Optimizing Resource Allocation Decisions

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Abstract. The paper explains how the analytical hierarchy process (AHP) theory of decision-making can be used to create justifiable, traceable resource allocation decisions in a resource-constrained organizational environment. By thinking about the decision as a six step process of: (1) framing the decision to be made, (2) identifying alternatives, (3) modelling-evaluating the trade study, (4) choosing an alternative, (5) conducting sensitivity analysis, and (6) implementing the selected alternative, key stakeholders can better understand how to reliably and repeat-ably make justifiable, traceable resource allocation decisions in the context of an enterprise systems framework.

Introduction

Leaders at all levels and the engineering community continue to raise expectations of technical, schedule, and financial performance. Delivering successful projects in this environment requires that systems engineers address the complexity and interdependencies of systems and systems of systems. However, development initiatives often require substantial resources for full implementation. Such resource allocation decisions must be carefully considered in the context of competing initiatives, and a structured decision making process can be used to determine how to allocate constrained resources for maximum benefit in a resource-restricted environment.

The INCOSE Handbook postulates that *"Making good decisions requires adequate information, experience and good judgment."* (INCOSE Handbook v 3.1, paragraph 7.1.2) We agree, of course, but also suggest that decision-making is a learnable skill in seemingly short supply within many organizations. Unfortunately, these organizations apparently reject various well-known, effective decision methodologies in favor of the more time-consuming and inefficient BOGGSAT decision-making technique. (BOGGSAT = Bunch Of Guys and Gals Sitting Around Talking)

The following paragraphs explain how the analytical hierarchy process (AHP) theory of decision-making can be used to create justifiable, traceable resource allocation decisions in a resource-constrained environment. We suggest that this technique is an effective methodology to determine the resource distribution—budget or staffing—for any organization. By thinking

about the decision as a six step process of: (1) framing the decision to be made, (2) generating alternatives, (3) modelling-evaluating the trade study, (4) choosing an alternative, (5) conducting sensitivity analysis, and (6) implementing the selected alternative, organization stakeholders can better understand how to reliably and repeat-ably make justifiable, traceable resource allocation decisions.

Decision – Making Approaches

Context

Managers and engineers at all levels make decisions constantly. The ability to quickly and efficiently structure and execute a technical trade study is a core systems engineering skill, yet relatively few systems engineers admit to receiving formal decision-making training, either in academic settings or elsewhere. A 2007 National Defense Industrial Association (NDIA) study of 46 U.S. Federal development projects revealed that the systems engineering discipline area of planning and executing trade studies well had a very high correlation to overall program success. In fact, the only other systems engineering skill area with a higher correlation to program success was architecture development. (NDIA *SE Effectiveness Survey*: *2005-2007*)

Similarly, it is our observation that comparatively few organization managers use any type of structured resource allocation process when adjudicating resources among competing projects and initiatives in the enterprise's overall portfolio. We are not sure how to explain this apparent absence of process rigor. Some reasons may include: over-reliance on intuition or engineering judgment, needless complexity in structuring decision processes using unwieldy operations research techniques that inhibit their practical use on projects, or simply over-commitment that causes us to look for apparent short-cuts. How many of us have experienced a "typical" budget build that involves using the previous year's budget as a baseline, then adjusting it up or down based on available funding for the coming year? We suggest that there is a better way to allocate constrained resources that not only permits traceability, but enables more efficient and effective resource decision-making to maximize organizational benefit.

The INCOSE Handbook and ISO/IEC 15288 address resource allocation decision-making as inherent to the Investment Management Process. According to INCOSE, "*the conduct of successful projects requires and adequate allocation of funding and resources and the authority to deploy them to meet project objectives."* (INCOSE Handbook v 3.1, paragraph 6.3.2)

The Handbook does not identify decision-making as a specific process activity within the Investment Management Process, but it does suggest that: *When investment opportunities present themselves, prioritize them based on measurable criteria such that projects can be objectively evaluated against a threshold of acceptable performance.* (INCOSE Handbook v 3.1, paragraph 6.3.5) This paper suggests a proven approach using AHP as a useful tool to meet this desired objective.

