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Title: A Study of Strategic and Tactical Decision Making Procedures

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Dr. James L. Riggs

An extensive literature survey investigated methods and approaches for evaluating intangible economic factors at the strategic and tactical levels of managerial decision making. These sources provided: 1) the background for a theoretical decision making algorithm developed for comparing alternative economic proposals for effectiveness at the strategy levels, and 2) a number of techniques for measuring intangible properties quantitatively at the tactical levels.

A technique developed by Barish, and in combination with a procedure by Churchman and Ackoff for comparing intangible and tangible objectives, was presented as a working method for comparing strategic alternatives. The comparisons thus derived for individual decision making can be integrated with the aid of Helmer's "anonymous debating procedure."

The initial development of a decision making algorithm, Part I, used subjective scales of relative effectiveness values representing the competing strategies. Paired comparisons were employed to achieve ordinal scales. Then, employing Siegel's "higher-ordered metric" scaling procedure, ordered metric scales

were developed, followed by more accurate higher-ordered metric scales of subjective effectiveness values.

In Part II of the decision process the best of three alternative methods for converting subjective ordered scales into interval scales was employed to attach quantitative values to scale positions; the Higher-Ordered Metric Minima approach was selected over the Ordered Metric Minima approach and the Standard Gamble approach.

In Part III the interval scales of Part II were transformed into ratio scales, based on known zero effectiveness strategies. Employing the weighted average method, the scales under each criteria were combined by having the experts weight themselves. Then the conflicting objectives were weighted according to an adaptation of Helmer's procedure, and the objective-strategy scales were combined into one scale of overall effectiveness.

A section was provided in which methods of assigning dollar values to intangible effects at the tactical levels were presented, considered under three general categories.

Under the category of "intangibles evaluative with respect to market values," examples of measuring intangible property values of a firm were given, according to Marston, Winfrey, and Hempstead. Under the category of "intangibles not evaluative in terms of market values," Helmer's "anonymous debating procedure" for arriving at median values by determining mean estimated values of experts was presented. Stanly's "expected cost" method, in which expected values were established through the multiplication of probabilities of occurrence by estimated values of occurrence was discussed. Secondly, a number of examples of associating dollar values to intangible effects were presented under the "valuation method." Thirdly, under the category of "complete intangibility," in which intangible effects are not considered evaluative in monetary terms, the exponential rating method was described, in which alternative proposals are subjectively rated according to their effectiveness in achieving intangible objectives, and all objectives are ranked in terms of their relative importances.

In conclusion, the decision making algorithm developed in this thesis represents an attempt to achieve systematic and objective decision making at the strategy level. Furthermore, it forces decision makers to concentrate on all aspects of competing strategies when making relative comparisons.

The intangible methods of evaluation presented at the tactical levels for measuring competing proposals monetarily are very limited in their accuracy; however, they cause the decision makers to consider important intangible effects and to attempt to dollarize them meaningfully.

A Study of Strategic and Tactical Decision Making Procedures

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CHAPTER I

INTRODUCTION

This thesis is concerned predominantly with the difficult and often complex problem of making relative evaluations of the various economic alternatives involved in a decision making problem at the strategy level, with respect to the many pertinent intangible objectives which exist. Of secondary importance, this thesis will bring to light available methods of quantitatively evaluating competing proposals at the tactical levels of decision making with respect to important intangible objectives which exist in conjunction with tangible criteria.

Motivation Toward Study of Intangibles

The motivation which created the writer's interest toward pursuing the area of intangible considerations in decision making came from two sources: 1) the desire to research the work done and methods espoused by engineering economists, mathematical and industrial psychologists, and operations researchers regarding the measurement of supposedly irreducible economic factors- and to put such approaches into perspective, hopefully adding some new insights into this nebulous area; and 2) the fact that so little success has been achieved in attempting to make relative evaluations of alternative program proposals with respect to intangible objectives (which are of primary importance at the strategy level of decision making when evaluating alternatives in business and governmental programming), makes this a lucrative area for investigation. Thus, as one author states, this quantification of intangibles is not only the most important part of the analysis of decisions, but also the most difficult and most primitive with respect to scientific development. Indeed, some people believe that science can never make much of a contribution to the problem, while others strongly disagree (Morris, 1960).

Engineering Relevance

Subjects discussed in texts on engineering economics are largely directed toward the problems of making tangible analyses and evaluations of engineering and business alternatives. Tangible evaluations are typically more accurate, objective, and reliable than intangible evaluations. However, it is frequently not realistic to evaluate only tangible factors pertinent to an economic decision. Thus, it would be beneficial if some successful means of evaluating intangible factors were available.

It is to be noted that the basic difference between tangible and intangible factors is the ease and cost of evaluating in dollars the costs and benefits of each factor associated with each alternative. Only the simpler managerial decisions made (involving only minor mechanical equipment investment, for example), are executed on the basis of cost and benefit information derived from solely tangible factor considerations (e.g., first cost, annual maintenance expense, annual production, salvage value); in this case alternative proposals are measurable in monetary units directly in terms of market values, and thus are compared in such common units. The only difficulties which arise are the firm's inability to forecast the discount rate (when making comparisons using present worth method), and the life pattern equipment and production values.

Most outcomes of investment proposals contain aspects which are relevant to the objectives of the firm but cannot be readily evaluated in terms of cost, profits, or whatever measures of value are being employed. While the monetary unit is the most popular, convenient, and universally comprehendible, not all aspects of a proposed outcome can be directly measured in these terms; and most firms have other objectives, such as customer service, goodwill, community reputation, job satisfaction, safety, employment stability, etcetera. These intangible factors are pertinent to engineering decision making, and need to be validly measured as objectively as possible to allow more accurate evaluation of competing economic proposals.

Statement of Problem and Objective

It is the predominant objective of this thesis to develop a systematic procedure for delineating and comparing alternative programs for achieving company goals when pertinent intangible objectives exist at the highest levels of decision making: the strategy levels. These strategic decisions are made at most levels within an enterprise. At the Global (Organizational) level (Starr, 1965), the company may be considering a particular venture in which to invest its resources. Should it make airplanes, automobiles, motor scooters, air-cars? Should the company enter the service business? Also, management may be considering the alternative of just investing available funds in stocks, bonds, and savings banks.

Once decisions are made at the highest levels, strategic alternatives begin to arise at each succeeding subordinate level of the organization. Kaiser Industries Corporation, for example, having made the decision to invest a given amount of resources in the production of aluminum, delegates to its aluminum division the responsibility of choosing between numerous possible consumer and industrial products to be manufactured in its many production centers. Then, based on marketing forecasts, resources available, competitor activities, and business trends, together with judgment and intuition, the products are chosen and quantities of each to be manufactured are determined.

At each strategy level of decision making, every alternative strategy involves at least one, and usually numerous, tactical approaches to achieve it. The important thing to be noted is the differentiation between the procedure for comparing alternative programs at the strategy level, versus the competing strategic implementation tactics at the tactical level. In Chapters II through VI a systematic decision making process at the strategy level will be developed, involving the determination of program objectives and alternative strategies, and the method of comparing alternatives when intangible objectives are important. In Chapter VII methods of quantifying intangibles at the tactical levels are presented.

Organization

Having stated the objectives of this study, the factors motivating it, and its engineering relevance, the following organization of subjects is presented to conclude the introduction:

Chapter II is a discussion of: 1) the determination of problem objectives, and 2) the patterns, extent, and techniques of generating alternative program strategies in preparation for the decision making stages of problem solution.

In Chapter III the results of an extensive literature research are reviewed. Pertinent theoretical techniques espoused by eminent representatives from diverse fields such as mathematical psychology and engineering economy, are extracted. These extracts establish the foundations for later development of the "subjective algorithm" for decision making.

Then Chapter IV presents the theoretical design of the "subjective decision making algorithm" at the strategy level which is emphasized in this thesis. This chapter incorporates the contributions of those referred to in Chapter III, in conjunction with the individual ideas of the writer.

Chapter V presents alternative approaches for transforming the subjective scales of relative values achieved in Chapter IV into objective internal scales. These methods include: the Ordered Metric Minima approach, the Higher-Ordered Metric Minima approach, and the Standard Gamble approach. Advantages and disadvantages of each are discussed. Chapter VI, entitled "Scale Synthesis," offers a method for transposing the interval scales of Chapter V into ratio scales so that the various scales for each decision maker can be combined. Methods for weighting each decision maker's responses regarding judgmental ability, and for weighting the various conflicting objectives are then presented. Using these contributions, the scales are combined into a consensus preferential scale of the decision maker's strategies.

Chapter VII reviews a number of proposed methods from the literature for measuring intangible effects at the tactical levels of decision making. Methods are recorded under three general levels of intangibility.

Finally, Chapter VIII summarizes the theoretical methods discussed in this thesis and draws tentative conclusions. In addition, some suggestions for future research are presented.

CHAPTER II

DEVELOPING ALTERNATIVE STRATEGIES

Determining Objectives

The first step in any decision making process is the formulation of the problem. It involves the resources available in the form of men, materials, and equipment inputs, the time limit and other restrictions for achieving a satisfactory output, and a precise statement of the tangible and intangible organizational objectives (goals), along with the criteria by which alternative strategies will be measured as to their effectiveness in achieving the objectives.

Of paramount importance in this initial stage of decision making is the specific delineation of organizational goals by the decision maker(s), since alternatives at every subordinate level will be measured and evaluated with respect to such goal effectiveness. (For specific qualification characteristics of goals, see p. 16 under Procedural Assumptions.) Such goals may be, for example: profit, company expansion, diversification, customer goodwill, safety, employment stability, research development, etcetera.

> Contradictory aims and nebulous goals result in confusing objectives. An assignment to get the 'finest equipment for the least amount of money' is bewildering. It may be possible to decide what is the 'finest' equipment, but it is unlikely to be the least expensive. In a similar vein, a charge to get the 'best equipment for our purposes' is too broad to be useful. Double standards and indefinite objectives lead to second-guessing. A precise statement of realistic goals simplifies the entire decision making process (Riggs, 1968, p. 14).

Generating Alternative Strategies

The next stage in the process is that of defining alternative proposals which will achieve the stated objectives with various degrees of effectiveness. The personnel involved in this task must have a clear picture of organizational goals, a broad knowledge of company resource capabilities and potential, and an acumen for creating alternative potential programs based on experience and knowledge.

Given Alternatives

Sometimes alternative courses of action are given to us, sometimes they are forced upon us, and sometimes they must be developed or discovered. Before going on to the process of generating alternative strategies, it is worth noting some of the conditions which lead to the assumption that alternatives have already been given: (Morris, 1960)

1. If it is believed that no alternatives exist beyond those already under consideration, it is natural to assume that the alternatives are to be taken as given. Also, the same assumption will be made if the decision makers believe that there are no better alternatives than those under consideration, or if the cost of discovering better alternatives is believed to be excessive.
2. The assumption that alternatives are given is used differently at different levels and positions in the organization. In more authoritarian organizations, alternatives

for subordinate level decision making are defined from above; under more permissive organization philosophies, subordinates are free, even urged, to create their own strategies.

3. Many of the conditions which lead to the assumption that the courses of action are given can be characterized by the term "institutional rigidity." This condition can be the result of individual or group resistance to change on the part of the decision makers, tradition and ego involvement which limits the spectrum of alternatives, or the influence of past decisions on the alternatives considered, which either forces management to pursue its present course of action, or makes it wary of new alternatives depending on resulting conditions of such past decisions.

4. Finding new alternatives takes time, energy, and money. Therefore, pressures resulting from limited supplies of any one of these factors limit the search for new alternatives.

5. If conditions which have led to a choice between fixed alternatives repeatedly in the past exist, company policy often exists which forces the continuation of this same choice. For instance, a firm which, when it falls behind some expected production schedule, always chooses between the strategy of working overtime or not working overtime, rarely considers other alternatives (e.g., subcontracting some work, revising production schedule,

increasing work force).

The overall question is, then, when is it necessary to search for new alternatives? A general principle which answers this question is presented in the statement of management of objectives, which suggests that as long as alternatives are available which will meet certain standards set by management, then there is no need to search for new ones. Because of the factors of time, energy, and money mentioned above, rarely does the search for satisfactory alternatives which will achieve company objectives become an exhaustive one in which only the optimal strategy is deemed acceptable.

Pattern of Search

When it is decided that additional alternatives should be searched out, two common approaches might be taken:

1. A random approach may be employed, in which the searchers simply use whatever information is available or remain alert for information as it arises, investigating potentials as they are brought to attention.
2. A systematic approach might be instituted, in which potentially lucrative areas for alternatives are divided and searched out. For example, a firm seeking a new plant site may divide the country into districts, number the districts, and then search through them in numerical order for alternative plant sites. Such a system may result in fewer alternatives being missed, and efficiency

being increased by reducing costs and search time. The problem with this approach, however, is that it requires advanced knowledge of alternatives normally not yet known, as well as where they may be found. Therefore, the more advanced information decision makers have concerning potential courses of action, the greater the possibility that a systematic search scheme may be designed to increase search efficiency.

Extent of Search

With regard to the question of how many alternatives should be obtained before terminating the search, it is usually true that an exhausting search will rarely be employed. Instead, the decision to stop looking may be made according to the following rules: (Morris, 1960)

1. Decide in advance the specific number of alternatives to be searched out before a decision is made. However, this arbitrary approach is hard to justify rationally.
2. Continue searching until the marginal cost of discovering an additional alternative is greater than the marginal gain to be derived from it. This rule is severely lacking in in possibilities for direct application since at the strategic level the decision makers are not equipped with specific marginal revenue data. Also, it is rarely possible to prognosticate in advance the marginal cost of discovering an additional alternative.

3. Search for alternative investment opportunities until one is discovered which will yield a return equal to the firm's minimum acceptable rate. This rule appears feasible, but is more readily applicable to tactical decisions at lower functional areas. If employed at the strategic level, this rule would require making a cost-benefit analysis of the tactical solutions to each strategy as it arises to determine the expected rate of return. This could be costly and time consuming; also, the risk of neglecting consideration of a superior alternative is great.

Because of ignorance, which prevents the application of a maximizing principle to the search process, such investigations are usually conducted with the goal of simply discovering satisfactory alternatives.

Techniques of Search

The general approach to discovering alternative strategies is characterized by the terms "creativity" and "imagination," the techniques of which are described fully in Alex Osborn's, Applied Imagination (1963) and in A. L. Simberg's, Creativity at Work (1965). A few useful schemes are presented here for developing alternatives:

Modification of Alternatives. This technique involves asking a series of suggestive questions relating to an existing or known alternative in an attempt to modify it. Such questions may be:

a. Can any part of the alternative be eliminated?

b. Can it be combined with other alternatives?

c. Can any aspects of it be increased? What happens if we maximize some aspect of it?

d. Can any aspects of it be decreased? What happens if we minimize some aspect?

e. Can the people involved be changed? Can the location be changed? Can the resources used be changed? Can the time be changed?

f. What if some aspect of the decision situation were different?

Group Processes - Brainstorming. A group brainstorming session can result in a wealth of creative and imaginative ideas, many of which form practical strategic alternatives. Unlike typical committee, research, desig n, or informal groups, the brainstorm group functions in a completely free atmosphere in which thought processes are stimulated to elicit highly original ideas. That is, the session is conducted such that fear of criticism or evaluation of ideas is non-existent so that group member inhibitions are alleviated as much as possible.

CHAPTER III

THEORETICAL BACKGROUND

Work Done by Others

Before progressing to the theoretical development of a technique for comparing alternatives for effectiveness, consideration will be given to an existing technique for comparison that has had applications in industrial situations. Barish (1962) developed a method for making comparisons between alternative strategies when intangible objectives are among the significant goals, based on a technique for comparing decision objectives created by Russell L. Ackoff and Charles W. Churchman (1954). This technique has also been discussed by Morris (1960).

The basic structure of the Churchman-Ackoff method for comparing intangible and tangible objectives in a decision situation is composed of the following steps:

1. Determine the relative importance (I_{θ_i}) of each n objectives ($\theta_1 \ldots \theta_n$) of the alternative proposals (A_j).
2. Evaluate how effectively ($E_{A_j\theta_i}$) each alternative meets each of the given objectives, employing an effectiveness rating.
3. Compute a rated value for each alternative by calculating the weighted average of the effectiveness ratings, i. e., the rated value for $A_j = \Sigma_{i,j} I_{\theta_i} E_{A_j\theta_i}$.

