projects is a candidate) such that total benefits are maximized without exceeding the constraints on total costs. The mathematical formulation is identical to the formulation for mutually exclusive and independent projects (since the sets from independent clusters are independent), except that the maximization involves choosing the best project sets (rather than individual projects) and the constraint is that at most one project set can be chosen from each project cluster.

Soft Budget Constraints

The basic formulation of the capital budgeting problem is somewhat unrealistic in that budget constraints are rarely completely hard. For this reason, it is often useful to solve the problem for alternative total budgets so as to measure the sensitivity of the solution and total benefit to the budget level.

Multi-Period Planning

The basic formulation can be extended to represent multi-period project planning with constraints. The simplest formulation merely requires specifying the multi-period funding requirements for each project and including each period's budget constraint. To illustrate, suppose the planning is for **T** time periods. Let the total cost constraint for period t be C_t. Suppose once a project i starts, it requires a specified investment c_{it} in each period t. Once completed, project i generates a net present value benefit of b_i. The problem is to select the projects for funding across the **T** periods that will maximize the total benefit subject to the period-by-period cost contraints:

$$\textbf{Maximize } \sum_{[i \in P]} b_i x_i$$

$$\textbf{Subject to: } \sum_{[i \in P]} c_{it} x_i <= C_t \textbf{ for all } t = 1, 2, ...T$$

$$x_i = 0 \textbf{ or } 1, \textbf{ for } i \in P.$$

Sensitivity to Delay

In some situations, there may be only a limited time window of opportunity to conduct some proposed projects. In such cases, the goal for each budget cycle of picking the project portfolio that maximizes benefit may not be appropriate. To illustrate, suppose you have a daily “budget” of $1. I offer you two “project” investment alternatives: With Alternative A, you invest $1 and immediately receive in return a financial benefit of $10. With Alternative B, you invest $1 and immediately receive a financial benefit of $5. Using the traditional approach of maximizing benefit you would, of course, choose Alternative A, because it creates greater total benefit.

Suppose, however, that I tell you that Alternative A will be available tomorrow, while Alternative B is only available today. You would then be wise to invest your $1 budget today in Alternative B and invest tomorrow's $1 budget in Alternative A. The table below shows that this choice maximizes the combined benefit derived from the today's and tomorrow's budgets:

	Today	Tomorrow	Total
Choice 1	A: Cost = $1 Benefit = $10	—	Return = $10-$1 = $9
Choice 2	B: Cost = $1 Benefit = $5	A: Cost = $1 Benefit = $10	Return = $15-$2 = $13

Of course, the above example assumes that you will have a dollar to invest tomorrow and that there will be no other investments tomorrow that will generate a $10 return. If, for example, you knew that tomorrow someone else was going to offer you a $10 return for a $1 investment, you would be wise to take Alternative A today. Roughly speeking, it really only makes sense to delay high-value projects if you believe there won't be equally valuable investments available in the future.

To properly select projects that differ in the degree to which they can be delayed requires simultaneously optimizing current and future choices so as to maximize total, multi-period, project benefit. One approach is to expand the multi-period project planning formulation described above to make the costs and benefits of projects depend on the period in which the project is funded. As described above, this formulation requires knowing what all of the future potential projects and project budget constraints are. If there's uncertaity over future project characteristics and budget constraints, the possibilities can be represented probabilistically, but, as you can see, solving the problem by formulated it as a mult-period project selection problem is complex.

Because of problem complexity (actually, the large and difficult nature of the required problem inputs), it is generally not feasible to simultaneously optimize project portfolios for multiple budget cycles. There is, however, an approximate approach that involves thinking one budget cycle ahead. With this approach, each proposed project is viewed as presenting three possibilities: (1) the project could be funded now out of the current period budget, (2) the project could be deferred and funded in the next budget period, or (3) the project can be eliminated and never funded. To implement the approach, a minimum benefit/cost ratio is established as a threshold for determining whether a project is attractive. Any project whose B/C ratio is below that threshold is eliminated from further consideration. Any project above the threshold is assumed to be funded either this period or to be deferred and funded in the following budget period. The goal for allocating the current budget, then, is to pick the portfolio of projects that produces the minimum lost value from delaying attractive projects.

To express this mathematically, suppose that **M** denotes the subset of "attractive" projects with benefit/cost ratios greater than some specified value R:

$$b_{i1}/c_{i1} > R, \; i \in M$$

where b_{i1} and c_{i1} are the benefit and cost of the i'th project if it is conducted this (1st) budget period. Let b_{i2} and c_{i2} be the benefit and cost of the project if it deferred and conducted next period. Let x_{i1} be one if the project is funded this period and zero otherwise. Since $b_{i2} - b_{i1} + c_{i2} - c_{i1}$ is the loss from delaying project i, to minimize the total loss from delay, we need to solve:

$$\text{Minimize } [\textstyle\sum_{[i \in M]}[(b_{i2} - b_{i1} + c_{i2} - c_{i1})(1 - x_i)]$$

$$\text{Subject to: } \textstyle\sum_{[i \in M]} c_{i1} x_i <= C, \; x_i = 0 \text{ or } 1, \text{ for } i \in M.$$