For the purpose of this paper, we will define "enterprise" as an organizational element that is capable of autonomous decision-making to affect business or mission outcomes. For example, the McDonald's Corporation is an enterprise. That corporation's leaders establish policies and

set standards for a global business. The local McDonald's restaurant around the corner is also an enterprise, since that local franchise makes some autonomous decisions, such as whom to hire, how to staff the drive through window, etc. Thus, "enterprises" may exist a many levels within organizational systems of systems—the distinguishing characteristic is whether a given organizational construct is capable of autonomous decision-making.

We will also adopt Kenneth Hammond's definition of a "decision" as a response to a situation in which: (a) there is more than one possible course of action, (b) the decision-maker can form expectations about the outcomes following each possible course of action, and (c) each outcome has an associated consequence that can be evaluated. (Hammond, pp. 25-26)

There are three common characteristics of most resource allocation decisions. First, there is usually a degree of conflict or disagreement among stakeholders. Second, these decisions are usually made with incomplete or inaccurate information that leads to uncertainty about the outcome of the decision. Third, there may be some level of ambiguity in key decision elements (e.g., lack of a clear objective). Conflict, uncertainty and ambiguity—some leaders thrive under those conditions, while others can be paralyzed by indecision.

Effective leaders systematically build decisions upon a solid foundation of knowledge of goals, objectives, and relevant information. Those decisions may be made under conditions of tremendous stress and uncertainty, or they may be made in a very rigorous, controlled process with data. Some decisions are most appropriately made using "automatic" thinking (intuition), while others benefit from structured analytic or statistical techniques. Nevertheless, the way in which these leaders think about the decision-making process itself usually remains consistent. Proponents of decision analysis tend to approach decisions from a probability and statistics framework, while advocates of intuition approach things from a sociological or psychological perspective. In fact, analysis and intuition are both useful techniques and by no means mutually exclusive.

An intuitive approach is most useful in high speed, high risk, high uncertainty situations with experienced decision-makers, while an analytic approach is often better in non-time critical situations where lots of data is available, or where the decision-makers may not have as much experience. An analytic approach is usually better in situations where predictive judgments must be made repetitively or when decision-makers must justify their conclusions to other stakeholders. Regardless of preferred approach, decision-makers are often required to exercise their best judgment under conditions of uncertainty, which usually means leveraging all available facts, as well as relying on intuition to see what makes the most sense. We suggest that the AHP decision analysis technique combines the best of both approaches. AHP leverages the decision-makers' intuition in the context of a systematic, traceable methodology that is especially useful in making resource allocation trade decisions.

A Systems Framework for Decision-Making

As we work with many different organizations from public and private sectors, we have concluded that a necessary condition for a consistent decision-making process is a "systems view" of the enterprise. This is particularly true for decisions about enterprise strategy, portfolio selection, and resource allocation. A systems view is a perspective that allows decision makers to

simultaneously consider how the interrelationships of organizational governance, strategy development and deployment, the voice of the customer, organizational knowledge management, employee and work systems, value creation processes, and support processes contribute to enterprise results.

Together with some leading thinkers on management theory, the U.S. National Institute of Standards and Technology (NIST) has been conducting research on the conditions for enterprise excellence for the past twenty years. Born out of an initiative begun in the mid-1980's as a way to re-energize American business competitiveness in the global marketplace, the work done by NIST provides us a systems framework through which to examine enterprise decision-making. Based on extensive research into what drives organizational success, NIST has developed a set of interlinked criteria that any organization may use to identify opportunities for improvement while pursuing organizational excellence. These criteria are a de facto set of requirements that define organizational success from both systematic and systemic perspectives.

The Criteria for Performance Excellence (Figure 1) are a set of eighteen individual requirements, grouped in seven categories, which are built on a foundation of Core Values and Concepts. These core values and concepts that are consistent with our aim to establish a consistent enterprise decision-making process include: visionary leadership, customer–driven excellence, agility, focus on the future, focus on results and creating value, and a systems perspective.

