A Structured Approach to the Evaluation and Comparison of Alternative Transportation Plans

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TRB Record # 619, updated 2003

ABSTRACT:

The process of evaluating alternative transportation plans is examined in an attempt to provide an overall structure to the process. A set of questions that can be used to define the evaluation process are given. These questions consider such issues as the scope of the process, its interface with other activities such as model development or plan design, the actual process of evaluation, and the interpretation of evaluation results. Within this framework a multidimensional evaluation process is described. This process involves the careful analysis and distillation of information contained in an evaluation matrix through a series of steps aimed at identifying significant differences among alternatives. Procedures are suggested for eliminating criteria that are not relevant to a decision and for eliminating alternatives that are clearly inferior. Such a process allows for a more careful examination of the trade-offs among alternatives and the implications of the criteria used to measure plan performance.

INTRODUCTION:

The process of evaluation may be one of the most crucial phases in the selection of an alternative course of action that best meets a previously defined set of goals and objectives. The final choice of the appropriate plan should be not only a choice of the best plan, but also a choice that has been strengthened through careful interpretation and that has been tested and found significantly superior to the alternative plans.

While there have been extensive efforts in the past to accurately forecast future travel-demand conditions, environmental impacts, and other factors, the levels of effort to develop evaluation procedures have not been as extensive. These previous efforts (1, 2, 3) have concentrated on defining the overall process of evaluation and outlining some basic principles to be applied to the process. The major emphases have been on the roles of different interest groups in the evaluation, the use of a systematic approach, the importance of an iterative process, and the need to consider nonquantifiable factors in the evaluation. These efforts have provided a substantial framework on which evaluation can be based. However, when the process of evaluation as it is practiced in many transportation agencies is viewed, one finds that there is a substantial gap between what is actually done and what should be done. Too often the actual evaluation process is overly mechanical, poorly documented, and done without consideration of many of the principles discussed in the references above. Moreover, the techniques and procedures used vary considerably from agency to agency. There is a need to define in greater detail a more open, yet structured, process of evaluation as it can be performed under the constraints of a transportation agency. This paper presents an attempt to structure the evaluation process and to suggest methods whereby it can be accomplished.

Publication of this paper sponsored by Committee on Transportation Systems Design.
The paper has two parts. In the first part, a series of questions have been prepared that can be used to define the overall scope of the evaluation process, its interface with other activities, the nature of the process, and the interpretation of evaluation results. The second part outlines a step-by-step procedure that can be used in a plan evaluation that attempts to clearly define the trade-offs among the alternative plans.

STRUCTURING THE EVALUATION PROCESS

Some basic questions must be addressed in order to structure a procedure for the evaluation of alternative land use and transportation plans. The questions are fairly general, and their purpose is to shape the sequence of steps that can be used for evaluation. (For the purposes of this paper, evaluation shall be defined fairly narrowly as the process of selecting the best plan from a given set of alternative plans according to a given set of objectives and criteria.) As will be illustrated by the set of questions, there are important links between evaluation and other phases of the planning process that must be carefully defined and analyzed.

Scope of the Evaluation Process

There is a need to define the scope of the evaluation process. The answers to the following questions may have a significant impact on the amount of time and effort that are necessary to perform an evaluation.

1. What should be the area levels of the evaluation? A plan that is good for an overall region may be very poor for certain subareas and very good for others. Other plans may have different subregional impacts. If these subregional impacts are significant, there may be a need for evaluation at subregional levels.

2. Should the evaluation be conducted separately for different population subgroups? Since different population groups may be affected in different ways by the plans, there may be a need to examine the plans separately for each subgroup. What subgroups should be analyzed and how should such evaluations take place?

3. For what time periods should the evaluation take place? Since the plans may be implemented at different rates, should separate evaluations take place, for example, for ten years from now, twenty years, or fifty years?

4. What procedures should be used to answer questions 1 to 3? How does one determine what subareas, subgroups, and time periods to analyze?

Interface of Evaluation Process With Other Activities

The evaluation process has important interfaces with other activities such as the development and the analysis of the alternatives, and answers to several questions in this area are needed.

1. To what extent is it possible to return to the analysis or development of alternative phases of a planning effort during the evaluation phase? If new alternatives emerge during the evaluation process is it possible to return to these phases and iterate the process?

2. What potentials exist for making partial decisions at one time and other decisions at a later time when additional information is available?

3. How will alternative elements of a plan be combined? When one element is included in a plan, its presence may dictate that other elements also be included so that a workable system exists.