The form for making the calculations is shown on the following page. Each objective is listed in rank order of relative importance

Objective or Criterion (θ_i)	Importance Rating (I_{θ_i})	Adjusted Importance Rating (I'_{θ_i})	Alternative 1		Alternative 2		----	Alternative m	
			Effectiveness Rating ($E_{A_1\theta_i}$)	Rated Value ($I'_{\theta_i}E_{A_1\theta_i}$)	Effectiveness Rating ($E_{A_2\theta_i}$)	Rated Value ($I'_{\theta_i}E_{A_2\theta_i}$)	----	Effectiveness Rating ($E_{A_m\theta_i}$)	Rated Value ($I'_{\theta_i}E_{A_m\theta_i}$)
(1)	(2)	(3)	(4)	(5)	(4)	(5)		(4)	(5)
θ_1	I_{θ_1}	I'_{θ_1}	$E_{A_1\theta_1}$	$I'_{\theta_1}E_{A_1\theta_1}$			---	$E_{A_m\theta_1}$	$I'_{\theta_1}E_{A_m\theta_1}$
θ_2	I_{θ_2}	I'_{θ_2}	$E_{A_1\theta_2}$	$I'_{\theta_2}E_{A_1\theta_2}$				$E_{A_m\theta_2}$	$I'_{\theta_2}E_{A_m\theta_2}$
⋮	⋮	⋮	⋮	⋮				⋮	⋮
θ_n	I_{θ_n}	I'_{θ_n}	$E_{A_1\theta_n}$	$I'_{\theta_n}E_{A_1\theta_n}$				$E_{A_m\theta_n}$	$I'_{\theta_n}E_{A_m\theta_n}$
Total		100	xxxxxx	$\Sigma_i\ I'_{\theta_i}E_{A_1\theta_i}$	xxxxxxx			xxxxxxx	$\Sigma_i\ I'_{\theta_i}E_{A_m\theta_i}$

Figure III-1. Evaluation Worksheet

in column (1). In column (2) the most important objective is given the rating of 100 and the remaining criterion are given ratings relative to it and to each other. Then, in colum (3) the total of all importance ratings is made to add up to 100 by adjusting the ratings in colum (2). This is accomplished by dividing each rating in column (2) by the total of that column, and multiplying the result by 100. In column (4) each objective is rated for effectiveness. Then, by multiplying each effectiveness rating in column (4) by the respective adjusted importance ratings, the rated values in column (5) are obtained. Adding these values in (5) and dividing by 100 gives the overall rating value for that alternative.

Procedural Assumptions

For the above procedure to be applied logically, a number of conditions must be satisfied by the various criteria involved:

1. Each objective must be distinct, i. e., one not implying or being part of another more comprehensive objective.
2. Independent - the achievement of one must not affect the achievement of any other.
3. Not contradictory - the achievement of any combination of objectives must be possible.
4. Additive - the degree of achievement of each objective should add to the overall desirability. For example, if the objective of "high quality" is rated as 40 per cent important and "low cost" as 30 per cent, then an alternative giving "high quality" and "low price" should be worth

70 percent as opposed to any other value greater than or equal to 70.

In actual application of this technique it is often difficult to satisfy entirely all the above conditions. However, the closer they can be adhered to, the more accurate will be the evaluation.

Improving Reliability of Importance Ratings

By instituting the following systematic procedure for checking judgments concerning relative importance ratings for each objective, one can improve the reliability and accuracy of these ratings:

1. List the objectives in descending order of importance ($\theta_1 > \theta_2 > \theta_3 \ldots > \theta_n$).
2. Compare θ_1, the most important objective, to all others combined. Determine whether it is less than, equal to, or more important than the others ($\theta_1 <, \overset{?}{=}, > \theta_2 + \ldots + \theta_n$).
3. If the first objective is more important than the others combined (i. e., $\theta_1 > \theta_2 + \ldots + \theta_n$), check its rating to make sure it reflects this judgment.
4. If the first objective is deemed equal to the others ($\theta_1 = \theta_2 + \ldots + \theta_n$), make sure its subjective rating equals the total combined ratings of the remaining criteria.
5. If the first objective is deemed less important than the others combined, (i. e., $\theta_1 < \theta_2 + \ldots + \theta_n$), check its rating and correct it, if necessary, so that it will adhere to this judgment.
6. In the event the first criteria was deemed more important

or equally important to all others combined ($\theta_1 \geqq \theta_2 + \ldots + \theta_n$), apply the same procedure to the second most important objective as was applied to the first criteria in steps (3), (4), or (5).

7. If the first objective was considered less important than all others combined, ($\theta_1 < \theta_2 + \ldots + \theta_n$), compare it to all other criteria except the lowest one ($\theta_1 \; ? \; \theta_2 + \ldots + \theta_{n-1}$). Is it more important, equally important, or less important to these criteria combined? Then continue as in (3), (4), or (5) above. If (3) or (4) apply, go next to step (6). If (5) applies, proceed through this step (7) again, comparing the first objective with all the remaining criteria except the lowest two ($\theta_1 <, \overset{?}{=}, > \theta_2 + \ldots + \theta_{n-2}$). As long as (5) applies, step (7) is repeated until the first objective is compared only to the second and third put together; then the procedure can continue on to (6).

8. Continue the above procedure until the third from the lowest objective has been compared with the two lowest objectives on the list.

9. Finally, after completing the procedure, review all comparisons to ensure that later adjustments have not destroyed relationships which were originally established.

A form for applying the above procedure is shown below:

Objective or Criterion (θ_i)	Initial Importance Ratings (I_{θ_i})	Importance Rating Revisions						Adjusted Importance Ratings (I'_{θ_i})
		1	2	3	4	---	r	
θ_1 θ_2 . . . θ_n	I_{θ_1} I_{θ_2} . . . I_{θ_n}							I'_{θ_1} I'_{θ_2} . . . I'_{θ_n}

Figure III-2. Criteria development sheet.

When more than six objectives are involved in the analysis, a modification of the procedure is necessary to keep it from becoming awkward:

1. List objectives in descending importance.
2. Select an objective (θ_i) at random.
3. Assign all remaining objectives randomly into groups of nearly equal size, with no more than five in a group.
4. Add the selected objective to each group and assign the importance rating of 100 to it.
5. With the rating of the selected criteria held constant at 100, rank the objectives in each group in descending importance and assign ratings to them.
6. For each group follow the procedure outlined previously, but without changing the selected objective rating of 100, and without adjusting ratings to total 100.
7. Make a combined listing of all the objectives in order of decreasing importance and compare this with the initial

one made in (1), noting any differences in ranking. Then, if the initial listing is still deemed correct, the steps of the previously outlined procedure should be repeated to adjust the affected groups and to reconcile evaluations.

Establishing Benchmarks for Effectiveness Ratings

The method established by Barish for establishing benchmarks for effectiveness ratings of intangible qualitative criteria involves the construction of "rough-and-ready" benchmarks. He constructs them using descriptive adjectives to describe the criteria (θ_i) achievement by the various competing alternatives, and then uses a benchmark table to find the effectiveness.

The following example using the criteria of "flexibility in meeting changing needs" illustrates the above method:

Benchmark	Effectiveness Rating
Extremely Inflexible	0
Moderately Inflexible	25
Average Flexibility	50
Moderately Flexible	75
Unusually Flexible	100

Figure III-3. Example of benchmarks for effectiveness.

Employing similar benchmarks for other criteria and subjectively rating each alternative with respect to each benchmark, the rated values for each objective-alternative pair can thus be computed.

Advantages of Barish, Churchman-Ackoff Technique

In many respects the technique developed in this section is feasible. The prominent virtues of the Barish, Churchman-Ackoff Technique are:

1. The method is quite simple to apply.
2. It has been applied successfully to some industrial decision problems (Ackoff and Churchman, 1954):
    a. To establish a priority list for equipment requested by various departments of a firm.
    b. To evaluate the relative importance of various product characteristics in a new-product search by a firm.
    c. To evaluate the following objectives of a firm for the purpose of making decisions about long-range plans: 1) security of existing management, 2) financial opportunity security, 3) financial opportunity, 4) security and promotion of key personnel, 5) labor stability, 6) technological leadership, 7) community service.
3. The scales of value measurement developed by Churchman-Ackoff for objective rating, and by Barish for effectiveness rating, can be classified as "Quasi-interval" scales, in that: a) arbitrary zero points are established, b) constant units of measurement in terms of utility units are "implied," and c) relative numbers are assigned to entities

based on subjective utility measurements.

4. The technique has the advantage of providing a systematic and organized way of checking consistency of value judgments regarding objectives.

Limitations of Barish, Churchman-Ackoff Technique

1. The basic value judgments are nothing more than judgments. This is, of course, a limitation of all techniques involving subjective, vis-a-vis objective, decision making. The quality of such judgments, then, improve with the competence of the decision maker(s), and with the procedure employed to achieve these judgments.
2. The technique concentrates on the determination of the relative importances of the objectives involved in the problem, with small mention of the method of achieving effectiveness ratings for competing alternative strategies. That is, the quantitative approach for rating these strategies is not expounded upon in a detailed analysis, and the manner of eliciting the decision makers' responses is not revealed. Perhaps such judgments could be made by a group of persons, such as the executive committee of the firm. One method would be to have each member of this group go through the process independently. The individual values may then be simply averaged or some process of discussion and search for consensus may be undertaken. Further, to weight every person's decisions

equally is democratic, but any number of other methods might be employed, perhaps weighting the results of some more than those of others.

3. The approach to quantifying the relative importance of the various objectives reveals only approximate values, since the values obtained are not unique. There are other sets of numbers which could also be shown to satisfy the judgments given in the procedure discussed.

4. It is important to keep in mind some important assumptions which form the basis for the foregoing technique:

    a. It is assumed the decision maker will be able to rank all of the outcomes.

    b. It is assumed the ranking will be transitive.

    c. It is assumed he can make meaningful assignments to points on a zero-to-100 scale. "Meaningful," as used here, implies that the scale values do somehow reflect his strength of preference.

    d. It is assumed that values obtained are additive, i.e., the value of the combination of two outcomes is the sum of their individual values.

Background for "Subjective Algorithm"

Having compiled a set of strategic alternatives, all of which achieve program objectives with varying degrees of effectiveness, the decision makers are now faced with the responsibility of employing both intuition and judgment, based on experience and knowledge, to evaluate and compare, alternative programs.

At this stage the intuition and judgment of qualified experts, intimately and expertly involved with the problem, will form the basis for comparison of strategies. "Intuition is liberally spiced with instinctive judgment. As such, it is a valid tool in the decision maker's repertoire, provided the logic is not dulled by fad rules-of-thumb or unrecognized bias"(Riggs, 1968, p. 7). Indeed, analytical, quantitative methods are more revealing and result in more confident, valid comparisons; however, in the framework developing here, more analytically-oriented comparisons are reserved for the tactical decision levels. The basis for such reasoning is; 1) the time, energy, and cost involved in comparing tactical efficiencies for several strategies is difficult to justify; 2) the complexity of determining the tactical efficiency relative to important intangible objectives compounds the problem. According to A. L. Stanley:

> An executive's decision making ability is a difficult art requiring the balancing of a multitude of factors and the application of judgment. Judgment is very important when considering the many factors of a noncommensurate intangible nature, not readily evaluatable in numerical terms. Judgment thus utilized is necessarily based in part on an intuitive evaluation, which is the integrated result of past experience, logical reasoning, and personal preference (Stanly, 1955, p. 778).

As contended in this section, the reliance on expert judgment is an indispensible part of comparing strategies, particularly when intangibles are pertinent in the evaluation. Furthermore, the range of required expertise is not likely to be found in one single individual at this level of decision making. Hence, to improve the overall validity of comparisons, a variety of experts need to be consulted. They are aware of the alternative approaches available and and have an insight into the possible tactical procedures which could be implemented to realize such strategies. Their situation is analogous to that of a staff of military generals meeting to determine the best strategy for employing the military resources available in order to achieve given war objectives. At the same time they are aware of the different tactical maneuvers related to each strategy. Should they invade Cuba, China, North Korea, or Berkeley? If the strategy is to invade Berkeley, should the tactics involve military power or flower power?

To illustrate the decision problem to be solved, the hypothetical example shown below could be the relationship between competing strategies and tactics as one expert pictures it:

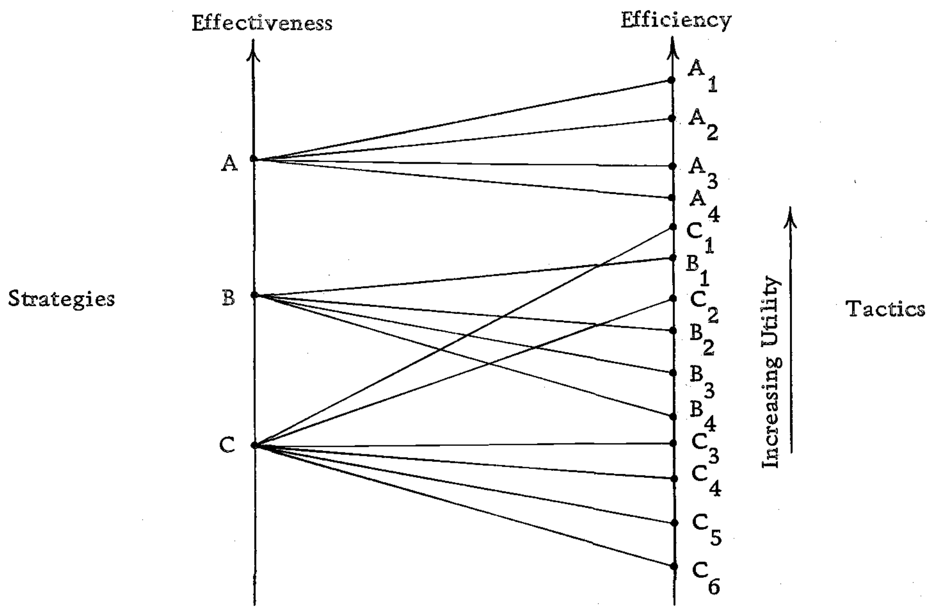


Figure III-4. Strategies and related tactics.

Each decision maker will have formed a judgmental picture, similar to that illustrated, which he arrived at by weighing the utilities of the strategic-tactical combinations, based on: 1) his subjective feeling for the degree of risk involved in the accomplishment of each one, 2) the time considerations related to their achievement, and 3) his judgment as to the actions in which competition will engage in the interim. From such a picture these experts will arrive at an ordinal scale of values, which will reflect their relative utilities for each strategy. The final problem is to combine the utility scales for each expert so as to achieve a panel consensus.

Contributions of Helmer to the Theoretical Development

Experiments have shown that the best use of a panel of experts is not made by the traditional method of having the issues presented to them and debated in an open forum until a consensus of opinion results by majority vote. Such sessions have psychological drawbacks involving such factors as group dominance by certain individuals, submissiveness and inhibition of thought by others, as well as the tendency toward conformism of opinion based on mental-emotional pressures vis-a-vis intelligent reasoning. Therefore, to alleviate these effects and to create a setting in which the pros and cons of the various strategies can be examined systematically and dispassionately, Helmer (Cleland and King, 1969), provides an atmosphere in which experts' opinions, as well as their arguments in defense of these opinions, are kept anonymous. With the aid of this anonymous debating procedure, it is hoped that a group position regarding the relative utilities of strategies can be attained.

Siegel's "Higher-Ordered Metric Scale"

Before continuing with the theoretical procedure for comparing alternatives at the strategy level, it is necessary at this point to develop, according to Siegel, the method for obtaining an higher-ordered metric scale. This scale will not only allow each decision maker, employing the paired-comparison method, to order with consistency the competing strategies involved on the basis of his utility preferences (ordinal scale), but also will reveal his judgment as to the relative sizes of the differences in utility between the strategies (higher-ordered metric scale), according to Siegel (1964).

Von Neumann and Morgenstern (1947), suggested that a person's utility could be measured to a higher degree than ordinality if: 1) the person can always say whether he prefers one entity to another, and 2) the person can also completely order probability combinations of the entities, i.e., combinations of entities with stated probabilities of attainment. Regarding the second condition, suppose a given individual rates three entities (A, B, C), in the order $A > B > C$, and then he is given a choice between (B, C; $\frac{1}{2}$), read: the combination of B and C, with probability $\frac{1}{2}$ of getting B and probability $\frac{1}{2}$ of getting C; and (A, A; $\frac{1}{2}$), i.e., getting A for certain. Here it is certain that he will choose (A, A; $\frac{1}{2}$) since $A > B > C$. Now suppose the individual is given a choice between (B, B; $\frac{1}{2}$) and (A, C; $\frac{1}{2}$). That is, he is to choose between the alternative of getting B for sure, or of getting either A with probability $\frac{1}{2}$ or C with probability $\frac{1}{2}$. This important decision yields added information and is the basis upon which the higher-ordered metric scale is built. If he chooses (B, B; $\frac{1}{2}$), then it is implied that B must be closer to C on the scale than it is to A. This information is not reflected in the ordered preference scale $A > B > C$, and it implies that the utility difference between A and B is less than that between B and C, or $\overline{AB} < \overline{BC}$.