This "minimize loss from delay" goal can be interpreted as reflecting an "options" view of the capital budgeting problem. Projects represent options for organizations. An option is an opportunity, but not an obligation. Proposed projects represent options because the organization has the opportunity to fund them, but is not required to do so. Since options have value (which can be quantified using real options analysis), organizations should consider how their decisions impact option value. Deciding to fund a project converts the project from an option to a commitment. The option value is lost, but that value loss is (presumably) justified by the value derived from doing the project. Deciding not to fund a project may or may not preserve its option value. If the project can be delayed without adverse impact, its option value is preserved. Conversely, if delay causes project benefits to decrease or its cost to rise, then some of its option value is lost if the project is delayed. Thus, optimizing a project portfolio based on minimizing the losses from delay can be regarded as a "real options" solution to capital budgeting.

◀ Introduction Methods for Solving the Capital Allocation Problem

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Methods for Solving the Capital Allocation Problem

A difficulty of the zero-one interger programming formulation of the capital budgeting problem is that, while it is relatively easy to express mathematically, it is difficult to solve. The number of possible solutions grows very fast (in an exponential fashion) with the number of decision variables. In the basic formulation where there are only two alternatives for each project (fund and not fund), if there are **N** projects, then there are 2^N potential solutions (including the possiblity of doing none of the projects). With 30 projects, for example, there are over 1 billion alternative project portfolios. If we consider more alternatives for each project, say m_1 ways of doing the first project, m_2 ways of doing the second project, etc., then the number of possible solutions is $(m_1+1)\times(m_2+1)\times\ldots(m_N+1)$. If there were two ways of doing each of the 30 projects, for example, there are more than 200 trillion possibilities to consider. It is only recently, with the advent of powerful desk-top and portable computers, that solving real-world capital allocation problems has become practical. Even now, unless we are dealing with situations involving only a few projects, it is not possible to solve the problem by simply trying all possibilities. More efficient solution methods are needed.

There are three common methods for solving the capital allocation problem: ranking, linear programming, and integer programming. To illustrate, we will use the simplified example introduced above. To review, we have $10,000 to spend on a subset of the following 4 projects:

Project ID	Cost	Benefit
1	$3571	$5714
2	$2857	$4286
3	$5000	$7857
4	$2143	$2857

The optimal allocation is the solution to:

$$\textbf{Maximize } [5.714x_1 + 4.286x_2 + 7.857x_3 + 2.857x_4]$$

$$\textbf{Subject to: } 3.5714x_1 + 2.857x_2 + 5x_3 + 2.143x_4 <= 10$$

$$x_i = 0 \text{ or } 1, \text{ for } i = 1,2,3,4.$$

Ranking Projects by Benefit/Cost Ratios

The easiest way of "solving" the capital allocation problem is to rank the projects by benefit-cost ratio (b_i/c_i) and then to fund the projects from the top down until the budget is exhausted. Provided that there are no project interdependencies (including mutual exclusivities), this approach often gives a reasonable solution. However, (as will be illustrated below) the solution is only approximate (even when there are no project interdependencies) and typically fails to use the entire budget.

For the example, the project ranking based on benefit/cost ratios is:

Rank	Project ID	Benefit/Cost	Cumulative Cost	Cumulative Benefit
1	1	1.60	$3571	$5714
2	3	1.57	$8571	$13571
3	2	1.50	$11428	$17857
4	4	1.33	$13571	$20714

Based on ranking, the solution is to choose projects 1 and 3 for a total benefit of $13,571. Note that with this solution $10,000 - $8,571 = $1,429 of the budget is unspent.

Linear Programming Solution

If we ignore the integer constraints and require only that the decision variables lie between zero and one, the problem becomes a linear program:

$$\textbf{Maximize } [5.714x_1 + 4.286x_2 + 7.857x_3 + 2.857x_4]$$

$$\textbf{Subject to: } 3.5714x_1 + 2.857x_2 + 5x_3 + 2.143x_4 <= 10$$

$$0 <= x_i <= 1, \text{ for } i = 1,2,3,4.$$

This reformulation can be easily solved using linear programming software (or by hand using the Simplex Method). The optimal solution is:

$$x_1 = 1,\ x_2 = 0.5,\ x_3 = 1,\ x_4 = 0$$

which gives a total benefit of $15,714.

The linear programming solution, of course, is not feasible. It is not possible to get half the benefit from project 2 by giving it half its required funding. However, based on "rounding", the solution obtained ignoring the zero-one constraints appears to add credence to the solution derived using ranking.

Since linear programs can quickly solve even very large problems, the technique may appear attractive for capital budgeting. However, unless there are multiple, more complicated (non-integer) constraints that must be satisfied, linear programming provides little beyond the simpler approach based on ranking. Also, even if some of the optimal values of the variables in the linear programming solution are integers, those values may not be very close to the correct solution. Linear programming solutions should be reserved for problems with multiple constraints (e.g., people and dollar constraints, different funds for different kinds of projects, multi-period constraints) that are so large that the more exact methods (such as integer programming) won't work.

