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Multiple-Objective Decision Analysis Involving Multiple Stakeholders

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Abstract Many operations researchers know about the use of decision analysis to help decide among alternative investments (such as pharmacological research and development investments) using decision trees with chance nodes to compute expected monetary value or return on investment of different alternatives. Such an analysis often aims to maximize a single evaluation measure for a single decision maker. We demonstrate less widely known decision analysis techniques using spreadsheet models that will help analysts understand and model the multiple objective perspectives of the stakeholders to a decision. Using this approach can aid in identifying mutually agreeable alternative actions, designing new and better alternatives, and foreseeing opposition to decisions. It can also help analysts understand the evolution of past decisions from multiple perspectives.

In some cases, one objectives hierarchy can be suitable for a set of stakeholders, and differences in opinions across stakeholders can be characterized by differences in weights on the multiple objectives. Examples include the analysis for the merger of the Operations Research Society of America and The Institute of Management Sciences to become INFORMS, Arizona water resources planning, and planning for protection against radioactive iodine releases in nuclear incidents. In other cases, an objectives hierarchy will be constructed for each stakeholder because their objectives are so different that construction of separate hierarchies better represents their divergent perspectives. Examples include a tuna fish supplier source selection decision (from the perspectives of StarKist, environmentalists, and the San Diego tuna fishing fleet), the potential siting of a new Home Depot in San Juan Capistrano (from the perspectives of Home Depot, the city, residents, and competing or complementary small businesses), and a prostate cancer treatment decision (from the perspectives of former Intel CEO Andy Grove, his family, his company, and his doctors).

Keywords decision analysis; multiple objectives; multiobjective, multistakeholder decision-modeling methodology; StarKist; Home Depot case; INFORMS merger; strategy; stakeholder analysis

1. Introduction

It's not hard to make decisions when you know what your values are.
—Roy Disney

Roy Disney would have been happy to hear that decision analysts are strong proponents of a value-focused approach to decision making (Keeney [14], Keeney and Raiffa [15], Kirkwood [21]). The basic idea is that your values express what you care about, and if

you focus on these values you will be able to make better decisions. For example, a value focus will sometimes help you in generating entirely new alternative actions or by figuring out what sorts of decisions you want to spend your time on. Decision analysts aid decision makers in thinking about their values by constructing a list of their fundamental objectives for the decision situation at hand.

Many important decisions require trade-offs between conflicting objectives. Often, different stakeholders to a decision will disagree on the appropriate trade-offs, and may even disagree on the objectives. Thus, Roy Disney might have agreed with us that it is easier to make decisions when you know both your values and the values of other stakeholders to the decision. This paper demonstrates decision analysis techniques using spreadsheet models that will help analysts understand and model the multiple objective perspectives of the stakeholders to a decision. We will show how creating a hierarchy of objectives is useful for generating new options, evaluating options, and understanding multiple perspectives for bargaining or for continuing relationships.

A decision model is an abstraction from reality. The modeling process can be taken step-by-step, and sometimes a simple model without many realistic details is sufficient for the purpose at hand. Sometimes it will be preferable to construct a more extensive model. We will show that, depending on the situation, you can carry out the modeling through a number of steps and stop anywhere along the way if the model suffices for the decision at hand:

- an objectives hierarchy for the main decision maker only,
- objectives hierarchies for other stakeholders,
- identification of consequences of alternatives on each objective, rating how well each alternative does on each objective, and
- given the consequences, putting weights on objectives for an additive multiple-objective preference model (or constructing a nonadditive model).

Perhaps the more familiar use of decision analysis among most operations researchers is using decision trees with chance nodes to compute expected monetary value or return on investment of different alternatives to help a decision maker decide among alternative investments (such as pharmacological research and development investments); see applications in Corner and Kirkwood [6]. Such decisions under risk can be extended to have multiple objectives rather than just a single objective (which is usually to maximize a monetary measure). For examples of multiobjective utility models for medical decisions, see Simon [25] and Eriksen and Keller [8].

2. A Single Set of Objectives

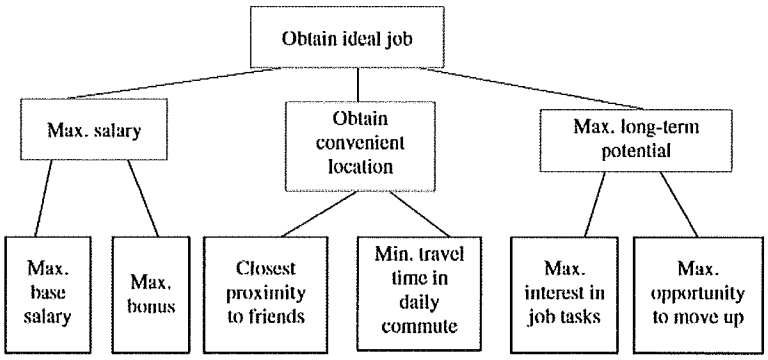
In some situations, it is sufficient to identify just one set of objectives for the main decision maker only. Other times, the views of multiple stakeholders will be able to be described with a single set of objectives with the possibility that stakeholders use different weights on objectives. Section 3 will present the construction of multiple hierarchies for multiple stakeholders.

2.1. Examples of Objectives Hierarchies

Figure 1 shows an example of an objectives hierarchy an MBA student might use in choosing a new job to take after graduation. The objectives are portrayed in a hierarchical tree structure, so we use the term "objectives hierarchy" to emphasize that objectives have been categorized into related groups.[1]

[1] Objectives hierarchies are sometimes called value trees; see von Winterfeldt [26].

FIGURE 1. Objectives in job selection.



You can also list objectives and subobjectives in the following outline format, like what would be used when placing them in a spreadsheet model:

1. Objective 1
   1.1. Subobjective 1.1
   1.2. Subobjective 1.2
2. Objective 2
   2.1. Subobjective 2.1, etc.

Constructing an objectives hierarchy can be useful for both personal and professional decisions. For example, Keeney [14, p. 373] has identified four personal strategic objectives to maximize his quality of life: enjoy life, be intellectually fulfilled, enhance the lives of family and friends, and contribute to society. For making professional decisions, Keeney [14] constructed his list of fundamental professional objectives to maximize the contribution of professional activities to his quality of life as follows.

