INCORPORATING ENVIRONMENTAL IMPACTS IN THE TRANSPORTATION SYSTEM EVALUATION PROCESS

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An increased social awareness and concern for the environment have added to the complexity of transportation decision-making. This paper attempts to synthesize and assess current system evaluation techniques that are potentially suitable for treating socioeconomic, environmental, and political impacts from the location and design of transportation facilities. The relative merits of several numerical techniques are presented through examples. The arrangement and comparisons developed are ultimately generalized into a cost-effectiveness framework, and dialogue with the operational planner is furthered through a general discussion of the decision-making and model choice problem and an overview of current theoretical research efforts in transportation systems evaluation.

•IN THE last several years, the processes of highway location and design have become increasingly complex, particularly in urban areas. Much of the added complexity is due to tremendous increases in population and advances in highway technology coupled with increased social awareness and environmental concern. The political response to these environmental issues at the federal level has resulted in legislative action that specifically deals with the environment as well as in particular sections of highway acts related to environmental impacts. Included in these are the 1969 National Environmental Policy Act, the 1970 Environmental Quality Improvement Act, the 1965 Highway Beautification Act, and the 1966 Department of Transportation Act. Section 4f of the 1966 act placed restrictions on the use for highway purposes of public parklands, recreation areas, historic sites, and wildlife and waterfowl refuges, and the 1969 and 1970 environmental acts require that consideration be made toward the preservation and enhancement of the environment for all federal-aid highway improvements (1, 2). This paper discusses several promising and potentially operational methods for consideration and evaluation of highway location and design decisions with respect to these social and environmental requirements.

ASPECTS OF LOCATION AND DESIGN DECISIONS

The modern highway decision process requires the generation of a facility location and design alternative, prediction and evaluation of the consequences, and accepting, modifying, or rejecting the alternative. Prediction and evaluation are required for the following:

1. Construction and right-of-way costs;
2. User costs of fuel, oil, and wear and tear on vehicle;

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3. Safety costs—accident rates and costs of accidents;
4. Maintenance costs of the facility; and
5. Environmental and social impacts as listed in the Appendix.

Obviously, the decision surrounding such a wide and interacting set of consequences is complex, and evaluation is difficult. Some weighting technique of part or all of the foregoing consequences may be desirable. Thus, the process should be actively involved within a framework containing the following elements:

1. Objectives—The highway decision should be a step toward accomplishing relevant local, state, or federal goals that can be enhanced by improved transportation systems, such as increased safety, lower travel time, lower commodity rates and prices, increased cultural and social mobility, and increased trade between regions.
2. Criteria—Where possible, yardsticks (termed criteria) for measurement of attainment of the above objectives should be employed. Some examples include, for increased safety, accident rate per mvm; for lower travel time, trip time in minutes from point A to point B; for increased trade, tons of commodity x shipped from A to B after facility opening as compared to before.
3. Alternatives—In fulfilling the objectives of improved transportation, it is necessary to develop a reasonable set of highway location and design alternatives, that is, the composites of alignment, profile, right-of-way, cross section, drainage, interchange and intersection configurations, and control types and devices that together form a design and/or location.
4. Resources and constraints—Usually money, time, soil type, original topography and surrounding land use, manpower, engineering designs, and local political pressures and viewpoints can be considered resources or constraints for a location and design problem.
5. Model—An evaluation technique (termed a "model") should attempt to integrate the aspects of the decision within the foregoing framework of objectives, criteria, alternatives, resources, and constraints and yield a set of feasible alternative locations or designs or, if possible, a "best" location or design alternative.

Although many evaluation methods, ranging from conceptual to fully tested and operational, are currently in use or proposed, the utility of these methods depends greatly on the knowledge, experience, and personal values of the evaluator(s). In addition, many of the methods available have application to only limited factors (i.e., user costs and benefits as in benefit-cost analysis) or project situations. The use of an evaluation method does not replace the elements of discussion and compromise needed to achieve a solution that optimizes the public interest. Accordingly, it is not possible at this time to recommend a single method, or combination of methods, for universal application. Although three general groups of techniques—visual, numerical, and combination—have been investigated, only the numerical techniques are described in this paper, which concludes with a discussion of current research and the future outlook for meaningful evaluation modeling (1).