Integer Programming Solution

As with linear programming, software packages are available for solving integer programming problems. However, requiring variables to be integer makes the solution much more difficult. Most software packages for integer programming are based on the solution method known as “branch and bound.”

Branch and bound solves the integer programming problem by creating a series of sub-problems that relax the integer constraints. Each sub problem is solved using linear programming. Eventually, a solution is found that maximizes the objective function while satisfying the integer constraints.

To illustrate using the example, branch and bound would begin by solving:

$$\text{Maximize } [5.714x_1 + 4.286x_2 + 7.857x_3 + 2.857x_4]$$

$$\text{Subject to: } 3.5714x_1 + 2.857x_2 + 5x_3 + 2.143x_4 <= 10$$

$$0 <= x_i <= 1, \text{ for } i = 1,2,3,4.$$

As we saw above, the solution is:

$$x_1 = 1,\ x_2 = 0.5,\ x_3 = 1,\ x_4 = 0$$

and the resulting benefit value is $15,714.

Since the solution is not purely integer, we have not solved the zero-one programming problem. Therefore, branch and bound creates two new sub-problems by "branching" on the non-integer variable x_2. Specifically, we define a sub-problem with x_2 set to zero:

Sub-Problem 1A

$$\text{Maximize } [5.714x_1 + 4.286x_2 + 7.857x_3 + 2.857x_4]$$

$$\text{Subject to: } 3.5714x_1 + 2.857x_2 + 5x_3 + 2.143x_4 <= 10$$

$$0 <= x_i <= 1, \text{ for } i = 1,3,4$$

$$x_2 = 0.$$

and a sub-problem with x_2 set to one:

Sub-Problem 1B

$$\text{Maximize } [5.714x_1 + 4.286x_2 + 7.857x_3 + 2.857x_4]$$

$$\text{Subject to: } 3.5714x_1 + 2.857x_2 + 5x_3 + 2.143x_4 <= 10$$

$$0 <= x_i <= 1, \text{ for } i = 1,3,4$$

$$x_2 = 1.$$

Based on the solution to the original, relaxed problem, we know that the integer solutions to each of these problems must have a value less than or equal to the upper "bound" of $15,714.

Branch and bound now proceeds to solve each of these sub-problems using linear programming. If the optimal solution to either is (coincidentally) integer, it is an optimal solution to the sub-problem, and the value can be used to terminate searches of all other sub-problems whose upper bounds are lower. If the solution is not integer, we must create two new sub-problems by again branching on the non-integer variable.

The solutions to the above sub-problems are:

Sub-Problem 1A: $x_2 = 0$

$$x_1 = 1,\ x_2 = 0,\ x_3 = 1,\ x_4 = 0.667$$

(Non-integer)

Benefit: $15,476.

Sub-Problem 1B: $x_2 = 1$

$x_1 = 1, x_2 = 1, x_3 = 0.714, x_4 = 0$

(Non-integer)

Benefit: $15,610.

Since neither solution is integer, both problems are "active", and we must continue branching. The next step would be to define sub-problems to 1B (since it yielded a solution with a higher benefit). Sub-problem 2BA would have the additional constraint that $x_3 = 0$ and sub-problem 2BB would have the additional constraint that $x_3 = 1$. Each of these sub-problems is solved to see if they remain active. A sub-problem does not become inactive until either all variables in the solution are integer or there is no feasible solution to it. The branch and bound process continues until there are no remaining sub-problems that are still active.

Continuing to branch and bound, the example eventually yields the solution:

$$x_1 = 0, x_2 = 1, x_3 = 1, x_4 = 1$$

which provides a total benefit of $15,000. Notice that this solution yields a higher total benefit than the solution provided by ranking or the feasible solution derived by rounding the linear programming solution. The fact that the simpler approaches did not yield the optimal solution illustrates the dangers of relying on approximate methods.

As illustrated by the above, the limitation of the branch and bound method is that it requires testing many combinations of specific integer values for the variables, and each combination requires the solution of a "normal" optimization problem. Thus, the number of possibilities increases exponentially with the number of decision variables (projects) that must be evaluated. This is a serious problem. Even with sophisticated integer programming software packages and modern supercomputers, if there are more than just a few hundred projects, it is often impossible to solve the problem using integer programming.

Choosing a Solution Method

Of the three basic solution approaches, ranking by benefit-to-cost ratio is usually the best choice for capital allocation when projects are independent with only one budget constraint. Although the solution is only approximate, if there are many projects such that the most costly projects make up only a small fraction of the budget, the result from ranking will be very close to optimal even for budgets that fall between the cumulative costs generated by the ranked list. Ranking is intuitive and less complicated than the other approaches. Furthermore, although not described here, the ranking approach can be modified to account for project interdependencies. Linear programming solutions are best when there are multiple constraints that must be satisfied and the problem is too large to be solved using integer programming. Integer programming gives the most accurate solution, but the slow solution speed and large memory requirements imposed may not be worth the added accuracy.