1. Maximize enjoyment
2. Maximize learning
3. Provide service
4. Enhance professional career
5. Maximize economic gain
6. Build good professional relationships
7. Minimize the time required
   7.1. Minimize time required [working] where I live
   7.2. Minimize time required away from home (Keeney [14, p. 379])

Additional examples using a single set of objectives are discussed in the following sections, including Arizona water resources planning, the analysis for the merger of the Operations Research Society of America (ORSA) and The Institute of Management Sciences (TIMS) to become INFORMS, and planning for protection against radioactive iodine releases in nuclear incidents.

2.2. Creative Structuring of Objectives

When beginning to identify objectives, you should first list possible factors or evaluation concerns for the decision being contemplated, then form groups of items into related categories, and then state items in the form of objectives. Once the objectives hierarchy is partially structured, to move lower in the objectives hierarchy, you should ask, "What do you mean by that?" To move higher in the hierarchy, you should ask, "Of what more general objective is this an aspect?"

2.2.1. List Possible Factors for the Decision and Group in Related Categories. As a first step in problem structuring, you may brainstorm about different factors (or evaluation concerns) involved in the decision. Following the rules of brainstorming requires a person or a group of people to freely imagine items, building from one idea to another, not judging the ideas while brainstorming, and recording the ideas. For this early stage in problem structuring, Keller and Ho [17, 18] present techniques to aid in thinking creatively, including (1) considering specific actions that might be taken and identifying potential evaluation concerns those actions would impact, (2) comparing two actions and describing how they differ in terms of potential evaluation concerns, (3) considering whether an evaluation concern might be sufficiently important to be subdivided into multiple concerns, and (4) considering whether some listed concerns should be combined.

There also may be a great deal of relevant information about key factors in a variety of existing sources, including an organization's mission statement, prior analyses, online websites, etc.

Keller et al. [20] examined existing print and online sources and then conducted interviews and surveys with Arizona water resources planning professionals to identify factors they used as evaluation concerns in water resources planning (see also Feng et al. [12]). Next, they grouped the factors into seven major categories:

1. Central Arizona socioeconomic impacts,
2. Financial and technical requirements,
3. Health and safety,
4. Impacts on the natural/biophysical environment,
5. Indirect/external impacts (broader impacts),
6. Political impacts and governance,
7. Sufficiency of water supplies.

In their online survey, Keller et al. [20] received responses from water resources professionals in eight different stakeholder groups; including those from federal entities ($n = 5$), Indian tribes ($n = 4$), state entities ($n = 7$), local water departments and regional agencies ($n = 11$), regional water providers ($n = 6$), private water providers ($n = 2$), private sector users ($n = 3$), and environmental groups ($n = 7$). Although these people were from different groups, they tended to agree on the terminology and the list of evaluation concerns, so a single hierarchy was deemed appropriate, with potentially different weights on objectives.

Note particularly that the factors listed above are not yet stated as formal objectives. Different stakeholders to water resource planning may agree on the general factors to consider but disagree on what direction is an improvement. For example, an environmentalist might want to minimize the amount of commercial development in a region, and a city planner might want to achieve commercial development of 50% of a region. In the next subsection we describe desirable properties of objectives.

2.2.2. Desired Properties of Objectives. To make an evaluation concern into an objective, we need to specify the direction (maximize/minimize/maintain) that makes attainment of the objective better. So, when a person says that "distance from relatives" is an evaluation concern for the choice of a new house location, it is important to specify which direction is better. Having a goal of "maximizing the distance from relatives" is quite different from "minimizing the distance from relatives." One can also specify an objective of being about two hours of travel time away from relatives. Grandparents, parents, and children may all agree that distance from relatives is a relevant evaluation concern, but they may disagree on the objective.

Keeney [14, pp. 82–87] describes desirable characteristics of sets of objectives. An objective should be essential, controllable, measurable, operational, decomposable, concise, and understandable. Furthermore, the set of objectives should be complete and nonredundant.

2.2.3. Construction of Objectives Hierarchy. Next, you construct an objectives hierarchy by placing the objectives you have generated into a tree structure. Buede [3] describes two general methods for structuring objectives hierarchies, using a bottom-up or a top-down approach.

The objectives on the lowest level of the tree structure can be used to evaluate possible consequences by creating a scale to measure them. For the job selection decision in Figure 1, a consequence with a specific job might be a salary level of \$100,000 and a bonus level of \$50,000. By convention, we do not put the different possible salary or bonus levels at the bottom of the tree.

Now that the set of objectives has been identified, it can be used to help aid in creatively generating new alternatives, in strategic planning, and in gaining insights.

2.3. Aid in Creatively Generating New Alternatives

When Keeney [14, pp. 396–397] and his wife were planning for the birth of their son, they wrote down a list of objectives for them to use in choosing their son's name. By first generating these objectives, they could use the list of objectives to think up new alternatives for names that would be promising, based on their preferences.

Based on the following set of objectives, try to think about some names that would perform well on these objectives. Knowing the child would be a son, they specified it should not be a unisex name. With the last name Keeney, they did not want any \ee" sounds. They wanted the name to not be unique, but also to be not extremely common. Other objectives were that the chosen name should have a single spelling, reasonable initials, understandable pronunciation (with last name, and with middle and last names), no obvious \unwanted" nickname, and have a nice rhythm (with last name, and with middle and last names). Furthermore, they specified it should be not religious, not named after anyone, nice sounding in foreign languages, and appealing. (Check the footnote to see what name they chose.[2])

Note that although a single set of objectives was constructed by the parents, the perspectives of other people were taken into account in their objectives. For example, by having the name be nice sounding in foreign languages, the parents' friends who were French and German would find the name pleasing. In other cases, equity and perceived equity may be added into the primary decision maker's objectives hierarchy, thus taking into consideration other stakeholders.

2.4. Aid in Strategic Planning

2.4.1. Generic Strategic Planning Objectives. Structuring multiple objectives is also useful for strategic planning within organizations. Dyer and Larsen [7] found maximizing profitability, achieving long-term growth, and maintaining security to be three generic objectives of management in decision analyses that used objectives hierarchies as decision aids for marketing and oil-exploration strategies.

