program or individual user-coded computer programs.

The design-synthesis approach to transit planning is a useful tool in a structured framework for transit system planning and design, is applicable to a wide variety of planning situations, and is a step toward the development of more effective multimodal design-synthesis planning.

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REFERENCES

1. R. H. Pratt and G. W. Schultz. A Systems Approach to Subarea Transit Service Design. HRB, Highway Research Record 419, 1972, pp. 37-47.
2. R. H. Pratt and H. W. Bevis. An Initial Chicago North Suburban Transit Improvement Program. North Suburban Transportation Council, Skokie, Ill., May 1971.
3. Systems Analysis Approach to Transit Route and Service Design. R. H. Pratt Associates, Inc.; San Diego Comprehensive Planning Organization, Aug. 1974.
4. Transit Development Plan and Program San Diego Metropolitan Area 1975-1980. De Leuw, Cather and Co., R. H. Pratt Associates, Inc., and D. H. James; San Diego Comprehensive Planning Organization, Feb. 1975.
5. Bus Design Systems Analysis Methodology. R. H. Pratt Associates, Inc.; Denver Regional Transportation District, Nov. 13, 1974.
6. Service Level Investigation. R. H. Pratt Associates, Inc.; Denver Regional Transportation District, Jan. 9, 1975.
7. Bus Network Descriptions. R. H. Pratt Associates, Inc.; Denver Regional Transportation District, Jan. 27, 1975.
8. Transit Concept Comparison, Long Range Transit Development Analysis. Denver Regional Transportation District, April 1975.
9. Transit Development Program 1975-1980. Denver Regional Transportation District, March 1975.
10. Implementation of the N-Dimensional Logit Model. Peat, Marwick, Mitchell and Co., Washington, D.C.; San Diego Comprehensive Planning Organization, May 1972.

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Accommodating Multiple Alternatives in Transportation Planning

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This paper, which is based on procedures used in the San Diego-Los Angeles Corridor Study, examines several methodological improvements that enable a wider range of multimodal alternatives to be included in the transportation planning process. Staging of the planning and evaluation processes is identified as a basic organizing strategy. The design of significantly different alternatives, in terms of primary service characteristics, is described, and alternative multimodal service combinations are emphasized. The paper discusses travel-demand analyses conducted at relatively low cost at a sketch-planning level of detail with multiple computer model runs and efficient model application. A goal-achievement-oriented evaluation framework is specified that permits the quantitative evaluation of a wide range of local and regional performance objectives. The role of judgmental assessment as well as several areas for additional methodological improvement is also discussed.

One of the more frequently expressed concerns in urban transportation planning involves the need for a wider range of alternatives (4, 8, 11). More alternatives are needed, for example, to explore greater variation in levels of transit service or to investigate additional right-of-way location opportunities. Incorporating a larger number of alternatives in the planning process will expand the level of effort involved. Improved methodologies must therefore be developed that better organize the sequence of planning and evaluation activities and accommodate a wider range of transportation planning alternatives.

Although multiple alternatives are important at each major planning level—corridor, subarea, regional system, interregional, state—the interregional planning level is used here for illustration. The general approach used to deal with the major methodological questions can be applied at other levels of planning. The San Diego-Los Angeles Corridor Study, sponsored cooperatively by the California Department of Transportation (CALTRANS), the Southern California Association of Governments (SCAG), and the Comprehensive Planning Organization of the San Diego Region (CPO), is used as a case study. The methodological topics addressed are (a) staging of the planning and evaluation process, (b) broad-brush design of alternatives, (c) travel-demand analysis (at a sketch-planning level of detail), and (d) goal-oriented evaluation of alternatives.

STAGING THE PLANNING PROCESS

When the number of alternatives to be analyzed in the planning process is significantly increased, some strategy must be devised for sequencing the work. Given the increasingly comprehensive depth of analysis (in environmental impact statements for example), it is unlikely that all alternatives can be examined at once. One way to deal with this problem is to stage the planning and evaluation process into two or more phases. Each successive phase can reduce the number of alternatives to be evaluated and, as the number of alternatives is reduced, the level of detail with which each is investigated can be increased. Such a process can affect the design and redesign of alternatives, the level of detail achieved in analyses of travel demand and indirect impact, and the level of detail pursued in the evaluation of alternatives.

The two-stage planning process used in the San Diego-Los Angeles Corridor Study is shown in Figure 1 (1). In the first stage, a series of 21 multimodal alternatives (or packages) were analyzed and evaluated. Only 14 objectives and 27 evaluation criteria were applied. Modal-improvement options were reduced at this stage from 21 to 7, and those 7 were then subjected to a second round of analysis. This second, more thorough stage, which used 25 objectives and 41 evaluation criteria, emphasized the analysis of indirect effects and resulted in the identification of a single, preferred multimodal improvement plan.

DESIGNING ALTERNATIVES

According to the basic staging strategy, the design of modal improvement alternatives can also follow a pattern of increasing detail for a smaller number of alternatives. Nevertheless, much of the basic work in defining alternatives should probably be done in the initial stage of the planning process (14). The primary service characteristics—route location, line-haul speed, number of access points, and frequency of service—must all be established. This was essentially the strategy followed in the case study: The second stage only refined operating and cost characteristics for the set of seven alternatives, to more carefully match supply with forecast demand. Regardless of how the design of alternatives is staged, developing significantly different levels of service among alternatives is essential, both among modes and within the alternative levels of improvement hypothesized for any single mode.