◁ **A Mathematical Model of the Capital Allocation Problem**

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PRIORITY SYSTEMS

Project Prioritization Tools — Which Approach is Best?

The following is a generalized version of a paper prepared for the First Annual Power Delivery Asset Management Workshop, New York, June 3-5, 2003 [1].

Introduction

To survive and prosper in today's competitive and cost-conscious environment, organizations must derive greater value from the projects that they conduct. Success requires doing the right projects, not just doing projects right. As organizations have begun to recognize the need to improve project-selection decisions and to better manage their project "portfolios," consulting companies and software vendors have rushed to offer tools for the job. These tools are variously marketed as tools for project portfolio management, multi-project management, capital allocation, asset management, project prioritization, etc.

As is often the case in new markets, the initial offerings differ greatly. For example,

- Some tools represent generic, off-the-shelf software while others are custom designs.
- Some are massive, all-encompassing packages that require considerable cultural changes by user organizations. Others are small-scale, "starter" tools or tools focused on narrow applications.
- Some designs are automated, data-driven tools, while others are fed entirely by judgments.

Although the approaches used by these tools to evaluate and prioritize projects may at first appear similar, there are actually important and fundamental differences. For example,

- Tools are variously advertised as being based on project net present value (NPV), economic value added (EVA), expected commercial value (ECV), balanced scorecards, decision trees, simulation, etc.
- Some tools involve ranking projects based on some measure of value, some are intended to define project portfolios that achieve some definition of balance, and some are based on matching projects to strategic objectives.
- Some tools use check list, yes/no questions for rating projects. Others use scoring models wherein projects are rated on 1-5, 0-10, or similar scales.

Most of the initial tools are, quite frankly, not very good. While it is true that a well-designed priority system can provide a consistent, logical way to evaluate and compare project proposals, a poorly designed tool or one that doesn't fit the need can distort decisions, increase costs, and create considerable frustration. I suspect that many organizations will be disappointed based on their first experiences using project prioritization and portfolio management tools.

So, how can an organization interested in project prioritization evaluate tools and select a good one? This paper offers guidance.

Decision Models

Before purchasing or developing a tool, it is helpful to understand how tools work. All project evaluation and selection tools, like all management science approaches, are based on models. The basic idea is to create an analytic representation (model) of the decision problem. The model is used to test and evaluate alternatives. If the model is a good one, an alternative that the model says will perform well is likely to perform well in the real world.

Project Selection Decisions Require Sophisticated Models

Because a successful model must capture every critical aspect of the decision, more complex decisions require more sophisticated models. “There is a simple solution to every complex problem; unfortunately, it is wrong” [3].

This reality creates a major challenge for tool designers. Project decisions are often high-stakes, dynamic decisions with complex technical issues. Project decisions are dynamic because a project may be conducted over several budgeting cycles, with repeated opportunities to slow, accelerate, re-scale, or terminate the project. Also, a successful project may produce time-varying benefits over many years. Project decisions also entail risk and uncertainty.

Furthermore, project selection decisions are complicated because they are strategic decisions. The projects a company chooses define the products it supplies, the work it does, and the direction it takes in the marketplace. Thus, project decisions impact every business stakeholder, including customers, employees, partners, regulators, and shareholders. Making good choices requires not just estimating return on investment; it requires understanding all of the ways that projects impact the ability of the enterprise to succeed. A sophisticated model is needed to capture the enterprise-level impacts of project selection decisions.

An inadequate tool can mislead decision makers, resulting in poorer and less defensible decisions than would be made without it. How can we determine whether a decision model/tool is adequate?

Why Models Work

Models are useful because they address key limitations of human problem solving. Research [2] shows that humans have limited information processing skills, can be biased when faced with competing objectives and uncertainty, and are often inconsistent when making choices. People are good at creative tasks like generating alternatives. They are also good at recognizing structure and at making “small”, well-defined judgments. Models break a complex problem into pieces, allowing people to do what they do best while enabling computers to do the calculations.

Benefits of Decision Models

A well-designed model can provide three types of benefits. First, a model can produce better choices by reducing errors, biases, and inconsistencies. If the model uses performance measures consistent with the organization's strategic objectives, it can help align decisions with strategy. A model can also create better choices by providing insights that suggest new alternatives and by controlling the role of politics.

Second, a model can improve the decision process. A model levels the playing field for the competition for resources by providing consistent rules for evaluating proposals. A model clarifies what information is needed and shows how it can be incorporated into decisions. A model can be used to involve stakeholders, for example, by allowing them to provide selected model inputs. A model tends to promote consensus, since it is often easier to get people to agree on the rules for making a decision than on the decision itself. In addition, a decision model can serve as a catalyst for action by providing a way to redirect and end unproductive and unfocused debate.

Finally, a model can increase the defensibility of decisions. It documents underlying assumptions and provides a logic for choice. A model also allows “what if” analysis wherein inputs are varied to see if recommendations change. This is often useful for demonstrating that a decision is not sensitive to a specific unresolved issue or disagreement.