In a retrospective analysis, Winn and Keller [28] examined company records and interviewed executives to structure StarKist Tuna Company's "business-as-usual" objectives hierarchy,[3] which contained six highest-level groups of objectives: minimize cost, maximize revenue, optimize industry competitive position, minimize legal and regulatory interference, maintain favorable stakeholder relations, and maintain reputation as a \good corporate citizen."

[2] The chosen name was Gregory; he recently graduated from college. Note that even with the vast number of potential names, it is often necessary to sacrifice performance on one objective to score well on most objectives. Gregory certainly has an "ee" sound, but it sounded good to both French and German speakers.

[3] Feng et al. [11] (Table 2), available freely online, contains a copy of the complete "business-as-usual" objectives hierarchy.

2.4.2. The INFORMS Merger Decision. In December 1993, one of us (Keller) was chairing a committee for ORSA and TIMS to evaluate alternatives for cooperation, including a potential merger of the two societies.[4] Decision analyst Craig Kirkwood was also on the committee. Keller and Kirkwood [19] describe the decision analysis approach followed by the committee to inform this strategic planning process.

By collecting information from members of the two societies, the committee identified 52 objectives for the planning process, and organized the objectives into five major categories:

1. Improve cost efficiency of TIMS/ORSA activities,
2. Enhance the quality or ORSA and TIMS products,
3. Establish a strong and coherent external image of field,
4. Manage the scope and diversity of the field,
5. Maintain/improve effectiveness of ORSA and TIMS operations.

Although different stakeholders held divergent views about the wisdom of a merger, it was felt that a single objectives hierarchy captured the objectives of these stakeholders, though they might place different weights on the objectives. For that reason, the most detailed version of the objectives hierarchy held 52 lowest-level objectives, so that all concerns of all stakeholders could be included in the hierarchy.

Five alternatives for cooperation were identified by the societies' leaders, including

SEP: Separation of ORSA and TIMS;
SQ: Status quo partnership;
SM: Seamless merger;
M2: Merge with ORSA and TIMS as subunits;
M3: Merge with no ORSA/TIMS subunits, subunits are represented on board.

2.5. Aid in Gaining Insights

Structuring the objectives hierarchy can aid in generating insights. For example, analysts can identify gaps in performance on objectives to find what actions are needed (Merrick et al. [23], see also Merrick and Garcia [22]).

For the INFORMS merger decision, a key insight was that vocal opponents of merger believed that it would be unacceptable to not retain the society name and job title of "Operations Research."

Feng and Keller [9] discuss a study conducted by the National Academy of Sciences, for which one of us (Keller) served on the committee. The resulting book (National Research Council [24]) advises states and local jurisdictions to use a multiple-objective decision analysis process to evaluate plans for distribution of potassium iodide (KI) to protect against thyroid cancer, when there will be radioactive iodine exposure as a result of an accident or terrorism at a U.S. nuclear power plant. The decision process features were proposed following public hearings involving multiple stakeholders with divergent political perspectives and varying assumptions about scientific evidence.

The types of KI distribution plans include the following:

- Predistribute to households, schools, hospitals, etc.,
  Via mail,
  Via voluntary pickup;
- Stockpile at evacuation reception centers;
- Do not predistribute.

[4] ORSA and TIMS ended up merging on January 1, 1995, forming the Institute for Operations Research and the Management Sciences (INFORMS).

The study recommended that the following objectives be used in the decision about what sort of distribution plan to choose for a specific region.

1. Minimize Radioactive Iodine Risk to Thyroid
   1.1. Maximize KI availability
   1.2. Optimize ability to take KI on time
   1.3. Minimize harm from inappropriate KI administration
2. Minimize Harm from Other Aspects of Incident
   2.1. KI procedures don't impede evacuation
   2.2. Avert mortality and morbidity from radiation or accidents
   2.3. Minimize panic/anxiety due to KI procedures
   2.4. KI procedures' resource use not excessive
   2.5. Simple KI procedures before/during incident
   2.6. Educate public to respond to nuclear incidents

One key insight from this study was that the people who need to be protected most against radioactive iodine's risk to the thyroid are young children and pregnant women (to protect their babies). So, the objectives hierarchy was constructed with three subobjectives under the objective of maximizing KI availability to emphasize this fact, which is not generally understood by the public.

1.1 Maximize KI availability
   1.1.1. Max. Availability for Children & Pregnant Women Residents
   1.1.2. Max. Availability for Other Residents
   1.1.3. Max. Availability for Mobile Population

Another insight was that the discussion of KI had been separated from other ways to improve public health and safety. So, the objectives hierarchy was constructed with a major top-level objective to "minimize harm from other aspects of incident."

Finally, this study is a good example of how valuable it is for the resulting model to aid decision makers, but not tie their hands about which plan should be chosen. Feng and Keller [9] developed an Excel spreadsheet with sliders for setting the weights on the objectives (see §6 below) to aid the committee members to see how the recommended decision process can be flexible for different stakeholders and can allow real-time decision aiding and sensitivity analysis.

3. Different Objectives Hierarchies for Different Stakeholders

Many personal decisions involve multiple stakeholders with potentially conflicting objectives. When deciding to have a (or another) baby, stakeholders may include the mother, father, baby, baby's siblings, and potential grandparents. When choosing a new job, stakeholders include the employee, his/her spouse, the new employer, and the former employer. Similarly, organizational decisions often have multiple stakeholders. Brazer and Keller [2] describe stakeholders to school board decision making as a stakeholder web, including (a) the school board itself; (b) parents, business leaders, and community members; (c) national, state or provincial, and local governments; (d) the district superintendent; and (e) national and regional associations.

When there are multiple stakeholders to a decision, sometimes a single objectives hierarchy can be structured. For example, Keeney et al. [16] worked with different stakeholder groups such as the Catholic Church and the Green Party to eventually structure a single objectives hierarchy for the multiple stakeholders in the former West Germany's energy supply system decision by combining their divergent views together and allowing different stakeholders to assign different weights to objectives (including zero weight).

