From: Ward Edwards and J. Robert Newman, Multiattribute Evaluation (Beverly Hills, Sage, 1982)

MULTIATTRIBUTE EVALUATION

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1. EVALUATION OF SOCIAL PROGRAMS

Evaluation is rapidly becoming Big Business. Questions like "Is this plan wise?" "Should I choose option A or option B?" "At what funding level should this program be supported?" How well is this program doing?" have been asked of social programs since long before we were born. But the idea that one could answer such questions systematically and in a manner other than simply looking at the object of evaluation and making an intuitive judgment is a development of the 1960s and 1970s. As inflated costs and less-inflated program budgets come into steadily escalating conflict, the task of weeding out the programs worthy of support from those that are not, and of providing guidance for programs in existence, will continue to grow in importance—as will the resources and attention devoted to developing satisfying methods of performing that task.

What Is Evaluation?

The literature of evaluation is already huge, and grows daily. The purpose of this paper is not academic, and we do not intend more than the

AUTHORS' NOTE: *This paper was developed under a grant from the National Institute of Law Enforcement and Criminal Justice, Law Enforcement Assistance Administration, Department of Justice (LEAA Grant No. 79-NI-AX-0002). Points of view or opinions stated in this document are those of the authors and do not necessarily represent the official position or policies of the U.S. Department of Justice.*

most cursory of references even to the literature on the method of evaluation that is our topic. For a recent and very scholarly presentation of evaluation methods and results from a broad spectrum of viewpoints, including our own, see Klein and Teilmann (1980). Edwards's chapter in that book will be of particular interest to scholars who find the ideas presented in this paper stimulating and potentially useful to them, since it discusses the same ideas in a far more technical way, reviews a significant amount of literature, and cites the literature of this and of other methods.

The purpose of this paper is to present one approach to evaluation: Multiattribute Utility Technology (MAUT). We have attempted to make a version of MAUT simple and straightforward enough so that the reader can, with diligence and frequent reexaminations of it, conduct relatively straightforward MAUT evaluations him- or herself. In so doing, we will frequently resort to techniques that professional decision analysts will recognize as approximations and/or assumptions. The literature justifying those approximations is extensive and complex; to review it here would blow to smithereens our goal of being nontechnical.

What is MAUT, and how does it relate to other approaches to evaluation? Edwards, Guttentag, and Snapper (1975) discussed that question in 1975, and we have little to add. MAUT depends on a few key ideas:

(1) When possible, evaluations should be comparative.
(2) Programs normally serve multiple constituencies.
(3) Programs normally have multiple goals, not all equally important.
(4) Judgments are inevitably a part of any evaluation.
(5) Judgments of magnitude are best when made numerically.
(6) Evaluations typically are, or at least should be, relevant to decisions.

Some of the six points above are less innocent than they seem. If programs serve multiple constituencies, evaluations of them should normally be addressed to the interests of those constituencies; different constituencies can be expected to have different interests. If programs have multiple goals, evaluations should attempt to assess how well they serve them; this implies multiple measures and comparisons. The task of dealing with multiple measures of effectiveness (which may well be simple subjective judgments in numerical form) makes less appealing the notion of social programs as experiments or quasi-experiments. While the tradition that programs should be thought of as experiments, or at least as quasi-experiments, has wide currency and wide appeal in evaluation research, its implementation becomes more difficult as the number of measures needed for a satisfactory evaluation increases. When experimental or other hard data are available, they can easily be incorporated in a MAUT evaluation.

Finally, the willingness to accept subjectivity into evaluation, combined with the insistence that judgments be numerical, serves several useful

purposes. First, it partly closes the gap between intuitive and judgmental evaluations and the more quantitative kind; indeed, it makes coexistence of judgment and objective measurement within the same evaluation easy and natural. Second, it opens the door to easy combination of complex concatenations of values. For instance, evaluation researchers often distinguish between process evaluations and outcome evaluations. Process and outcome are different, but if a program has goals of both kinds, its evaluation can and should assess its performance on both. Third, use of subjective inputs can, if need be, greatly shorten the time required for an evaluation to be carried out. A MAUT evaluation can be carried out from original definition of the evaluation problem to preparation of the evaluation report in as little as a week of concentrated effort. The inputs to such an abbreviated evaluative activity will obviously be almost entirely subjective. But the MAUT technique at least produces an audit trail such that the skeptic can substitute other judgments for those that seem doubtful, and can then examine what the consequences for the evaluation are. We know of no MAUT social program evaluation that took less than two months, but in some other areas of application we have participated in execution of complete MAUT evaluations in as little as two days—and then watched them be used as the justification for major decisions. Moreover, we heartily approved; time constraints on the decision made haste necessary, and we were very pleased to have the chance to provide some orderly basis for decision in so short a time.