A second source drawn upon in higher-ordered metric measurement is Lattice Theory (Birkhoff, 1948), which offers a heuristic device for indicating what minimum information is necessary for achieving a higher-ordered metric scaling. Such a lattice, involving only five entities, is shown below. It serves to give a descriptive ordering of probability combinations of the entities (based on the decision maker's preference rankings), and also to reveal which probability combinations are not orderable, (i. e., are nonorderable), simply from knowledge of the preference rankings.

In the lattice shown on the next page, where there is a connecting line between two probability combinations, the higher probability combination is preferred to the lower. Hence, any two probability combinations on the lattice that can be connected with a line which is consistently going up (or down) can be ordered. For example, (A, A; $\frac{1}{2}$) > (A, B; $\frac{1}{2}$) > (A, C; $\frac{1}{2}$) > (A, D; $\frac{1}{2}$) > (A, E; $\frac{1}{2}$). However, the simple ranking does not reveal information concerning the nonorderable combinations not connected by a line always going in the same direction with respect to horizontal and vertical (e. g., (A, E; $\frac{1}{2}$) ? (B, C; $\frac{1}{2}$); (A, C; $\frac{1}{2}$) ? (B, B; $\frac{1}{2}$); (B, E; $\frac{1}{2}$) ? (C, C; $\frac{1}{2}$)).

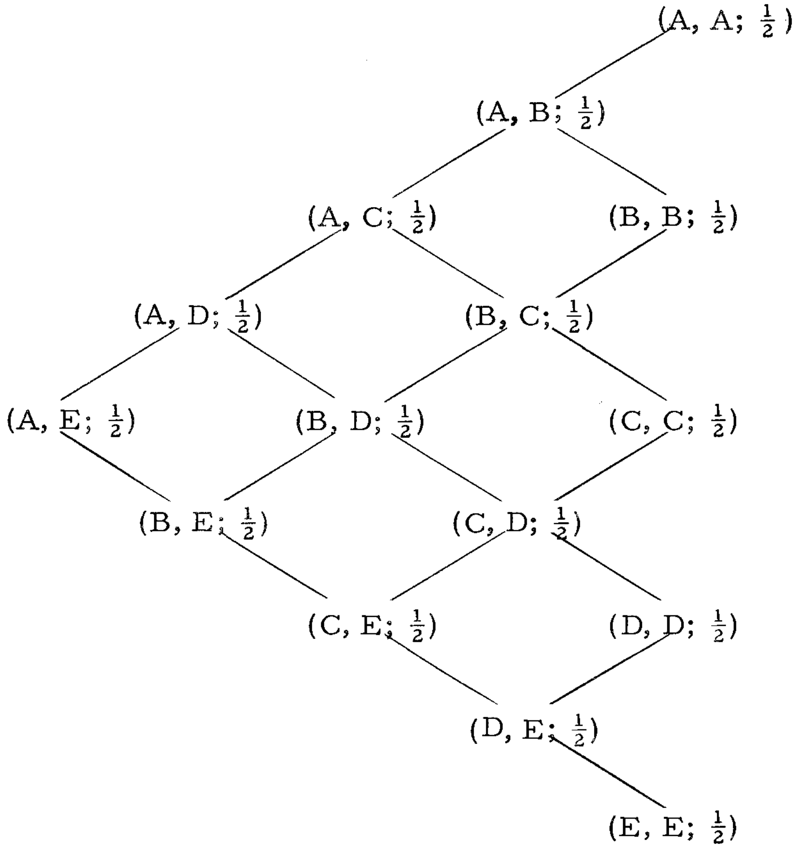


Figure III-5. Lattice of probability combinations.

Therefore, knowing the relations between these nonorderable pairs of probability combinations, we can construct a higher-ordered metric scale from an ordinal scale. It can be shown, according to Siegel (1964), that if N is the number of entities to be scaled, then the number of nonorderable probability combinations is computed from the combinatorial formula: $\binom{N+1}{4}$. Not all nonorderable combinations are necessary to form a higher-ordered metric; the remaining ones are, however, used as a check on consistency.

The general method of obtaining a higher-ordered metric scale can now be outlined according to Siegel:

1. Require the decision maker to rank, using the paired

comparisons method, the entities involved.

2. Ask the person to reveal his preference between each nonorderable pair of probability combinations.

3. Observe those choices which will allow the determination of an ordered metric scale, which orders the distances between <u>successive</u> entities (i.e., $\overline{DE} > \overline{AB} > \overline{CD} \cdots$, where $\overline{DE}$ denotes the difference in utility between D and E, etc.).

4. Note those choices which allow the determination of a higher-ordered metric scale.

5. Check whether the remaining choices are consistent with the scale achieved in step four. If all of these choices are consistent, then all of the previously nonorderable pairs of probability combinations are consistent with each other and can be predicted from the higher-ordered metric scale derived.

CHAPTER IV

DESIGN OF DECISION MAKING ALGORITHM

Now that the necessary background has been established, a theoretical procedure for determining group consensus regarding competing alternative strategies will be delineated in the next three chapters. This chapter will be devoted to defining the procedural steps for arriving at subjective scales reflecting a decision maker's judgments. In the process of design a simulated decision making problem will be utilized to clarify the subjective algorithm approach outlined. Chapter V will reveal alternative methods for transposing the subjective scales of this chapter into objective, interval scales of values. Chapter VI will discuss approaches for combining scales for all decision makers and for all objectives.

Procedure

Define Decision Problem

In any problem situation (e.g., involving human relations, industrial enterprise, government policy-making, etc.), a decision is required regarding the transformation of resource inputs in the form of labor, energy, and materials, by some process into a specified set of outputs, based on predetermined objectives for accomplishment.

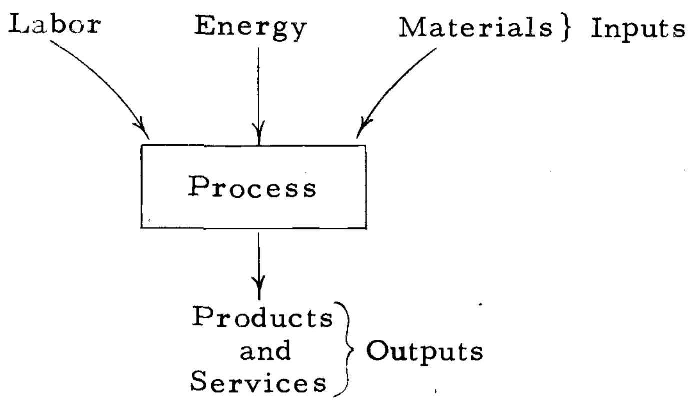


Figure IV-1. Input - output process model.

For simple illustrative purposes, a realistic problem could be one involving graduating college seniors subject to military duty after graduation. The problem for them is, what course of action should they take concerning their military obligation. For these students, the problem involves determining the best course of action (process), to employ to transform their human resources into desired outputs as specified by the problem objectives.

Determine Decision Making Panel

Because anonymity will be provided for, regarding individual decisions of experts, along with their responses in defense of their decisions, in theory an arbitrary group size can be chosen. Regarding the problem stated above concerning the graduating college students, the appropriate decision making panel would be a group of graduating male college seniors, all representing similar academic backgrounds except for individual uniqueness regarding major concentrations of interest. Therefore, with respect to a number of student-related problems, these individuals are experts: each having intimate knowledge of such problems as well as unique solutions based on their individual experiences, backgrounds, and special knowledge.

Hypothetically, the derived consensus of this panel regarding the solution to the military problem will affect each member equally. That is, the assumption is that the decision of the panel will define the mutual course of action to be taken by each member.

Define Tangible and Intangible Objectives

Unless the problem objectives have been "given" to the group in the problem statement, it is the job of the panel of experts to define the major criteria upon which subjective evaluations will be made regarding the relative effectiveness of each strategic approach to solving the problem.

In the case of our student decision makers, the pertinent objectives they would employ as a basis for measuring strategic effectiveness would probably be:

a. Minimize time in the military.

b. Maximize image of respect and admiration of others.

c. Maximize revenue to be earned during time period being considered (i. e., until military obligation period ends).

d. Minimize risk of losing life.

Define Strategy Set

The next step is the statement of the alternative strategies, given to or proposed by the panel, for meeting the problem objectives. (See previous chapter on generating alternatives).

For the student decision makers, the strategy set may consist of the following alternatives:

a. Enlist in the military upon graduation.

b. Wait for an induction notice.

c. Join the Peace Corps.

d. Obtain a position with a company in a necessary defense industry.

e. Leave the country (Canada).

Order Objective Preference

Having completely defined the problem and strategies facing the panel of experts, the next step in this theoretical development involves the construction of ordinal scales of relative effectiveness which are derived by each individual panel member to reveal the degree to which he feels the competing strategies achieve each given objective. This step is carried out by having each member reveal his strategy preference while in isolation from the other decision makers. In this way, group influences on judgment and behavioral-psychological difficulties are eliminated.

Hypothetically, one of the student decision makers might reveal his subjective preferences, employing the method of paired comparisons, regarding each objective as illustrated below:

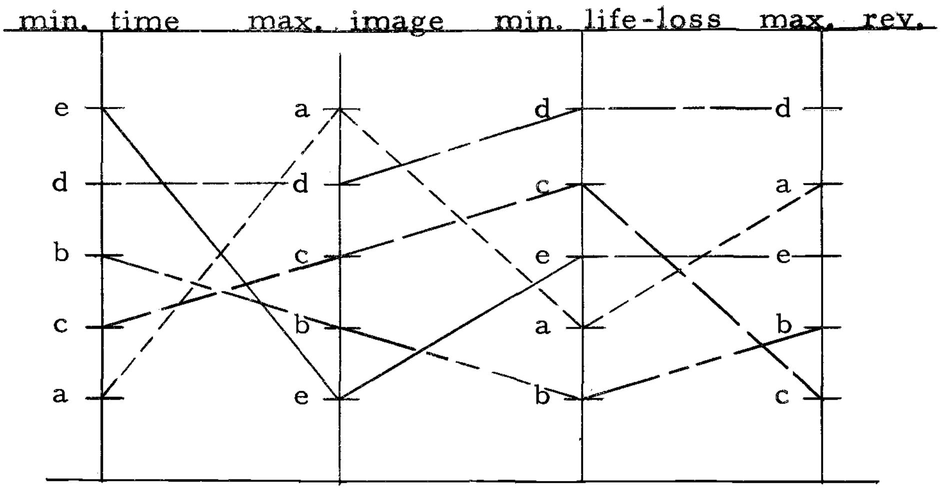


Figure IV-2. Paired comparison example: expert #1.

Another expert, #2, might make the following initial comparison judgments:

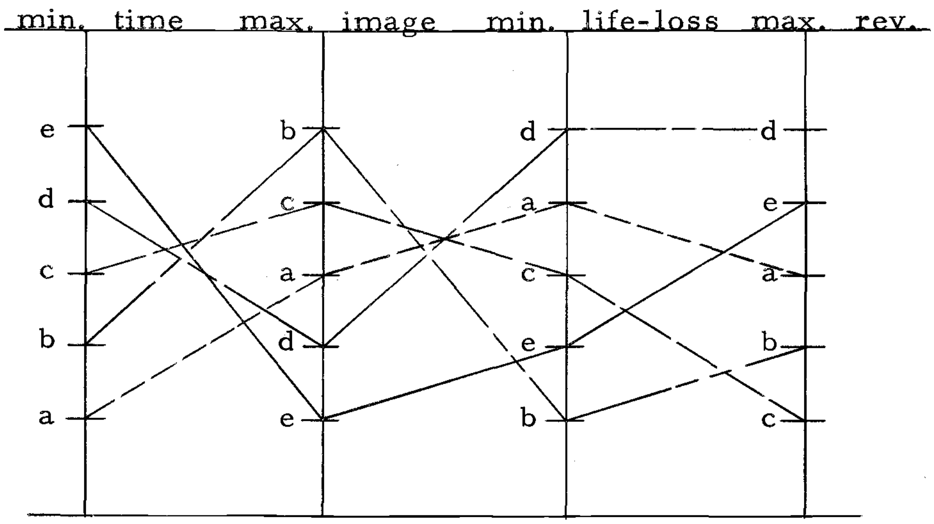


Figure IV-3. Paired comparison example: expert #2.

The differences in the judgments made by these two experts could be due to a number of causes: 1) difference in comparative knowledges concerning strategies and tactics; 2) difference in feelings of intuition and risk; 3) difference in judgmental processes, and; 4) difference in background and experience.

Communicate Information

Now that each man has developed a series of ordinal scales of subjective relative utility preferences, he has had the opportunity to employ his reasoning processes in evaluating the alternative strategies. It is appropriate, therefore, that the next step of the technique involves the communication of information between all decision makers regarding each one's reasons for ordering his preferences for the strategies as he did. Again, to preserve anonymity, each individual is asked to state concisely in written form the pertinent reasons for listing each strategy as he did under each objective. Then his responses in defense of his preferences are collected, duplicated, combined with responses of others, and submitted to all members on the panel. In this way, through the mutual sharing of all significant reasons employed in deriving the subjective preferences, the differences in background, experience, and knowledge between each member can be minimized with respect to the problem concerned.

Of course, as noted previously, it is imperative at the outset that each member be a qualified expert who is able to make such evaluations. Furthermore, it is imperative also that each man is similar in background such that he is able to understand the communications of all of his fellow decision makers. Only then can the exchange of information provide meaningful, thought-provoking material with which each expert can reexamine his initial utility preferences.

Reevaluate Ordinal Preferences

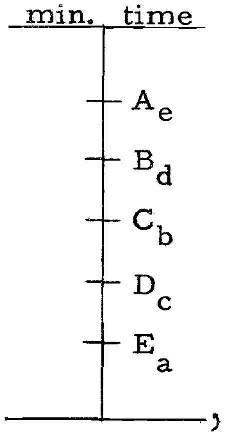
After the "anonymous" information exchange executed in the previous stage, it is possible that certain of the panel members have changed their relative utility preferences for some strategies regarding some objectives. Therefore, this phase of the procedure will be performed by having each expert reevaluate his ordinal preference scales using paired comparisons.

As a result of the Communication Stage, then, it may be expected that respondents with well-founded judgments on a subject will be swayed little by counterarguments or by the opinion of the majority, whereas the opinions of those respondents who feel unsure of their positions will be influenced by valid arguments. The induced process of convergence (toward consensus), one may hope results from an increased understanding of the issue rather than from false persuasion (Helmer, 1969).

Develop Higher-Ordered Metric Scales

In this important stage of the algorithm each decision maker will be asked to make comparisons between all nonorderable probability combinations for the existing strategies, as described in the development of the technique by Siegel (1964), in Chapter III. The result for each panel member will be the formation of higher-ordered metric scales for each objective considered.

Referring again to the simulated example problem facing the college graduates, let us hypothetically develop one student's higher-ordered metric scale for the objective of "minimizing time in the military." Assume his ordinal scale to be:



e - leave country
d - procure job with defense company
b - wait for draft
c - join Peace Corps
a - enlist in military

Figure IV-4. Example of ordinal scale of preferences.

where the capital letters designate preference order (A> B>C>D>E), and the lower case subscripted letters refer to the alternative strategies.

Next, this respondent's "ordered-metric" scale is developed through the following preferences responses:

$(A, C; \frac{1}{2}) > (B, B; \frac{1}{2})$ implies $\overline{AB} > \overline{BC}$

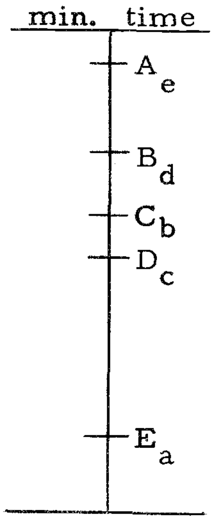
$(B, D; \frac{1}{2}) > (C, C; \frac{1}{2})$ implies $\overline{BC} > \overline{CD}$

$(D, D; \frac{1}{2}) > (C, E; \frac{1}{2})$ implies $\overline{DE} > \overline{CD}$

$(C, D; \frac{1}{2}) > (B, E; \frac{1}{2})$ implies $\overline{DE} > \overline{BC}$

$(B, D; \frac{1}{2}) > (A, E; \frac{1}{2})$ implies $\overline{DE} > \overline{AB}$

Therefore, his ordered-metric scale appears as:



$\overline{DE} > \overline{AB} > \overline{BC} > \overline{CD}$

Figure IV-5. **Ordered** metric scale.

