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Rethinking Project Selection at the Monterey Bay Aquarium

James C. Felli — *Defense Resources Management Institute, Naval Postgraduate School, Monterey, California 93943*

Randall E. Kochevar — *Monterey Bay Aquarium, Monterey, California 93940*

Bruce R. Gritton — *Monterey Bay Aquarium*

In 1995, the Monterey Bay Aquarium started an experimental business unit called Electronic Outreach. Electronic Outreach's mission was to employ emerging technologies to deliver the aquarium's messages of ocean stewardship to diverse and scattered audiences. Faced with many projects from which to choose, the Electronic Outreach team wanted to determine which projects were most likely to succeed before they actually had to dedicate resources to development. We constructed two models to help them accomplish this: a multiattribute-value model to quantify a project's alignment with the aquarium's mission and a discounted-cash-flow model to quantify a project's viability as a business venture. We then combined the outputs of these two models into a two-dimensional framework to allow the Electronic Outreach team members to focus on monetary-nonmonetary trade-offs when evaluating potential projects.

The Monterey Bay Aquarium (MBAQ) is a nonprofit organization dedicated to promoting stewardship of the Monterey Bay and the world's oceans. The aquarium was founded in 1984 to maintain innovative exhibits, provide public education, and undertake scientific research. In 1997, the organization employed approximately 400 staff, some 50 of whom were managers, and utilized over 800 volunteers to

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DECISION ANALYSIS—APPLICATIONS
DECISION ANALYSIS—MULTIPLE CRITERIA

help serve its 1.8 million visitors. In the early 1990s, the aquarium became interested in forging electronic connections with its target audiences, locally and throughout the world. In 1995, it initiated an experimental business unit called Electronic Outreach (EO) to develop and market electronic products, such as web sites, interactive CD-ROMS, and educational software.

The MBAQ wanted EO to employ emerging electronic technologies to deliver its messages on ocean stewardship to diverse and scattered audiences, many of which might never visit the aquarium. To do this effectively, the EO team needed to disseminate distinct conservation-oriented messages to specific audiences while sustaining itself with the external revenue generated by its products. Furthermore, because the EO business unit was experimental, the EO team believed that its existence would depend largely on the success of its first product. Faced with an abundance of projects from which to choose, the EO team sought to determine which project was most likely to succeed before dedicating time and expense to developing it.

The Strategic Environment

The MBAQ's competitive landscape changes constantly. New venues arise that compete for its audience's entertainment and education dollars, and developing technologies spawn new opportunities for more effective delivery of its messages. To incorporate the institution's broad policies and objectives into its project selection process, the EO team first examined how the aquarium identified, analyzed, and reacted to new challenges and opportunities.

The MBAQ's executive director, in concert with its board of directors, considers the aquarium's long-term technological, societal, and environmental future and formulates policies. These policies are communicated to the aquarium's managing director and leadership council. The managing director is an appointed position. The leadership council consists of aquarium vice-presidents and division directors.

Given a policy statement, the managing director and leadership council elicit institution-wide participation to evaluate the aquarium's strategic opportunities and environmental constraints. They consider events in the outside world, people's responses to the MBAQ's messages and demographic changes, and develop strategic imperatives relative to three activity categories: the day-to-day operations of the aquarium's facilities (Operations), the cultivation of financial benefactors (Development), and the delivery of messages to audiences (Programs). Because EO was established specifically to deliver messages to external audiences, we limited our focus to strategic imperatives pertaining to Programs.

Strategic imperatives relevant to Programs are passed from the managing director and leadership council to the programs committee. The programs committee varies in composition but includes those division directors and department heads responsible for implementing strategic imperatives, fostering synergy across new and existing programs, and setting operational priorities for the aquarium's business units.

Each business unit determines what activities and budget it needs to do its part in achieving its operational priorities. It may accentuate or de-emphasize aspects of its operation, scale-back existing activities, or propose the adoption of new projects.

Because of the close relationships between those at the executive and strategic levels, and the overlap in the membership of the leadership council and the programs committee, the EO team assumed that the program priorities set by the programs committee fully and clearly reflected the aquarium's policies and strategic imperatives. By complying with those priorities, the EO team expected to integrate the MBAQ's policies and direction into its project-selection process.

The Conceptual Framework

To encourage value-focused thinking [Keeney 1992], the EO team defined a project as any closely related activities intended to achieve a specific purpose. For example, a project might consist of all the activities required to develop and market an interactive educational CD-ROM. The team divided the project-selection process into four activities (Figure 1): identifying opportunities to meet program priorities, developing strategies to exploit the opportunities, identifying projects to implement the strategies, and identifying the resources needed for the projects. We based our conceptual framework on the underlying principles of the Department of Defense's planning, programming, and budg-