Classes of Purposes for Evaluations

Evaluations can be done for various reasons; different reasons can and do lead to different forms of evaluative activities. The most common reason for evaluation is that it is required; perhaps by mandate from Congress or from a sponsor or perhaps by rules internal to the program organization.

The organizational requirement for an evaluation is normally based on the supposition that decisions need to be made. Sometimes the question is whether the program should be continued, modified, or scrapped. Sometimes it is simply what relatively minor changes, if any, should be made in program design, management, or functioning to improve its effectiveness. Sometimes no specific decisions are behind such mandated evaluations; the spirit of such evaluations is somewhat similar to the spirit that leads to annual external audit of corporate books.

Major evaluations are often required as a basis for potential major programmatic changes—up to and including the most major of all changes: the birth or death of a program. Sometimes such decisions are pure life-or-death choices; at least equally often, some social problem requires attention, and the decision problem is which of several alternative approaches to dealing with it looks most promising. Funding-level decisions are also programmatic choices; the same program at two substantially different funding levels is really two different programs.

From this welter of considerations, we think we can distinguish four different classes of reasons for evaluations: curiosity, monitoring, fine tuning, and programmatic choice. Curiosity in itself is seldom a basis for wisely performed evaluations, since most programs are too specific in character for the kinds of generalizations to which wisely applied curiosity can lead, and generalized curiosity is a poor guide to choice of evaluative methods or measures.

Monitoring is both an appropriate and a necessary function for any program, and we believe MAUT offers useful tools for monitoring. Monitoring shades over into fine tuning; the same tools are relevant to both. Programmatic choice is the most important use to which evaluative information can be put, and the tools of MAUT are most directly relevant to it.

These reasons for evaluation share two common characteristics that make MAUT applicable to them all. The first is that, implicitly or explicitly, all require comparison of something with something else. This is most obvious in the case of programmatic choice. But even monitoring has the characteristic, since one normally wonders whether or not some minor change would change significantly one of the monitored values. An important implication of the comparative nature of virtually every evaluation is that some of the comparisons are inevitably between the program as it is and the program as it might be—that is, between real and imaginary programs or programmatic methods. The necessity of comparing real with imaginary objects is one of the problems that most approaches to evaluation find very difficult to solve. The normal approach of traditional methods is to make the comparison object real, typically by embodying it in an experimental (or control) group, locus, or program. We admire such comparisons when they can be made (e.g., in drug trials), but consider them impractical for most social program evaluations. MAUT deals with this problem by accepting data and judgments on equivalent footings; judgment is the most generally useful tool we know of for assessing the consequences of nonexistent programs. (Such judgments, of course, are best when based on relevant data, e.g., from other programs in other places.)

The second characteristic that the various reasons for evaluation share is that programs virtually always have multiple objectives; consequently, evaluations should assess as many of these as seem important.

We use the word "program" in a broader sense than has been common; we are concerned with many social programs other than social service delivery programs. We consider arms procurement, treaties among nations, labor contracts, choices made by businesses about such questions as where to locate new plants, and other similar public decisions with major impacts on people to be "programs," and to deserve evaluation. One version or another of the methods we discuss has been used for purposes as diverse as deciding whether to expand a Community Anti-Crime Program area, evaluating the Office of the Rentalsman in Vancouver as a dispute resolution mechanism, evaluating alternative school desegregation plans for Los Angeles, choosing among alternative sites for dams and nuclear power plants, evaluating competing bids for various kinds of military hardware, formulating U.S. negotiating positions in international negotiations, and assessing the combat readiness of Marine Corps brigades. For more information and a number of references to such applications, see Edwards (1980).

Since we claim that MAUT can be applied to evaluative problems of each of the kinds we can identify, are we asserting that it is a universally applicable mode of evaluation—perhaps a substitute for alternative modes? No. MAUT is, we believe, a very widely applicable method of organizing and presenting evaluative information. As such, it is compatible with any other evaluative activity designed to yield numbers as outputs. Since the ideas of MAUT do not limit the sources of the evaluative information, they can be combined with whatever data sources the evaluator finds satisfying and relevant to his or her problem.

Is MAUT an evaluative method at all? Without an answer to the question about where the evaluative information it must use will come from, the answer is no. However, chapter 6 of this paper presents some ideas about answers to that question. Whether those answers are a part of MAUT or external to it is obviously only a question of definition; the reader can choose.