Finally, the higher-ordered scale is determined by these responses:

$(D, D; \frac{1}{2}) > (A, E; \frac{1}{2})$ implies $\overline{DE} > \overline{AD}$

$(A, D; \frac{1}{2}) > (B, B; \frac{1}{2})$ implies $\overline{AB} > \overline{BD}$

$(A, D; \frac{1}{2}) > (B, C; \frac{1}{2})$ implies $\overline{AB} > \overline{CD}$

$(B, B; \frac{1}{2}) > (A, E; \frac{1}{2})$ implies $\overline{BE} > \overline{AB}$

$(C, C; \frac{1}{2}) > (B, E; \frac{1}{2})$ implies $\overline{BE} > \overline{BC}$

$(B, C; \frac{1}{2}) > (A, E; \frac{1}{2})$ implies $\overline{CE} > \overline{AB}$

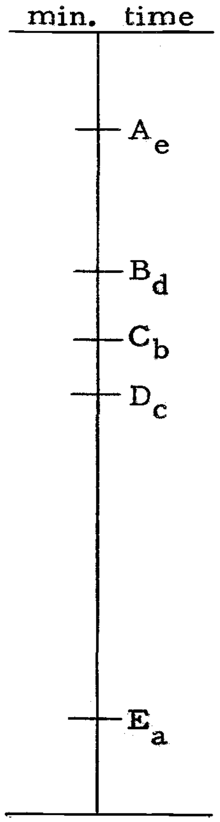
$(A, D; \frac{1}{2}) > (C, C; \frac{1}{2})$ implies $\overline{AC} > \overline{CD}$

$(D, D; \frac{1}{2}) > (B, E; \frac{1}{2})$ implies $\overline{DE} > \overline{BD}$

$(C, D; \frac{1}{2}) > (A, E; \frac{1}{2})$ implies $\overline{DE} > \overline{AC}$

$(C, C; \frac{1}{2}) > (A, E; \frac{1}{2})$ implies $\overline{CE} > \overline{AC}$

The first two responses (relationships) are sufficient to describe the scale, while the remaining relationships provide checks for consistency of the expert's responses. The resulting scale is shown on the next page:



$\overline{AE} > \overline{BE} > \overline{CE} > \overline{DE} > \overline{AD} > \overline{AC} > \overline{AB} > \overline{BD} > \overline{BC} > \overline{CD}$

Figure IV-6. Higher-ordered metric scale.

CHAPTER V

SCALE TRANSFORMATION

Techniques Based on Metric Scales

The intent of this chapter is to achieve an objective, interval scale of values, based on one rationalizing assumption. That is, if it is assumed that the ordered relationships determined in Chapter IV hold most validly and accurately when their utility differences are at a minimum, then it is possible to transcend the subjective scale and thereby construct an interval scale of preferences.

The first two theoretical approaches developed in this chapter for assigning numerical scale values to competing strategies are based on the subjective scales presented in Chapter IV, and on the assumption that "the decision maker's knowledge is limited regarding the higher-ordered relationships derived." That is, with respect to the information required to develop the ordered metric or higher-ordered metric scales, the decision maker revealed only that he considered the differences in effectiveness utility between certain strategies to be greater than effectiveness utility differences between other strategies (e.g., $\overline{AE} > \overline{BE} > \overline{CE} > \ldots > CD$). He does not know how much greater some utility distances are than others. A practical, conservative approach, then, would be to give the strategies scale positions so as to minimize these "greater than" relationships.

"Ordered Metric Minima" Approach

A simple, practical method of numerically specifying the scale positions of the competing strategies of a decision maker with respect to a given objective is based on the ordered metric scale, developed by Siegel (1964) as an intermediate scale before the derivation of the higher-ordered metric scale.

As revealed in the theoretical development by Siegel, the ordered metric scale shown below can be derived from the following rankings of differences regarding alternative strategies A, B, C, D, and E:

$$\overline{DE} > \overline{AB} > \overline{BC} > \overline{CD}$$

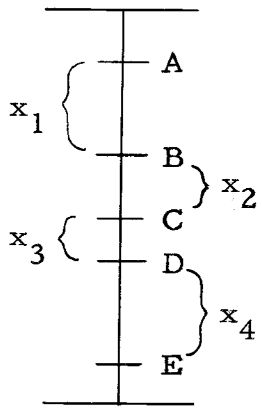


Figure V-1. Ordered metric basis for transformation.

Outline of Approach. These derived subjective relative utility distances between adjacent strategies on the utility scale based on effectiveness considerations regarding different probability combinations of strategies, can be transposed into objective measurements by the easy-to-apply technique outlined below:

1. Order the utility distances between adjacent strategies

from smallest to largest. Since, in the example, the derived preference relationships are $\overline{DE} > \overline{AB} > \overline{BC} > \overline{CD}$, then the rank order is:

1. $\overline{CD}$
2. $\overline{BC}$
3. $\overline{AB}$
4. $\overline{DE}$

2. Associate directly with each ranking a number, equal in numerical magnitude, which will represent a specific number of utiles of distance between strategies. In the example, $\overline{CD}$ (i. e., the distance between C and D) equals one utile, $\overline{BC}$ equals two utiles, etcetera.

3. Draw the scale to reflect these distances, beginning with the "worst" strategy arbitrarily assuming a scale position of zero. In the example below, the scale on the right is achieved directly from this step:

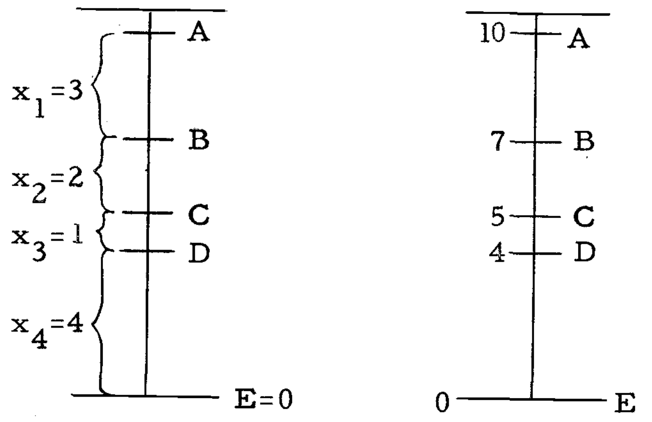


Figure V-2. Ordered metric interval scale derivation.

4. The objective scale formed in step (3) validly reflects the

ordered metric relationships. Further, it adheres to the relationship specifications to a minimum degree with respect to <u>integral</u> distances.

<u>Advantages and Disadvantages.</u> In summary of this technique, it is worth noting its advantages and disadvantages. First, its advantages are:

1. The relative subjective utility distances between different pairs of adjacent entities are derived using a valid method for obtaining an ordered metric scale.
2. The method is simple and easy to apply by the decision maker himself.
3. The objective measurements validly reflect the ordered metric relationships determined subjectively.
4. The "conservative" numerical scale positions which result are based on <u>minimum</u> utility differences as reflected by minimum <u>integral</u> differences in utiles, and with respect to the scale used.
5. The time involved to achieve the interval scale is relatively short.
6. The problem of inconsistencies developing is of relatively little concern with respect to the other approaches.

Conversely, disadvantages of this approach include:

1. The ordered metric scale employed is not based on as much information as the higher-ordered metric scale. The ordered metric scale is based on utility preferences regarding <u>all the pairs of adjacent strategies</u> on the scale;

the higher-ordered metric scale is formed from relationships between all possible pairs of strategies, and thus is a more accurate scale in reflecting preferences.

2. The minimum utility distances achieved are reflected by unit increases from the smallest interval to the largest, rather than more refined measurements in fractions of a utile. Ideally, the "minima" assumption is a basis for achieving a mathematically precise minimum. The approach employed here is a heuristic one, not involving mathematical techniques which may be applicable. However, any attempt to make precise mathematical statements from subjective judgments would be very difficult to defend.

Higher-Ordered Metric Minima Approach

An improved heuristic minimization method, having similar advantages as the "Ordered Metric Minima" technique while not having one of its major disadvantages, is that involving the higher-ordered metric scale. The technique is outlined as follows, along with the example illustration from Chapter IV:

1. Having developed the higher-ordered metric scale preference relationships from expert judgments, rank the relative utility differences between all pairs of strategies from the smallest to the greatest difference:

$$\overline{CD} < \overline{BC} < \overline{BD} < \overline{AB} < \overline{AC} < \overline{AD} < \overline{DE} < \overline{CE} < \overline{BE} < \overline{AE}$$

2. Draw a vertical scale line from which to derive the scale positions.

3. Assign the lower utility member of the pair of strategies with the smallest difference ($\overline{CD}$) to a position on the scale line. Then assign the higher utility strategy of the pair to a minimum position of one utile above the first.

4. Next assign the subsequent pair of strategies from the list in step (1), BC, to positions on the scale line having a utility difference of one utile more than the distance between the first pair on the scale:

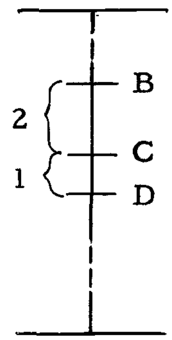


Figure V-3. Initial stages of Higher-Ordered approach.

5. Assign each succeeding pair of remaining pairs to the scale, allocating the smallest scale distances possible with respect to previously established positions and relationship constraints. (Refer to the illustration on the following page).

In this way the minimum integral utility differences can be attained when all possible pairs of strategies are involved and interrelated. Each succeeding pair in rank order of utile distance is positioned on the scale with respect to each previous positioning.

6. Knowing the scale differences between each strategy, the final step is to translate this information into an interval scale of values, as shown below. Here again the lowest strategy is arbitrarily assigned the value of zero. Instead of this approach, we could have assigned A an arbitrary value of say, 100, and related B, C, D, and E to it.

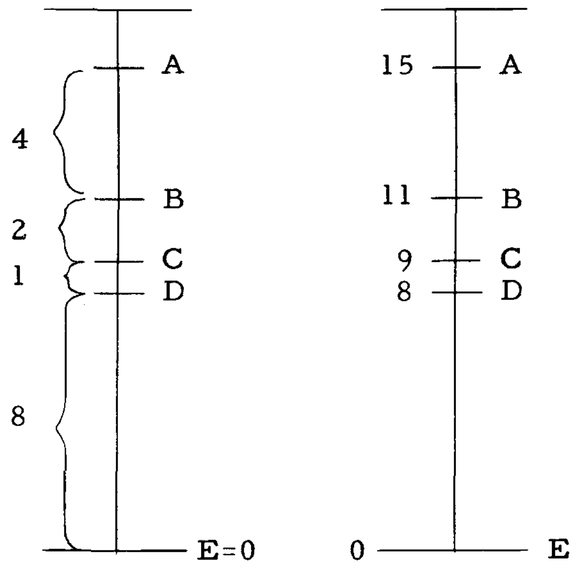


Figure V-4. Higher-ordered metric interval scale.

In conclusion, critical examination of this minima approach reveals certain advantages and disadvantages:

1. The relative and actual time involved in deriving the higher-ordered metric scale is not significantly greater than for the ordered metric scale. According to Siegel, with five alternatives, after deriving the ordinal scale of values, only three to six nonorderable relations must be found to achieve ordered metric scaling; only ten

at most are required to achieve higher-ordered metric scaling (Siegel, 1964).

2. It is possible for the decision maker to derive his own scale of values. However, determining which probability combinations need to be tested in the process of ordering all combinations of utility distances can be more difficult than for the Ordered Metric Minima approach, particularly when a large number of strategies are being compared (e.g., greater than five).

3. The chance of inconsistencies between judgments increases when employing this approach versus the ordered metric approach. The probability of inconsistencies occurring depends, of course, on many factors (e.g., the decision maker's ability to discern consistently between entities, the number of alternatives involved, time available, or the number of nonorderable probability combination questions).

4. The accuracy of scaling is increased by employing this technique due to increased information gained.

Standard Gamble Method

A third approach to quantifying scale positions of entities on a scale of subjectively derived values, might be achieved by employing the "Standard Gamble" technique. By having the decision maker state his preferences between two alternative proposals: 1) a first alternative involving two different entities with different probabilities of achievement, and 2) a "sure" alternative involving one entity with 100 per cent probability of achievement, a numerical scale of values can be assumed, based on probabilities.

Methodology

The technique is based on the principle that a response of indifference between two alternatives in a choice situation implies that the two alternatives have equal expected utility. Thus, in the approach taken here, the decision making subject is given a choice consisting of alternatives A_1 and A_2. A_1 involves risk, and A_2 is a certain option in that it can result in only one outcome with probability of one. The procedure for arriving at a point of indifference between these two alternatives is outlined below: (Dervitsiotis, 1968)

1. Set up a table for decision making. It will include: a) the two possible outcomes from choosing alternative A_1, along with initial respective probabilities of achievement; and b) the single "sure" outcome resulting from the choice of alternative A_2. The certain outcome will be a strategy which is "enveloped" between the two outcomes of alternative one on the ordinal scale of preferences determined by the decision maker. Decisions involving probability combinations can only be made when choices are to be made between two outcomes of one alternative versus a second which is "sandwiched" between these two.

A_1		A_2
Probability	Outcome	Certain Option
$p_1 = .75$	A	B
$p_2 = .25$	C	

Figure V-5. Sample probability comparisons.

2. Ask the subject to select one of the alternatives given, with respect to the initial probabilities in A_1. If he chooses A_1 over A_2, this implies that the utility for A_1 exceeds A_2 with respect to that combination's effectiveness in achieving company goals, or

$$U(A_1) > U(A_2).$$

Otherwise, if he chooses A_2 over A_1, then

$$U(A_2) > U(A_1).$$

He may, however, express indifference between A_1 and A_2, or

$$U(A_1) = U(A_2).$$

3. If one of the alternatives was preferred to the other (e.g., $U(A_1) > U(A_2)$), alter the probabilities in A, in an attempt to achieve an indifference point between A_1 and A_2.
4. Again request a choice preference from the subject. If indifference is not achieved manipulate the probabilities once more.

5. Continue this process until an indifference point is converged upon, based on indifference probabilities. An hypothetical convergence process is shown below:

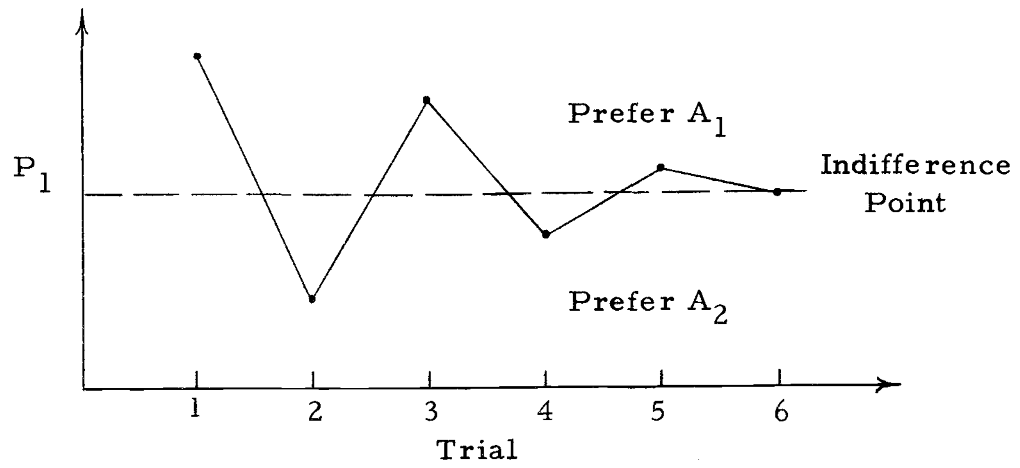


Figure V-6. Converging on indifference point.

6. Once an indifference point is achieved for each choice situation, the "enveloped" strategies can be positioned on the rank order scale with a specific utility scale value. In general, N-2 indifference points are required from the combinations (A, α_N) versus B, C, D, . . ., α_{N-1} where α is the letter corresponding to the lowest utility strategy, and the subscript N, N-1 refers to the number of strategies involved. For example, if the initial ordinal scale includes the strategies A, B, C, D in rank order, then by ascertaining the indifference probabilities between (A, D) and C, and (A, D) and B, the scale positions of B and C can be specified. This is reflected in the simulated situation below for A arbitrarily fixed at 1.0 utile, and D at 0.0 utiles. Let us hypothesize that

U(A, D) = U(C) when P(A) = 0.4 and P(D) = 1-P(A) = 0.6, and,

U(A, D) = U(B) when P(A) = 0.7 and P(D) = 0.3.

Then, by using the probabilities of <u>A</u> to define <u>C</u> and <u>D</u> scale positions, the scale can be constructed:

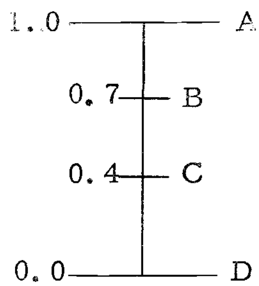


Figure V-7. Standard gamble interval scale.