NUMERICAL TECHNIQUES

Ranking Method

The simplest of the numerical techniques that can be used to compare alternate highway improvements is the ranking method (3, 4). In using this procedure, each alternative is ranked with respect to its ability to satisfy the social, environmental, and economic factors under consideration. As shown in Table 1, the effects of the improvement are optimally oriented, a rank of 1 is assigned to the alternative that best satisfies a particular factor, and a rank of n (where n equals the number of alternatives) is assigned to the alternative that is least desirable with respect to the factor.

For impacts that are quantifiable (e.g., number of dwelling units destroyed) the procedure is easily applied. For nonquantifiable factors (e.g., effects on wildlife protection), a rank is assigned by applying judgment on the basis of a pairwise comparison of the alternatives. In either case, the data requirements correspond to the minimum level required for other numerical methods, data consistency rather than precision being of primary importance.

The most prominent disadvantage of the ranking method is its nonlinearity, which fails to distinguish incremental differences among alternatives. This nonlinearity, coupled with the fact that the factors under consideration may not all be of equal importance, generally precludes the analyst from reaching a decision on the basis of rank summation. In a typical case, as shown in Table 2, no alternative will show a clear superiority to all others. This is a reflection of the fact that each alternative was chosen for consideration in the decision-making process because it is superior to other alternatives with respect to at least one of the factors under consideration. As a result, it is frequently not possible to select the best alternative by the ranking method.

The ranking method is useful in the evaluation of minor projects where the null alternative is environmentally undesirable and in the screening of an unusually large number of projects for the purpose of deleting from consideration those projects that consistently rank poorly.

Rating Methods

Two of the inherent deficiencies of the ranking procedure, the nonlinearity of the scale and the varying levels of importance of the factors under consideration, can be remedied, either individually or collectively, through the use of a weighting scheme. Such schemes, in which the alternatives and/or the impact factors are related to an arbitrary weighting scale, are referred to as rating methods (5, 6). Specifically, one of the following methodologies is employed:

1. The impact factors are weighted according to their relative importance to the community; for example, noise abatement may be considered of more importance than preservation of open space. With appropriate weighting, this procedure permits the inclusion of comparatively minor impacts in the analysis.
2. An arbitrary rating scale is established whereby the impacts may be compared in a consistent and linear manner. With respect to land values, a possible rating scheme would be

50 percent increase in value	rating = 1
10 percent increase in value	5
30 percent decrease in value	9

The application of this second procedure is shown in Table 3, where a set of 7 rating scales (for factors A through G) was hypothesized and applied to the data in the previously discussed ranking example. If all of the socioenvironmental factors were of equal importance, it would be possible to reach a decision by summing the ratings for each alternative. Because of the rating convention used in this example, alternative 4, with the lowest summation, would be the most desirable.

The more enlightened decisions that can be made as a result of the rating methods involve additional expense. This expense is reflected by the increased level of effort that must be expended in the data collection and analysis phases. Although achieving homogeneity of scales used in the rating of alternatives may pose a minor problem, obtaining a consensus with respect to the value judgments employed in factor rating is frequently time-consuming and rather difficult. The method has been shown to work satisfactorily when a representative citizen's advisory group is involved. Differences in community values preclude the adoption of a universal factor rating scheme, and therefore each community must evaluate these factors in accord with local situations. However, the additional effort required is normally worthwhile for the evaluation of major improvement projects.

Rank-Based Expected Value

An interesting modification of the ranking method results in the rank-based expected value technique in which both the factors to be considered and the alternatives are ranked.

Table 1. Example ranking of alternatives versus dwelling units destroyed.

Alternative	Dwelling Units Destroyed	Rank
V	0	1
W	2	2
X	20	3
Y	24	4

Table 2. Ranking example for five alternatives and seven factors.