In other cases, an objectives hierarchy will be constructed for each stakeholder because their objectives are so different that construction of separate hierarchies better represents their divergent perspectives. In such situations, stakeholders use very different terms to describe their objectives, with relatively little overlap in their evaluation concerns, so a

single objectives hierarchy is not warranted. Examples include a tuna fish supplier source selection decision, the potential siting of a new Home Depot in San Juan Capistrano, and a prostate cancer treatment decision.

Feng et al. [11] demonstrate how this multiobjective, multistakeholder decision-modeling methodology can be taught. This methodology has been taught successfully in decision analysis courses both for MBA (including full-time MBA students, and business and healthcare executive MBA students) and undergraduate students.

3.1. The StarKist Tuna Fishing Decision

Winn and Keller [29] show how StarKist's decision to stop fishing for tuna when dolphins are at risk can be portrayed as a multiple-stakeholder decision with multiple objectives hierarchies for StarKist, the San Diego tuna fishing fleet, and the Earth Island Institute (an environmentalist group aiming to protect marine mammals).[5] In this case, the environmentalists wanted to stop killing of dolphins, stop cruelty to dolphins, and improve the prestige of their interest group. In contrast, the tuna fishing fleet wanted to maintain their livelihood and maintain the quality of life in their local community. Because the different groups used such different terminology and focused on such different objectives, their hierarchies were kept separate.

StarKist considered three main decision alternatives:

- Legal quota: Maintain current practices and stay within legal limits;
- Limited mortality: Step up efforts to reduce the number of dolphins killed;
- Zero mortality: No fishing associated with setting nets on dolphins.

After intense consumer pressure, StarKist executives felt they were in a crisis mode in which the future of the company was at risk, and decided to be "dolphin safe" and not buy tuna caught in the Pacific Ocean along the West Coast of the United States or farther south. Because dolphins only swim with tuna in this locale, dolphins were no longer at risk, but the San Diego tuna fishing fleet lost their livelihood.

3.2. Home Depot

Feng et al. [11] describe the case of the potential siting of a new Home Depot[6] in San Juan Capistrano, California, from the perspectives of Home Depot, the city, nearby residents, other area residents, and competing or complementary small businesses. Table 5 in Feng et al. [11] contains the complete objectives hierarchy for the City of San Juan Capistrano. There is also an online supplement to the paper with an Excel file for analyzing the Home Depot case, which considers the possibility of the city selling land to Home Depot so it could develop a new store, not developing the land, building an RV park on the site, and developing retail specialty stores on the site.

The city put the question to the voters in a referendum to advise the city on whether they should sell the land, and the majority of the voters recommended that they not sell the land to Home Depot.

3.3. Andy Grove's Prostate Cancer

Former Intel CEO Andy Grove described his own decision process when he faced prostate cancer in an article by Grove and McLean [13] in Fortune. In the fall of 1994 he received an

[5] Feng et al. [11], available freely online, contains the complete objectives hierarchies for the environmental interest group (Table 3) and the fishing fleet (Table 4). Winn and Keller [28] also created separate objectives hierarchies for different stakeholders in a forestry management decision by MacMillan-Bloedel (subsequently acquired by Weyerhaeuser).

[6] The Home Depot and the Andy Grove prostate cancer cases were developed from publicly available information and were not done in conjunction with Home Depot or Andy Grove.

TABLE 1. Objectives hierarchy for Andy Grove.

- A1. Maximize success of eliminating tumor
  - A1.1. Increase 5-year survival rate
  - A1.2. Decrease recurrence rate
  - A1.3. Limit spread of cancer cells
  - A1.4. Eradicate tumor cells
- A2. Minimize side effects
  - A2.1. Decrease chance of impotence
  - A2.2. Decrease chance of incontinence
  - A2.3. Decrease chance of diarrhea
- A3. Minimize disruption of career
  - A3.1. Limit outpatient procedures
  - A3.2. Limit follow-up visits
  - A3.3. Limit time away from work

abnormal prostate-specific antigen (PSA) test result. Because his PSA result was just over the upper limit of normal, he elected to repeat the test in early 1995 in case his results were within the error margin of the test. The results suggested more strongly the presence of a tumor and he visualized a sugar-cube-sized tumor in his prostate. These tests results convinced him of the need to see the urologist for a biopsy to determine if the test result was a true positive or a false positive. The biopsy results indicated his PSA result was a true positive. He did have prostate cancer. This led to the formulation of his decision problem. What type of treatment should he pursue? There appeared to be four main decision alternatives. One option was to have the tumor and prostate gland surgically removed. Another alternative was to receive radiation treatments in the form of "seed" implantation to destroy the cancer cells. A third alternative was cryosurgery, or freezing the tumor cells. The last option was to do nothing, taking the "wait and see" approach.

As a class exercise, we developed a case (Feng et al. [10]) from this article, in which we have groups of students role-play different stakeholders to this prostate cancer treatment decision (from the perspective of Andy Grove, his family, his company, or his urology and oncology doctors). Each role-playing group is asked to identify objectives from their perspectives for use in choosing among treatment options. Included are sets of objectives for Andy Grove (Table 1), the urologist (Table 2), and the oncologist (Table 3). Although the different stakeholders will often agree on many objectives, they will differ on others, such as the

TABLE 2. Objectives hierarchy for Urologist.

- U1. Maximize success of eliminating tumor
  - U1.1. Increase 5-year survival rate
  - U1.2. Decrease recurrence rate
  - U1.3. Limit spread of cancer cells
  - U1.4. Eradicate tumor cells
- U2. Minimize side effects
  - U2.1. Decrease chance of impotence
  - U2.2. Decrease chance of incontinence
  - U2.3. Decrease chance of diarrhea
- U3. Maximize profit
  - U3.1. Increase revenue
  - U3.2. Increase patient referrals
  - U3.3. Create positive patient–MD relationship
- U4. Optimize competitive position
  - U4.1. Promote surgical approach
  - U4.2. Provide data for surgical studies
  - U4.3. Create general positive public image

TABLE 3. Objectives hierarchy for Oncologist.