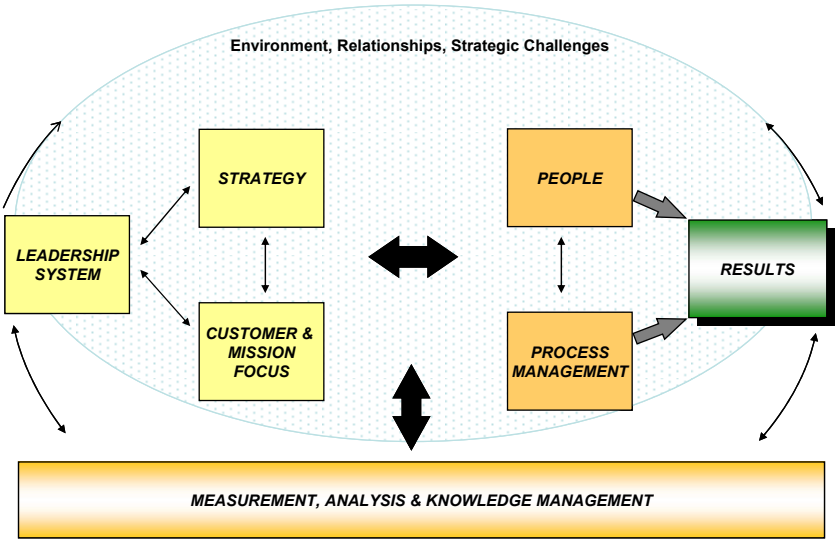

Figure 1. Criteria for Performance Excellence

Results are those outcomes by which the organization—and external stakeholders—measure success. Leaders are responsible for setting strategy based on customers and markets (or statutory missions in the case of government organizations) and then guiding the organization to execute to get results. Leaders are constantly gathering inputs from the customers and the markets and making decisions to set strategy. Effective leaders strive to gather diverse viewpoints as inputs to better understand the dimensions of their problem before making a

decision. Once the leadership sets the strategy, it has to be implemented and executed by the people in the organization who set up processes to carry out strategic goals and objectives. Measurement, Analysis, and Knowledge Management represent the measures that people use to gather the facts upon which decisions are made and processes are executed.

The Criteria and the core values establish the building blocks to enable organizational alignment and integration. Our recommended resource allocation trade study decision-making method is a practical technique to create that alignment and integration via reasoned, justifiable, and traceable organizational trades.

Structuring Organizational Trades

Considering the importance of decision-making in determining whether a given enterprise succeeds or fails, few organizations devote much effort toward defining a "process" of decision-making. Organizations tend to focus on measuring the outcomes of decisions, but rarely do they concentrate sufficiently on the input side of the decisions or the process of deciding itself. The input side of decisions includes determining who participates in the decision, how they will participate, what information needs to be available for a good result, and over what time period must the actual tradeoffs take place leading to a final choice or prioritization.

The decision to apply resources and effort to an enterprise initiative often must be traded against other project efforts and routine operating expenses associated with supporting/enabling organizations (e.g., infrastructure, human resources, security, etc.). Managers must determine where to apply resources to maximize benefit to the overall organization in the context of desired results, yet each manager often has a significant incentive to optimize his/her individual part of the organization at the expense of the overall enterprise. While this conflict may appear obvious to a disinterested observer, we suspect that many of us suspend our systems thinking skills when it comes to our own initiatives.

The elegance of the AHP method of decision-making is its ability to enable decision makers to use their intuition in the context of a systematic method for organizing the decision-making process. The result is a method for setting priorities that is adaptable to a wide variety of decisions. AHP can create a framework for formalizing decision processes throughout an organization and it is completely customizable to the unique environment, relationships, and strategic challenges of any organization. It enables leaders and managers to challenge and prod the decision making process in a very explicit manner to continuously improve on both inputs and results of decisions in the systems framework defined by the Criteria for Performance Excellence. The formalization of the process does not and should not limit intuition, but rather makes intuition explicit in order to better understand how various stakeholder perspectives actually help to inform priorities and make choices.

The process of structuring an AHP decision process is straight-forward. The decision team must develop a fundamental understanding of the decision that is to be made ("framing"), articulate the alternatives under consideration, establish a consistent set of criteria by which to judge the alternatives, analyze their preferences in the context of those criteria and resource constraints, conduct sensitivity analysis as necessary, then implement the decision. This process

is illustrated in Figure 2.