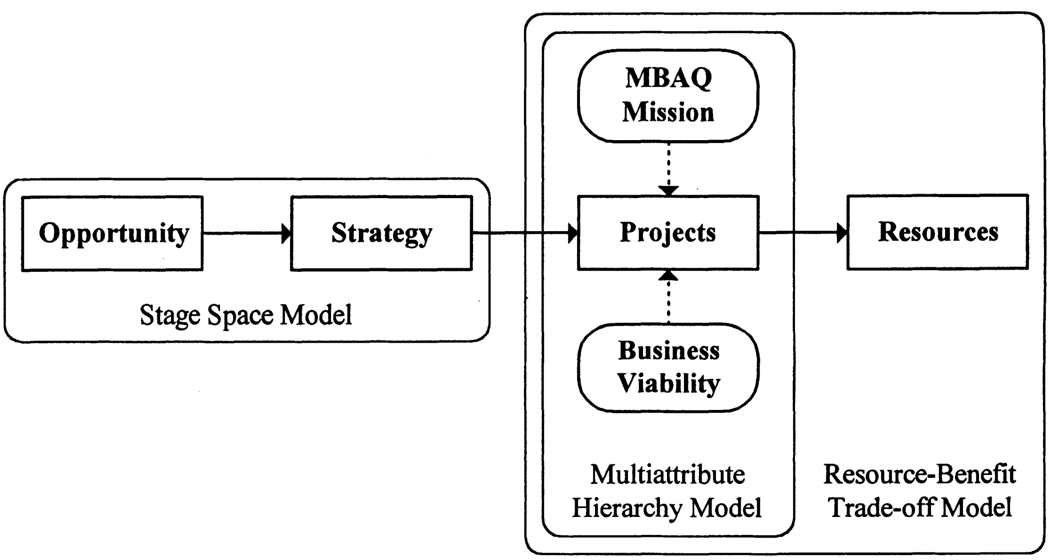

Figure 1: A project is any group of closely related activities intended to achieve a specific purpose. That purpose in turn supports a strategy for capitalizing on a perceived opportunity. To be acceptable, a project must be economically feasible and organizationally desirable. Projects require resources. We group these functions into the three models that made up the EO team's model for selecting projects: a stage-space model to match opportunities with strategies; a multiattribute hierarchy model to evaluate a project based on its support of the aquarium's mission and its market appeal; and a resource-benefit trade-off model to emphasize the monetary-nonmonetary trade-offs faced when selecting a project.

eting system [Department of the Navy 1994].

The EO team developed its conceptual framework (Figure 1) to serve three purposes: to explicitly recognize that opportunities suggest strategies, which suggest projects, which require resources; to emphasize that projects must both serve the mission of the MBAQ and satisfy viability criteria as business endeavors; and to highlight the roles of the three models that made up the final model for selecting projects. These component models are a stage-space model, a multiattribute-hierarchy model, and a resource-benefit trade-off model.

The Stage-Space Model

The EO group considered projects to be interdependent elements in the MBAQ's portfolio of activities. To help define the role of EO projects, we used a partition of the MBAQ audience developed by the programs committee. The committee identified six mutually exclusive and collectively exhaustive stages through which the MBAQ hoped to move its audiences. For a given MBAQ issue X, these stages were

—unaware (the target audience is unfamiliar with issue X),

—aware (the target audience possesses knowledge of issue X),

—interested (the target audience wants to know more about issue X),

—motivated (the target audience feels inspired to pursue issue X),

—committed (the target audience feels emotionally dedicated to issue X),

and

—active (the target audience is eager to take political/social/personal action on issue X).

Based on this partition, the EO team decided that its projects should help to bring a specific audience from unaware to active on a specific aquarium issue (or set of related issues). Because the members of the EO team thought it unlikely that any single project could move an audience directly from unaware to active, we envisioned the MBAQ using multiple projects to move an audience through a succession of stages. Inspired by the state-transition diagrams used in discrete Markov models, we created a stage-space model (Figure 2) that uses projects to effect stage transitions.

We postulated that a lack of projects in a cell along the tactical path (the heavily outlined cells in Figure 2) showed potential opportunities, whereas multiple projects within a cell flagged potential duplication of effort. Projects off the tactical path exposed possible misallocation of resources.

The EO team used the stage-space model to determine a project's stage-space priority. A project that would fill an empty cell along the tactical path was of high priority. Projects that would add to nonempty cells along the tactical path were of medium or low priority, depending on the number and nature of the other projects in the cell. Projects that would fall into any cell off the tactical path were of low priority. The EO team believed that projects with high stage-space priority for issues germane to the MBAQ's strategic imperatives would have a higher likelihood of being supported by the programs committee.

The Multiattribute-Hierarchy Model

To identify which projects best served

Ending Stage

Starting Stage	Unaware	Aware	Interested	Motivated	Committed	Active
Unaware		A				
Aware			B C D E	F		
Interested		G		H		
Motivated				I	J K	
Committed						L M
Active						N

Figure 2: The stage space for a given issue is a 6 × 6 matrix that depicts the contributions of relevant projects to the target audience's progression from unaware to active. The letters A-N represent 14 projects in a hypothetical portfolio for a given issue X and were placed in cells defined by the single stage transition they were designed to effect. Project A makes an unaware audience aware of issue X. Project G increases the awareness of parties interested in X and is not crucial: audiences that are interested should become motivated, not made more aware. Project N sustains audiences that reach active. The heavily outlined cells mark the tactical path along which the MBAQ would like to move X's target audience. Projects F, G, and I are superfluous. They should be discontinued and their resources reallocated. Projects B, C, D, and E might all be necessary to make aware parties interested; conversely, savings might be realized by eliminating substitutes within the group.

the MBAQ's mission and EO's economic sustainability as a business unit, the EO team had to decide what *best* meant. The team decided that the overall value of a project should be a function of two things: (1) its capacity to support the MBAQ's mission (in light of the programs committee's directives) and (2) its potential as a business activity (as reflected in its technical and economic viability). We employed an additive-value function defined over a hierarchy of attributes [Keeney and Raiffa 1976; von Winterfeldt and Edwards 1986] to incorporate both aspects into a measure of a project's overall desirability.