Criteria for Evaluating Tools

Six criteria are relevant for evaluating tools: (1) accuracy, (2) logical soundness, (3) completeness, (4) practicality, (5) effectiveness, and (6) acceptability [4]. The subsections below clarify these considerations.

The Tool Must Be Accurate

The value of a project prioritization tool depends most critically on its ability to produce accurate recommendations. Important questions include: Is the tool biased toward or against certain projects, interests, or considerations? Are results highly sensitive to untested or untestable assumptions? Does the tool produce outputs with an acceptable level of confidence and precision? Does the tool indicate the confidence level or precision associated with outputs?

Unfortunately, flaws and omissions in decision models can produce large errors in recommendations. As evidence, see the examples in the boxes below.

Intuitive and Reasonable-Sounding Tools Can Be Inaccurate

In the mid 1980's, the Los Alamos National Laboratory (LANL) was seeking a tool for prioritizing equipment purchases, seismic upgrades, and other high-cost investments. The lab reviewed a half dozen prioritizing models used in industry and by government agencies, noting that each involved a very different approach.

A team consisting of experts from LANL, two other national laboratories, management consultants, and universities was formed to develop an improved prioritization model, called the Laboratory Integration and Priority System (LIPS) [5]. Unlike the other models, LIPS was based on a formal theory for prioritizing projects known as multi-attribute utility analysis (MUA) [6]. A test was conducted to compare project rankings produced by LIPS with those produced by other models. The results surprised many. Even though the other models seemed intuitive and reasonable, projects that ranked the highest using LIPS were often ranked low by other models.

Being Well-Established Is No Guarantee that a Tool Is Accurate

As another example, in the late 1980's Congress ordered the Environmental Protection Agency to evaluate whether its Hazard Ranking System (HRS), used to place contaminated sites on the National Priorities List for accelerated clean up, was the best-available site-ranking model. The analysis consisted of comparing site rankings produced by the HRS and other models (used by various states and other government agencies) with a ranking produced by an expert panel. The analysis also included developing a model based on multi-attribute analysis (MUA, see box to left).

Once again, the results were surprising. Although the expert and MUA model rankings were very highly correlated, none of the site-ranking models produced rankings that correlated with each other or with the ranking provided by the expert panel. Several models, in fact, produced rankings that were negatively correlated with the expert ranking [7].

Two considerations can help ensure that a tool produces accurate recommendations. As described below, the tool must be logically sound and it must be complete.

The Tool Must Be Logically Sound

There are two ways to demonstrate that a tool is logically sound, empirical evidence and theory. It is difficult to collect empirical data for validating a tool's recommendations (few organizations are willing to fund recommended and not-recommended projects for the purpose of testing a tool!). Therefore, the logical defensibility of a tool is primarily a function of the degree to which it can be justified by accepted theory. Relevant theories include multi-attribute utility analysis (MUA) [6], decision theory [8], modern portfolio theory [9], optimization theory [10], and real options [11]. These theories are well established within the technical and academic communities.

There is an important distinction between the above theories and the terms usually cited as the bases for prioritization tools (e.g., ECV, balanced scorecards, decision trees, simulation, etc.). Theories are “axiomatic.” They begin with a set of axioms (assumptions) that you are free to accept or reject. For example, decision analysis is based on axioms intended to define “rational choice.” One (known as transitivity) states: “If there are 3 possibilities, labeled A, B, and C, then, if you prefer A to B and you prefer B to C, you must prefer A to C.” A theory derives (through mathematical "proofs") conclusions that follow from its axioms. In other words, if you accept the axioms (and the math is correct), the rest of the theory follows.

Balanced scorecards, decision trees, Monte Carlo simulation, etc., are not theories. Rather, they are model forms that can be conveniently solved. In each case there is a solution algorithm that may be used to optimize or solve for some characteristic of the model. Models can be used to apply the theories, but only if the models are consistent with the assumptions required by the associated theory. For example, decision trees represent a

The Concepts Need to Be Right

Success may be in the details, but the first step is to get the concepts right. As an example, an organization was using a scoring approach wherein candidate projects were awarded points based on judged performance along various dimensions (financial reward, strategic fit, leverage, probability of success, etc.). The points were added and the result used to rank projects. Although no one objected to the logic, there was a suspicion that something was wrong. Large projects were nearly always high on the list and small projects near the bottom. One major flaw of the tool is that it fails to account for the resource constraint. The relevant logic is ranking projects by the ratio of benefit-to-cost, not benefit alone. Another flaw is that adding the points awarded in the various dimensions does not measure project benefit. The aggregation equation must correspond to the way that the various performance dimensions actually influence value (as described by an applicable theory, such as MUA). For example, points indicating probability of success should not be added. Probability of success should be a multiplier—If a project has zero probability of success the project will generate no benefit whatever.