Thus, an interval scale of utilities is achieved for all enveloped strategies in terms of indifference point probabilities of the highest utility strategy (A). It is easily shown that the scale values of A and D could be ascertained according to indifference probabilities of A, also. Obviously, if the choice was between: 1) (A, D) with P(A) = 1.0, and 2) strategy A, then indifference would arise and A would assume the scale position of 1.0. Further, for the choice: 1) (A, D) with P(A) = 0.0, and strategy D, then this indifference situation would define strategy D at 0.0 on the scale.

7. In order to validify the scale values derived in the previous six steps it is imperative that a consistency check be executed. This is done by the same "indifference

point method" used above for every "enveloped" combination possible from existing strategies. When five strategies are involved, (A, B, C, D, E), then it is necessary to compare (A, D) versus (B), (A, D) versus (C), (A, C) versus (B), (B, E) versus (D), (B, E) versus (C), (B, D) versus (C), and (C, E) versus (D). For N strategies there are {2(N-3) + 3(N-4) + 4(N-5) + . . . + (N-3) [N-(N-2)] + (N-2) (1)} enveloped combinations to check for consistency against the original scale determinations. Such a consistency check would appear to be a difficult task to achieve.

8. Upon the conclusion of the consistency checks for validity, the original scale positions should be changed to reflect average values. That is, if the results of the validation procedure did not reveal significant differences in scale values from the original ones, (say, $\pm$.05 utiles), then the final scale positions should be determined by calculating the average of all the derived values for each strategy throughout the process. In this way, the true utility positions can be determined, based on the decision maker's overall judgments. Specifically, this approach, based on a number of derived values for each position, should alleviate the apprehension involved when determining the exact indifference point of convergence in each individual decision situation. Consider the hypothetical situation in which a number of values (four) for strategy C have been

determined from the decisions regarding the combinations (A, E) versus (C), (A, D) versus (C), (B, E) versus (C), (B, D) versus (C). Supposing the resulting positions were $C_1 = .35$, $C_2 = .35$, $C_3 = .30$, and $C_4 = .25$, the final scale value of C is the average of C_1, C_2, C_3, and C_4, or .31 utiles.

Advantages and Disadvantages

As an alternative approach, or a supplementary tool for the previously described methods for quantifying scale positions of subjectively determined values of alternative strategies, the "Standard Gamble" technique has certain advantages and disadvantages. First, its advantages are:

1. The technique is easy to apply and can be utilized by the decision maker working alone.
2. Confronted with numerous choice situations, the decision maker is forced to utilize all his knowledge and intuition regarding the strategies involved when forming probability judgments.
3. The method does achieve an interval scale of utility values for competing strategies; thus, the subjective ordinal scale has been transposed into an objective scale of values.
4. This indifference approach could be used as a further check on consistency of the Ordered Metric Minima approach, or the Higher-Ordered Metric Minima approach. In doing so, only "spot checks" would be

necessary, and only a few of the alternative pairs of combinations would need to be considered.

The disadvantages of the Standard Gamble technique are:

1. The method of achieving indifference points is time-consuming, especially when five or more strategies are involved and consistency checks must be made.
2. To arrive at consistently valid scale values, the "expert" must have great ability to discriminate accurately between different sets of alternatives. That is, he must be well-qualified to relate different combinations of alternatives (e.g., (A, E) versus (C), (A, D) versus (C), (B, E) versus (C), (B, D) versus (C)), consistently such that he reveals an accurate judgmental value (based on his discriminal processes) for the "certain outcome" of interest (C, in the example). This does not imply that he should mentally "manipulate" the probabilities such that the different resultant values coincide; instead, it implies that the resultant values should be close due to his ability to weigh the alternatives consistently. Realistically, this approach seems to tend toward inconsistent judgments for rather simple problem situations. For complex organizational problems, this technique appears to be rather unworkable by human mental processing.
3. Converging to a set of indifference probabilities is a difficult task, possibly one approaching the point of absurdity with respect to the "feeling" required of the deci-

sion maker in being able to discriminate between preference or indifference at $P(A_1) = .80$ or $P(A_1) = .75$, for example. The contention here is that, after a point, the expert's ability to discriminate probabilities decreases rapidly, as does his confidence in the validity of the result.

CHAPTER VI

SCALE SYNTHESIS

As a result of the previous two chapters, the following has been achieved: 1) a subjective algorithm has been developed which allows each member of a group of decision makers to derive an individual subjective scale of effectiveness values for each objective being attained by the competing strategies; and 2) three alternate approaches have been discussed for transposing each subjective scale of values into interval scales of values, based on one major "limited knowledge" assumption. It is the purpose of this chapter to develop a means by which: 1) the individual scales for a decision maker can be combined into one "weighted" scale of values reflecting his overall preferences, and 2) to synthesize the "weighted" scales of all decision makers into one comprehensive scale reflecting the preferences of this panel of experts, such that the resulting scale can be used for ultimate decision making.

To illustrate the problems which need to be resolved before a definitive set of preferred strategies can be achieved, the hypothetical situation illustrated on the following page is constructed. The interval scales of values shown, (which represent the preference judgments of one expert), resulted from the application of the Ordered Metric Minima technique. Scrutinizing these scales, it can be seen that the following obstacles must be overcome before the ultimate comprehensive scale can be developed:

1. The scales must be transposed into ratio scales, having

absolute zero scale positions, or absolute maximum scale positions.

2. Possibly the decision makers should each be given "weights" for each objective, reflecting their relative competences to make judgments regarding the effectiveness of each strategy for achieving them.

3. The various objectives involved must be weighted relative to each other so that their relative importances can be established.

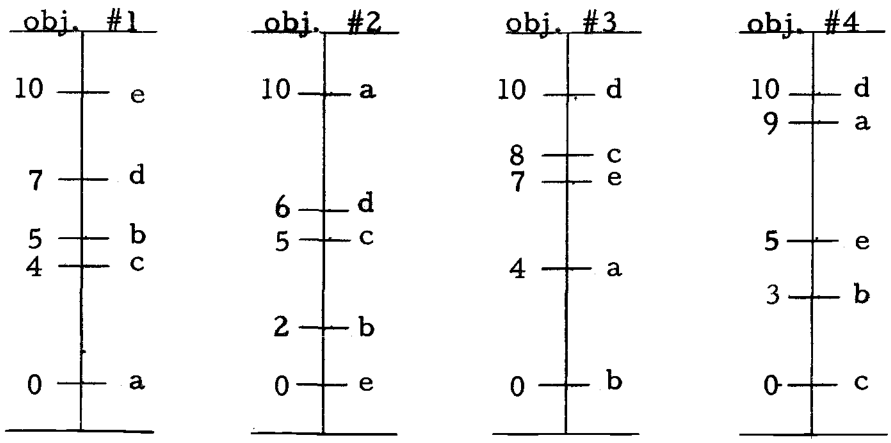


Figure VI-1. Objective-strategy scales for one expert.

In this chapter the aforementioned obstacles will be considered in turn; then a procedure will be outlined for synthesizing the respective scales into an overall scale reflecting the panel consensus.

Developing Ratio Scales

The scales developed in the previous chapters reflected the characteristics of interval scales. They had, then, only arbitrary zero points; they did not have <u>meaningful</u> zero points. Therefore, because of this lack of unique zero points, it is not yet possible to combine the objective-effectiveness scales for all decision makers meaningfully and validly. As Thurstone explains it:

> The situation is analogous to that in which we know the differences in elevation between pairs of mountains. Such data give no information about the elevation of any one of the mountains. Numerical values can then be assigned to the stimuli only by setting an arbitrary origin at any one of the stimuli, such as the lowest stimulus (Thurstone, 1963, p. 195).

Specifically, for example, if four decision makers are to be able to combine their individual preference scales for objective number one, the relative scale position values can only be integrated if the scales are based on a standardized origin for the group. In this way, the numerical values have the same meaning on all scales because they are related to a common origin. The question is, how can a common origin be achieved for each objective?

Minimum Strategy Approach

The approach to be discussed here for resolving the above dilemma involves the determination of an agreed upon "worst" strategy for each objective, to be inserted among the alternative strategies generated initially before the decision making process begins (Chapter II). This strategy will then enter into the scale developments, and will hence assume the absolute zero position on all scales related to the particular objective involved.

Alternatively, perhaps the problem could be solved by determining agreed upon "maximum possible" ideal strategies which would achieve the objectives to the greatest possible degree. However, such hypothetical "Grand" strategies often are impossible to define specifically, and thus cannot practically be entered into the decision making process where relative judgments must be made. Furthermore with regard to maximizing an objective, this is often an impossibility also; some objectives can have unlimited degrees of achievement. For example, maximization of customer satisfaction, to the highest degree, company revenue, and safety are for all practical purposes unattainable objectives.

Defining "minimum possible" effectiveness in achieving intangible objectives is a much simpler task, mainly because in many cases doing nothing is an alternative strategy which would achieve zero effectiveness with respect to a given objective. In other instances, well-defined minimum strategies are imaginable which would essentially achieve the given objectives with zero effectiveness, while achieving other objectives with significant effectiveness. These strategies could very well be some of the competing strategies being evaluated.

To illustrate simply the adoption of zero effectiveness strategies, consider the military draft problem referred to in Chapter IV in which graduating college students were faced with alternative strategies for achieving overall optimization of effectiveness for the four objectives: 1) minization of time in the service, 2) maximizing image, 3) minimizing the risk of losing one's life, and 4) maximizing revenue over the time period considered. Respectively, the following alternatives might be chosen as having zero effectiveness for these objectives:

1. Enlist, one of the existing alternatives, probably would be unanimously accepted by the decision makers as having zero effectiveness for the objective, minimize time in the service.
2. Commit a crime, would be accepted as minimizing the objective, maximize image.
3. Commit murder, in some states, would have zero effectiveness for minimizing the risk of losing life.
4. Join the Peace Corps, would be acceptable as minimizing revenue.

In conclusion, the prerequisites for accepting a strategy as having zero effectiveness are that: 1) all the experts agree to use it as a minimum; and that 2) the experts can gain a mental image of it, especially regarding its relative value with respect to other strategies. A final, practical example will clarify these prequisites.

Consider a corporation which is deciding on the location of a new industrial plant based on the following major objectives:

1. Maximize proximity to raw material resources.
2. Maximize manpower pool available in the area.
3. Maximize proximity to major rail facilities.
4. Minimize risk of natural catastrophy.

For the first objective, an agreed upon "zero" strategy could relate to any of a number of locations where the necessary raw materials do not exist. The second objective can be minimized by including a location where unemployment is at a minimum, and/or where the necessary skilled or unskilled workers do not exist, and/or where individuals in the required age brackets are available in minimal quantities. The third objective can simply be minimized by defining a location where the necessary rail facilities do not exist. Finally, for the last objective, a "worst possible" location within the geographical boundaries being considered would be that in which damaging natural catastrophies occur with maximum frequency (e.g., in the Midwest: tornadoes, or Southeast Coastal areas: hurricanes).

Weighting Decision Maker "Competence"

Having established "zero based effectiveness scales" for each objective, the validity of the combination of these scales will be enhanced. However, before combining the scales for each decision maker under each criteria, it may be desired to weight each individual according to his degree of competence in making judgments regarding a given objective. At these executive levels of decision making it may occur that some experts will feel less qualified to make judgments concerning certain objectives than other members of the group. In this situation the accuracy of the results might be further enhanced by having each member make a self-evaluation regarding each criteria, and to use this self imposed rating as a weighting factor when combining preference scales.

Specifically, to achieve individual ratings, respondents could be asked to assign a decimal fraction grade to each criteria, reflecting his degree of competence to make evaluations concerning it. Due to the difficulty of deciding accurately the degree of complete knowledge one has concerning a particular area, at least some improvement will be achieved if the members choose ratings from a set having large differences between values. For example, each one could evaluate himself based on the following percentages of "omnisciency": zero per cent, twenty-five percent, fifty per cent, seventy-five per cent, one-hundred per cent.

Once these competence percentage evaluations are made, they can be incorporated into the scale synthesis procedure by multiplying them by the respective scale position values as illustrated below in an hypothetical example:

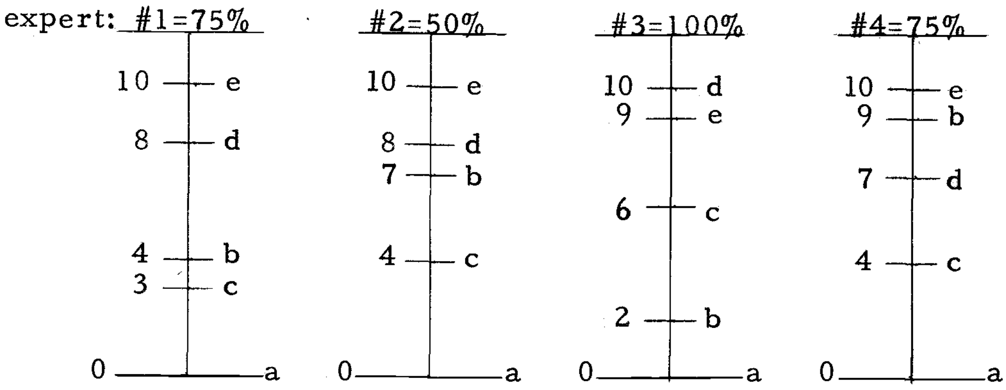


Figure VI-2. Scale values for objective #1 before weighting.

Multiplying all values by respective weights gives the scales on the following page.

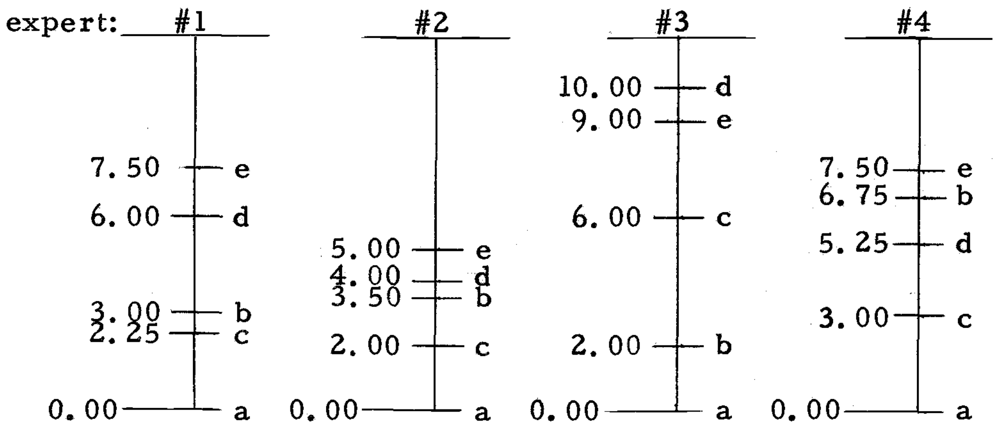


Figure VI-3. Weighted interval scales for objective #1.

Combining these scales results in one overall consensus scale of effectiveness values for objective number one:

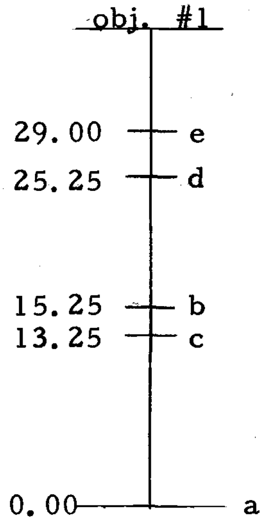


Figure VI-4. Consensus scale for objective #1.

Weighting Objectives

The final stage in the scale synthesis involves the combination of all the intermediate objective scales into the ultimate consensus scale of preferences upon which subsequent decisions will be based. Before this can be done with validity the different objectives involved must be given weighted values, analogous to the weighted ratings given the experts in the previous section. The methods to be discussed here for weighting the criteria have all been developed previously in this thesis. The use of alternative weighting methods may result from the existence of two distinct situations to be discussed.

Predetermined Objective Weightings

Weightings Given. In some cases the relative importance of conflicting criteria may have already been determined historically and have been rated accordingly.

Weightings Determined by an Individual. In some cases the importance ratings for objectives may be determined by an individual executive, such as the company president. In such a situation, the responsibility can be executed by either following the procedure outlined by Churchman and Ackoff in Chapter III, or by the more objective procedure for developing a higher-ordered metric scale of importance ratings discussed in Chapters IV and V.

Objectives Weighted by the Panel of Experts

In the situation in which the decision makers themselves have the responsibility of determining the relative importance ratings, a practical approach is to apply the "anonymous debating procedure" by Helmer referred to in Chapter IV, and completely developed in the chapter on tactics (Chapter VII).