Steps in a MAUT Evaluation

It may be helpful at this point to summarize concisely the steps involved in any MAUT evaluation. This will (1) summarize the remainder of this paper; (2) provide a brief procedural guide; and (3) identify, but not define, the technical terms (they are defined one by one in the remainder of the paper).

First, a note about technical terms. There are a lot of them, and many will seem nonstandard to those familiar with the MAUT literature. In every case that we can identify, use of a nonstandard term corresponds to a shading of difference between what this paper discusses and what previous publications (including many of which Edwards was an author) have discussed. Many more versions of MAUT exist than researchers active in developing it. While all depend on the same basic ideas, details of implementation change, and such changes produce corresponding changes in jargon. Many nontechnical readers will wish to skip this section and go on to the next.

Step 1. Identify the objects of evaluation and the function or functions that the evaluation is intended to perform. Normally there will be several objects of evaluation, at least some of them imaginary, since evaluations are comparative. The functions of the evaluation will often control the choice of objects of evaluation. We have argued that evaluations should help decision makers to make decisions. If the nature of those decisions is known, the objects of evaluation will often be controlled by that knowledge. Step 1 is outside the scope of this paper. Some of the issues inherent in it nave already been discussed in this chapter. Chapter 2, devoted to setting up an example that will be carried through the document, illustrates Step 1 for that example.

Step 2. Identify the *stakeholders* (technical terms to be explained later are set in italics). Chapter 3 discusses this in detail.

Step 3. Elicit from stakeholder representatives the relevant *value dimensions* or *attributes*, and (often) organize them into a hierarchical structure called a *value tree*. Chapter 3 both explains how to do this and presents several real examples.

Step 4. Assess for each stakeholder group the *relative importance* of each of the values identified at Step 3. Such judgments can, of course, be expected to vary from one stakeholder group to another; methods of dealing with such value conflicts are important. Chapter 4 presents assessment techniques and introduces some discussion of value differences. Chapter 7 returns to the issue of value differences.

Step 5. Ascertain how well each object of evaluation serves each value at the lowest level of the value tree. Such numbers, called *single-attribute utilities* or *location measures*, ideally report measurements, expert judgments, or both. If so, they should be independent of stakeholders and so of value disagreements among stakeholders; however, this ideal is not always met. Location measures need to be on a common scale, in order for Step 4 to make sense. Chapter 5, which is so far as we know unique in this literature in its emphasis on simplicity of methods, discusses both how to obtain location measures and how to put them on a common scale.

Step 6. Aggregate location measures with measures of importance. This is the topic of chapter 6.

Step 7. Perform *sensitivity analyses*. The question underlying any sensitivity analysis is whether a change in the analysis, e.g., using different numbers as inputs, will lead to different conclusions. While conclusions may have emerged from Step 6, they deserve credence as a basis for action only after their sensitivity is explored in Step 7. Chapter 7 shows how some fairly simple sensitivity analyses can be performed.

Steps 6 and 7 will normally produce the results of a MAUT evaluation. Chapter 7 also has suggestions about how such results can be presented.

The Relation Between Evaluation and Decision

The tools of MAUT are most useful for guiding decisions; they grow out of a broader methodological field called decision analysis. The relation of evaluation to decision has been a topic of debate among evaluation researchers—especially the academic evaluation researchers who wonder whether or not their evaluations are used, and if so, appropriately used. Some evaluators take the position that their responsibility is to provide the relevant facts; it is up to someone else to make the decisions. "We are not elected officials." This position is sometimes inevitable, of course; the evaluator is not the decision maker as a rule, and cannot compel the decision maker to attend to the result of the evaluation, or to base decisions on it. But it is unattractive to many evaluators; certainly to us.

We know of three devices that make evaluations more likely to be used in decisions. The first and most important is to involve the decision makers heavily in the evaluative process; this is natural if, as is normally the case, they are among the most important stakeholders. The second is to make the evaluation as directly relevant to the decision as possible, preferably by making sure that the options available to the decision maker are the objects of evaluation. The third is to make the product of the evaluation useful—which primarily means making it readable and short. Exhaustive scholarly documents tend to turn busy decision makers off. Of course, nothing in these obvious devices guarantees success in making the evaluation relevant to the decision. However, nonuse of these devices comes close to guaranteeing failure.

By "decisions" we do not necessarily mean anything apocalyptic; the process of fine tuning a program requires decisions too. This paper unabashedly assumes that either the evaluator or the person or organization commissioning the evaluation has the options or alternative courses of action in mind, and proposes to select among them in part on the basis of the evaluation—or else that the information is being assembled and aggregated because of someone's expectation that that will be the case later on.