Tools Not Based on Sound Theories Are Exposed When Subjected to Technical Review

Congress required the Department of Energy (DOE) to rank potential sites for disposing of radioactive waste from nuclear power plants. To select the best site, the DOE initially used a version of the balanced scorecard approach particular type of model often used to operationalize decision theory. Theories tend to last a long time, whereas models are often replaced and improved upon (for example, increasingly powerful computers allow bigger models to be solved). The defensibility of an approach depends on the defensibility of the theories that it is based upon, but, more importantly, it depends on whether the model is consistent with any defensible theory.

As an example of the dangers of using tools not based on relevant theories, see the side box example describing DOE's attempts to site a nuclear waste repository. Although most project decisions aren't as controversial as this one, some (such as an electric utility's decision to acquire right-of-way to construct a transmission line) can be. Using a logically sound approach avoids errors associated with unsound methods and reduces the risk of successful challenges to the credibility of decisions. Although logical soundness does not guarantee accuracy (see below), it is safer and wiser to use a tool based on sound theory than one that merely "seems" reasonable.

The Tool Must Be Complete

Being complete means accounting for all significant and relevant considerations. A logically sound tool that is incomplete gives, at best, the right answer to the wrong question. A tool might leave out important considerations because those considerations are difficult to accommodate (e.g., it may be too hard or too costly to obtain the necessary input data). A tool can also leave out important considerations because they are impossible to accommodate (because the issues are beyond the scope of its decision model).

As noted earlier, project decisions tend to produce broad, enterprise-level impacts. This makes creating a complete model extremely challenging. As illustrated by the example in the side box, a complete model is often large, requiring many inputs and sophisticated mathematical algorithms.

The Tool must be Practical

Accuracy, logical soundness, and completeness are the reasons that prioritization tools must be sophisticated. But, a tool must also be practical. Building an effective tool that is practical is the biggest challenge facing tool designers.

To be practical, users must have expertise to correctly apply the tool. The tool's inputs must be available, and the inputs provided must be consistent with the tool's assumptions. Computational resources must be adequate, and sufficient time must be available for applications.

How can such challenges be addressed? Obviously, care should be taken to design the tool to make it as practical as possible without sacrificing accuracy, soundness, or completeness. At the same time, the organization can take steps to make it practical to use sophisticated tools. These steps include investing in internal training, reassigning responsibilities, developing new sources of data, and adjusting budgeting schedules.

Although the above recommendations may seem daunting, it is worth noting that it is common for an organization to initially view a quality tool as "too complex" and then later, after gaining experience with its use, to desire to make the tool even more sophisticated (see the side box example). Thus, organizations should avoid simplistic tools and tools whose capabilities cannot be expanded as experience and understanding grows.

The Tool Must Be Effective

Being effective means achieving the specific goals that motivate using a tool. For example, a tool intended for back-room use would be designed differently than one whose purpose is to demonstrate to regulators and local citizens that

often recommended for comparing alternatives: Each site was rated against each of the objectives established for a good site, the objectives were weighted, and the rates and weights were combined to rank the sites. Hanford, a site in Washington State, ranked highest, and the DOE published the results in a draft Environmental Impact Statement. The choice was criticized, especially by officials from Washington State, and the DOE asked a board of the National Academy of Sciences (NAS) to review the basis of its decision. The board, which included experts in decision theory, responded that DOE's method was “unsatisfactory, inadequate, undocumented, and biased” [12]. DOE was told to redo its analysis (a site ranking model based on MUA was developed). The new analysis ranked Yucca Mountain, Nevada, highest. DOE was forced to change its decision, causing the agency considerable embarrassment.

Completeness Requires the Capability to Address "Hard" and "Soft" Considerations

A water utility desired a system for prioritizing capital improvements. To fully value such investments, it was necessary to include "soft" project benefits, such as enhanced public health and safety, reduced flood risk, increased community recreational opportunities, and expanded capability and knowledge. Providing inputs for quantifying project value required information from databases associated with many different applications, including asset utilization systems, customer information systems, GIS, work management systems, and investment modeling applications. Furthermore, it was clear that field personnel had local knowledge of needs and the effectiveness of proposed projects that was not captured by historical data. Thus, the resulting priority system included both an extensive scoring logic (to capture judgments) plus analytic techniques for logically combining empirical and judgmental data.

Experience Creates Capability and Demand for More Sophisticated Tools

In the early 1990's, a client operating an oil and gas pipeline sought help in designing a system for prioritizing investments to reduce risk. The new system was much more detailed and formal than existing practices. It required training, implementing new processes, constructing additional databases, and creating computationally sophisticated evaluation software. The first system documentation manual was more than 200 pages in length. Many outside the development team argued that the system was "far too complicated." However, backing of senior management was secured when it was demonstrated that the system uncovered ways to significantly reduce risks without increasing total costs. The client has continued to use the system independently for many years, and each year the system has been expanded. Experience, better documentation and internal training led to increased confidence and expertise, promoting the desire for more capability and accuracy.

Being Effective Often Requires a New Approach

A recent effort was conducted for an electric utility to provide a system for prioritizing bids for long-term (greater than 10-year) energy contracts. Standard contract the organization's project decisions are in the best interests of the community. Not only would the latter have different user characteristics, the definitions of project costs and benefits would be quite different.