Evaluation Process

Other questions relate to the procedural steps that will take place during evaluation and to the methodology that will be employed.
1. What general method will be used to examine the evaluation matrix? Two basic methods can be used to examine an evaluation matrix. These are weighting techniques in which the information in the matrix is collapsed into single-number and multinumber techniques in which the matrix is kept intact as comparisons are made. Single-number techniques have some advantages but can also lead to difficulties if not used with extreme care. Some of these difficulties are the masking differences and trade-offs between alternatives, problems in assigning weights, dealing with intangibles, and mathematical inconsistencies. Multinumber techniques allow for a more careful analysis of the trade-offs between alternative plans but have not been used widely.

2. What rules can be used to combine or eliminate criteria? If all alternative plans perform equally well on certain criteria, these criteria can be eliminated from the matrix because they will not affect the decision. Some rules are needed (for example, if all are within 5 percent) to eliminate these criteria.

3. What is the significance of the measures used to indicate plan performance? General statements of goals will have to be interpreted by a set of quantitative and qualitative measures of plan performance. There is a need to ensure that the measures used adequately represent the interest of the goal and that they are sensitive to differences in plans.

4. Can the criteria be interpreted on a linear basis? For example, is a travel time of 10 min. really twice as bad as one of 5 min.?

5. What are the threshold values of certain criteria? There may be certain minimum levels of goal attainment that are necessary for an alternative to be considered. If this is the case, procedures must be developed to determine these values.

6. How will value systems be represented? Certain criteria are more important than others and there must be a procedure to determine a value system. This could also be a set of value systems if different subgroups of people are being examined.

7. Who will do the evaluation? Who will be involved in the evaluation process and how will this involvement take place?

8. Who will make the decision? What is the relation between the decision maker and the persons developing and analyzing alternative plans? How does communication take place?

9. What are the mechanics of the evaluation procedure? How will the various persons and committees involved operate? What are their information needs? What turnaround time is needed? How well defined are the roles of the various persons involved in the process?

Interpretation of Evaluation Results

Once a tentative decision has been made there is a need to make it a strong decision. Interpretation of the decision is necessary to develop confidence in the choice made and to assess its relative merit over other alternatives.

1. Are differences in the preferred plan significant from a sensitivity point of view? The selection of a plan may be sensitive to a number of factors such as basic input data, definition of networks and zones, types of models used, parameters of the models, choice of criteria, parameters used in the evaluation itself, and procedures used to interpret the evaluation matrix. If slight changes in key parameters and assumptions shift the choice, further work to refine the choice may be necessary.

2. How well does each plan perform in situations that may not be probable but are still possible? An analysis should identify the possible contingencies, describe how they might occur, forecast the performance of the alternatives in the contingent situation, and compare these performances. Plans that perform well in a contingent situation should be preferred to those that do not. Some contingencies that might be considered are changing population and economic conditions, changing resource availability and environmental conditions, changing land use patterns, and changes in governmental policies.

3. What are the variations in plan performance that are necessary to make the second-best plan equal to the preferred plan? If these variations are major differences, there should be a greater degree of confidence in the preferred plan than if they are minor differences.
4. How well do the criteria reflect the goals? How can they be interpreted to reflect the goals? What are the subjective interpretations of how well each plan meets the goals?

MULTIDIMENSIONAL EVALUATION PROCESS

Evaluation can be conducted at a number of different levels. It can be conducted at the overall regional level, for subareas of the region, for subgroups of the population, and for different periods in time. What may be a good plan at one level may not be a good one at a different level. If a plan performs well at the regional level, it should be further analyzed to determine how well it performs at some of the sublevels. Since the process of land use and transportation planning is a continuing one, some subregional evaluations should take place before and during the process of implementing a regional plan. It is important to clearly define the decisions that properly should take place at the regional or systems level and those that can be properly considered at a later stage. The initial evaluation should be undertaken with a set of alternatives that define a broad spectrum of options. From the testing of these initial alternatives, a second series of alternatives should be developed to represent the balance between the extremes of the earlier alternatives. This second set of alternatives should be tested against a wider set of criteria and under alternative future conditions, and it may be possible at this point to eliminate a number of alternatives because of obvious shortcomings or inferiority. Certain other plans may be eliminated because they seriously fail to meet overriding considerations for plan development and thus cannot be implemented. This would narrow the choice to a few alternatives that could be studied in greater detail at the regional level. In this analysis, the alternative plans would be compared to each other on an objective-by-objective basis.