TABLE 1
MKDC CAC Value Attributes

Number	*Title of Attribute*	*Importance Weight*
1	**Reduce Crime**	.141
2	**Reduce Fear of Crime**	.140
3	**Increase Police Responsiveness**	.119
4	**Serve Community Ombudsman Role**	.126
5	**Increase Resident Involvement**	.149
6	**Institutionalize Organization**	.111
7	**Provide Technical Assistance**	.104
8	**Integrate Other Social Services**	.110
		1.000

An Example of a MAUT Analysis

The Office of Community Anti-Crime Programs (OCAP) of the Law Enforcement Assistance Administration (LEAA) funded a number of community-based anticrime projects throughout the country. Decision Science Consortium, Inc. was hired to perform a large MAUT analysis of this whole program; the key people in that evaluation were Dr. Kurt Snapper and Dr. David Seaver. A more detailed discussion of the evaluation as a whole appears in chapter 3 of this paper.

The following discussion of a specific decision within that evaluation program is condensed from Snapper and Seaver (1978). One of the community projects within OCAP's program was that of the Midwood-Kings Highway Development Corporation (MKDC) in Brooklyn. The objectives (called *attributes* in this paper) of that particular project, and the *weights* given to them by its director, are given in Table 1. Note that all attributes are approximately equally important—a quite unusual finding. These attributes and weights were elicited in the first year of the MKDC project. The project was quite successful in improving on the preproject scores on these objectives in its area.[1]

In 1979, a decision problem arose. The City of New York adopted a "coterminality" policy; police and other service delivery areas were to become aligned or "coterminous" with community districts. Since MKDC served a part of the area served by the Midwood Civic Action Council (MCAC), the problem was whether to expand MKDC's area of service to include all of MCAC's area—a 50% expansion. No additional LEAA funds were expected for MKDC, so the concern was that expansion

TABLE 2
A MAUT Analysis of the MKDC Expansion Decision

Value Attributes	*1979*	*1980*	*1981*
Option 1: Expand to include all the MCAC area			
1. Reduce Crime	68	78	85
2. Reduce Fear of Crime	43	64	90
3. Increase Police Responsiveness	63	83	98
4. Serve Ombudsman Role	25	42	83
5. Increase Resident Involvement	28	69	95
6. Institutionalize Organization	46	70	105
7. Give Technical Assistance	25	40	80
8. Integrate Social Services	75	88	97
Aggregate Utility	46	67	92
Option 2: Do not expand at all			
1. Reduce Crime	68	81	89
2. Reduce Fear of Crime	43	71	97
3. Increase Police Responsiveness	63	84	100
4. Serve Ombudsman Role	25	50	100
5. Increase Resident Involvement	28	85	100
6. Institutionalize Organization	46	66	100
7. Give Technical Assistance	25	50	100
8. Integrate Social Services	75	90	100
Aggregate Utility	46	73	98

of the service area would lead to dilution of service quality and effectiveness. On the other hand, political considerations of various sorts argued for the expansion.

Working with Dr. Seaver and Dr. Snapper, the MKDC project director did a MAUT analysis of the two extreme options: to expand or not. The results are presented in Table 2. It is important to note that the measures on which Table 2 are based are judgments of the MKDC project director, and refer to the MKDC area alone. The baseline or *zero point* on each attribute is pre-MKDC project measures. The *100 point* on each dimension is the project director's judgment of the best that could be expected to be accomplished by the project. The weights used to combine the various utilities on each attribute into aggregate utilities come from Table 1. The

TABLE 3
Project Effectiveness in the Full MCAC Area, Assuming Expansion

Value Attributes	*1979*	*1980*	*1981*
1. Reduce Crime	−5	63	76
2. Reduce Fear of Crime	10	53	81
3. Increase Police Responsiveness	0	63	84
4. Serve Ombudsman Role	10	35	60
5. Increase Resident Involvement	15	43	90
6. Institutionalize Organization	NA	66	70
7. Give Technical Assistance	0	25	50
8. Integrate Social Services	0	75	90
Aggregate Utility	5	53	76

aggregate utility serves as one basis for the evaluation—the higher these values, the better the option. Note that both are sets of judgments by the project director. A less abbreviated MAUT would have included other stakeholders.

The project director was relatively surprised by the results presented in Table 2; he had expected that expansion of the service area would lead to much more degradation of service than Table 2 shows. He therefore chose to go ahead and expand the area, since he felt that in the presence of such a relatively minor effect on service, the political considerations were compelling.

Political events in New York City have delayed implementation of coterminality, and there is some doubt about whether it will ever be implemented. However, MKDC is now considering petitioning LEAA to expand its target area to all of MCAC's area.