Before building or purchasing a tool, think carefully about what the tool needs to do to be effective. For example, a key design decision is what the model's "decision variables" should be. Should the tool be designed merely to give yes/no decisions for each project, or does it need to evaluate alternative funding levels for projects as well?

Sometimes, being complete requires using new or unconventional approaches. As illustration, see the side box example.

valuation methods were overly sensitive to disc assumptions. Therefore, an alternative model n dependent on discount rates was developed ba options theory [10]. Real options is a relatively n approach that adopts the view that projects and create options (e.g., a contract creates the optio energy according to a predetermined price rule) options tool did not replace the utility's conventi contract valuation tool. Rather, it is used to mak choices about contract durations while the utility conventional tool is still used to support specific

The Tool Must Be Acceptable to Stakeholders

A tool that is practical and effective is not always acceptable to decision makers and other stakeholders. An acceptable tool must be compatible with existing organizational processes and culture. It must be understandable and understood. A tool that impacts funding decisions will be perceived as a threat to some interests. All key stakeholders must have confidence that the tool will help them, as well as the organization, to succeed.

Gaining adequate acceptance is critical to the success of the tool. For a dramatic example of a tool that was widely regarded as technically defensible, complete, accurate, and practical and, yet, was rejected, read "The Rise and Fall of a Risk-Based Priority System" [13].

The most effective way of generating acceptance is to involve those who will use and be impacted by the tool in its design and development. A collaborative process helps ensure that the tool will have exactly those characteristics necessary to best suit the organization and its needs. Equally important, involving stakeholders in the design process creates buy-in by allowing skeptics to express their concerns and see first hand how those concerns are addressed. See the side box for an example.

Developing the Tool as a Collaborative Effort Promotes Buy-In

A client was investing heavily in information technology. A system was desired that would prioritize proposals submitted by different departments. Department managers were naturally concerned about how the new system would affect their ability to obtain funding. One department head, responsible for core systems, was particularly pessimistic about the ability of a tool to fairly evaluate his projects. "How can you quantify the value of adding capacity? Our projects don't increase revenue or reduce costs, and they are invisible to our customers. The only time we ever get more funding is when things stop working." The manager only agreed to participate after attempts to get his projects exempted from the system failed. To address the concerns, the selected design included a feature not common to priority systems--If an infrastructure project enabled or facilitated another project, the enabling project obtained a share of the benefit derived from the enabled project. The approach worked, and the core systems department obtained approval for several projects that had historically been denied funding.

Custom-Designed vs. Tailored Tools

Obviously, building a custom-designed priority system is more time-consuming than purchasing an off-the-shelf tool. If the generic tool can be tailored and obtaining buy-in is not a problem, is it more cost-effective to purchase an off-the-shelf tool?

The answer is, "Maybe". There are three reasons for the equivocal response. First, some software tools cost more than it would cost to construct a custom tool. Second, of the few generic project prioritization software tools that I have reviewed, none are fully consistent with MUA or any other accepted, internally-consistent, decision theory. Some software vendors make it very difficult to obtain documentation describing the underlying mathematics of their tools. Perhaps one reason is a desire to avoid peer review that would point out flaws and limitations. Third, a generic tool can only be adjusted within the limitations dictated by its underlying decision model. If the model doesn't fit, no amount of tailoring will make the tool appropriate.

Some off-the-shelf prioritization tools are based on ranking projects according to the ratio of total-project-benefit to total-project-cost. The recommendation is to fund projects from the top down until the budget is exhausted. Although a such a system can be effective, there are situations where project ranking is inconsistent with an organization's decentralized decision making structure. The side box provides an example. No amount of tailoring can convert a project ranking tool to one based on an alternative approach.

A common but indefensible variation is to rank projects based on alignment with the organization's strategy. Elements of the organization's strategy are identified, and projects are scored based on how well they they achieve each element. Choosing projects that implement organizational strategy is important. However, using strategic alignment as a basis for prioritization makes no sense at all. Strategic alignment is not a surogate for "bang-for-the-buck." Therefore, the approach will not even approximate value-maximizing project portfolios.

Even ranking by benefit-to-cost is not always a logically sound approach. Ranking gives approximate answers only. It doesn't work at all if there are project inter-dependencies (e.g., infrastructure projects and projects that use the infrastructure). Ranking can result in one project being above the funding cutoff line while another that it depends on falls below the line.

Different Organizations Require Different Approaches

An electric utility desired a system for allocating its $250 million O&M budget. The organization had a decentralized decision-making structure, and the application involved allocating funds across different business units run by managers who have line authority to decide how to spend their own project budgets. A centralized, project ranking system was unacceptable, since it would be inconsistent with existing decentralized decision-making structure. The selected system [14] used an alternative approach that evaluated alternative funding levels for each department, based on the projects that would be conducted under each funding level. This design allowed area managers to retain authority to prioritize and select projects within their

Since there is a limit to how much a generic model can be tailored, be sure that the model fits before committing to it.

respective areas while rewarding managers whc projects consistent with corporate objectives.