O1. Maximize success of eliminating tumor
O1.1. Increase 5-year survival rate
O1.2. Decrease recurrence rate
O1.3. Limit spread of cancer cells
O1.4. Eradicate tumor cells
O2. Minimize side effects
O2.1. Decrease chance of impotence
O2.2. Decrease chance of incontinence
O2.3. Decrease chance of diarrhea
O3. Maximize profit
O3.1. Increase revenue
O3.2. Increase patient referrals
O3.3. Create positive patient–MD relationship
O4. Optimize competitive position
O4.1. Promote radiological approach
O4.2. Provide data for radiology studies
O4.3. Create general positive public image

doctors promoting different treatment approaches. They also may differ on the weights placed on the objectives, as well as the chances of success and side effects.

4. List Consequences of Alternatives on Each Objective

In what decision analysts call a decision under certainty, probabilistic uncertainty is not formally modeled, so there are no chance nodes in a decision tree representation of the model.[7] In such situations, a useful way to represent the decision is in a spreadsheet model with the rows being the objectives and the columns corresponding to the different alternatives. Then each alternative can be described by what consequence (also called features or outcomes, which is often used when probabilistic events are involve) would be experienced on each objective if that alternative is chosen.

Sometimes merely listing the consequences of each alternative on each objective in side-by-side comparisons may suffice for decision making. When shopping on the Internet, such side-by-side listings on product features are often offered by websites. For example, when looking for a new house, houses are often described by their features (number of bedrooms, square footage, number of bathrooms, etc.) rather than how those features will impact a person's lifestyle (good party house, lots of privacy, etc.).

Here it is good to make the distinction between the physical features of a product or other alternative and what the decision maker cares about. Butler et al. [4] discuss e-shopping sites that enable multiple-attribute decision making. They describe a camera shop site that allows shoppers to specify if they are expert or novice users. Novices will have different objectives in purchasing a camera and will need different descriptions of features based on their objectives in buying and using a camera.

Personnel selection is a typical example where the decision maker may find it sufficient to lay out a side-by-side comparison of the consequences of hiring the potential employees. Sometimes going on to the next step of rating performance on the consequences will help employers quickly compare across a number of possible new hires.

[7] When chance events are modeled, there could be a separate sheet describing the outcomes under each event in the spreadsheet model, or a decision tree with chance nodes could be used, with the final outcomes described by the performance on a set of objectives.

FIGURE 2. Partial objectives hierarchy for environmental interest group.

Partial Objectives Hierarchy for Environmental Interest Groups	Decision Alternatives		
	Keep Status Quo	Reduce Dolphin Mortality	Go Dolphin Safe
PROTECT MARINE MAMMALS			
E1. Stop Killing of Dolphins			
E1.1. Protect Intelligent Large Marine Mammals	-	-	+
E1.2. Protect Species from Extinction	-	?	+
E2. Stop Cruelty to Dolphins			
E2.1. Prevent Herding by Helicopter & Detonations	-	?	+
E2.2. Prevent Harm from Entangling	-	-	+

5. Given the Consequence That Would Occur, Rate How Well Each Alternative Does on Each Objective

Next, you can assign a rating of how good a specific consequence is on an objective. Thus, on the objective of maximizing salary, you can assign a rating of how good a salary of \$100,000 is. At the early stages of the modeling process, the rating may be quite qualitative. In the StarKist case, Winn and Keller [29] used a scale of + for favorable, − for unfavorable, 0 for neutral or balanced, and ? for insufficient information. In the INFORMS merger analysis, Keller and Kirkwood [19] used the following rating scale:

2. Seen by average member as improved;
1. Seen by officers as improved, but not by average member;
0. No change;
□ 1. Seen by officers as worse;
□ 2. Seen by average members as worse.

In the StarKist case, the cells with the plus signs were color coded to be green ("GO"), negative signs were color coded to be red ("STOP"), and zeros or question marks were yellow, like the yellow "SLOW" light). Figure 2 shows a partial spreadsheet for the environmentalist groups, showing the color coding. (In black and white, the colors appear as upward diagonals for red, a light color for yellow, and a dark color for green.)

(For the spreadsheet formats of the complete objectives hierarchies of the three stakeholders (StarKist, environmentalists, and the San Diego fishing fleet) with the ratings of the alternatives, see Tables 2, 3, and 4 in Feng et al. [11], which is available online in INF□RMS Transactions on Education.) This color coding allows us to quickly see which alternatives are favored by different stakeholder groups, even when they have different sets of objectives, as long as each has a spreadsheet set up with the same columns for the decision alternatives. In personnel evaluations, such a color-coding scheme allows interviewers to quickly summarize how well potential hires scored on each objective.

In later and more formal modeling stages, single-attribute value functions (for decisions under certainty) or utility functions (for decisions under risk) could be constructed, using more elaborate rating scales or functional forms.

6. Put Weights on Objectives for an Additive Multiple-Objective Preference Model

Once we have the objectives listed, if we are using an additive preference model,[8] we can represent those preferences using "swing weights." We assign to each lowest level objective

[8] See Kirkwood [21] for conditions required for an additive preference model (multiple-attribute utility for decisions under risk or multiple-attribute value function for decisions under certainty).

in the hierarchical tree a weight that indicates how much importance is being placed on it. These swing weights define the trade-offs that the decision maker will make between objectives. The decision maker judges the weights to be placed on the objectives. The sum of the weights on the lowest-level objectives must be 100%. Each individual swing weight therefore defines the percentage of importance placed on that particular objective.

It is important to note that these swing weights depend on the ranges attainable on each objective (Clemen [5], Kirkwood [21], von Winterfeldt and Edwards [27], Borcherding et al. [1]). The larger the disparity among outcomes on a particular objective, the more importance will be placed on it.

Thomas Jefferson provided information on his trade-off between two objectives[9] when he said, "Health is worth more than learning." But, using the swing weight concept, Thomas Jefferson could have been more specific, perhaps by contemplating a thought experiment where he would imagine he had crippling arthritis and was illiterate. Then, given the choice of improving health from crippling arthritis (which he had) to perfect health, or going from illiteracy to being well read, he would choose to improve his health rather than his learning. In Excel, we use sliders to set the weights, to allow for real-time adjustments of weights in a dynamic sensitivity analysis. (See Table 5 in Feng et al. [11] for the City of San Juan Capistrano's spreadsheet. See the online supplement to Feng et al. [11] with the Excel file for the Home Depot case for an example of sliders.)