	Alternatives				
Socioenvironmental Factors	No. 1	No. 2	No. 3	No. 4	No. 5
A—Market access (avg. time to county center, min)	5 (20)[a]	3 (16)	1 (12)	2 (15)	4 (19)
B—Level of service (avg. travel speed, mph)	1 (45)	3 (40)	4.5 (36)	4.5 (36)	2 (42)
C—Provision of public service (police response time, min)	4 (10)	3 (9)	1 (6)	2 (8)	5 (12)
D—Disruption (number of homes taken)	2 (12)	3 (14)	5 (40)	4 (20)	1 (4)
E—User costs (annual $, in millions)	3 (1.0)	3 (1.0)	1 (0.8)	5 (1.6)	3 (1.0)
F—Sonic pollution (db at 100 ft)	5 (75)	3 (65)	4 (70)	1 (50)	2 (60)
G—Others (ranked by engineering judgment)	1 (2)	3 (6)	5 (10)	2 (4)	4 (8)

[a] Actual numerical values of factors are shown in parentheses.

Table 3. Example of rating method application.

	Alternatives				
Socioenvironmental Factors	No. 1	No. 2	No. 3	No. 4	No. 5
A	10	6	2	5	9
B	3	5	7	7	4
C	5	4	1	3	7
D	3	4	10	5	1
E	5	5	4	8	5
F	10	6	8	1	4
G	2	6	10	4	8
Summation	38	36	42	33	38

Table 4. Example of rank-based expected value technique.

		Alternatives				
Socioenvironmental Factors	Rank Order Value	No. 1 (0.8)[a]	No. 2 (0.6)[a]	No. 3 (0.7)[a]	No. 4 (0.6)[a]	No. 5 (0.9)[a]
A	7	1	3	5	4	2
B	3	5	3	1.5	1.5	4
C	5	2	3	5	4	1
D	2	4	3	1	2	5
E	6	3	3	5	1	3
F	1	1	3	2	5	4
G	4	5	3	1	4	2
Plan value		63.2	50.4	71.75	50.1	63.9

Note: Rankings are on scale with an optimal orientation different from that shown in Table 2.

[a] Probability of implementation.

Table 5. Example of value matrix application.

	Alternatives				
Socioenvironmental Factors	No. 1	No. 2	No. 3	No. 4	No. 5
A	0	6	20	7.5	2.5
B	9	6.7	3	3	8
C	4	5	10	6	2
D	11.7	10.8	1.7	8.3	15
E	10	10	14	0	10
F	1	3	2	10	6
G	15	9	3	12	6
Summation	50.7	50.5	53.7	46.8	49.5

The former are ranked according to their relative degree of importance, while the alternatives are ranked in the order of their effect on the factors. Application of this method in Wisconsin (7, 8), shown in Table 4, involved the following steps:

1. The ranking of n plan objectives (or factors) in order of importance and assignment of values of n, n - 1, n - 2, . . . , 1 in descending rank order;
2. The rank ordering of m plans (or alternatives) under each objective and assignment of a value m, m - 1, m - 2, . . . , 1;
3. The estimation and assignment of a probability of implementation for each alternative; and
4. Obtaining the score or value of each alternative by multiplying the rank of the objective by the rank of the alternative and the probability, if required, and summing the products for each alternative.

For example, the score of alternative i can be expressed as follows:

$$V_i = P_i(n_1m_1 + n_2m_2 + \ldots + n_nm_n)$$

where

V_i = score of alternative i;
P_i = probability of implementing alternative i;
n_1 = the rank for factor number one; and
m_1 = the rank for plan m for factor number one.

In the example in Table 4, plan 3 has the highest value and is thus the best alternative.

One of the major advantages of the rank-based expected value method is its ease in application. The objectives must be rank-ordered and the rank value of each alternative for each objective must be determined. However, this is easier to do on a relative basis than on an absolute value scale. For small-scale decision situations (i.e., comparison of project alternatives), changes in ranking to test for sensitivity would be feasible. On the other hand, system-wide alternatives would be too large for this to be practical and the development and use of a computer program for sensitivity analysis would be necessary.