Early in the modeling process, the EO team decided to compare projects on the basis of delivered benefits versus resource requirements. We therefore performed separate benefit (nonmonetary) and resource (monetary) analyses for each project and then combined the results in a resource-benefit framework (Figure 1). In developing our hierarchy, we focused solely on the perceived nonmonetary benefits that the MBAQ would gain from the EO team taking on a project. We show our project-evaluation hierarchy in Figure 3.

Because of the EO team's assumption that the MBAQ's policies and strategic imperatives were fully reflected in the pro-

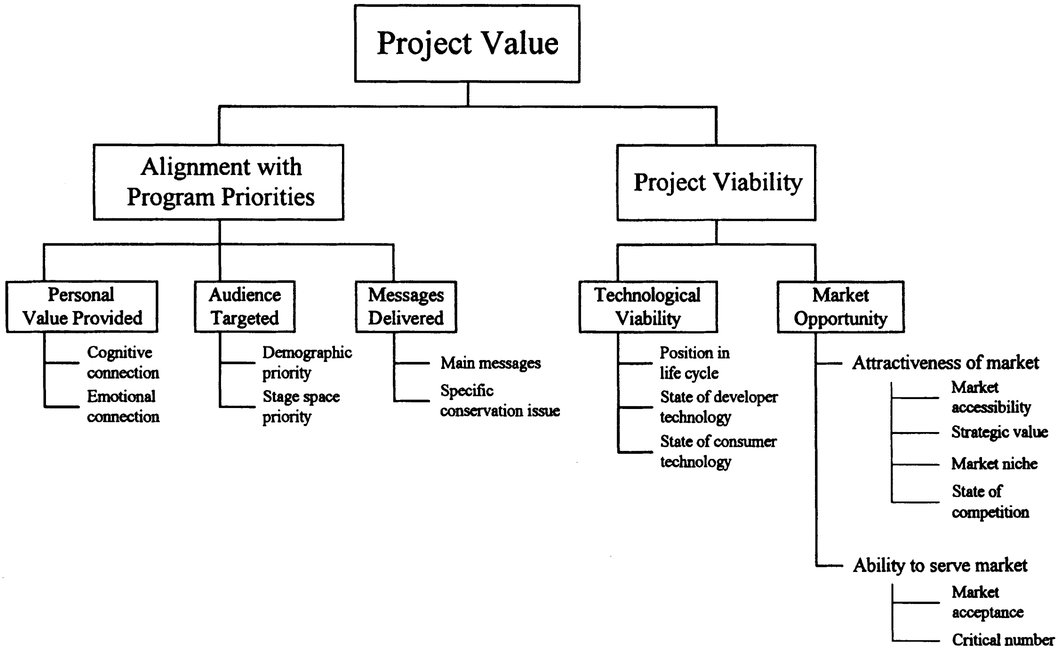

Figure 3: The EO team's project-attribute hierarchy emphasizes two primary components of a project's value. First is the degree to which a project supports the programs committee's program priorities, as reflected by the personal value it provides, the audience it targets and the messages it delivers. Second is the project's viability from a technological and business perspective. To be technologically viable, a project's underlying technology must be maintainable and available both to developers and consumers; to be viable as a business venture, a project must exploit an opportunity within an attractive and serviceable market.

gram priorities the programs committee established, our construction of the alignment-with-program-priorities subhierarchy was straightforward. With the exception of stage-space priority, the terminal attributes followed directly from the program priorities that the programs committee communicated to the EO team. We used cognitive and emotional connection to measure the extent to which the target audience relates intellectually and emotionally to the issue presented. We used demographic priority and stage-space priority to measure the importance of reaching the project's target demographic audience (for example, children as opposed to adults) and achieving its intended stage transition (for example, aware to interested). Main messages and specific conservation issue refer to the number of aquarium messages a project delivers and whether or not it addresses an explicit conservation topic (for example, overfishing).

With regard to project viability, the EO team decided to consider a project viable if it was feasible and marketable. To separate feasibility issues from marketability concerns, we partitioned project viability into technological viability and market opportunity. The hierarchy for technological viability was much more difficult to construct than we initially expected. This was because EO projects were to be based on emerging technologies, so we had no established criteria by which to judge technological feasibility. In the end, we decided to focus on three general criteria: the state of project-specific technology available to developers, and the state of project-specific technology available to consumers, and the life-cycle position of the project's underlying technology (the probability that it would be available and maintainable for five years). The first two criteria were critically tied to the success

The greatest challenge we faced was getting stakeholders to express their beliefs, preferences, and expectations.

of the product: they concerned "can we make it?" and "can they use it?" For example, the EO team could develop an interactive computer simulation model, but the target audience might lack the sophisticated equipment required to use it. We included life-cycle position to force us to think about whether a technology had long-term potential.