After the regional level analysis, additional analyses can take place by subarea, subgroup, or time period. After these analyses, a tentative choice would be made and would then be subject to interpretation to determine whether it is a valid choice. If the tentative choice meets further tests and analyses, it can become a final choice and move toward regional adoption. All of the steps in the process should be fully documented and presented to the decision makers at key points in the process. The sequence of steps that would be used in the overall process is given in the following sections.

Feasibility Test of Each Alternative Plan

Each plan should be tested to see whether it meets the needs of the overriding considerations for plan development. These considerations might, for example, be that each proposed alternative must constitute an integrated system, that it must be within the economic capability of the agency to implement the plan, and that the plan must be in compliance with national and state regulations and standards. If a plan fails one or more of these tests, it should be dropped from further consideration, although if some dispute exists as to whether or not a plan meets the needs, the plan should remain for further analysis at subsequent phases of the evaluation.

Overall Evaluation

The remaining alternatives should then be compared on a regional level, but a plan should be acceptable on an overall basis before it is examined on a sublevel basis. The following steps should be used for such an evaluation.

1. Test the adequacy of the measures used as criteria. The means used to measure how well an objective is met should be reexamined to determine whether they portray the objective in a proper manner. Criteria can be measured as totals, averages, or as a net change over a base. The change caused by a plan may be insignificant when compared on a total or average basis but significant when the increment over a base value is examined.

2. Develop a set of rules for eliminating criteria. If all plans are equally or almost equally successful at meeting certain criteria, those criteria will not affect the decision and can be eliminated.

3. Eliminate criteria by using the rules developed in step 2.
4. Eliminate plans by principle of dominance. If any plan falls below any other plan in all criteria, it is dominated by the superior plan and can be eliminated.

5. Examine the remaining criteria to determine those that are (a) threshold values that must be met, but are not significant beyond that, (b) characteristics of the input used to develop the alternatives, or (c) representative of differences in the ability of each plan to meet the overall objectives. Possibly some of those in the first two categories can be eliminated since they may not be relevant to the decision.

6. Combine criteria where possible. If a set of criteria are similar in what they are measuring, they can be combined into a single measure.

7. Repeat steps 3, 4, and 6 as often as necessary until no more changes occur. At that point, a reduced evaluation matrix in which no one plan dominates and all criteria measure significant differences in the remaining alternatives will remain. The subsequent steps in the evaluation will be aimed at defining the trade-offs between the alternatives and the issues involved in each choice.

8. Study the marginal costs and gains. Arrange the remaining plans in order of increasing costs and examine the marginal gains as the costs increase in a manner similar to marginal benefit-cost analysis. Some plans will have a lower marginal gain per unit cost than others at this point and can be dropped from further consideration.

9. Define the trade-offs. By this point the matrix will be reduced to a more manageable size and the differences between plans should be evident. These trade-offs should be defined, and an attempt should be made to present the issues involved in as concise terms as possible for the decision makers. The trade-offs can be developed by comparing the alternatives in pairs in a sequence of increasing costs and should indicate the gains that would occur if the more expensive plan were chosen over the less expensive one and the costs necessary to obtain these gains.

10. Develop additional alternatives. At this point new alternatives that combine some of the best features of the earlier alternatives may be developed. These alternatives would then be analyzed in a manner consistent with the original alternatives and carried through the above processes.

11. Select plans for sublevel analysis. From the information obtained from steps 2, 9, and 10 certain plans can be eliminated from further consideration because they are unacceptable at the overall level. Among the plans that are acceptable, there are three possible outcomes: (a) One alternative may be clearly preferable to the others in nearly all respects; (b) a number of alternatives may be essentially equal in nearly all categories; or (c) some alternatives may excel in some categories and others may excel in other categories, but there will be no clear choice without serious trade-offs. Except for the first outcome, further analysis at the sublevel is necessary.

Sublevel Analysis

The plans can be evaluated by subarea, subpopulation group, or for different time periods.

Tentative Selection Among Alternatives

This selection should be labeled as a tentative choice and will require careful interpretation before it becomes the final choice. It is important that this distinction be emphasized so that an objective interpretation can take place. The option of changing the tentative choice should remain open, and adequate time should be allocated to the interpretation phase so that all analysis (and iteration, if necessary) can be done.

Interpretation of Tentative Selection

Once the tentative selection has been made, it should be interpreted in order to strengthen the choice. The process of alternative development and testing involves a series of simplifications and assumptions that must be examined to determine their effects on the choice, and certain factors that have not been
explicitly included in the analysis and their effects on the choice should also be examined. The interpretive phase should involve the following activities (not necessarily in the sequence shown).