Indeed, a distinct difference exists between the decision making regarding strategy preferences, and regarding objective preferences. The former is based more on the expert's knowledge and experience concerning the attainment of stated objectives. The latter is based more on the intuitive preference judgments of the members. Therefore, a debating procedure such as the one outlined by Helmer is a most logical attempt at bringing about a rational, effective interaction of ideas and organizational philosophies between the group members. Specifically, perhaps the objectives can be rated on a scale from one to ten employing Helmer's procedure. Then the resulting ratings can be used as weights in the synthesis of the objective scales. Muliplying the various objective-strategy scale positions by the respective weights for each scale, and adding scale values directly, results in the final consensus scale of effectiveness values for the original alternative strategies. From the hypothetical scale below the strategy conceived to have the greatest overall effectiveness for achieving the given objectives is seen to be strategy d:

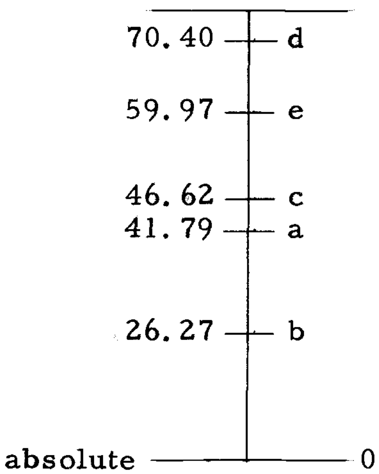


Figure VI-5. Overall effectiveness scale.

CHAPTER VII

DECISION MAKING AT TACTICAL DECISION LEVELS

> The problem of value measurement is the most significant block to progress in the analysis of decisions. It is at present the subject of research, both formal and experimental, which has a considerable ways to go before placing "cook book" methods in the hands of engineers. (Morris, 1960, p. 430).

Introduction

In the previous chapters the discussions and theoretical developments were carried out specifically regarding methods of subjective decision making at the strategy levels, and were aimed at evaluating relative utilities of competing alternatives with respect to their effectiveness in achieving predetermined intangible and tangible objectives. It is the purpose of this chapter to reveal more objective methods of comparing alternative tactical procedures for implementing a chosen strategic proposal. The competing tactics at lower levels of the organizational hierarchy ideally must be compared with respect to their relative efficiencies in terms of dollar costs and benefits for achieving the intangible and tangible objectives of the parent strategy. At this point it is worth digressing for a moment in an effort to bring the two concepts, strategies and tactics, into perspective, with the purpose of better preparing the reader to differentiate between tactics and strategies as discussed in this thesis.

Strategic decision problems occur at the highest levels of an organization (i. e., executive planning levels), and are characterized by the high degree of subjectivity involved in the evaluations made by the decision makers. Subjective judgments are necessary because of the predominance of intangible factors (e. g., objectives, risks), as well as the inadvisability of associating dollar costs and benefits other than "ball-park figures" to tangible objectives at this level. The reason for this latter restraint is that exact dollar information about some factors does not add significant information at this level, and thus, if it was obtainable for all the competing strategies the cost of doing so would be difficult to justify.

These strategies, as defined above, exist at all levels of the organization due to at least one of the reasons given. At the highest organizational levels all the reasons given are relevent. At lower managerial levels (i. e., middle managers and line managers) the term "strategies" is still applicable due predominantly to the latter reasons given regarding expense involved in "dollarizing" all competing strategies and associated tactics.

Furthermore, as noted previously, at each of the succeeding strategy levels, the strategy chosen as being the most effective has associated with it a number of different "tactics." This term conveys the information that these alternative approaches for carrying out the strategy are more concrete than the present strategy; i. e., they represent a degree of refinement of the strategy. Thus, the more refined the strategy, the more tangible the evaluation involved.

Furthermore, as soon as the optimal tactic is chosen from the set, it becomes a strategy in the next level of decision making (i. e., if it too is capable of further refinement with respect to alternative methods of implementation).

In concluding this digression, it is hoped that this clarification of terminology has allowed the reader to visualize the procedure more clearly and to discern the gradual transition from subjectivity to objectivity of measurement as reflected by the example diagram below:

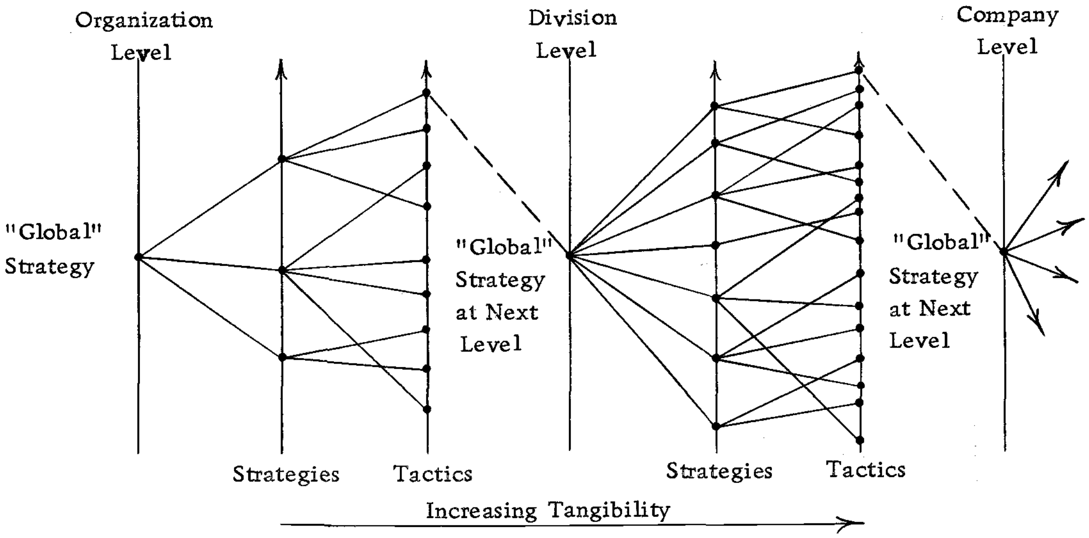


Figure VII-1. Transition from intangible to tangible decisions.

Also, it can be seen that as subsequent lower level decisions are approached, the tactics involved become more and more amenable to accurate monetary cost-benefit descriptions. Therefore, it is at these levels in which monetary evaluations are made as a basis for comparison, that consideration will now be given.

In this chapter approaches to evaluating tactics with respect to their dollar efficiency in achieving intangible strategic objectives will be presented at various levels of intangibility. Specifically, three general levels of intangibility will be considered: 1) "quasi-intangible" valuations, in which competing alternatives are indirectly measurable, in terms of market values, in their achievement of "quasi-intangible" objectives; 2) intangible valuations where tactics are commensurable directly only in physical units because no market value exists; 3) subjective evaluations where effects cannot be satisfactorily measured monetarily by direct or indirect means (complete intangibility). "Quasi-intangible" valuations will be considered first.

Measuring Quasi-Intangible Efficiency

In the process of objectively evaluating costs and benefits realized as a result of instituting different governmental or industrial projects, many of the goods and services involved, which have the power of satisfying human wants and which can be increased or decreased in availability as a result of a project, can be measured monetarily by referring indirectly to the market exchange process.

> Specifically, some project effects cannot be evaluated directly on the basis of market prices, but their values may in some cases be derived or estimated indirectly from prices established in the market for similar or analogous effects or may be derived from the most economical cost of producing similar effects by an alternative means (United States Inter-Agency Committee on Water Resources, 1958, p. 27).

Excellent examples of methods of valuation based on the market exchange value concept are based on the accountant's synthesis of values from the expenses of the firm. These are methods for measuring intangible property values to a firm (Marston, Winfrey, Hempstead, 1953):

Organization and Financing. (See Appendix for definitions). These costs can be appraised on the basis of original cost or replacement cost with allowance for depreciation.

Going Value. This can be appraised in one of three ways:

1. It can be estimated, based on a company's expenditures made in carrying out a program of promotion, which is an approximation of the cost of acquiring the present business. To the extent that cost is a measure of value, this estimated cost of acquiring customers may be used as an evidence of the going value.
2. It can be measured by determining the annual difference between the annual returns of the enterprise and the fair return on the investment in the enterprise. The aggregate of "return forgone" for the development period may be pertinent evidence of the going value.
3. Going value can be appraised by making estimates based on a comparison of potential returns of an "assembled and established plant" with one "not thus advanced." The latter enterprise is a theoretical duplicate of the established plant, but at the date of valuation possesses no customers. The present worth of the differences of the probable returns of the two plants for the period required for the latter plant to acquire the customers is one measure of the value of the established business.

Contracts. Contracts can be valued based on an estimate of the probable future dollar earnings to be derived from the intangible. Necessary data required for this valuation are: 1) the probable future life of the intangible, 2) average annual returns of the firm anticipated, 3) the fair market rate of return. When contracts have firm price provisions which are significantly different from average prevailing prices, then these agreements can be appraised on the basis of the present worth of the extra return attributed solely to the ownership of the specific contract.

Options. These can be valued at the fair market price of similar entities comparable to them.

Goodwill. A procedure for calculating an estimate of the value of goodwill is outlined below:

1. Estimate the fair cost, adjusted for depreciation, for the tangible properties owned by the enterprise. Add the fair cost of intangibles such as organization, financing, and others which were acquired by investment.
2. Estimate the average return of the entire enterprise based on a three to five year average of normal past and present operations.
3. Determine the fair rate of return for the enterprise in the given industry.
4. Determine the annual return of specific other intangible properties for which a specific annual return can be estimated, (such as contracts, active patents, and trade secrets).

5. Determine the excess return attributable to the possession of goodwill, using the following formula:

$$\begin{pmatrix}\text{Annual} \\ \text{Return} \\ \text{Attributed} \\ \text{to Goodwill}\end{pmatrix} = \begin{pmatrix}\text{Average} \\ \text{Annual} \\ \text{Return}\end{pmatrix} - \begin{pmatrix}\text{Fair Rate} \\ \text{of} \\ \text{Return}\end{pmatrix} \times \begin{pmatrix}\text{Investment} \\ \text{in the} \\ \text{Enterprise}\end{pmatrix} - \begin{pmatrix}\text{Annual Return} \\ \text{Credited to} \\ \text{Specific Other} \\ \text{Intangible} \\ \text{Properties}\end{pmatrix}$$

Now consider the two possible conditions of the firm's goodwill. If the goodwill is assumed to continue indefinitely at its present level, then:

6a. Estimate an appropriate rate of capitalization to be used in appraising the goodwill, considering the risk associated with the indefinite continuance of the excess returns.

7a. Capitalize the returns attributed to goodwill at the appropriate rate.

If it is concluded that the returns attributed to goodwill continue for only a limited period, then:

6b. Estimate the number of years the excess returns may be expected to continue.

7b. Compute the present worth of these returns at an appropriate rate of return.

The above two conditions were considered because a potential purchaser of the firm very possibly would be willing to pay much more than <u>one</u> year's excess return to acquire the goodwill of the enterprise.

Intangibles not Evaluative in Market Terms

Methods of Valuation

Certain project effects which can be measured in physical units but for which no market values exist (e.g., prevention of the loss of a life) may be given values based on agreed upon qualified estimates of acceptable expenditures for these entities. Three techniques applicable under these conditions will be delineated here. The decision to employ any one of them would depend on the particular circumstances involved and on the decision maker's preferences.

Qualified Estimates of Authorities (Helmer, 1969). The group decision making approach of Helmer referred to in the chapters on strategic decision making is applicable here in the form as he espoused it. The steps of the procedure are outlined below for quantifying a particular factor N (e.g., the cost of an entity, or the value of a benefit in achieving a particular intangible objective):

1. Have each expert give an independent estimate of the value of N.
2. Arrange the responses of the experts in order of magnitude, and determine its quartiles, Q_1, M, Q_2, so that one quarter of all estimates lie in each interval; e.g.,

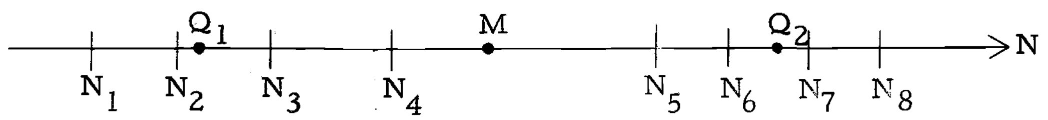


Figure VII-2. Helmer's scale for deriving consensus.

3. Reveal the values of each interval to each member, ask him to reconsider his previous estimate, and if his new estimate lies outside the interquartile range, Q_1 to Q_2, ask him to state his reasons why the answer should be lower (or higher) than that of the seventy-five per cent majority opinion expressed in the first round.
4. Give these new responses back to all respondents by communicating the magnitude of the new quartile values, along with stated reasons why changes had been made by respondents. The experts are now asked to consider the reasons given, weight their feasibility, and revise their own previous estimates accordingly.
5. If newly revised answers still fall outside the second round interquartile range, respondents are asked to state why they found previous arguments unconvincing enough to draw them toward the median.
6. In the fourth round the quartile results of round three along with the counter arguments elicited, are submitted to respondents, who are asked to make a final revision of their estimates.
7. The median value of the resulting round four estimates is taken as the group response as to what N should be.

To improve the above procedure, respondents could be asked to assign a letter grade to each response, reflecting his degree of competence to make such an evaluation. Then, in round four the median value chosen as the group response would be the median of all estimates from competent respondents regarding that particular question.

Utilizing the procedure outlined above, it is expected that respondents with well-founded opinions on a subject will be swayed little by counterarguments or by majority opinion, whereas opinions of respondents feeling unsure of their positions will be influenced by valid arguments; thus the process tends to result in convergence of opinion.

Expected Cost Method (Stanly, 1955). The types of intangible factors considered here are more specifically describable as "improbables." They are large in magnitude and infrequent in occurrences. Thus, their evaluation involves assessing the product of a large quantity and a small probability; hence ∞ x's 0 = an indeterminate quantity. The technique proposed for calculating these intangibles consists simply of calculating the "expected cost or value" of one occurrence of the event.

Again, as at the higher strategic levels of decision making where subjective judgments were being made, at these lower levels the judgment utilized in arriving at quantitative evaluation is the integrated result of past experience and knowledge, and logical reasoning.

In relating the fundamentals of this approach, an hypothetical example will be discussed. In it we will be considering a manufacturer who is anxious to expand his manufacturing facilities, and is considering California, except for the possibility of earthquakes occurring. In considering the potential cost of such an earthquake on his facilities (in the course of evaluating that alternative's costs and benefits toward achieving different objectives, such as low damage risk), the manufacturer might employ one of two approaches: 1) approaching the problem intuitively, he will consider the possibility of an earthquake as an intangible factor and will make his decision in part on the basis of his existing emotional concern with regard to natural catastrophies, 2) he will estimate the cost of a quake if it occurs, assuming he is qualified to do so and/or has sufficient statistical data upon which to base such an estimate.

Considering the latter approach, first, let us assume the manufacturer is able to associate a damage figure of \$50, 000 maximum to a \$100,000 plant, plus a cost in lost good will, unavailable capital, and lost prospective sales, of \$50, 000; hence, a total loss of \$100, 000. Second, he must be able to associate an estimated probability figure to the occurrence of a severe quake (severe enough to cause significant damage). Let us assume the probability of a severe quake at the plant site in the next ten years, based on historical records over the last 50 years, equals one in 2, 000. The expected cost, then, is computed to be $\$100,000 \times \frac{1}{2000} = \$50$/occurrence. Even if this figure is in error by an order of ten, it still implies the expected cost of quake damage is relatively small; hence, quake damage would be eliminated from consideration.

The calculation of expected cost involves the multiplication of two crudely estimated quantities. Even though the validity of these quantities is of question, it is to be noted that the conclusion drawn from the resulting expected cost was definite and unequivocal. Further, because probabilities are involved, and because it is possible to make errors of estimate with regard to situations which do not as yet exist, the technique proposed is subject to error. However, the proposed technique of evaluating intangibles should always be at least a better guide than simple intuition since it requires a breakdown and examination of the contributing factors of each consideration and thereby localizes and minimizes the possibility of error.

Valuation Method. To some extent intangibles can always be made tangible if enough time and effort is expended in determining their dollar value, and if the decision maker is willing to incur a large enough uncertainty regarding the accuracy of his estimates. The decision as to how far one should pursue such quantification is based on economics and judgment (Barish, 1962). The general approach considered here offers another means of attaching dollar values to effects which are measurable in other than monetary numerical terms.

Consider a proposed tactical alternative which will increase the safety of the plant, and hence, is expected to save X number of lives annually. What, then, is the value of each worker's life.

1. The company could value it at the cost to the firm of replacing a disabled or fatally injured worker at a given work station, and repairing physical damage probably incurred in the event of such a mishap. This would

require totalling the cost of recruiting, selecting and training a new worker, settling with the family of the injured worker, repairing equipment, etcetera.