As a proxy for a project's market opportunity, the EO team used its ability to serve an attractive market. We deemed a market attractive if it (1) possessed some strategic value, (2) was accessible through existing marketing and communication channels, (3) supported few direct competitors, and (4) had a well-defined niche the intended project could fill. We defined a project's ability to serve its market as its ability to satisfy some real need of a critical number of consumers (for example, the number of buyers EO needed to break even).

Assessing Weights and Values

Using an additive-value function essentially reduces to calculating a weighted average (Appendix). The quantities the EO team averaged were the values ascribed to a project's attributes weighted according to each attribute's relative importance in delivering project viability and alignment with program priorities. Because of the EO team's limited experience with decision analysis, we started with the simplest possible model and built from there, stopping when the team saw no appreciable benefit to further development. Consequently, we started with the hierarchy shown in Figure 3, weighting all attributes equally and assigning scores of bad (0) or good (1).

As expected, the ensuing discussion precipitated changes in most weights and attribute ratings. At this stage, we scored all attributes in natural units. In some cases, we maintained a binary scoring (for example, did the project promote a specific conservation issue: Yes or No); in others, we used a low-medium-high scoring system (for example, for cognitive connection). Through the course of debate, the EO team determined that measures for demographic priority and main messages were explicitly defined in the programs committee's directives, that state of competition and critical number pertained to countable quantities, and that position in life cycle and accepting market were best represented by probabilities.

Once the EO team settled on suitable natural ratings, we conducted marginal analyses to determine the team members' preferences for levels of each attribute. Our task was made easy by the familiarity of those involved with graphical representations of data. (For groups lacking such familiarity, this process could be arduous, and we recommend using a facilitator.) In the end, we came up with 15 functions that we used to transform the attributes' natural ratings into measures of value. We then used these measures of value to calculate a project's measure of benefit (MOB).

With the refinements in attribute measures, the EO team reconsidered the relative importance of the attributes by considering the interattribute trade-offs it was willing to make. Trade-offs were based on the abstract nature of the attribute (for example, What is more important: demographic priority or stage-space priority?) as well as its range of natural scores (for example, How do you feel about going from 0 to 5 in demographic priority versus going from low to high in stage-space priority?). We considered several methods, such as swing weighting and pairwise comparisons, during the weight-assessment phase, but in the end the EO team opted for direct assessment. In part, the team members recognized that other decision makers (for example, the programs committee) would have to provide the final weights for a project's alignment with program priorities, so any weights the EO team assigned to that portion of the model were only estimates. Furthermore, as the team's primary goal was to obtain insight rather than to optimize, the members thought that approximate weights were sufficient for their initial screening of projects. Consequently, we stopped when we had a model whose practical utility would not have been served by further technical sophistication.

A Measure of Benefit

Once the EO group determined the weights and value functions, we used an additive-value function to calculate a project's MOB (Table 1, Figure 4).

A project's MOB is an aggregate measure of its value to the EO team. Given several projects, the team would prefer the one with the highest MOB. However, the trade-offs implicit in selecting one project over another are also important, especially when MOBs are very close. These trade-offs are reflected in the relative contributions of a project's underlying attributes to its MOB. For example, in choosing project D over project C, the EO team must sacrifice audience targeted for personal value provided (Figure 4). Is this reasonable? Do the relative strengths and weaknesses of the two projects appear consistent with their MOBs? If not, the EO team must reconsider not only the scores they assigned to the projects' attributes (Table 1), but also the weights and value functions they used to calculate a project's MOB. This may result in a different preference ranking. To facilitate consideration of trade-offs, we used stacked bar graphs to show each project's MOB as an aggregate of its lower-level attributes.

Resource Issues

To be consistent with the MBAQ's recent move toward activity-based budgeting, the EO team decided to assign all costs relevant to a project directly to that project. For example, if Project A required hiring a technician, that technician's salary and benefits would be reflected in the personnel costs associated with Project A. Although this level of analysis required the team to take each project's conceptual de-

Project Attributes	Projects Under Investigation A	B	C	D	E
Cognitive Connection	M	H	H	M	M
Emotional Connection	H	M	L	H	M
Demographic Priority	3	5	4	2	3
Stage-Space Priority	M	H	L	L	H
Main Messages	3	3	1	1	2
Specific Conservation Issue	Y	N	N	N	Y
Position in Life Cycle	0.9	0.5	0.6	0.4	0.1
State of Developer Technology	H	M	H	H	H
State of Consumer Technology	L	M	M	M	H
Accessible Market	Y	Y	N	N	Y
Strategic Value	M	H	L	M	M
Market Niche	L	H	H	M	L
State of Competition	2	3	0	1	5
Accepting Market	0.5	0.7	0.5	0.8	0.8
Critical Number (Thousands)	10	40	100	80	40

Table 1: The EO team initially scored the 15 attributes used to determine a project's final measure of benefit in one of the following natural units: yes or no; low, medium, or high; probabilities; or cardinal numbers. We devised the five hypothetical projects depicted here with actual projects in mind. The first six attributes are associated with alignment with program priorities; the rest with project viability.

velopment farther than was typical for an aquarium business unit, it considered the additional effort justified because assigning revenue and expense streams to specific categories better enabled the team to examine the projects' relative impacts on the unit's anticipated resource reserves.