Break-Even Analysis

This is an analysis of how much better the best alternative is than the second-best. Such an analysis is relatively easy to perform with single-number evaluation techniques. An important question is, are the differences between the best and second-best alternatives significantly large enough that they are not within the range of differences that might be expected from the data and procedures used? Such an analysis would be conducted in a manner similar to the marginal cost versus gain process described in step 8. The marginal gain of the best plan over the second-best plan should be examined in relation to the process used to delineate the differences in the plans. If the differences are beyond the range of variance due to the forecasting techniques, there should be a greater degree of confidence in the best plan than if the reverse were true.

Sensitivity Analysis

The purpose of this analysis is to identify the effects of the various parameters and assumptions used in the forecasts and evaluation. The results of the forecasting procedures may be very sensitive to some parameters and insensitive to others. The sensitivity analysis can be directed at the criteria themselves or at the data processing effort. In the first case, the sensitivity of the choice of the best alternative to the means used to define a criterion is examined. In the second case, the sensitivity of the data used and forecasting techniques are examined. Obviously the second case would involve considerably more effort than the first. For example, it might involve the following steps: (a) Identify the parameters used in the forecasts; (b) examine the range of values used; (c) review the process used to set values on the forecasts; (d) estimate the possible range of values the parameter could have as the result of statistical, conceptual, or assumption errors; and (e) determine how these errors would be carried through the process and how they might have a differential effect on the different alternatives.

Contingency Analysis

A contingency is an event whose occurrence is possible but not probable. For example, the effects of severe long-term shortages in petroleum-based fuels, the effects of major changes in population growth, or the effects of major shifts in land use patterns might be viewed as contingencies. Because of the uncertainty of the future, it is desirable to examine how well the best alternative performs under contingent situations. Such an analysis might involve the following steps: (a) Identify the contingent situations, (b) develop scenarios as to how they would occur, (c) forecast the performance of the best alternative under the contingent situations, and (d) compare the performance of the best alternative under normal and contingent situations.

Impact and Incidence Analysis

The impact (upon whom) and the incidence (at what period of time) of the costs and gains associated with the best alternatives should be examined. The costs and gains for two plans may be very similar in the aggregate but very dissimilar in their effects on those who receive them or the times in which they occur.
Implementation Feasibility

The relative ease with which a plan can be implemented should be examined. A superior plan with a low probability of implementation might be rejected in favor of a lesser plan with a higher probability of implementation. In addition, plans might be combined to increase implementation probabilities or efforts might be made to reduce barriers to implementation if they can effectively be identified.

Qualitative Analysis

This is a catchall that would include a careful examination of the best choice in the light of factors omitted in the analysis, assumptions made, factors that could not be quantified, uncertainties, and the results of the other phases of interpretation.

Feedback

The plans developed should be presented to the appropriate agencies and persons for their reactions and subjective evaluation. This should be a continuing process throughout the evaluation phase. The information developed in the previous steps should be sufficient to focus on the differences among plans so that a well thought-out decision can be made.

Modification of Plan

It is probable that in the evaluation and interpretation of alternative plans for the region certain features of one plan might be combined with other features of another plan. Such opportunities should be explored and tested whenever they occur although it may be necessary in some cases to return to earlier steps to compare the modified alternative with the other alternatives.

Selection of Plan

From the information and analyses developed above, it should be possible for the appropriate persons to select a plan of action. Once this plan has been selected, it should be adopted by the appropriate agencies and efforts should be initiated to determine the steps necessary to implement the plan.

EXAMPLE

The multidimensional process described in the preceding section can be illustrated by a simple example. Four hypothetical plans are to be evaluated against nine standards as shown in Table 1. These four plans are all feasible. Plan A is the do-nothing alternative, plan B is an alternative with limited investment in new facilities, and plans C and D both involve major investments in new facilities.
Table 1. Hypothetical evaluation matrix.