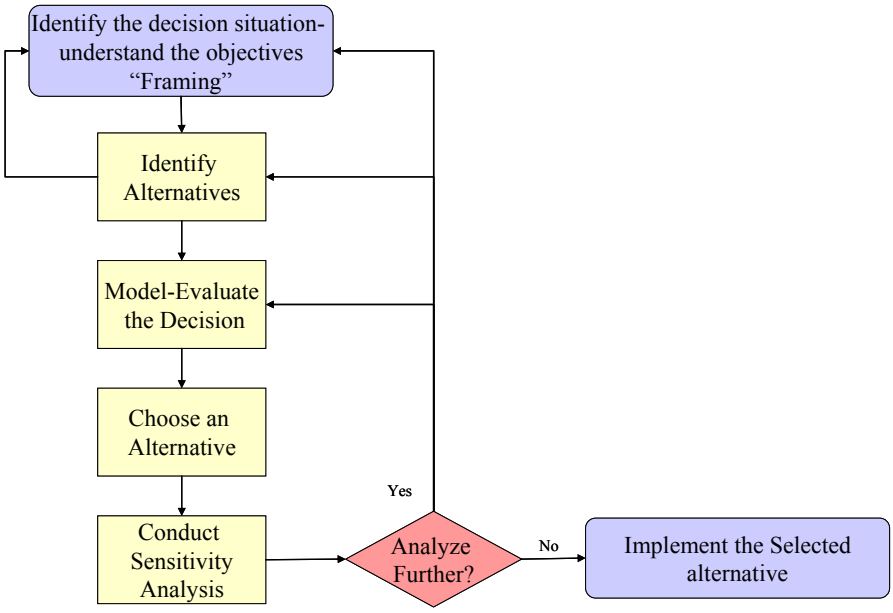

Figure 2. Resource Allocation Decision-Making Process

Convening the Resource Allocation Decision Team

The collaboration of the enterprise decision-making team can be an effective insurance policy against the cognitive biases that often interfere with good judgment when relying on intuition. People are unique; each one of us perceives the world differently. Our brains filter incoming information based on what we are "ready" to see, thereby exposing us to the risk of overlooking key dangers and/or opportunities. Perhaps the overriding advantage of having more than one person involved in the decision process is the diversity of perspectives one gains, which provides additional insight into possible opportunities or risks. Moreover, people tend to support best that which they helped create. If you need the commitment of a group of people to execute a decision (remembering that an unimplemented decision is an academic exercise at best), get them involved in the decision process.

Nothing in life is free, and the price of additional perspectives and enhanced "buy-in" is time and effort. Collaborative decisions generally take longer than independent ones because one must allow for open dialog and a free exchange of ideas. In addition, one must manage the group's dynamics for useful decisions to result. Most of us have had the unenviable experience of sitting through long, boring meetings (the weekly project status meeting?) where nothing substantive gets decided.

Collaborative decision meetings must be carefully planned and facilitated. A good way to think about the structure of a decision meeting is illustrated in Figure 3. During the first part of the meeting, ideas must be allowed to diverge sufficiently to ensure consideration of fresh perspectives and to encourage creativity. In the second part of the meeting, the group begins to drive to closure in order to select an alternative. Another way to express this idea is divergent thinking (opening up the realm of the possible), followed by convergent thinking (making a choice).

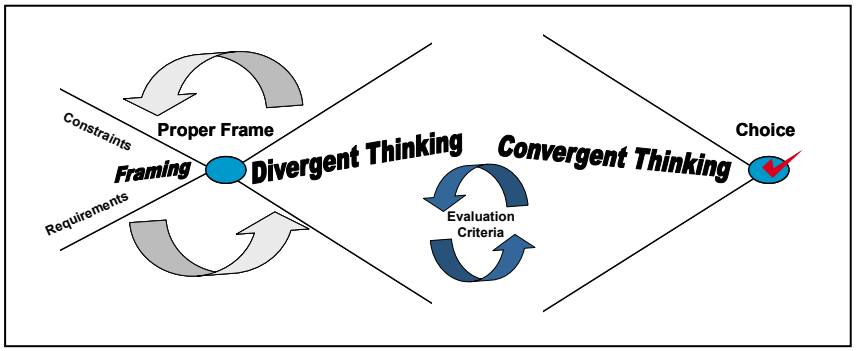

Figure 3. Decision Process Flow

A few cautions about collaborative decision-making are in order. First, individual self-interest can overcome the drive to make a choice for the common good at the enterprise level. For example, in how many meetings have you participated where a department manager announced that he/she did not need all of the budget allocated for a particular department that quarter and therefore intended to return it to the corporate level to reallocate for the good of the organization? Second, if the "bullets are flying," it is probably not a good time to convene a decision meeting. Finally, if the decision-makers are not directly affected by the outcome of their decision, there is a danger that they will not take the process seriously enough to really take a critical look at all of the ideas before making a selection.