Once we have determined the weights on each objective, we need to compute the overall value achieved by an alternative. We do this by computing a weighted average of the rating values obtained on the objectives (where the weights are the decision maker's swing weights). This is simply a matter of multiplying each objective's weight by the rating of the performance of the alternative on that objective, and then taking the sum over all objectives. The SUMPRODUCT function in Excel will calculate the sum of the products of the weights times the ratings, in this "weight and rate" approach. The recommended alternative is the one with the highest resulting overall value.

6.1. INFORMS Merger Case

Figure 3 shows the INFORMS merger spreadsheet filled out by Keller. She judged the value ratings for five alternatives on 52 lowest-level objectives, and judged the weights for these 52 objectives. As can be seen in the spreadsheet, the Merger M3 option had the highest overall value, based on her judgments, at 0.86 on the +2 to −2 scale. Note that this means that the best alternative only scored near a +1, meaning that only officers would notice an improvement, on average. Some people used this spreadsheet format to evaluate the options, but committee members and interested others were not required to reveal their own judgments, or even use the form. The spreadsheet definitely aided in creating a focus for continued discussions and negotiations regarding the planned merger. The actual final decision by the officers was to present the seamless merger (SM) option to the members, and the members voted to merge.

6.2. Home Depot Case

For the Home Depot case, role-playing participants were assigned to different stakeholder roles and instructed to decide on their objectives, the weights on the objectives, and the ratings of alternatives on objectives, and then compute the overall value of each alternative. Table 4 shows an example of the calculated overall values for the alternatives in the Home Depot case, where the numbers in the bold and large fonts in each row show the alternative preferred by the stakeholder to which the row corresponds.

[9] Jefferson, the third United States President, wrote this in a letter to his cousin John Garland Jefferson on June 11, 1790.

FIGURE 3. Keller's evaluation of merger alternatives.

Robin Keller's Evaluation, 12/21/93

Evaluation of ORSA/TIMS Cooperation Alternatives											
Evaluation consideration	Top level weight	2nd level weight	3rd level weights	4th level weights	Judged weights	Judged Score on Cooperation Alternatives: SEP	SQ	SM	M2	M3
1. Improve cost efficiency of TIMS/ORSA	0.050									
1.1 Maintain efficient use of funds		0.015								
1.1.1 Exploit economies of scale			0.005		0.005	–2.0	0.0	1.0	–1.0	1.0
1.1.2 Balance dues rate and fee-for-services			0.005		0.005	–2.0	0.0	1.0	–1.0	1.0
1.1.3 Remove doubled dues			0.005		0.005	–1.0	0.0	2.0	1.0	2.0
1.2 Allocate well revenues/expenses		0.005			0.005	–1.0	0.0	1.0	–1.0	1.0
1.3 Maintain efficient use of time		0.030			0.030	–1.0	0.0	2.0	–1.0	2.0
2. Enhance quality of ORSA/TIMS products	0.720									
2.1 Provide high quality conferences		0.240								
2.1.1 Provide quality program			0.170		0.170	–2.0	0.0	0.0	–1.0	0.0
2.1.2 Manage balance between acad./prac.			0.050		0.050	–1.0	0.0	0.0	–1.0	1.0
2.1.3 Set fair cost to member			0.020		0.020	–1.0	0.0	0.0	–1.0	1.0
2.2 Provide high quality publications		0.240								
2.2.1 Maintain successful editorial oversight			0.020		0.020	–1.0	0.0	0.0	0.0	1.0
2.2.2 Maintain/increase circulation			0.010		0.010	–1.0	0.0	1.0	0.0	1.0
2.2.3 Maintain reputation of journals			0.040		0.040	–1.0	0.0	0.0	0.0	0.0
2.2.4 Improve readability of tech. journals			0.030		0.030	0.0	0.0	0.0	0.0	0.0
2.2.5 Provide outlet for applied papers			0.040		0.040	0.0	0.0	0.0	0.0	1.0
2.2.6 Provideforum for prof. comm.			0.080		0.080	–1.0	0.0	0.0	0.0	1.0
2.2.7 Maintain fair subscription costs			0.020		0.020	–1.0	0.0	1.0	0.0	1.0
2.3 Provide appropriate career services		0.080								
2.3.1 Support degree/cont. education			0.020		0.020	–1.0	0.0	0.0	–1.0	1.0
2.3.2 Facilitate networking			0.020		0.020	–2.0	0.0	0.0	–1.0	0.0
2.3.3 Provide successful job placement			0.020		0.020	–2.0	0.0	0.0	–1.0	0.0
2.3.4 Increase job opportunities			0.010		0.010	–1.0	0.0	0.0	0.0	1.0
2.3.5 Stimulate research/applications			0.010		0.010	–1.0	0.0	0.0	–1.0	1.0
2.4 Provide support for sub-units		0.105								
2.4.1 Provide start-up financial support			0.005		0.005	–1.0	0.0	0.0	–1.0	1.0
2.4.2 Maintain loose/tight mgt. of sub-units			0.005		0.005	–1.0	0.0	0.5	–1.0	1.0
2.4.3 Provide business office support			0.010		0.010	–1.0	0.0	0.5	–1.0	1.0
2.4.4 Support sub-unit tracks in main confer.			0.040		0.040	–1.0	0.0	0.0	–1.0	1.0
2.4.5 Support sub-unit conferences/journals			0.040		0.040	1.0	0.0	0.0	–1.0	2.0
2.4.6 Retain current/potential sub-units			0.005		0.005	–1.0	0.0	0.0	–1.0	1.0
2.5 Provide other member services		0.055								
2.5.1 Take lead in use of info. Technology			0.020		0.020	–1.0	0.0	0.5	–1.0	1.0
2.5.2 Improve quality of trans. with offices			0.005		0.005	–1.0	0.0	0.5	–1.0	1.0
2.5.3 Outreach to affiliate with related prof. act.			0.005		0.005	–1.0	0.0	0.0	–0.5	2.0
2.5.4 Provide improved support for practitioners			0.010		0.010	–0.5	0.0	0.0	–0.5	0.5
2.5.5 Provide improved support for Interpract.			0.010		0.010	–0.5	0.0	0.0	–0.5	0.5
2.5.6 Provide improved support for academics			0.005		0.005	–0.5	0.0	0.0	–0.5	0.5
3. Establish a strong/coherent ext'l image of field	0.100									
3.1 Increase visibility & clout of OR/MS		0.080								
3.1.1 Clarify image of OR/MS and ORSA & TIMS			0.010		0.010	–2.0	0.0	1.0	–1.0	2.0
3.1.2 Make name & activities known to press			0.020		0.020	–2.0	0.0	1.0	–1.0	2.0
3.1.3 Support develop./retention of OR units			0.040		0.040	–1.0	0.0	0.5	0.0	1.0
3.1.4 Improve liaison role			0.010		0.010	–1.0	0.0	0.5	0.0	2.0
3.2 Foster professional identity		0.020								
3.2.1 Closeness of job title match to name of org.			0.001		0.001	0.0	0.0	0.0	0.0	–1.0
3.2.2 Maintain OR/MS & ORSA/TIMS name rec.			0.010		0.010	–0.5	0.0	0.0	0.0	–0.5
3.2.3 Make membership signal prof. Identity			0.009		0.009	–0.5	0.0	0.0	0.0	0.5
4. Manage the scope and diversity of the field	0.050									
4.1 Maintain appropriate member. comp.		0.045								
4.1.1 Maintain/increase number of members			0.020							
4.1.1.1 Retain current members				0.010	0.010	–0.5	0.0	0.5	–0.5	1.0
4.1.1.2 Attract young people to the field				0.005	0.005	–0.5	0.0	0.5	–0.5	1.0
4.1.1.4 Attract non-members to the field				0.005	0.005	–2.0	0.0	0.5	–0.5	1.0
4.1.2 Manage diversity of members			0.025							
4.1.2.1 Foster international memberships				0.010	0.010	–0.5	0.0	0.0	0.0	0.0
4.1.2.2 Strike balance bet. business/engineering				0.005	0.005	–1.0	0.0	0.0	0.0	1.0
4.1.2.3 Support institutional members (Roundtable)				0.010	0.010	–0.5	0.0	0.0	0.0	0.0
4.2 Create strong relations. w/ other soc.		0.005			0.005	–1.0	0.0	0.0	0.0	1.0
5. Improve effectiveness of operations	0.080									
5.1 Improve quality of govern. process		0.020								
5.1.1 Streamline governance structure			0.010		0.010	–2.0	0.0	2.0	–2.0	1.0
5.1.2 Improve sub-units' representation			0.005		0.005	–2.0	0.0	0.0	–2.0	2.0
5.1.3 Speed up decisionmaking process			0.005		0.005	1.0	0.0	2.0	–2.0	2.0
5.2 Improve quality of operations		0.060								
5.2.1 Focus collective resources on import.. act.			0.030		0.030	–2.0	0.0	2.0	–2.0	2.0
5.2.2 Decrease overlap in offices' responsibilities			0.020		0.020	–2.0	0.0	1.5	–2.0	2.0
5.2.3 Decrease overlap in activities, sub-units, etc.			0.010		0.010	–2.0	0.0	2.0	–2.0	2.0
Total sum of judged weights, should = 1.00	1.000	1.000			1.000	–1.13 SEP	0.00 SQ	0.35 SM	–0.70 M2	0.86 M3
Calculated weighted average of overall value for each alternatives, based on judged weights	OVERALL VALUE OF ALTERNATIVE				Formula for overall value of SEPARATION= SUMPRODUCT ($H11:$I78,G11:G78)					