One reason for that decision is yet another version of the analysis. Recall that Table 2 is based only on predicted measures within the original MKDC area. If the area were to be expanded, it would be appropriate to take those measures over the whole MCAC area instead. Table 3 shows the result of a MAUT analysis based on predicted measures covering the whole MCAC area. Note that expansion of the area leads to severe initial degradation (for the year 1979) of the project effectiveness measures, since the new area includes a substantial region within which the old MKDC project, which had been very successful, had not been operating. However, the forecast leads to the conclusion that, although the figures are not as high as either of those in MKDC are alone, they show major improvement with time. This invites the idea that "the greatest good of the greatest number" is well served by expanding, even in the presence of constant funding.

The director also judged that a funding difference of only $60,000 would make the difference between leaving the original MKDC project ineffectual and giving it the necessary resources to serve all of the MCAC area as well as it was then serving MKDC. This is obviously an interesting assessment to report to LEAA in connection with any application to expand the MKDC area.

This is an example of a MAUT analysis carried out in a day. In spite of its brevity and omissions (e.g., of other stakeholders and of assessments of the political consequences of expanding or not expanding the area), it led a decision maker in a criminal justice project to change his mind, and provided him with the necessary information and analysis to defend that change of mind to sponsors, peers, and those he serves.

Summary

Chapter 1 begins by defining the purpose of the paper: to present a version of Multiattribute Utility Technology (MAUT). The version chosen for presentation emphasizes multiple stakeholders, multiple program objectives, wholehearted acceptance of subjectivity, and linkage of evaluation to decision. The chapter distinguished four reasons for evaluation: curiosity, monitoring, fine tuning, and several forms of programmatic choice. MAUT is useful to them all because it implies comparison of something with something else with respect to multiple objectives. MAUT is not a mode of evaluation in itself; instead, it is a way of organizing and aggregating evaluative efforts. The chapter briefly lists the seven steps of a MAUT, discusses the relationship between evaluation and decision, and makes suggestions about how evaluative efforts can be made more likely to influence decisions. It concludes with an instance of a MAUT evaluation that led to a decision.

2. AN EXAMPLE

In this chapter we present a fairly simple example of how to use multiattribute utility technology for evaluation. The example is intended to be simple enough to be understandable, yet complex enough to illustrate all of the technical ideas necessary for the analysis. Every idea introduced and illustrated is discussed in more detail in subsequent chapters. The example itself also reappears in later chapters.

Unfortunately, we cannot structure our discussion around the real example that we presented in the last chapter. It does not have all of the features of MAUT that we need to examine. So we have invented an example that brings out all the properties of the method, and that will, we hope, be sufficiently realistic to fit with the intuitions of those who work in a social program environment.

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Analyzing SUBJECTIVE DECISIONS *with a* SPREADSHEET