For the purposes of this analysis, the EO team wanted to compare one-time and recurring costs across projects using net present value (NPV). To do this, it needed a time horizon. The team recognized that not all projects would have the same life; however, it suggested using five years as a reasonable basis for an initial comparison. We limited our analysis to four cost categories: facilities, equipment, personnel benefits, and operations and maintenance (Table 2).

The NPV-MOB Space

To integrate the results of our resource and benefit analyses, we employed a two-dimensional framework, dubbed the NPV-MOB space (Figure 5). In this framework, we plotted a project's aggregate measure of benefit (MOB) against the net present value of its expected five-year cash flows (NPV). We used a project's position in the NPV-MOB space as a proxy for its overall value.

The NPV-MOB space enables the decision maker to consider trade-offs between a project's monetary and nonmonetary values. Any project that has both a lower MOB and lower NPV than another project is dominated and can be summarily rejected. Ideally, the EO team was looking for nondominated projects deep in the

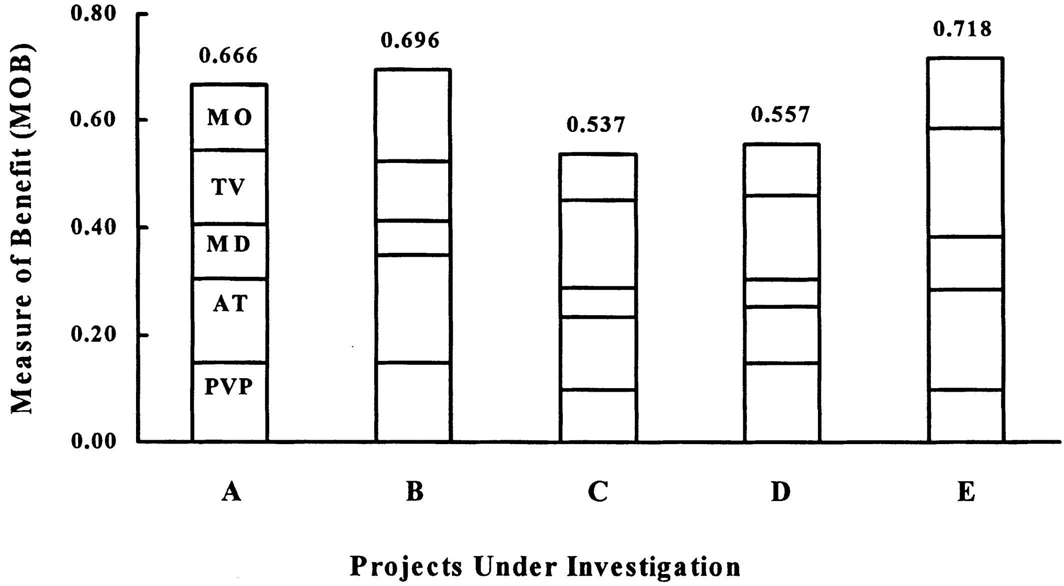

Figure 4: The measure of benefit (MOB) for a project is the sum of the marginal contributions of its lower-level attributes in Figure 3. These include: personal value provided (PVP), audience targeted (AT), messages delivered (MD), technological viability (TV), and market opportunity (MO). We show the MOBs of the five hypothetical projects described in Table 1. MD, AT, and PVP correspond to the higher-level attribute alignment with program priorities; MO and TV with project viability. From a benefit-only standpoint, project E is the preferred choice because it has the highest MOB.

northeast region of the NPV-MOB space.

The EO team's project selection protocol was to pick a project from the set of non-dominated projects by trading off MOB against NPV within budgetary guidelines. If sufficient resources remained once a project was selected, the team would repeat the process using the new efficient set of remaining projects. The team would continue in this manner until all its resources were allocated.

Discussion

We tried to develop a tool that the EO team could use to identify projects that best served both the MBAQ's mission and the EO team's economic sustainability. The team believed that if it could prescreen feasible projects using the same criteria it would eventually use to make final choices, then those that passed the filter would be more likely to be approved for development and prove successful when brought to market. Focusing on such projects would consequently improve EO's chance of maturing into a regular MBAQ business unit.