Value Matrix

A technique similar to the rank-based expected value method is referred to as the value matrix method (9, 10). Instead of ranking the factors according to their degree of importance, they are weighed with the most important receiving the highest weight. The previously described rating technique is then used to rate the alternatives to show their effect on the factors. The value for an alternative is obtained by summing the product of the weight of each factor and the rating of the alternative for that factor.

Following the itemization of community objectives, this technique involves these steps:

1. Determine the parameter that best measures each objective. Some suggested measures are indicated for the objectives listed for the ranking method.
2. Assign a weight (or utility value) to each objective to reflect community values.
3. Study the parameter chosen to measure each objective and determine the value for each alternative. If this is done on a weighting basis, the alternative that best meets that objective would receive the highest weight, the alternative that is next best in meeting the objective would receive the second highest weight, and so on until the worst alternative (with respect to that objective) would receive the least weight.
4. Select the best alternative. This technique would select the alternative with the highest value as best meeting that particular combined set of objectives, shown in Table 5 as alternative 3.

Utility curves or the combination of utility curves and relative rating may be used in steps 2 and 3 above.

Schimpler and Grecco (10) suggest some modifications in using the value matrix technique. The major change is in establishing weighted community decision criteria by community decision-makers and professional planners acting as the criteria evaluation group or committee. After individual weighting of the various sets of criteria, the entire group meets and is asked to reevaluate their initial weighting.

A significant advantage of the value matrix technique is its ability, in a systematic framework, to handle a mixture of both subjective measures and values from rigorous mathematical techniques.

Desirability Ratings (Utility Theory)

The formal mathematical attributes of "utility theory", which attempt to measure the worth or value of a set of alternatives or objects to an individual or a group, are utilized in a set of techniques referred to as desirability ratings (11, 12, 13).

The desirability of a highway design or location is one's measure of its worth to him. That is, for location and design alternative 1, we associate a value, V_1, which may be in dollars, a value or a scale from 0 to 100, or any other arbitrary scale consistent with the individual's point of view. This method, as an input to other evaluation techniques, seeks to describe such possibilities of arrival at reasonable scales, which are as follows:

1. Location 1 has several impacts a, . . . , n (capacity alteration, change in accident rate, homes taken, businesses taken, pollution emissions, etc.). The decision-maker associates a set of consistent values $V_{1a}, V_{1b}, \ldots, V_{1n}$ with these n impacts. Then the utility or worth of location 1 is $U(1) = V_{1a} + V_{1b} + \ldots + V_{1n}$, which is the sum of the individual values. That is, the utility structure is additive, yielding a final value for the project.
2. Using the same example, $U(1) = V_{1a} \cdot V_{1b} \cdot V_{1c} \cdot \ldots \cdot V_{1n}$, which is the product of the several individual values associated with the several impacts. That is, the utility structure is multiplicative, compounding over the several values attached to individual impacts.
3. If the several a, . . . , n impacts are uncertain, and there exists $P_a, P_b, \ldots, P_n$, where P_i is the percentage chance that a particular individual impact i will occur, the utility structure may be $U(1) = P_aV_{1a} + P_bV_{1b} + \ldots + P_nV_{1n}$, yielding a final "expected value" of location.
4. Finally, in general, $U(1) = f(V_{1a}, \ldots, V_{1n})$, that is, $U(1)$ may be some complex mathematical function of the several individual values, involving addition, subtraction, multiplication, division, or powers.
5. General transitivity of the utilities of several alternatives is assumed; that is, if the value of location 1 is greater than the value of location 2, and the value of location 2 is greater than the value of location 5, then the value of location 1 is greater than the value of location 5.

A major advantage of this procedure is its ability to develop an abstract measurement scale that is relevant to the concerned groups' points of view, and in so doing to allow the combining of the valuation of several independent results of location into simple or complex functional mathematical forms, as required. As a result, it broadens and moves away from the traditional strict monetary evaluation process. To an extent greater than that cited for the rank-based expected value technique, it allows the combination and inclusion of information about uncertainty of impacts into the evaluation process. And finally, it forms a usable and common input into several currently used evaluation techniques.