The Proper Frame

The single most important step in our recommended resource allocation method is establishing a proper frame for the decision. How one defines the problem or decision defines the available alternatives from which a selection can be made. While the Criteria for Performance Excellence provides a useful systems thinking framework for resource allocation decisions, the decision frame is defined as the context or goal for the decision. Relevant questions include: "What is the ultimate objective of the decision?" and "What is the root-cause of the issue/problem?" Decision-makers sometimes lock onto a particular decision frame without critically examining the overall goal of the decision itself.

The proper decision frame opens up the spectrum of possible solutions, allowing truly creative possibilities to emerge. The typical decision-maker tends to focus on point solutions (the way we've always done things) instead of taking the time to step back and really examine the underlying goal(s) of the decision. Asking the fundamental question "why?" a decision-maker can see alternatives and options that are not readily apparent if the chosen frame is constrained to answering the question "what's wrong?"

Establishing an appropriate frame for a resource allocation decision requires an open and honest discussion about what is truly important to the enterprise—in the larger enterprise systems context offered by the Criteria for Performance Excellence framework. One method that can be useful in helping the decision team to understand its array of objectives is the Means Objective Network technique (Figure 4). The team simply brainstorms all the objectives that are important to various stakeholders, then relates each objective to every other objective by asking the question, "Why is that important?" Eventually the relationships among the various objectives are revealed, with the "fundamental objective" at the top of the resultant hierarchy. This fundamental objective describes the overall decision frame, while the supporting objectives are the "means" to that fundamental objective.

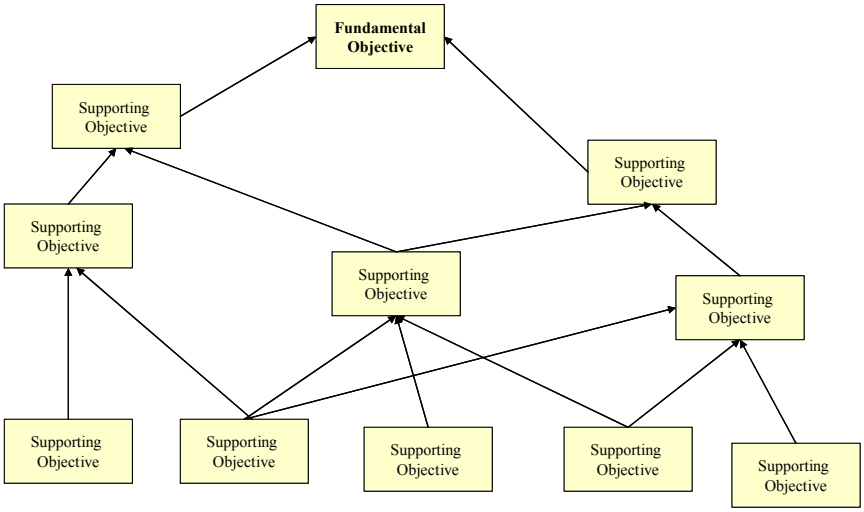

Figure 4. Means Objectives Network

With the fundamental objective revealed, our decision team must choose from among the supporting or means objectives to select a few, well-defined criteria that will be useful in discriminating from among the various enterprise initiatives (alternatives) under consideration. The AHP technique requires at least three levels in the decision hierarchy: (1) a defined decision goal and (2) a set of criteria by which to judge the (3) decision alternatives (Figure 5).

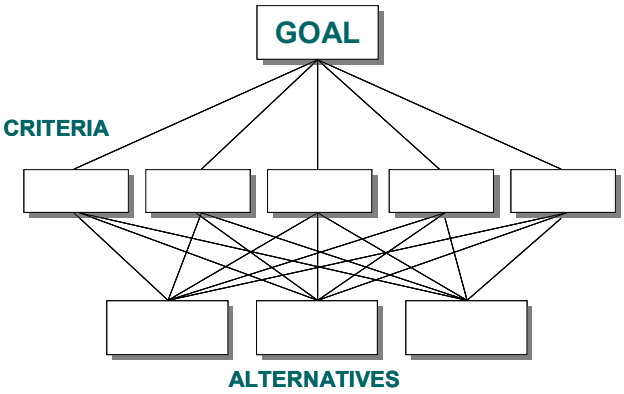

Figure 5. AHP Decision Hierarchy

The AHP technique relies on carefully selected decision criteria by which the alternatives are judged. These decision criteria should be few in number, reasonably independent of one another, and be clearly and unambiguously defined. Decision-makers often run into trouble when the decision criteria (and/or associated rating scales) are not consistently defined by all decision-makers. If the decision criteria do not have a common definition for all members of the team, the team results should be called into question, since various team members may have evaluated the alternatives differently. Similarly, too many criteria (i.e., more than nine) often result in an inability to reach a conclusion due to insufficient discrimination among competing alternatives.