We held our initial discussions about using a decision analytic approach to develop a project-selection tool in January 1997. We presented a spreadsheet implementation of the final multiattribute-value model and NPV-MOB framework to senior management in September 1997. The presentation was very well received and stimulated enthusiastic discussions about the model's broader applications. The managers agreed that the model served three important purposes. First, it allowed

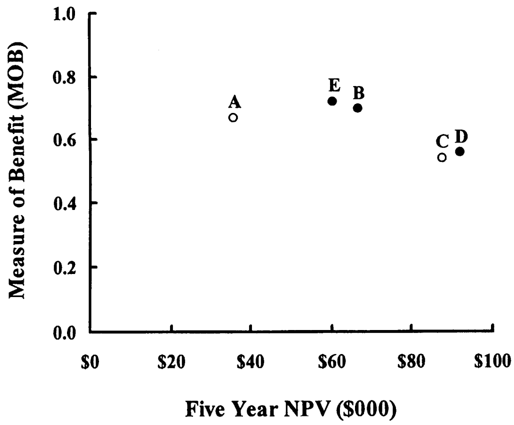

Figure 5: We plotted the aggregate measure of benefit (MOB) of the five hypothetical projects in Figure 4 against their respective five-year net present value (NPV) in thousands of dollars. Those projects exhibiting both high MOB and high NPV tend toward the upper right. Dominated projects are denoted by white circles. Based solely on MOB, the EO team would choose project E; based on profitability alone, it would choose project D.

decision makers to evaluate independently a project's suitability as an MBAQ activity and its viability as a business opportunity. Second, it made the decision process transparent by identifying all critical project attributes, their relative importance, and their contribution to the project's overall measure of value. Third, it readily accommodated changes in the underlying data and assumptions (for example, changes in weights and values). Furthermore, the MBAQ leadership found great potential in the final integration of the resource and benefit analyses. Because the NPV-MOB space enabled decision makers to look at a group of projects, immediately identify a set of efficient candidates, and then focus on the resource-benefit trade-off in moving from one to another, it possessed merit as a high-level planning tool for resource allocation among aquarium operating units.

Despite its favorable reception, the EO team did not use the model to select a final project. By the time we finished the model, the EO team's political and operational environments had changed, and it had to choose a project quickly. Although the EO team used insight gained from the model-building process to cull several ob-

Project E	Year 1	Year 2	Year 3	Year 4	Year 5
Annual Revenue	$0	$130	$163	$183	$205
Cost Incurred					
Facilities Construction Remodeling	$50				
Equipment Purchases and Refitting	$85				
Personnel Costs	$0	$72	$79	$83	$88
Operations and Maintenance	$0	$20	$24	$27	$29
Net Values Realized					
Annual Net Value (Revenue − Cost)	($135)	$38	$59	$73	$88
Discount Factor (Mid-Year; 10%)	0.9535	0.8668	0.7880	0.7164	0.6512
Discounted Net Value	($129)	$33	$47	$52	$57
Undiscounted Net Present Value	$123				
Discounted Net Present Value	$60				

Table 2: The EO team considered five cash flows for each project: a revenue stream and four cost streams. In this five-year profile for hypothetical Project E, all figures are in thousands of dollars. We used a mid-year discount factor to calculate discounted present values at a 10-percent discount rate. All figures are given in thousands of dollars.

viously inferior projects from its feasible set, it no longer had the time or resources to determine the attribute measures and financial figures needed to use the model to discriminate between the remaining feasible alternatives. Furthermore, the EO team was an experiment on the part of the MBAQ: the self-imposed pressure to identify a successful project prior to development was secondary to the pressure the aquarium imposed to take a project to market. In the end, the EO team selected from the feasible set that project that seemed most likely to gain the programs committee's support.

That the team never used the model to select a final project reinforces conventional wisdom: it takes time and energy to properly develop and implement a useful decision analytic model. Any institution considering a decision-theoretic approach to project selection must realize that the model-building process itself will demand significant resources; consequently, all stakeholders must buy in to the endeavor at the onset. Furthermore, once built, the model will be useful only in comparing projects that have been fairly well defined. The organization may have to develop concepts in more detail than it typically does prior to committing resources. Consequently, the stakeholders must both support the development of the model and the estimation of the information the model requires.

Although this may seem onerous, our experience clearly demonstrated that the process of building a decision-analytic model carried with it an unexpected benefit: by requiring extensive conversations to explicitly define and weigh the relative importance of the criteria upon which projects would ultimately be evaluated, the model-building process provided the decision makers with a rare opportunity to make explicit all their beliefs, assumptions, and agendas and to validate them before evaluating or developing a project. Because the participants had these discussions before they were vested in specific projects, they did less position defending and political maneuvering than people typically do when they bring their personal favorites to the table. Furthermore, in these discussions, the participants came to a clear common understanding of the EO team's objectives, thus increasing their subsequent effectiveness in developing a project, even though they did not use the model to compare projects.

In thinking back over the development and implementation of our project-selection model, we found a certain irony. Throughout the project, we repeatedly encountered concerns regarding the quantitative nature of our approach. In most cases, these concerns were rooted in the belief that the use of quantitative methods in decision making somehow undermined the creativity and human elements of the decision-making process. Despite this widespread sentiment, the greatest challenge we faced in developing our model was getting stakeholders to express their beliefs, preferences, and expectations openly and honestly. They may have wanted to maintain political flexibility; however, we suspect that they simply did not feel comfortable quantifying their beliefs or that they simply did not really know how they felt. Our experience suggests that the greatest hindrance to the effective development and implementation of a decision-analytic model lies not in the model's limited capacity to represent human feelings and preferences. Instead, the difficulty lies in getting stakeholders to express their feelings and preferences clearly enough so that they can be properly embedded in the model.