2. From a social standpoint, Stanly (1955, p. 779) contends that:

> . . . it appears reasonable to equate the economic value of a human life at that amount of money which can be afforded to prevent its accidental loss in our society. This amount of money varies in a variety of circumstances but can be assessed as normally being less than $100, 000 and more than $10, 000. To be conservative, we may postulate an allowable expenditure of $50, 000 per life saved.

   This method, however, appears to include much more subjective assuming than the first method, and fails to consider the particular situation where the injury occurs. However, it approaches the problem from a social (human) standpoint, whereas the first method simply treats the individual as a resource in need of replacement. From a quantitative standpoint it would be more accurate and realistic as far as company accounting is concerned.

3. Another method could involve averaging the current level of court awards in compensation suits involving accidental death.

4. Another method could involve determining how much companies or governmental units are willing to spend to reduce the risks of loss of life and compute the implied value of a human life.

Some of the above methods are more general than others.

Method (1) involves assessing the worth of the individual based on his resource value in a particular situation. Others assess all individuals equally. The approach taken is left to the decision maker; but the result is a value in monetary terms, with questionable accuracy. The important thing to note is that different descriptions or measurements may be used for different purposes. Any suggestion that there is only one way of doing it is therefore unrealistic and ridiculous.

Evaluation of Complete Intangibles

Completely intangible costs of a project may be the result of such effects as the possible loss of a scenic or historic site connected with a proposed dam (governmental), or the loss of favorable community attitude or product quality (industrial). Attempting to estimate such costs would be an arduous task resulting in little conviction that the results were satisfactory. Such is the case, also, in attempting to measure intangible benefits concerning such effects as the strengthening of national security, or the increase of provisions for the enjoyment of recreation and wildlife.

If completely intangible project effects, which cannot be evaluated in monetary terms, are considered sufficiently significant to influence the selection of competing alternative projects, it is obvious that such benefits and/or costs should be indicated subjectively in some units so that comparisons can be made. Also, as a result, the scale of development of a project with respect to such intangible objectives may be either curtailed or expanded.

A general method for subjectively rating pertinent, intangible effects, and for entering such ratings into an overall comparison analysis of pairs of alternative tactical proposals is espoused by Starr (1964), and has been referred to alternatively as the nondimensional rating method, and the exponential rating method. This technique of comparison which eliminates differences in units between different effects, while combining the numerical ratings or quantifications of all pertinent effects, is outlined below:

1. Based on a scale of one to ten, rate each intangible effect involved in the various tactics, with the value of one representing the best possible result and the value of ten being the least desirable. To illustrate, the example below is presented in which a new plant location is being determined between Plan 1 (Boston) and Plan 2 (Los Angeles). Plan 1 is seen to be far superior in its flexibility to adapt to situations that are likely to occur in in the industry. It is also favored with respect to community attitude and product quality. Plan 2 is favored when the tangible aspects are considered.

Effects	Plan 1	Plan 2	Weight
Building costs and equipment costs - yearly depreciated value	$1,000,000	$600,000	4
Taxes (per year)	$50,000	$20,000	4
Power cost (per year)	$20,000	$30,000	4

Community attitude	1	2	1
Product quality as a function of worker morale and skill	2	3	6
Flexibility to adapt to situations that are likely to occur	1	8	5

2. Next, "weight" each entity in the set of outcome-objectives being analyzed so as to reflect their relative importance as categories. From the example, product quality is seen to be the most important effect being considered, whereas community attitude is least important.

   Various approaches can be used for obtaining the weights, including a) using the estimates of that individual who is responsible for this decision, b) using an average value, obtained by pooling the opinions of a number of individuals holding various responsible positions regarding the project, c) employing an informal debating procedure between a number of responsible individuals to develop a set of estimates and weights that are agreeable to all concerned parties, such as the procedure espoused by Helmer (1969).

3. Express the overall preference as the products of the outcomes (effects) raised to powers for each plan. Then the plans can be compared in ratio with each other.

$$\frac{\text{Preference for Plan 1}}{\text{Preference for Plan 2}} = \left(\frac{O_{11}}{O_{21}}\right)^{w_1} \left(\frac{O_{12}}{O_{22}}\right)^{w_2} \cdots \left(\frac{O_{1j}}{O_{2j}}\right)^{w_j} \cdots \left(\frac{O_{1n}}{O_{2n}}\right)^{w_n}$$

Where the j and n subscripts denote the particular outcomes related to a plan.

In the example it is seen that, since lower numbers implied better results, Plan 1 is preferred to Plan 2:

$$\frac{\text{Preference for Plan 1}}{\text{Preference for Plan 2}} = \frac{(1,000,000)^4\ (50,000)^4\ (20,000)^4\ (1)^1\ (2)^6\ (1)^5}{(600,000)^4\ (20,000)^4\ (30,000)^4\ (2)^1\ (3)^6\ (8)^5} = 0.0001$$

Since the ratio is less than 1.0, the numerator is less than the denominator, and Plan 1 is deemed superior. If the ratio had exceeded 1.0, then the alternative represented in the denominator would have been chosen.

The non-dimensional rating method has a number of advantages and disadvantages regarding the validity of the results. The basic advantages are:

1. It allows the comparison of alternatives when completely intangible effects exist among objectively evaluative effects.
2. It allows the combination of competing objectives, having different dimensions, to provide a reasonable basis for evaluation.
3. It forces the decision makers to consider all pertinent effects of the competing tactics.

Major disadvantages of this method are:

1. The intangible effect ratings are the result of subjective evaluations by the decision makers, and thus do not reflect the same degree of validity as do the objective tangible evaluations. Therefore, the overall accuracy of the computed results are threatened.
2. The weightings assigned each effect are also subjectively determined, and their accuracy depends on the ability of the decision maker(s) to accurately gage their relative importances. Such weightings are indeed flexible, as they represent assignments for a particular set of decision maker(s) and circumstances.
3. The resulting comparisons do not express differences between competing tactics in monetary terms. The ratios only reveal which alternatives are preferred, in paired comparisons, over others. The resulting ratios are in the form of pure numbers with no dimensionality.

CHAPTER VIII

SUMMARY, CONCLUSIONS, RECOMMENDATIONS

Summary and Conclusions

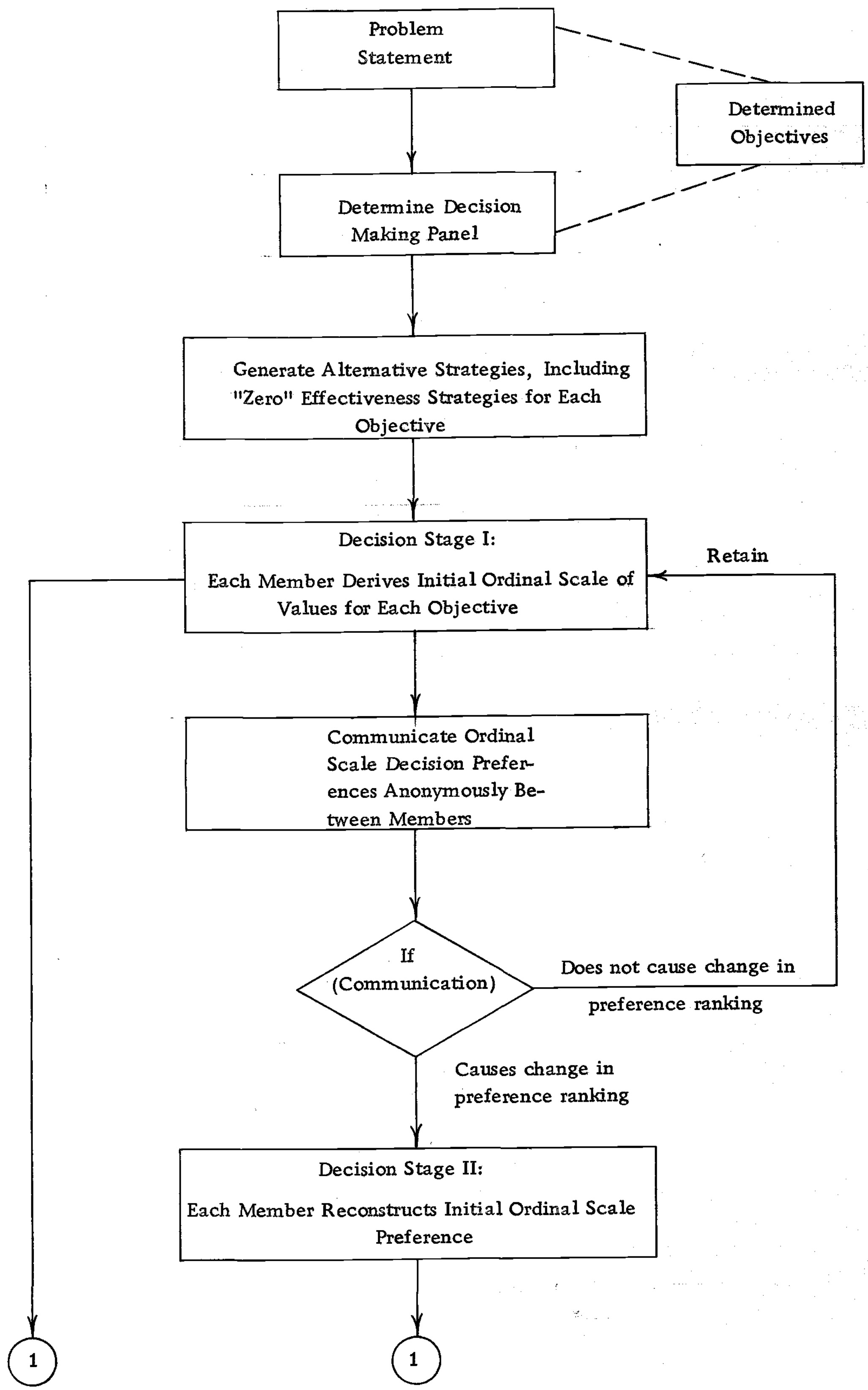
It was the writer's primary intention in this thesis to develop a systematic algorithmic procedure for delineating and comparing alternative programs at the strategic levels of decision making. In the process of developing the various stages of this algorithm there were at times alternative approaches for achieving the same ends. Appropriately therefore, in this concluding chapter a final procedural outline will be presented in which the different stages will be brought into perspective in summary form, and the best of alternative approaches will be included and defended. A generalized flow diagram, presented on the following three pages, represents the decision procedure.

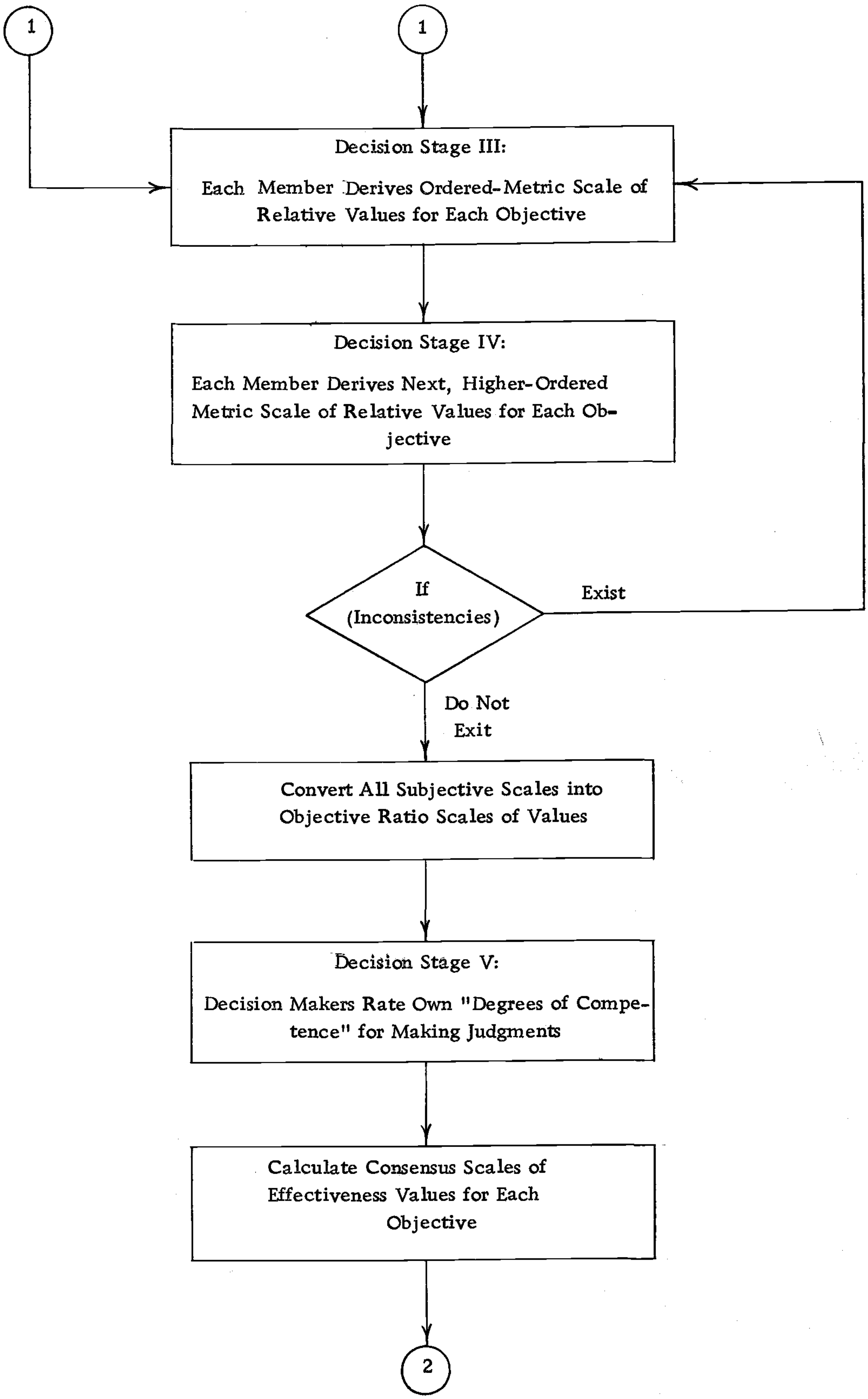
Procedural Outline for Strategic Decision Making

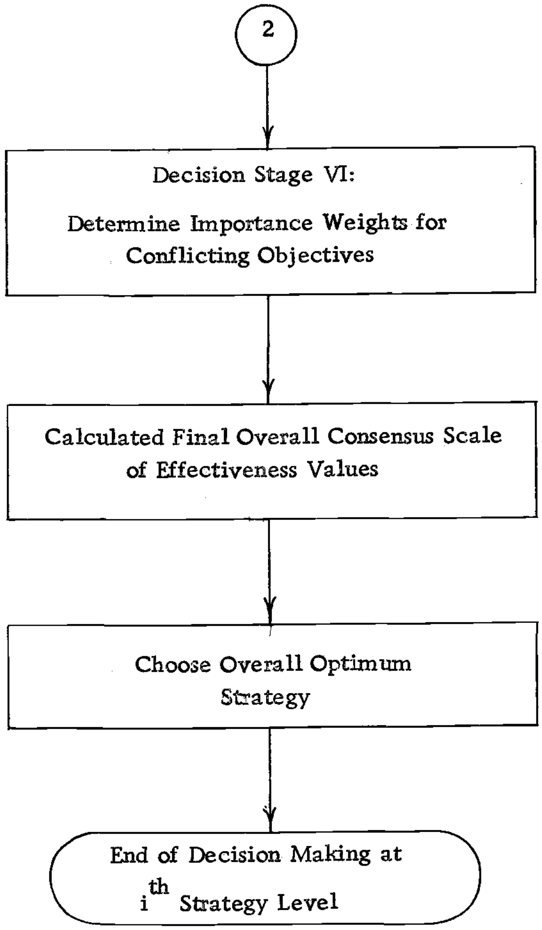
State Problem. Initially a venture is brought to the attention of the executives of an organization regarding the potential investment of given resources in the form of men, capital, and equipment. The successful solution of the problem will be achieved as a result of comparing a number of competing alternative strategies:

Input: (Available Resources + Time Limit + Criterion + Unequal Alternatives) → Decision Process →
Output: (Specification of Optimum Strategy)

Strategic Decision Flow Diagram




1
1
Decision Stage III:
Each Member Derives Ordered-Metric Scale of Relative Values for Each Objective
Decision Stage IV:
Each Member Derives Next, Higher-Ordered Metric Scale of Relative Values for Each Objective
If (Inconsistencies)
Exist
Do Not Exit
Convert All Subjective Scales into Objective Ratio Scales of Values
Decision Stage V:
Decision Makers Rate Own "Degrees of Competence" for Making Judgments
Calculate Consensus Scales of Effectiveness Values for Each Objective
2


2
Decision Stage VI:
Determine Importance Weights for Conflicting Objectives
Calculated Final Overall Consensus Scale of Effectiveness Values
Choose Overall Optimum Strategy
End of Decision Making at i^{th} Strategy Level

Determine Decision Making Panel. The executives who are to be responsible for solving the problem are restricted to those who: a) are knowledgeable of its various aspects (e.g., resource availability, restrictions, market conditions, competition); b) have, through experience, knowledge, and recognized decision making ability, sufficient insight into various potential strategies to be considered; c) have sufficient time available to allocate for considerations of the problem being evaluated.