Notable among the shortcomings of this procedure is the assessment of the values of the impacts associated with a location (i.e., $V_{1a}, \ldots, V_{1n}$), which is often difficult for each concerned group. Likewise, estimation or measurement of the chances of each impact occurring ($P_a, \ldots, P_n$) is often difficult. The most complex task encountered in the application of this technique is the approximation of the appropriate value or utility function for an alternative; that is, is it additive, an expected value, multiplicative, or some complex functional form, and what are its units, e.g., dollars, lives lost, or some final level on a scale whose values range over selected bounds?

In conclusion, the technique in determining basic value or desirability of a location has merit in discovering the underlying value structure and broadening the evaluation format. However, efficient use in light of its shortcomings should emphasize simple, readily identifiable functional forms of V(1), logically relatable to the points of view of the concerned groups. Complex functional forms should only be used where a very great amount of certainty exists that the mathematical statement is in fact correct and meaningful in relation to the location process and the groups concerned.

Competitive Decisions

The competitive decision model, popularly termed "game theory", attempts to capture the structure of conflict and citizen values inherent in the location process and the struggle between subgroups to effect the alteration of locations and designs that have adverse impacts. It is presented here for its underlying logic fit in the highway decision process and its insight in structuring groups' and community strategies on projects having a significant set of public impacts. Three general types of game-theoretic models are appropriate (14, 15):

1. A 2-person zero sum game, where two opposing individuals or groups are in conflict, and the negative impact on one group is equivalent to the positive impact on the second group.
2. A 2-person open sum game, the same as above except that the amount lost by one group is not identical to the amount won by the other.
3. An n-person open sum game, where there are several groups in conflict, each encountering different losses or gains associated with various combinations of impacts.

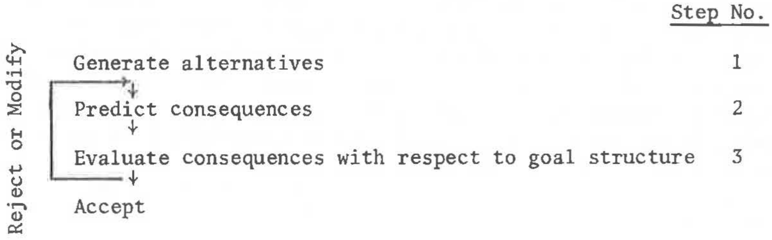
In all of the above contexts, each group assesses several location alternatives and supports the acceptance of them to a greater or lesser extent, depending on their value structure and the opposing pressure being exerted for each of the alternatives by other community groups. Where possible, formal solutions to the structures yield a relative measure of support that each group involved in the location process should attach to each alternative to minimize their losses, considering similar maneuvering of emphasis by other groups. Under the current planning process, such support or pressure occurs through the public hearing process, appropriate planning or public works commission meetings, or informal expression of the group's point of view to responsible professional and public officials.

The significant advantage of this technique, in spite of its mathematical and computational complexity, is its ability to adequately structure the citizens' group political and public hearing process and the underlying community power struggle in location decisions as well as in the final implementation and construction phases. As a practical logic framework for the resolution of locational conflicts and insight to forces behind implementation of highway construction, it can be an excellent tool.