In conclusion, we feel that our effort to develop a decision-analytic project-selection model provided the MBAQ with two important outputs: (1) the model itself, and (2) the process through which it was built. We maintain that the model would have been an effective tool for comparing projects had the set of projects available been sufficiently developed. We hope that we will have an opportunity to test the model in the future. As for the model-building process, the participants found it valuable for discussing and establishing objectives for their work group. The model-building process offered them an opportunity to align the EO team's objectives with the MBAQ's overall program goals and to consider a spectrum of possible project opportunities in an objective setting. Most important, the process fostered open and honest communication and forced them to define all their assumptions clearly in a way they might not otherwise have attempted. To the members of the EO team, that deeper level of communication and consequent insight into themselves and the MBAQ constituted a very worthwhile, albeit nontangible, return on their investment of time and energy in the model's development.

APPENDIX

We ranked alternative projects based upon an additive-value function of the form:

$$\text{value of project } X = V(X) = \sum_{i=1}^{N} w_i v_i(X)$$

where the weights w_i for each attribute i were such that $0 \le w_i \le 1$ and $w_1 + \ldots + w_N = 1$. We provide each attribute's final weight w_i, along with the natural rating scheme and value function we used in our analyses. The attribute and cost data in Tables 1 and 2 are hypothetical.

Linear Scale (Figure 6)

$$v_{\text{lin}}(x, L, U) = \frac{\hat{x}}{U - L}$$

$$\text{where } \hat{x} = \begin{cases} x - L & \text{if bigger is better,} \\ U - x & \text{if smaller is better.} \end{cases}$$

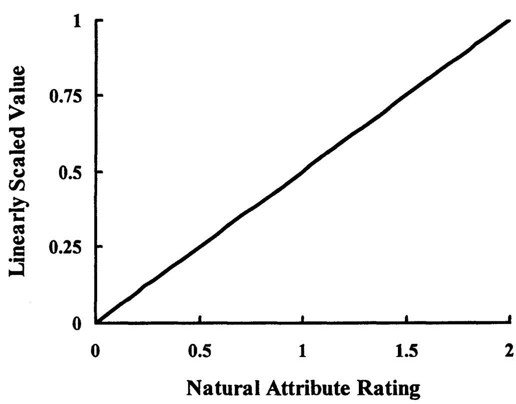

Figure 6: We used a linear value function to transform the natural attribute ratings of cognitive connection, emotional connection, stage-space priority, specific conservation issue, state of developer technology, state of consumer technology, accessible market, and strategic value into measures of value. The function shown is for cognitive connection with $L = 0$ and $U = 2$. For this attribute, bigger is better, so the value function slopes upward with larger attribute ratings. The natural ratings of low, medium, and high translate to values of 0, 0.5, and 1.

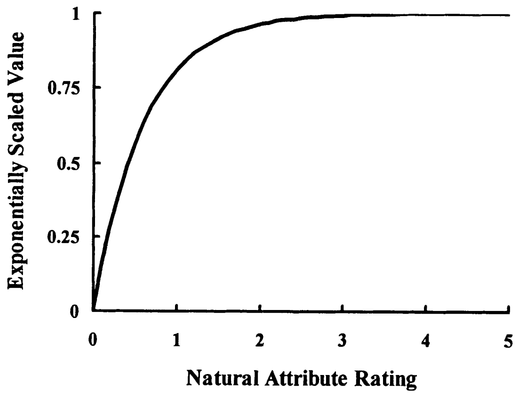

Figure 7: We used an exponential value function to transform the natural attribute ratings of main messages, position in life cycle, market niche, state of competition, and market accepting into measures of value. The function shown is for main messages with $L = 0$, $U = 5$, and $k = 0.6$. For this attribute, bigger is better, so the value function slopes upward with larger attribute ratings. The natural ratings of 0, 1, 2, 3, 4, 5 translate to values of 0, 0.811, 0.965, 0.994, 0.999, 1.

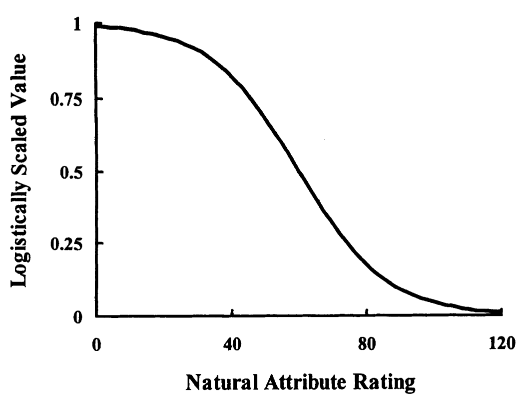

Figure 8: We used a logistic value function to transform the natural attribute ratings of demographic priority and critical number into measures of value. The function shown is for critical number with $L = 0$, $U = 120$, $v(L) = 0.99$, and $v(U) = 0.01$. For this attribute, smaller is better, so the value function slopes downward with larger attribute ratings. The natural ratings of 0, 40, 80, and 120 translate to values of 0.99, 0.822, 0.178, and 0.01.