The results from Table 4 can be represented in two different ways. In Figure 4, note the large disagreement on Option 1 (build Home Depot). In Figure 5, note that the two groups most opposed to Home Depot are the competing local small businesses and the nearby residents.

TABLE 4. Example of Home Depot case results.

	Overall values			
	Option 1 Build Home Depot	Option 2 Don't develop the land	Option 3 Build RV park	Option 4 Build specialty retail
City of San Juan Capistrano	4.5	4.2	4.2	**5.6**
Competing local small businesses	0.6	3.0	5.0	**8.0**
Complementary local small businesses	**10.0**	5.0	5.7	3.5
Home depot	**9.4**	1.0	1.0	1.0
Nearby residents	1.0	**5.2**	1.4	4.2
Other area residents	**6.2**	3.8	0.8	3.6

FIGURE 4. Each alternative from different stakeholders' viewpoints.

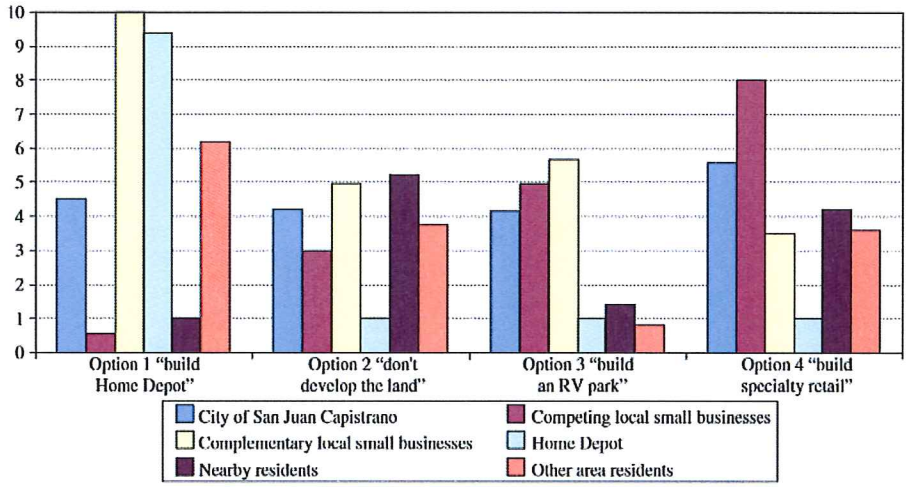


FIGURE 5. Each stakeholder's view of different alternatives.