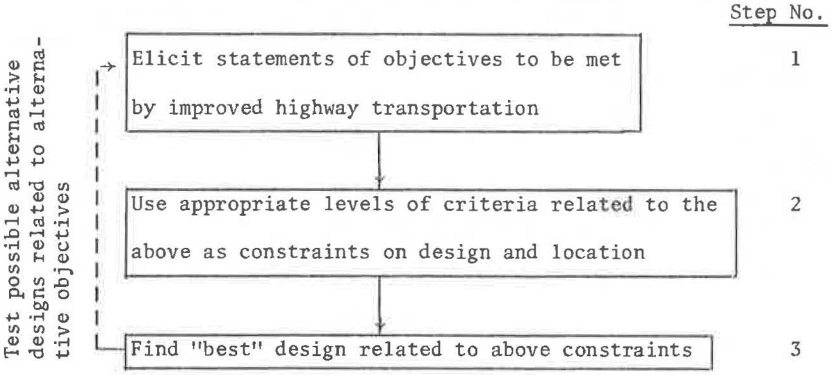
DISCUSSION OF THEORETICAL RESEARCH ISSUES

Throughout this paper, review and analysis have been undertaken of evaluation techniques that illustrate a variety of methods for combining knowledge about consequences of highway location and design and weighting these in some manner. This section attempts, in a general manner, to discuss theoretical research techniques currently under investigation. These techniques expand on those already presented and make their solution more straightforward. In addition, they may allow for refinement as additional consequence information becomes available or permit clearer interaction between the community and technical subgroups involved.

One such research technique relates to the alteration of general evaluation formats to encourage response on goals and objectives at the outset of the design process and use of appropriate techniques to subsequently respond with only the best solution relating to these goal and objective statements (16). Previously, evaluation has followed the concept of



It should be noted that the objectives related to the provision of improved transportation facilities are brought into the evaluation at Step 3. Recent research has related to changing the order of the evaluation format, developing the following:



The above format, termed "backward seeking" as compared to the previous "forward seeking" approach, uses statements of levels of service or standards as criteria that are compatible with the objectives. Through consideration of these, all alternatives not satisfying any of the stated criteria are rejected, resulting in acceptance of the alternative satisfying the objectives at their highest possible level within the confines of the stated constraints. Research involving this approach is conducted within the general framework of mathematical techniques referred to as optimization theory and/or statistical decision theory.

Another approach utilizes the ability to introduce uncertainty into the analysis and to refine the analysis when increased information is available. Many of the consequences of highway improvement, their costs, and their value to the community are not known with 100 percent certainty. Hence, recent research has focused on the parameters $P(I_j)$, the probability that an impact of type j will have a relevant reasonable level I; $P(V_j)$, the probability that the community will place a relevant value or worth of V on it; and $P(C_j)$, the probability that it will cost an amount C to alter or arrive at the level I.

Obviously, as more information is gathered through research on impacts and their relation to communities, $P(V_j)$, $P(C_j)$, and $P(I_j)$ should change (17). Hence, Bayesian statistical techniques employing increased information such as historical or laboratory experiments in the community can be used to update the probabilities from time to time, yielding new $P'(V_j)$, $P'(C_j)$, and $P'(I_j)$ as revised estimators of appropriate probabilities related to impacts.

A third approach relates to increased research to develop measuring techniques for inducing individuals' valuation of impacts. Emphasis in this paper has been on the examination of methods that enable individuals or groups to place a value on the consequences of an alternative (18, 19). Continuing research effort is being made to select appropriate interviews, questionnaires, and attitudinal or preference measurement

Table 6. Typical cost-effectiveness analysis of alternatives.

Alternative	Construction and Right-of-Way Cost Net Present Value ($)	Decrease in Corridor Travel Time to CBD (min)	Predicted Accident Rate (acc./mvm)	Dwelling Units Taken	Business Establishments Taken
1	1,500,000	12	1.0	100	25
2	1,000,000	10	1.5	60	20
3	700,000	5	4.0	15	14
4	0	0	7.0	0	0

Figure 1. Cost-effectiveness array of impact.