Identifying Alternatives

The second step of our resource allocation decision-making method is to identify the alternatives under consideration. This is where decision-makers may leverage creativity for good decision-making. The more options and alternatives considered by the decision team, the greater the likelihood the team will encounter an innovative solution or alternative. Decision expert, Robin Hogarth sums it up succinctly:

> *Imagination and creativity play key roles in judgement and choice. ...predictive judgement requires the ability to imagine possible outcomes. ...in many choice situations alternatives are not given but must be created. ...Indeed, it can be said that a person who exhibits neither creativity nor imagination is incapable of expressing 'free' judgement or choice.* (Hogarth, p. 153)

In most cases, the organization will have defined a set of alternative initiatives that are competing for the constrained resource—and that resource is usually budget. It is imperative that the members of the decision team have a common baseline understanding of each alternative in order to judge how well a given alternative satisfies the set of decision criteria. One approach that has worked in many organizations is to distribute a "read-ahead" package that describes in detail each initiative under consideration. Subsequent to issuing the read-ahead materials, members of the decision team are required to become familiar with each alternative *prior* to the decision meeting.

Structuring the Trade Study

Once the group has properly framed the resource allocation problem and documented the alternatives under consideration, they must begin the process evaluating the trades. The key challenge for the decision team is to find a way to systematically analyze how the alternatives stack up in order to choose the "best," or most preferred alternative. This can be efficiently accomplished by using the AHP methodology to weight the decision criteria, then rating the alternatives against those weighted criteria.

Criteria weighting using the AHP methodology can be vastly simplified if the decision matrix is perfectly consistent. The author of the AHP theory writes:

If the comparison matrix is perfectly consistent, the priorities of the elements can be obtained by adding he numbers in each row and dividing each sum by the total sum of the rows, a process called normalization. (Saaty, p. 16)

While this enforced consistency forgoes the benefit of testing for consistency during the decision process itself, the opportunity to use simple arithmetic instead of matrix algebra when calculating criteria priorities (weights) makes it more likely that the decision team will spend their time productively discussing the merits of the alternatives rather than analyzing eigenvectors. An example of a simplified AHP matrix is included as Figure 6.

							Row Total	Weight
	Operability	**Maintainability**	**Reliability**	**Option Confidence**	**Schedule Risk**	**Growth Potential**		
Operability	1	3	3	0.2	2	0.33	9.53	13.2%
Maintainability	0.33	1	0.25	0.2	5	0.33	7.11	9.9%
Reliability	0.33	4	1	0.2	6	3	14.53	20.1%
Option Confidence	5	5	5	1	9	3	28	38.8%
Schedule Risk	0.5	0.2	0.167	0.11	1	0.33	2.307	3.2%
Growth Potential	3	3	0.33	0.33	3	1	10.66	14.8%
							72.137	
							Grand Total	

1 Equal importance
3 Moderate importance of one over another
5 Strong or essential importance
7 Very strong or demonstrated importance
9 Extreme importance
2,4,6,8 Intermediate values

Figure 6. Simplified AHP Matrix

Note that the matrix is perfectly symmetric about the diagonal axis. The matrix is evaluated from left to right (column to row) using the "Saaty scale" of 1 to 9. Each criterion in the column is compared to the criteria on the top row, with integers representing a preference for the criterion in the column and fractions representing a preference for the criterion in the top row. All the cells below the shaded diagonal axis in the matrix are calculated as the reciprocal of the same judgement pair above the diagonal, which allows us to sum the rows and normalize each row total to calculate the relative weight of each criterion.