<table>
<thead>
<tr>
<th>Criterion</th>
<th>Plan A</th>
<th>Plan B</th>
<th>Plan C</th>
<th>Plan D</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Maximum transit headways</td>
<td>Met</td>
<td>Met</td>
<td>Met</td>
<td>Not met</td>
</tr>
<tr>
<td>2. Transit use to major trip generators</td>
<td>40</td>
<td>42</td>
<td>41</td>
<td>42</td>
</tr>
<tr>
<td>3. Congested highways, km</td>
<td>175</td>
<td>85</td>
<td>70</td>
<td>72</td>
</tr>
<tr>
<td>4. Average speeds, km/h</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>a. Transit</td>
<td>20</td>
<td>25</td>
<td>25</td>
<td>25</td>
</tr>
<tr>
<td>b. Highways</td>
<td>51.3</td>
<td>51.6</td>
<td>51.8</td>
<td>52.0</td>
</tr>
<tr>
<td>5. Total daily vehicle hours</td>
<td>125,000</td>
<td>123,000</td>
<td>122,000</td>
<td>121,000</td>
</tr>
<tr>
<td>6. Households displaced</td>
<td>0</td>
<td>450</td>
<td>1,250</td>
<td>1,320</td>
</tr>
<tr>
<td>7. Businesses displaced</td>
<td>0</td>
<td>45</td>
<td>125</td>
<td>195</td>
</tr>
<tr>
<td>8. Annual public cost, $</td>
<td>20,000,000</td>
<td>60,000,000</td>
<td>90,000,000</td>
<td>100,000,000</td>
</tr>
</tbody>
</table>

Note: 1 km = 0.62 mile.

The number of criteria has been limited to conserve space, but it should be recognized that additional criteria beyond those shown should be used in an actual evaluation. Criteria 2, 4b, and 5 can be eliminated since they show few significant differences among the plans. Criteria 6 and 7 can be combined since they both are measures of disruption and are roughly proportional to each other. Plan D can then be eliminated since it is dominated by plan C, and once plan D is eliminated, criterion 1 can be eliminated. The resulting evaluation matrix, shown below, has three alternatives and four criteria.

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Plan A</th>
<th>Plan B</th>
<th>Plan C</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>175</td>
<td>85</td>
<td>70</td>
</tr>
<tr>
<td>4a</td>
<td>20</td>
<td>25</td>
<td>25</td>
</tr>
<tr>
<td>7 and 8</td>
<td>0</td>
<td>495</td>
<td>1375</td>
</tr>
<tr>
<td>9</td>
<td>20</td>
<td>60</td>
<td>90</td>
</tr>
</tbody>
</table>

The choice of a plan then reduces to an examination of the trade-offs between the plans.

<table>
<thead>
<tr>
<th>Plans</th>
<th>Trade-offs</th>
</tr>
</thead>
<tbody>
<tr>
<td>B versus A</td>
<td>Gains: Reduction of congested highways by 90 km; increase in transit speeds from 20 to 25 km/h Costs: Displacement of 495 businesses and households; extra annual public cost of $40,000,000</td>
</tr>
<tr>
<td>C versus B</td>
<td>Gains: Reduction of congested highway by 15 km more Costs: Disruption of 880 additional properties; additional annual public cost of $30,000,000</td>
</tr>
</tbody>
</table>
Plan B provides a reduction in congestion and an increase in transit speeds at the cost of some disruption and an increase in cost. Plan C further reduced congestion, but by a small increment and at the cost of further disruption and increases in cost. This information and earlier steps should be given to the relevant decision makers and advisory groups for their consideration. The final choice of a plan then becomes a question of the relative degrees of importance placed on each of the associated gains and costs.

This example illustrates that the issues involved in a complex decision can be successfully identified through a process of carefully narrowing the choices and the criteria used for evaluation. Such a process can be used as an effective aid to decision making and to overcome some of the shortcomings inherent in overly mechanical techniques of planning evaluation.

SUMMARY

This paper has examined the process of evaluating alternative transportation plans in an attempt to provide an overall structure to the process. This has been done by presenting a series of questions that must be answered prior to any evaluation effort and by presenting a technique that can be used to narrow the choice to a limited number of alternatives having significant trade-offs among them. It is important that the process of evaluation be given careful consideration and substantial effort, but it is even more important that the techniques for evaluation be viewed as aids to decision making and not as the means for making decisions. That process is one that should be made through the best judgment of the decision maker with proper consideration of the trade-offs among the alternatives and the implications of the choice. To assist the decision maker in making this choice, there should be careful efforts to ensure that the criteria and measures of effectiveness used in evaluation are closely related to the goals of the plan, and the careful interpretation of the choice in the light of contingencies, sensitivity-omitted factors, and nonquantifiable factors should be viewed as an important part of the evaluation process.

ACKNOWLEDGMENTS

The work described in this paper is related to efforts underway at the Southeastern Wisconsin Regional Planning Commission. The helpful comments and suggestions of its staff are appreciated and acknowledged. The opinions expressed remain those of the author alone and should not be interpreted as the policy of the planning commission.

REFERENCES