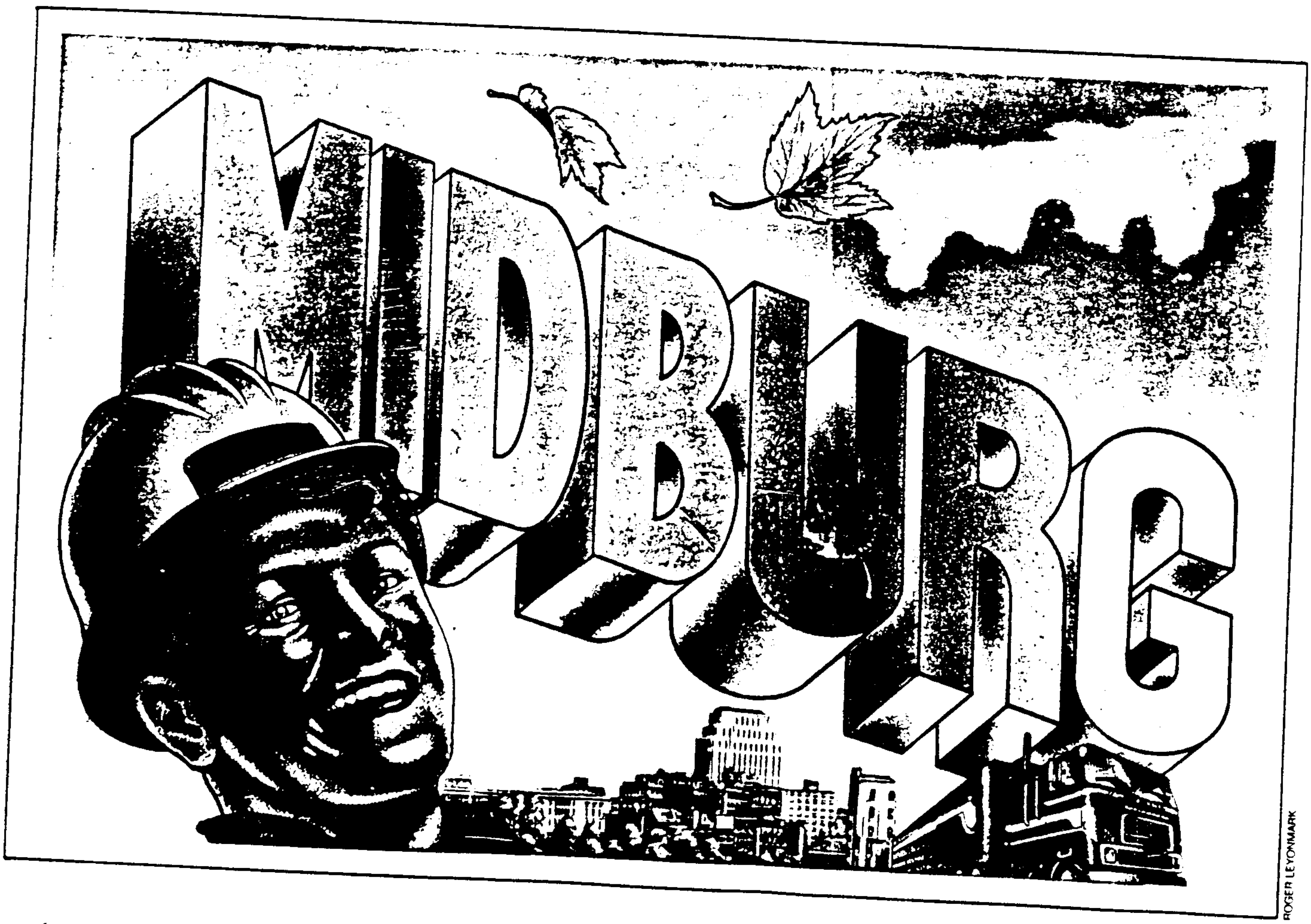
Use the techniques of dimensionless analysis to weigh the subjective factors influencing your business decisions.

BY EVERETTE S. GARDNER JR.

Business decisions are rarely based on costs or profits alone. Usually there are subjective considerations that muddy the waters and make decisions a lot tougher than simply choosing the alternative with the best "bottom line."

Suppose your company plans to open a new plant in another city. It is easy to estimate the operating costs at different locations, but this is only part of the story. Some locations may have competitive advantages. The labor supply may be important. Most companies will also consider the quality of life in different cities, especially when employees must relocate.

Decisions like this, where many of the decision factors are subjective in nature, may seem beyond the scope of a worksheet model. Not so. You can build a



ROGER LEYONMARK

1-2-3 or *Symphony* model that analyzes a variety of subjective decision factors and finds the best trade-off available. You can even mix subjective factors with objective factors such as costs or profits.

Now let's work through an example—a plant-location decision faced by Maxwell Industries, a manufacturing company. The principles involved apply to virtually any business decision that depends on subjective input.

Maxwell Industries' sales have grown enough to justify an additional plant. The executive committee has already narrowed the list of candidate sites down to Midburg, a large industrial city in the midwest, and Fort Mudge, a smaller city in the Sunbelt region. The worksheet used to choose between the two cities is shown in figure 1. There are five steps involved in building this type of worksheet.

STEP 1: LIST THE DECISION FACTORS

List all of the factors that are relevant to the decision. Don't be afraid to list something that seems only marginally important. Sensitivity analysis will reveal whether a factor is or is not important.

Set up the worksheet in *1-2-3* or *Symphony*. Set the column widths as follows: A–26, B–10, and C–10. To set column widths in *1-2-3*, press slash, select Worksheet Column Set-Width, and enter the width number; in *Symphony*, press MENU, select Width Set, and enter the width number. Enter the labels in rows 1 through 6 and the decision factors in column A.

STEP 2: SCORE THE DECISION FACTORS

Now assign a score to each decision factor. The meaning of the score depends on the nature of the factor.

The first three factors are objective and thus easily quantified. For annual manufacturing costs, the scores are in thousands of dollars. For the cost of living, the scores are indexes, with the lower of the two expressed as a percentage of the higher. Fort Mudge has a cost of living that is 87% of Midburg's, so set Midburg's cost of living at 100 and Fort Mudge's at 87. The average commuting distances to the plant sites are scored in miles.