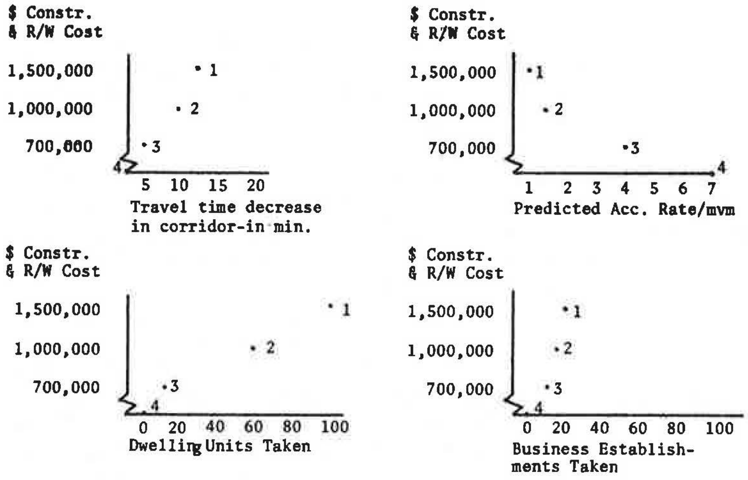
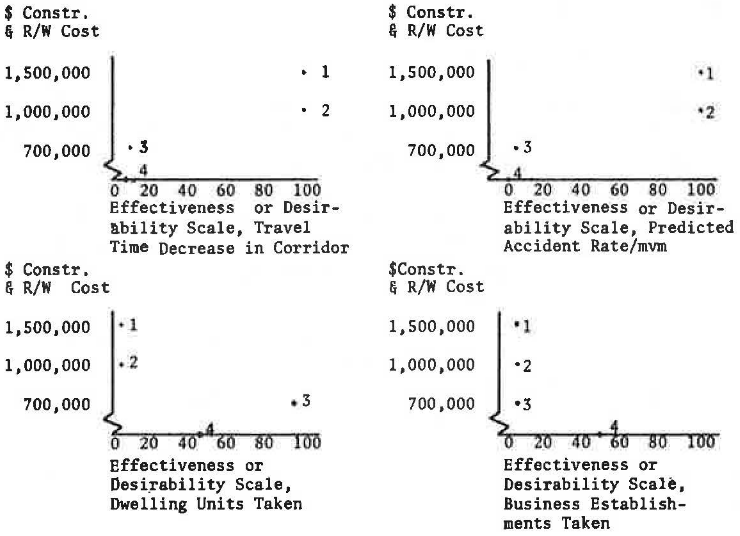


Figure 2. Typical value structure of a community subgroup.



formats that will accurately and logically detect a value structure for levels of consequences relating to the vaguer impacts, such as some of those listed in the first three categories of the Appendix.

A fourth concept calls for increased research in applying the foregoing to the competitive aspects of community location decisions. The value structures in location and design decisions are often revealed prior to or within the public hearing process. As indicated earlier, the primary shortcoming of competitive decision models is their inability to adequately handle processes of several groups in conflict, particularly where each group does not necessarily accrue the same loss or gain due to the location decision. Continuing research emphasis is being placed on efforts to make use of improved measurement techniques in a more liberal interpretation of community conflict (15). This should allow more accurate inclusion of citizen-political interchange and compromise on location and design decisions with respect to the value structure as it truly occurs in a community.

Finally, integration of the various techniques within the broad concept of cost-effectiveness must be considered. The most constructive and representative trend in evaluation research for the appropriate employment of techniques discussed herein exists within the general context of the approach termed cost-effectiveness (20). In this approach, the applied and theoretical research techniques consider positive and negative impacts of a transportation decision for each subgroup, ultimately allowing them to trade off levels of consequences by design type. The crucial impacts for a hypothetical situation where three alternatives for realignment and upgrading of an obsolete facility are being considered are given in Table 6. Each impact is shown in Figure 1, plotted on a capital and right-of-way cost axis.

Alternatively, dwelling units taken could be shown in dollars of tax loss to the community, and businesses taken could have been expressed in total dollar volume of business loss to the area. A community subgroup may put other weightings or interpretations of effectiveness or desirability on these alternatives, as shown in Figure 2.

In light of its value structure, the community group may continue to investigate the alternatives, trading off between alternatives 1, 2, 3, and 4 to ultimately decide on a location and design. It is important to be aware that another subgroup will probably attach substantially different weightings or desirability to these impacts. The values and decisions on alternatives by each subgroup are carried forth into political activity for implementation (council meetings, public hearings, zoning boards, etc.), and there, the trade-offs are reexamined within and across each group's values, resulting in rejection, acceptance, or modification of the location and design alternatives.