Rating Alternatives and Resource Optimization

Once we have established the weights for our set of decision criteria, we must evaluate each initiative using a consistent ratings scale based on that set of criteria. A straight-forward method of comparison is a ratings model, with each initiative listed in the column on the left side of the matrix. Note that we have defined a tailored ratings scale for each criterion, which fosters consistency among the decision team when applying the numerical score associated with each criterion level. With the scales so defined, the decision team can focus their efforts on discussing how a particular initiative rates in a particular criterion dimension. Once scored, each cell in the matrix is multiplied by the appropriate criteria weight and the totals summed to reveal a total

score for each alternative. The highest scoring alternative, by definition, yields the maximum benefit to the organization.

		Operability	Maintainability	Reliability	Option Confidence	Schedule Risk	Growth Potential	Totals
	weight	13%	10%	20%	39%	3%	15%	
Initiative A		100	60	60	60	30	100	70.3
Initiative B		100	60	100	100	60	30	84.3
Initiative C		30	100	100	30	100	60	57.6

100	< 40 hrs Training	MTTR < 8 p-hrs	MTBF >10K hrs	Very High	Low	Modular Design
60	40-80 hrs Training	MTTR 8 - 24 p-hrs	MTBF 5K - 10K hrs	High	Moderate	Upgradeable
30	80-100 hrs Training	MTTR 24 - 40 p-hrs	MTBF 1K - 5K hrs	Moderate	High	Poor Growth Potential
0	>100 hrs Training	MTTR > 40 p-hrs	MTBF < 1K hrs	Low	Very High	Closed Architecture

Figure 7. Alternative Ratings Model

Once all the alternative initiatives are evaluated and a composite benefit score for each alternative is calculated, the decision team must determine what "basket" of alternatives yields an overall maximum benefit to the enterprise, given the resource constraint. For example, each initiative will have an associated cost, and we can optimize for benefit, given an overall budget constraint. While it may be tempting to simply list the initiatives in descending order of benefit and draw the line when we run out of money, that approach may not yield the true optimal benefit, given the constraining resource of budget. A more rigorous resource optimization can be calculated with a linear programming technique or software tool (e.g., Excel Optimizer). More sophisticated software tools, such as Decision Lens Suite™ permit dynamic sensitivity analysis of optimization on the constraining resource while allowing for various user-defined constraints (e.g., specified minimum funding, projects that must be done in sequence, etc.).

Sensitivity Analysis

Once an optimum portfolio of initiatives are selected, the decision team is well-advised to conduct sensitivity analysis to determine whether their conclusions are sensitive to small changes in their judgments. If the team has used an Excel-based matrix to calculate the weights and ratings scores, it is a simple matter to vary inputs in the context of "what if" scenarios to examine overall results. More sophisticated decision tools (e.g., the Decision Lens Suite™) permit more sophisticated sensitivity analyses, to include dynamic sensitivity analysis in multiple dimensions. Such sensitivity analysis is often useful in explaining results to stakeholders, encouraging decision transparency through process traceability.

Implementation

We recently applied this methodology to help a public sector organization establish organizational priorities for eleven unfunded initiatives in FY 2007. Although the organization had allocated 100% of its assigned budget consistent with its enterprise systems framework based on the Criteria for Performance Excellence, there were eleven major projects that remained unfunded. However, in anticipation of a possible end-of-year budget reallocation, this organization chose to systematically evaluate the unfunded initiatives using the resource

allocation methodology described in this paper. The organization's leaders came to a common understanding of their fundamental objective and selected five decision discriminators (criteria) from their Means Objective Network. Using a simplified AHP matrix, they established relative priorities for each of the criteria, then systematically rated each initiative using a tailored ratings scale for each criterion. The result after about 3 hours of focused dialog was a consensus decision on which initiatives should be funded, if additional budget was identified. The organization's parent agency is undertaking a dramatic restructuring as this paper is being written, and there is reason to believe that this modest investment of time may yield a dramatic return by enabling the organization to respond quickly to an uncertain future with traceable and justifiable conclusions.

Summary

The resource allocation decision-making method is a structured approach to decision-making that aligns with the INCOSE Handbook and ISO/IEC 15288 Investment Management Process and has wide applicability to many types of organizational decisions. When organizations are struggling with an important resource allocation decision, the decision team must be careful not to let conflict, uncertainty, and ambiguity interfere with the selection of the optimal portfolio. This resource allocation decision-making method can help organizations effectively and efficiently make decisions to optimize benefit to the overall enterprise.

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Biography

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