Conclusions

Tools for project prioritization can help organizations improve the selection and management of their project portfolios. Tools promote a more deliberate, careful, and consistent evaluation of alternatives. They force the generation of more and generally better project data. Many of the available tools provide excellent data management and reporting capabilities, making it much easier for managers and executives throughout the organization to better understand the work that is being conducted. The major weakness of the available tools is their ability to make logical and defensible decision recommendations. Most tools fail to provide accurate estimates of project portfolio risk and value and, therefore, do not provide much help for making tough project choices. Although some tools are clearly better than others, no one approach is best (or even adequate) for all circumstances. The choice of a project prioritization tool needs to be made differently for different organizations and applications.

In summary, the following advice is offered to those who design, select or use project prioritization tools:

- Choose a tool that reflects an "enterprise-level" view of project benefits and a life-cycle view of project costs.
- Make sure the tool captures all considerations critical to the application. Commonly ignored considerations include various soft project benefits, investment urgency (as opposed to investment value), project sequencing and other types of project interdependencies, and risk (especially market risks and other "correlated risks" that similarly impact multiple projects).
- Don't use tools that are not firmly based on accepted mathematical theories. If in doubt, get an independent technical review.
- Plan on the need for education and training. Having a thorough understanding of concepts is as important as knowing how to use the tool.
- Unless your organization is very small, use a phased approach to implementation. Start with one department, conduct a post-implementation lessons-learned review, and make changes before you move to the next level.
- Make sure that all stakeholders have necessary buy-in and confidence in the tool. Otherwise, insufficient effort will be devoted to generating inputs and/or model recommendations won't change decisions.
- If the answer seems wrong, then either your intuition is wrong or there is a flaw in the model. Check the model logic. A good model will have a compelling logic. If you still don't agree, don't trust the model (and consider replacing it). Remember, a tool is an aid, not a substitute, for decision making.

Notes

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PRIORITY SYSTEMS

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Approach

A Collaborative Process is key to the success of our approach. Creating the priority system as a team effort allows us to capture the organization's unique opportunities for creating value; account for all relevant organizational issues; and generate the confidence, understanding, and buy-in necessary for effective and continued use. The priority system (software plus processes for collecting all necessary inputs) is validated through a pilot test. A full-scale application is conducted to prioritize current projects, and the priority system is transferred to the client for on-going, royalty-free use.

Methodology

We use efficient decision analysis processes and accurate valuation models based on multiattribute utility analysis and real options. Multiattribute utility is a method for quantifying the "soft" benefits of projects (e.g., improved capability, increased knowledge, enhanced brand image). Real options analysis accounts for the impacts of funding choices on future opportunities (a project's current priority depends on whether delaying it is an option). Multiattribute utility and real options are mathematically sound, well-established theories, not management fads that go in and out of style.

Features

Our approach:

- Enables management to agree upon and articulate measurable business objectives.
- Provides a framework and graphic tools for understanding and communicating about the strategic value of investments.
- Quantifies the dollar value of projects, accounting for soft benefits, project interdependencies, and risk.
- Provides outputs and "what if" capability to support a continuous process of project evaluation, project selection, and project portfolio management.

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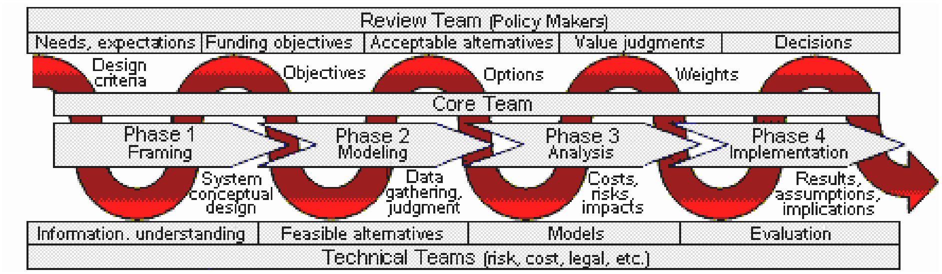
Collaborative Process

Client participation is essential to create an effective priority system and to achieve necessary "buy-in" and understanding for continued use. Three "teams" are established:

1. A **Core Team** composed of the client resource manager, support staff, and our consultants. The Core Team is responsible for constructing, testing, and applying the priority system.
2. An **Executive Review Team** composed of client policy makers. This team is responsible for guiding the design and providing all policy inputs (e.g., system weights).
3. **Technical Teams**, as needed, responsible for ensuring proper representation of relevant technical considerations (e.g., regulatory issues, sources of project risks, etc.).



Each phase involves workshop meetings. The Core Team meets with the Technical Teams to ensure that technical issues and assumptions are accurately captured. Meetings with the Review Team are conducted to validate and approve the key steps. Facilitation aids and structured processes are used to minimize client time commitments and to produce outputs at each meeting that demonstrate to those involved that investment of their time and effort is justified.

In addition to creating a powerful tool, our process improves decision clarity and positions the client team for successful ongoing applications. The organization becomes more focused on business value drivers and far more effective at allocating its resources.

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