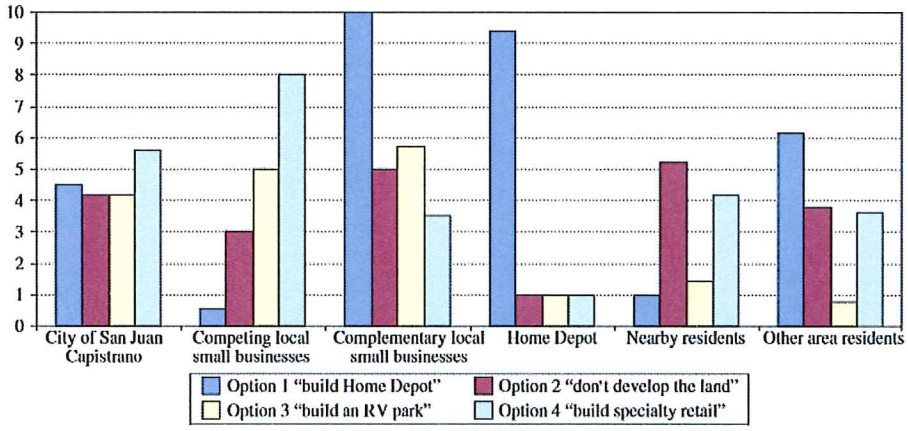
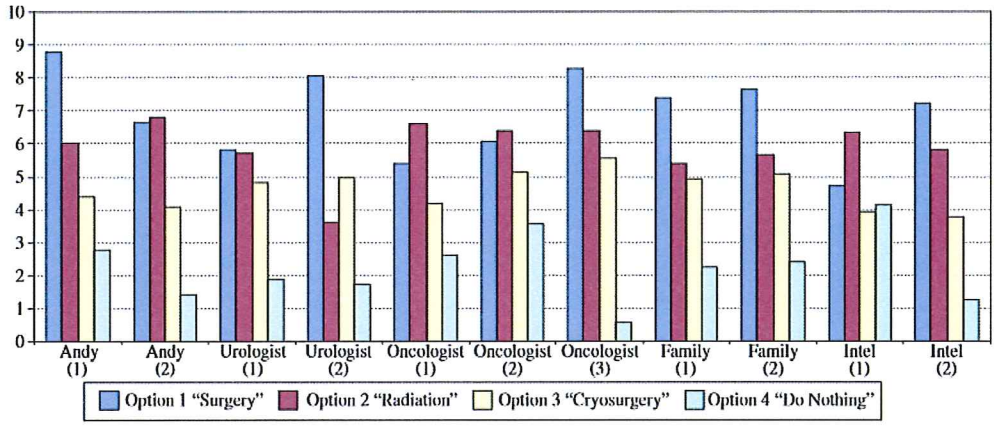


FIGURE 6. Overall values for each stakeholder in the Andy Grove case.



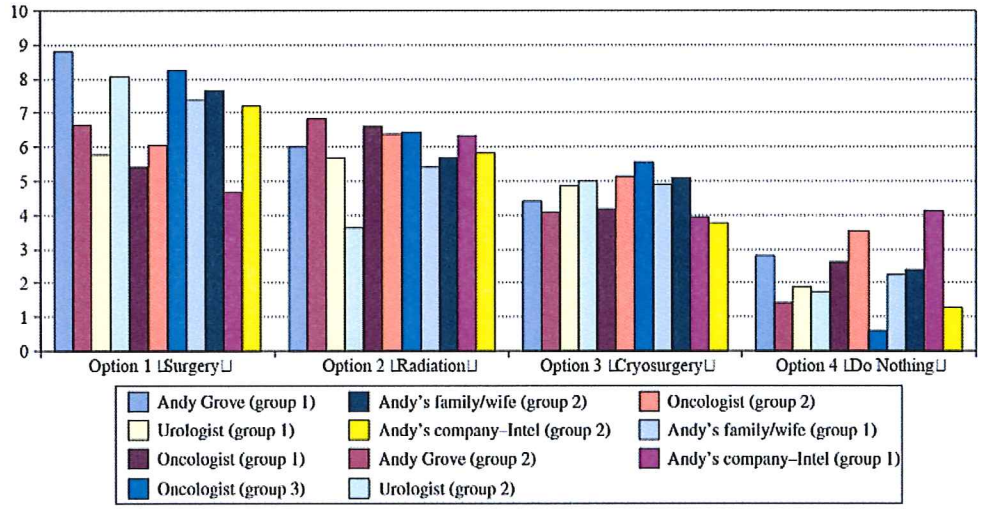
6.3. Andy Grove Case

For the Andy Grove prostate cancer case, role-playing participants were assigned to different stakeholder roles and instructed to decide on their objectives, the weights on the objectives, and the ratings of alternatives on objectives, and then compute the overall value of each treatment alternative. Figure 6 shows the overall values calculated by different role-playing stakeholder groups. Figure 7 shows the same data organized by the overall values for each treatment option. These displays aid us to find quick insights about the agreements and disagreements among stakeholders. For example, the role-playing stakeholders agree that the "do nothing" option is generally worse than the other options in this case.

7. Summary

The aim of this tutorial is to help analysts understand and model the multiple objective perspectives of the stakeholders to a decision. Using this approach can aid in identifying mutually agreeable alternative actions, designing new and better alternatives, and foreseeing opposition to decisions. It can also help analysts understand the evolution of past decisions from multiple perspectives.

FIGURE 7. Overall values for each treatment option in the Andy Grove case.



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—Decision Analysis (http://da.pubs.informs.org/)
—Decision Analysis Society of INFORMS (http://www.informs.org/Society/DA)
—Microsoft Decision Theory Group (http://www.research.microsoft.com/research/dtg/)
—Society for Judgment and Decision Making (http://www.sjdm.org/)
Society for Medical Decision Making (http://www.gwu.edu/~smdm/)
Explore Operations Research: The Science of Better (http://www.scienceofbetter.org/)