The remaining six factors are subjective and less

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	A	B	C	D	E
1	PLANT LOCATION ANALYSIS TEMPLATE				
2					
3					
4		MIDBURG	FT. MUDGE	-------	---------
5	DECISION FACTORS	SCORE	SCORE	WEIGHT	(M/F)^W
6	----------------	---------	---------	-------	---------
7	Annual Manufacturing Costs	$4,380	$4,325	5	1.07
8	Cost of Living Index	100	87	3	1.52
9	Average Commuting Distance	27	10	2	7.29
10	Skilled Labor Supply	1	6	4	0.00
11	Ability To Subcontract	3	9	3	0.04
12	Government Attitude	7	1	4	2401.00
13	Quality of Schools	8	3	4	50.57
14	Cultural Opportunities	2	8	2	0.06
15	Climate	9	2	1	4.50
16					
17		PREFERENCE NUMBER:			11.51
18					
19		YOUR DECISION IS:			Ft. Mudge

FIGURE 1. In this subjective decision-analysis worksheet, each of the scores in column B is divided by the adjacent score in column C. The result is raised to the power of the weight factor in column D. This yields a preference number (column E) for each decision factor listed in column A. Preference numbers are then multiplied together to calculate a final preference number in cell E17. This number indicates (by being less than or greater than 1) which of the two options is preferred. The label in cell E19 can be created by an @IF formula (*1-2-3* Release 2 and *Symphony*) or by a simple macro (*1-2-3* Release 1A).

easily quantified. They are scored on a scale of 10 (worst) to 1 (best). You don't use the usual 1-to-10 scale here because you must be consistent with the first three factors, where lower numbers are more desirable than higher ones. There'll be more on this later. You can use any scale for subjective factors as long as it is consistent. These scores, found in cells B10 to C15 in figure 1, are consensus scores assigned by the members of Maxwell's site-search committee.

Enter the scores in columns B and C. Format cells B7 and C7 for currency with no decimal places. The format of these cells doesn't affect the results, but it helps clarify the worksheet.

STEP 3: WEIGHT THE DECISION FACTORS

Express the importance of each decision factor by assigning weights to them. Consensus weights determined by the site-search committee are assigned as shown in figure 1. The weight values range from 1 to 5; the greater the weight, the larger the value, the more important the decision factor. Annual manufacturing cost is most important. It is assigned a weight of 5. Climate is least important and gets a weight of 1. Other factors fall between the two extremes. Enter the weights in column D.

STEP 4: COMPUTE WEIGHTED RATIOS

Now you're ready to write formulas to analyze the decision. A common approach is to take a sum or a weighted average of the scores in columns B and C. This approach makes little sense, however, because the scores are measured on different scales. Simply adding these scores together yields the classic mistake of mixing apples and oranges.

A better way to compare the decision factors is to convert the scores to ratios, one for each decision factor, then raise each ratio to a power equal to its weight. Then multiply all the ratios together to get a number that indicates the better alternative. This number is called a preference number, and it is free of incompatible-scale problems.

Enter the formula (B7/C7)^D7 in cell E7, and format this cell for two decimal places: Select /Range Format Fixed (in *Symphony*, MENU Format Fixed), press Return to accept 2, and press Return again. This is the ratio of manufacturing costs in Midburg to manufacturing costs in Fort Mudge, raised to the power of 5, the assigned weight for that factor. The same formula is used for all the factors, so copy cell E7 to range E8..E15.

By converting the numbers to ratios, you eliminate the "apples and oranges" problem. For a given decision factor, a ratio simply indicates which city is preferable—in cases where Midburg "wins," the ratio is less than 1; where Fort Mudge "wins," the ratio is greater than 1. This is because a ratio with a numerator greater than its denominator will always be greater than 1. If the numerator is less than the denominator, the ratio will always be less than 1. Furthermore, raising a ratio to any power (other than Ø) does not affect its being less than or greater than 1.

As long as the two scores for each factor are values you can sensibly compare, it doesn't matter whether the numerator and denominator are measured in dollars, miles, or anything else. It also doesn't matter whether the numerator and denominator are scaled as long as the scaling is consistent. For example, the ratio of $4,380 to $4,325 is the same as the ratio of $4,380,000 to $4,325,000.

STEP 5: COMPUTE THE PREFERENCE NUMBER

Combine the weighted ratios. Move the pointer to cell B17 and enter the label PREFERENCE NUMBER:. Give cell E17 the Fixed format with two decimal places and enter the following formula:

+E7*E8*E9*E10*E11*E12*E13*E14*E15

The result, 11.51, indicates by being greater than 1 that Fort Mudge is the better choice.