CONCLUSIONS

From the material presented in this paper, it should be obvious that no general transportation evaluation model currently exists that can accurately and rationally deal with the subtleties of the impact of any transportation technology on the entirety of groups affected by it. Further, the gap is great between currently available operational techniques and the theoretical questions that must be answered in a rigorous and comprehensive manner to render operationality of evaluation at a more accurate and sophisticated level. Increased effort to this end must be achieved through activities that pursue the following research goals simultaneously:

1. Vigorous theoretical modeling work on relevant community decision and capital investment processes, as discussed in the previous section;
2. Interpretation of such results into a nontechnical library of evaluation techniques for operating engineering and planning personnel; and
3. Effective communication and interchange of ideas concerning the problem structure with operating engineers and planning personnel as well as with the lay community at large affected by highway decisions.

The authors are pursuing such activities through further investigation of the evaluation techniques in specific location and design situations. Problems under study include alignment processes, urban intersection alternatives, transit network problems, and gross regional transportation planning alternatives. The ultimate intent is to develop an operational framework to match appropriate evaluation techniques with system design and location issues.

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APPENDIX

SOCIOECONOMIC AND ENVIRONMENTAL FACTORS FOR CONSIDERATION IN HIGHWAY LOCATION AND DESIGN

The following lists identify general factors that may be deserving of consideration in the evaluation of a transportation system improvement. Although the lists are reasonably comprehensive, the decision-maker must exercise judgment in determining if other specific or unique factors should be considered in the analysis of a particular project.

For convenience, the factors have been divided into four broad, although not mutually exclusive, categories:

1. Effects on the stationary environment,
2. Effects on the transient environment,
3. Neighborhood and community impacts, and
4. Traditional factors in highway improvement analysis.

Effects on the Stationary Environment

1. Aesthetics
2. Agriculture
3. Aquatic life protection
4. Coastal areas, estuaries, waterfowl refuges, and beaches
5. Farms, forests, and outdoor recreation areas
6. Flood plains and watersheds
7. Mineral land reclamation
8. Navigable airways
9. Navigable waterways
10. Raw material production
11. Scenic enhancement
12. Soil, plant life, erosion, and hydrological conditions
13. Wildlife protection
14. Other topographic factors

Effects on the Transient Environment

1. Air quality and air pollution control
2. Chemical contamination and food production
3. Climatological features
4. Disease and rodent control
5. Health hazards and other dangers
6. Herbicides and pesticides
7. Human ecology
8. Noise control and abatement
9. Radiation and radiological health
10. Sanitation and waste systems
11. Water quality and water pollution control

Neighborhood and Community Impacts

1. Activity patterns
2. Community pride

3. Cultural and recreational opportunities
4. Community protection services
5. Domestic privacy
6. Economic stability of the community
7. Educational systems
8. Employment opportunities
9. Energy generation and supply
10. Historical and archeological sites
11. Housing and building displacement
12. Impacts on other institutions
13. Land values and uses
14. Neighborhood disruption
15. Personal and community identity
16. Population distribution
17. Preservation of open space
18. Property tax base
19. Relocation assistance
20. Special impacts on low-income areas
21. Utility services
22. Visual quality of the environment
23. Zoning regulations

Traditional Factors in Transportation Improvement Analysis

1. Business and trade
2. Congestion in urban areas
3. Construction material availability
4. Disruption during construction
5. Existing transportation system
6. Facility appearance
7. System costs and system economics
8. International implications
9. Land access
10. Low travel costs
11. Modal choice and compatibility
12. Multiple use of highway rights-of-way
13. National defense
14. Regional comprehensive planning
15. Special impact on regional jurisdictions
16. Tourism
17. Transport system reliability
18. Transportation and handling of hazardous materials
19. Transportation safety
20. Travel convenience and efficiency