Exponential Scale (Figure 7)

$$v_{\text{exp}}(x, L, U, k) = \frac{1 - \exp\left(\frac{-\hat{x}}{k}\right)}{1 - \exp\left(\frac{L - U}{k}\right)}$$

$$\text{where } \hat{x} = \begin{cases} x - L & \text{if bigger is better,} \\ U - x & \text{if smaller is better.} \end{cases}$$

Logistic Scale (Figure 8)

$$v_s(x, L, U, a, b) = 1 + \alpha\exp\left(\frac{(L - x)\log\left(\frac{\alpha}{\beta}\right)}{(U - x)}\right)$$

where $v(L) = a$, $v(U) = b$,

$$\alpha = \frac{1 - a}{a}, \ \beta = \frac{1 - b}{b}.$$

The value functions used in the analysis are listed below. The natural scales employed were yes-no, low-medium-high, probabilities, and cardinal numbers.

Cognitive Connection
- Weight: 0.10
- Natural Scale: $L/M/H \rightarrow x \in \{0, 1, 2\}$
- Attribute Value: $x \rightarrow v_{\text{lin}}(x, 0, 2)$

Emotional Connection
- Weight: 0.10
- Natural Scale: $L/M/H \rightarrow x \in \{0, 1, 2\}$
- Attribute Value: $x \rightarrow v_{\text{lin}}(x, 0, 2)$

Stage-Space Priority
- Weight: 0.06
- Natural Scale: $L/M/H \rightarrow x \in \{0, 1, 2\}$
- Attribute Value: $x \rightarrow v_{\text{lin}}(x, 0, 2)$

Demographic Priority
- Weight: 0.14
- Natural Scale: $x \in \{0, 1, \ldots, 5\}$
- Natural Scale Definitions:
  - 0 Adults unlikely to visit MBAQ
  - 1 Children unlikely to visit MBAQ
  - 2 Families unlikely to visit MBAQ
  - 3 Adults likely to visit MBAQ
  - 4 Children likely to visit MBAQ
  - 5 Families likely to visit MBAQ
- Attribute Value: $x \rightarrow v_s(x, 0, 5, 0.2, 0.99)$

Main Messages
Weight: 0.065
Natural Scale: $x \in \{0, 1, \ldots, 5\}$
Attribute Value: $x \rightarrow v_{\mathrm{exp}}(x, 0, 5, 0.6)$
Specific Conservation Issue
Weight: 0.035
Natural Scale: $Y/N \rightarrow x \in \{0, 1\}$
Attribute Value: $x \rightarrow v_{\mathrm{lin}}(x, 0, 1)$
Position in Life Cycle
Weight: 0.05
Natural Scale: $x \in [0, 1]$
Attribute Value: $x \rightarrow v_{\mathrm{exp}}(x, 0, 1, -0.35)$
State of Developer Technology
Weight: 0.10
Natural Scale: $L/M/H \rightarrow x \in \{0, 1, 2\}$
Attribute Value: $x \rightarrow v_{\mathrm{lin}}(x, 0, 2)$
State of Consumer Technology
Weight: 0.10
Natural Scale: $L/M/H \rightarrow x \in \{0, 1, 2\}$
Attribute Value: $x \rightarrow v_{\mathrm{lin}}(x, 0, 2)$
Accessible Market
Weight: 0.034
Natural Scale: $Y/N \rightarrow x \in \{0, 1\}$
Attribute Value: $x \rightarrow v_{\mathrm{lin}}(x, 0, 1)$
Strategic Value
Weight: 0.025
Natural Scale: $L/M/H \rightarrow x \in \{0, 1, 2\}$
Attribute Value: $x \rightarrow v_{\mathrm{lin}}(x, 0, 2)$
Market Niche
Weight: 0.034
Natural Scale: $L/M/H \rightarrow x \in \{0, 1, 2\}$
Attribute Value: $x \rightarrow v_{\mathrm{exp}}(x, 0, 2, -1.5)$
State of Competition
Weight: 0.032
Natural Scale: $x \in \{0, 1, \ldots, 10\}$
Attribute Value: $x \rightarrow v_{\mathrm{exp}}(x, 0, 10, -2)$
Market Accepting
Weight: 0.075
Natural Scale: $x \in [0, 1]$
Attribute Value: $x \rightarrow v_{\mathrm{exp}}(x, 0, 2, -0.4)$
Critical Number
Weight: 0.05
Natural Scale: $x \in \{0, 1, \ldots\}$
Attribute Value: $x \rightarrow v_S(x, 0, 120, 0.99, 0.01)$

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Diane Sena, Managing Director, Monterey Bay Aquarium, Monterey, California 93940, writes: "... I am responsible for facilitating effective decision making.... To facilitate our decision making processes we pursued the development of a decision model within the context of a potential new business unit called Electronic Outreach.

"With the aid of a professional decision analyst we developed the project selection model presented in the paper.... A major benefit was immediately obvious; the development process itself was allowing us to surface and make explicit those values we considered most important to our future. This benefit alone made the activity worthwhile. However, we expect to use the model to help us evaluate and compare multiple project alternatives for Electronic Outreach. I expect that as we develop expertise in the use of the model we will consider extending its use to compare projects across all program areas at the aquarium. Further, I believe the approach we have taken may be useful to the general non-profit community.

"The aquarium has benefited from exposure to the complex and compelling field of decision analysis. We believe and hope that these benefits will expand over time."