Determine Objectives. The delineation of problem objectives, tangible and intangible, may be a part of the problem statement given to the panel members or may result from mutual determination by the members themselves. The important considerations in defining objectives are that ideally: a) each objective should be distinct, not implying another; b) each should be independent - the achievement of one not affecting the achievement of any other; c) should not be contradictory - the achievement of any combination of objectives should be possible; d) be additive, in that the achievement of each objective should add to the overall desirability.

Generate Alternative Strategies. The set of alternative strategic proposals for meeting given objectives may be partially given to the decision makers: a) from above, b) as a result of ignorance, c) due to institutional rigidity, d) from past experience, or e) it may to some extent be achieved by a process of searching for new alternatives, employing principles of creativity and imagination. In addition, "zero" effectiveness strategies should be determined for each objective.

Decision Stage I. Each member derives initial ordinal scales of strategy preferences under each given objective. The ranking of the strategies is based upon their relative effectiveness in achieving the respective criteria.

Communicate Scale Results to Each Member. In this anonymous exchange of information, each member contributes a list of reasons for each objective-strategy ranking scale, explaining why he ordered the alternatives as he did. These lists, in written form, are collected, duplicated, and combined with other member responses; then sets are submitted to all panel members.

Decision Stage II. Each member reconsiders his initial ordinal scales of preferences, based on the new information provided in the communication exchange above. The initial scale differences between members were due to: a) differences in knowledge concerning alternative proposals and related tactical means of effecting them; b) differences in feelings of intuition and risk involved with respect to each strategy; c) differences in background and experience. These differences are minimized, hopefully, after the communication stage, when the experts reconsider their initial scales using equal equal information.

Decision Stage III. Each member derives ordered metric scales of relative values for each objective strategy set by comparing appropriate nonorderable probability combinations, according to Siegel's technique.

Decision Stage IV. Each member derives the higher-ordered metric scales of subjective relative values for each objective, extending the information gained in Decision Stage III by comparing necessary remaining probability combinations. In addition, comparison of all other combinations is required as a check on the consistency of the expert's responses.

Conversion from Ordinal Scaling to Ratio Scaling. In this step the Higher-Ordered Metric Minima approach is employed to achieve objective, ratio scales of values from the previous subjective, ordered scales, based on the assumption that "each decision maker knows no more than the minimum degree of preference reflected in his effectiveness comparisons."

In Chapter V three alternative approaches were presented for quantifying the effectiveness scale positions of the strategies, along with the important advantages and disadvantages of each. It is concluded here that the Higher-Ordered Metric Minima approach is the preferred method of quantification over the Ordered Metric Minima approach and the Standard Gamble approach, based on the following characteristics of excellence: 1) the relative time required for scale derivation; 2) the feasibility of attempting to apply the technique to strategic economic decision problems (i. e., with respect to the degree of complexity of discrimination involved in the comparisons involved, and the subsequent probability of inconsistencies resulting); 3) the relative facility of comprehension of the technique by decision makers for the purpose of self-application (i. e., the simplicity of the technique mechanics); and 4) the relative amount of information achieved using the technique.

The table on the next page reveals subjective evaluations of these three approaches, resulting from their examination in application by the writer. Four subjective ratings were used in the relative evaluation: 1) poor, 2) fair, 3) good, 4) excellent. Importance of the criteria are rated one to four on the basis of one as the most important qualification, with respect to probable decision situations.

Importance / Characteristics / Technique	(4) Derivation Time	(1) Decision Problem Applicability	(3) Simplicity of Mechanics	(2) Amount of Information Achieved
Order Metric Minima Approach	Good	Good	Good	Fair
Higher-Ordered Metric Approach	Fair	Good	Good	Good
Standard Gamble	Poor	Poor	Good	Excellent

Figure VIII-1. Comparison of interval scaling techniques.

The Standard Gamble approach is eliminated first because of its inability to fulfill the most important qualification of applicability. In deed, this method requires the decision maker to make very difficult judgments in being able to discriminate between probability values when attempting to define indifference points. The chance of inconsistencies occurring when employing this approach is great. Further, as the table shows, if a consistent scale of values was attainable for a decision problem, the amount of information acquired concerning the expert's preferences would be rated as excellent. However, this is a highly improbable result when employing the Standard Gamble approach.

The Ordered Metric Minima approach was considered second best to the Higher-Ordered technique because of the greater amount of information revealed when employing the latter technique.

As revealed in Chapter IV, the ordered metric scale orders the distances between successive pairs of entities; the higher-ordered metric scale, however, orders all possible combinations of scale distances between entities. Regarding the other criteria, the two methods are similar in quality, except for the fact that the higher-ordered metric scales take a little longer to derive owing to a few more probability combination relationships needed for each objective-strategy set.

Decision Stage V. Decision makers weight their own "degrees of competence" regarding ability to make judgments according to each objective. Ratings are made according to the following percentage values: zero per cent, twenty-five per cent, fifty per cent, seventy-five per cent, one-hundred per cent.

Compute Consensus Scales of Effectiveness Values for Each Objective. By multiplying competence ratings by scale values for each objective and for each decision maker, and by adding the resulting respective scale values under each objective, overall consensus scales of effectiveness values are achieved for each criteria.

Decision Stage VI. Importance weightings are determined for the conflicting objectives by employing Helmer's "anonymous debating procedure" described in Chapter VII under the heading: Qualified Estimates of Authorities.

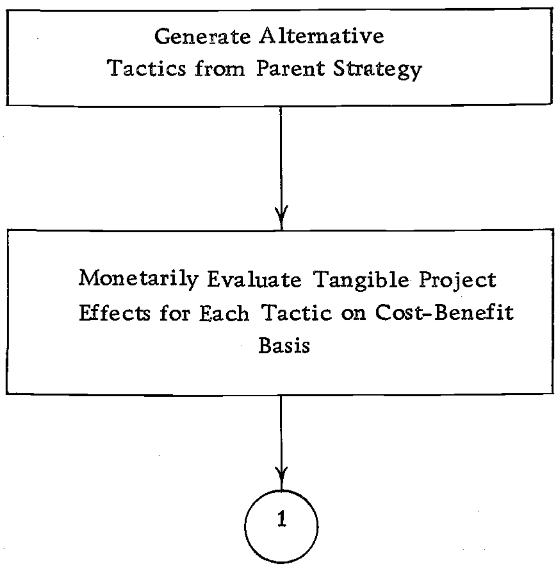
Calculate the Overall Consensus Scale of Effectiveness Values. By multiplying scale values by objective weightings and adding the respective weighted scale values, the final consensus scale of effectiveness values for the competing economic proposals results.

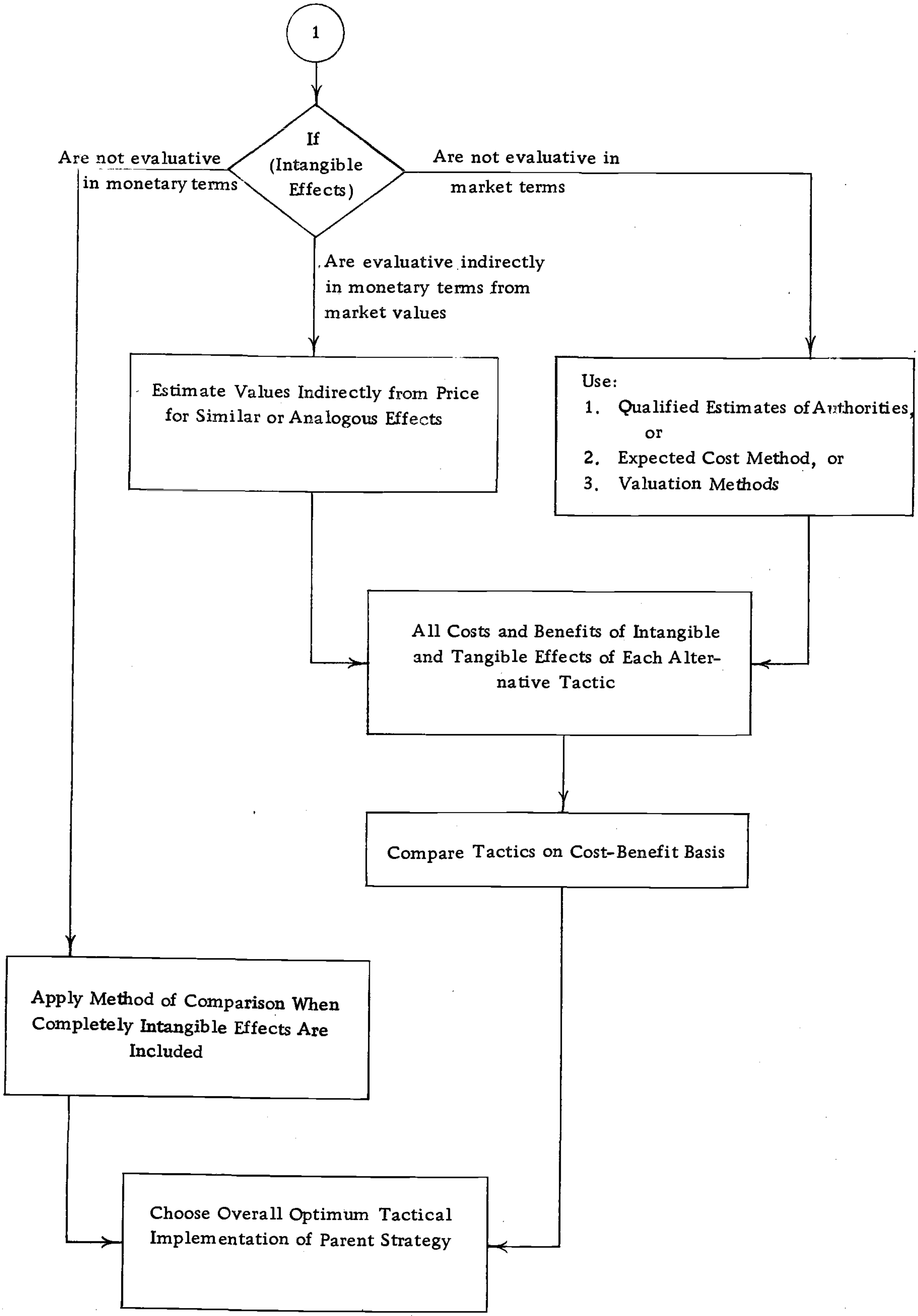
Choose the Overall Optimum Strategy. From the final effectiveness scale the strategy conceived to have the greatest overall effectiveness for achieving given objectives is chosen.

With the choice of this optimum strategy, the decision making procedure is concluded at the i^{th} strategy level. The decision at this level, however, spawns numerous analogous decision problems at the next lower strategy level involving various affected departments within the organization.

Decision Flow Diagram at Tactical Level

The flow diagram shown below is presented to summarize the procedures for comparing economic alternatives at the various tactical decision making levels of the organization.




1
If
(Intangible
Effects)
Are not evaluative
in monetary terms
Are not evaluative in
market terms
Are evaluative indirectly
in monetary terms from
market values
Estimate Values Indirectly from Price
for Similar or Analogous Effects
Use:
1. Qualified Estimates of Authorities,
or
2. Expected Cost Method, or
3. Valuation Methods
All Costs and Benefits of Intangible
and Tangible Effects of Each Alter-
native Tactic
Compare Tactics on Cost-Benefit Basis
Apply Method of Comparison When
Completely Intangible Effects Are
Included
Choose Overall Optimum Tactical
Implementation of Parent Strategy

Recommendations for Future Research

Future study in the area of decision making at the strategy level could proceed in a number of ways. First, as an attempt at validating the theoretical procedure proposed in this thesis, the next step should involve the application of this decision algorithm to a realistic organizational decision problem. In this way, the pros and cons of this procedure can be revealed, and its overall success in determining the optimum strategy can be investigated. Further, the results of such an application will reveal aspects of the procedure which need to be further analyzed and corrected. Specifically, the three approaches for deriving ratio scales of utility values proposed in this thesis should be compared with respect to: 1) the time required to develop scales; 2) the problems incurred in their application to decision problems, including the mechanical aspects of developing the scales; and 3) the occurrence of inconsistent comparisons.

Secondly, another lucrative area of investigation might be in relation to the important step of the decision algorithm involving the location and generation of alternative strategies. Certainly, the degree to which the decision making process achieves optimization depends upon the quality of the initial set of competing strategies. Therefore, it would be desirable to develop systematic procedures or techniques under different problem situations.

Regarding the second lucrative area of strategy generation, perhaps a stepwise procedure such as the following could be developed, employing the principles of creativity:

1. Define the problem, including resources available and restrictions,
2. List specific objectives,
3. Seek out alternatives which would effectively accomplish the first objective listed, by first using imagination to the fullest extent, and then, after running out of new ideas, applying the stepwise checklist of adaptation, modification, magnification, minification, substitution, rearrangement, and combination questions found in texts on creativity; assure that the alternatives adhere to problem constraints.
4. Similarly, seek out alternatives which would effectively accomplish each succeeding objective.
5. Construct a two-way table of strategies versus objectives, and eliminate obviously inferior strategies which accomplish few of the objectives effectively.
6. List the strategies to be evaluated.

In conclusion, whatever stepwise procedure is developed, it should be systematic to the extent that it minimizes as much as possible the chance of overlooking potentially lucrative strategies with respect to problem objectives.

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APPENDICES

GLOSSARY OF RELEVANT TERMS

Contracts: are agreements providing for the rendering of a service or granting of a privilege under stipulated conditions at a stipulated price.

Effectiveness: a measure of success in achieving objectives, in terms of estimated utility values representing decision maker preferences.

Efficiency: a measure of success in achieving objectives, as determined by cost-benefit analyses in monetary terms.

Financing: includes the costs of issuing and selling securities of the enterprise.

Going Value: is the element of value of an assembled and established plant, doing business and earning money, over one not thus advanced.

Goodwill: is often a significant intangible effect of the firm, contributing toward the procurement of excess profits over and above a fair return on the investment in the enterprise. It is reflected by the many customers who continually patronize the firm in bad times as well as good. It may result from such causes as: 1) favorable personal relationships between customers and employees of the enterprise, 2) popular brand-name trademarks achieved through effective advertising, or 3) effective business policies.

Higher-Ordered Metric Scale: a subjective ordered scale of preferences in which all intervals between all entities are ranked with respect to the perceived utility distances between them. The scale is developed based upon preferences made regarding probability combination choices.

Intangible: an economic entity or effect which is not measurable directly in terms of market values. "Quasi-intangibility" implies intangibles which are commensurate indirectly in terms of market units. Complete intangibility denotes an entity which is incommensurate directly or indirectly in market terms.

Interval Scale: a scale of measurement in which entities are assigned numerical ratings. Based on an arbitrary zero point, entities are scaled according to a constant unit of measurement.

Objective: a tangible or intangible goal governing the solution of a decision problem. Strategies and tactics are compared with respect to their capabilities in achieving problem objectives.

Optimality: is the condition achieved when one or more objectives are all achieved to the maximum degree possible. Usually, when conflicting multiple objectives exist, it is almost always true that all of them cannot be optimized at the same time. Therefore, when competing alternatives are being compared, the selection made is of that alternative which achieves overall optimization of the decision criteria.

Options: are particular kinds of contracts. They are contracts purchased at prices greater than prevailing market prices, which have values due to the increases which they will effect in future incomes.

Ordered Metric Scale: a subjective ordered scale of preferences in which successive intervals between scale entities are ranked with respect to the perceived utility distances between them. The scale is developed based upon preferences made regarding probability combination choices.

Ordinal Scale: a scale of order or rank of given entities with respect to certain common characteristics; the order is with respect to greater or less than subjective values reflecting degrees of magnitude of the perceived characteristics.

Organization: is the name for the expenses incurred in the inception and organization of the enterprise; it includes the costs of promoting ideas and organizing the business.

Ratio Scale: a scale of measurement having all the properties of the ordinal and interval scales, plus an absolute zero point, and thus the property of additivity, which allows different scales to be combined.

Strategy: a decision alternative which is measured in terms of its effectiveness in achieving given objectives at the highest levels of an organization.

Tactic: a decision alternative which is measured in terms of its efficiency for achieving given objectives at lower organizational levels in which effects are measured in monetary units; tactics are also defined as means of executing strategies.

Utility: is the subjective value attached to an entity or effect in the course of measuring and comparing different factors with respect to their relative effectiveness in achieving given objectives.