Don't try to attach any meaning to the magnitude of the preference number. The value in cell E17 doesn't mean that Fort Mudge is 11.51 times better than Midburg; it only means that it is better. Remember, too, it's mathematically possible for the preference number to be exactly 1. This does not happen often, but if it had, Maxwell Industries could consider the plant-location decision to be a toss-up.

Now put a label prompt in the worksheet to remind

	G	H	I	J	K	L
1	\d	{GOTO}result~				
2		/XInumber=1~TOSSUP~				
3		/XInumber<1~MIDBURG~				
4		/XInumber>1~FT MUDGE~				
5						
6						

FIGURE 2. This simple *1-2-3* Release 1A macro causes one of three labels to appear in cell E19 of the subjective-analysis template. The macro helps you determine which relocation alternative is indicated by the preference number generated by the calculations.

you of which city wins. If you're using *1-2-3* Release 2 or *Symphony*, move the pointer to cell B19 and enter the label YOUR DECISION IS:. Then enter the following formula in cell E19:

@IF(E17=1,"TOSSUP",@IF(E17<1,
"MIDBURG","FT MUDGE"))

The formula says, "If H17 is equal to 1, display the label TOSSUP; if H17 is less than 1, display the label MIDBURG; and if H17 is greater than 1, display the label FT MUDGE."

In *1-2-3* Release 1A, use a simple macro to accomplish the task. Type the macro that appears in figure 2, then position the pointer in cell H1, select /Range Name Create and enter *d*. You must also provide range names for two other cells. Name cell E17 *number* and cell E19 *result*. To run this macro, hold down the Alt key and press D. Any time you change any of the values to see if the outcome changes, run the macro again.

SENSITIVITY ANALYSIS

Now let's see how the decision changes if the inputs change. To illustrate, let's experiment with the weight assigned to the cost of living. Move the pointer to cell D8 and change the weight from 3 to 2. (In Release 1A, run the macro by pressing Alt-D.) The decision stays the same, Fort Mudge. Try a weight of 1. Fort Mudge is still better. Now try 4 and 5. Since the cost of living already favors Fort Mudge, these greater weights naturally don't change the outcome either. Thus the decision is not sensitive to differences in the cost of living. Now change the weight in cell D8 back to 3.

Suppose a member of the search committee is concerned that the weights on the decision factors favoring Midburg are too low. Let's see if these weights make any difference.

Three factors favor Midburg: skilled labor supply, the ability to subcontract work, and cultural opportunities. Move the pointer to cell D10 and change the weight for skilled labor supply to 5. The decision stays the same. Change the weight in cell D10 back to 4. Now move the pointer to cell D11, and change the weight for the ability to subcontract work to 4. The decision stays the same. Now try 5. The decision is still the same. Change the weight back to 3.

Finally, experiment with the weight given cultural opportunities. Move the pointer to cell D14 and change the weight to 4. A preference number less than 1 (0.72) results, changing the decision to Midburg. Since the search committee may balk at a cultural-opportunity weight of 4 in this decision, you may want to reevaluate the weight assigned to this factor. Change the weight back to 2.

USING AND MISUSING DIMENSIONLESS ANALYSIS

The worksheet in figure 1 is called a dimensionless analysis model because the preference number has no natural dimension, such as dollars or miles. This number merely indicates the decision that is consistent with the preferences (the scores and weights) expressed in the model.

Dimensionless analysis can compare only two alternatives at a time. If you have more than two alternatives, start with any two and find the better choice. Take the better choice and compare it with another alternative. Keep going in pairs until you cover all the alternatives.

In setting up a model, make sure that you are consistent in assigning scores. In figure 1, lower numbers mean better scores throughout the model. A preference number less than 1 favors alternative A (Midburg), while a number greater than 1 favors alternative B (Fort Mudge). You could choose to have larger scores mean better throughout the table, where preference numbers less than 1 favor B, while numbers greater than 1 favor A. Just be consistent. Don't use smaller numbers to represent better scores for some factors and worse scores for other factors. If you do, the preference number will be meaningless.

Sometimes it is hard to be consistent. Suppose, for example, that in the Maxwell Industries scenario you wanted to use profits rather than manufacturing costs, but keep all the other numbers the same. The solution is to multiply the weight assigned to profits by −1. Then the formula in cell E7 would be (B7/C7)^−D7, which inverts the ratio. If Midburg's profits are larger than Fort Mudge's, the negative weight makes the ratio less than 1, which is consistent with the rest of the model. This is your only option unless you find another way to set up the problem.

Like any other model, dimensionless analysis is a limited abstraction of the real world. But it is a considerably richer abstraction than models that deal only with costs or profits. The real advantage of dimensionless analysis is that it forces you to organize and evaluate all the data relevant to a decision, however fuzzy that data might be. ■

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