There are two general ways in which the number of transportation alternatives under consideration can be increased.

1. Expand the number of modes investigated (4). In urban area transportation planning this generally calls for a broader consideration of transit alternatives in which different technologies are treated as alternative modes (e.g., bus rapid transit, heavy-rail mass rapid transit, light rail transit, small-group rapid transit, personal rapid transit). Metropolitan transit planning studies are only beginning to give comprehensive consideration to the many technology options. At the intercity or statewide planning level a number of modes, some with further technology options, already exist: automobile-highway, intercity bus, intercity rail, air, and in some cases water. These five modes were included in the San Diego-Los Angeles corridor planning project.
2. Devise a strategy to span the range of reasonable improvement alternatives within a given mode by examining several alternative levels of improvement (13, 16). Two to five alternative levels, from a minimum-improvement base through increasingly ambitious service and facility expansions, may be appropriate. Initially, such alternate improvement levels can be devised to reflect a broad understanding of current urban area or interregional travel patterns, short-range improvement plans, and various technological options reported in the literature. Such improvement levels should be designed for basic service characteristics at a sketch-planning level of detail (by including only generalized route alignments or station locations, for example).

As given in Table 1, 21 different modal-improvement alternatives were defined in the San Diego-Los Angeles case study for four service characteristics: number of routes, number of access points, maximum line-haul speed, and one-way frequency of service (1). Introducing a larger number of alternatives means dealing with intermodal relationships (15), which are crucial in demand analyses. Multimodal demand models currently available for projecting modal market shares hinge on the relative level of improvement in each mode. The different levels of improvement in a mode must be combined with varying levels of improvement in other modes to form multimodal packages for demand-analysis testing. When the number of alternatives is significantly increased, the number of possible multimodal packages quickly becomes unmanageable. A simplifying process that incorporates the staging strategy discussed above is necessary. In the case study the first-stage analysis defined only 21 multimodal packages by holding all modes except the subject mode at a base level of improvement (level 0). This allowed travel demand analysis and other analyses to focus on the relative effects of service improvements, one mode at a time.

Level 0 for each modal-improvement alternative should generally reflect current short-range regional and local transportation plans. This baseline should not only include existing facilities or services but also all relevant projects and programs contained in the 5-year implementation program of the local governments and transit operators concerned. Level 0 might thus be regarded as a no-build or low-capital-intensive alternative. Additional levels of improvement within a given mode can then be devised in an incremental manner, each built on the last. Questions of supply and demand and cost versus revenue can be made a part of the overall evaluation as the alternatives are narrowed down.

ANALYZING TRAVEL DEMAND

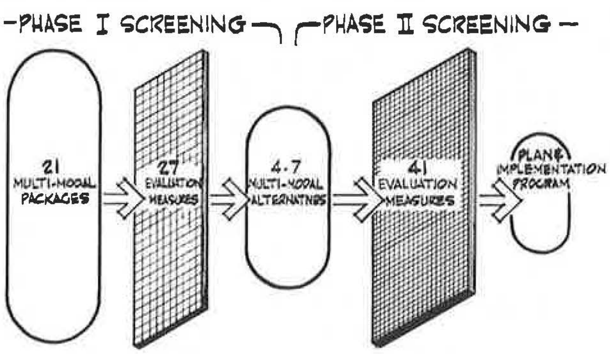
The progress made in recent years in improving urban travel demand models has been aided particularly by the urban transportation planning system (UTPS) package and its component models as well as by various add-on models, subroutines, or modifications that can be incorporated in UTPS, including logit-type mode-choice models calibrated on the basis of disaggregate, individual trip records and direct-demand models combining trip generation, distribution, and mode choice within a single-decision forecasting step. These modeling advances, which promise to improve substantially the overall transportation planning process, are well-documented in the literature (6).

Important progress has been made in developing or adapting models that can be applied at a sketch-planning (large-zone) level of detail; the number of alternatives that can be considered has thus been greatly increased. For example, a recent transit planning case study in the Milwaukee area involved adapting large-zone modeling techniques within the UTPS framework and testing a wide range of regional dual-mode-guideway network configurations (7). The analysis involved three stages: manual sketch-planning (and simplified modeling) analysis of 15 initial baseline systems; computer-based analysis for three refined baseline systems, including mode split and transit network assignment for a 100-zone system; and a series of 150 modeling runs for a variety of parametric analyses to systematically test variations in different service characteristics. Considerable flexibility and range were achieved in the number of alternatives accommodated.

A recent Los Angeles study of regional mode-choice incentives and disincentives achieved similar flexibility and multiple-run capability (18). In this case, a large number of transportation control strategies had to be evaluated relatively quickly and related to various improvements in level of transit service (routes and schedules). These control strategies included restrictions on parking cost and supply, preferential freeway ramp and lane treatment for multiple-occupancy vehicles, constraints on gasoline price and availability, and carpooling incentives. A modified DODOTRANS modeling package at a 107-zone level of analysis was developed and applied to permit the essential quick turnaround time in travel-demand model application (12). Fifty-five combinations of transportation control strategies were then tested.

Other approaches to travel-demand modeling at a sketch-planning level of detail are being developed and

Figure 1. Basic plan-evaluation process of San Diego-Los Angeles Corridor Study.



applied but cannot be adequately treated here (6). Instead, the intercity demand forecasting performed as part of the San Diego-Los Angeles Corridor Study is briefly reviewed to demonstrate how sketch-planning models are applied in a multiple-alternative context (2).

The multimodal, direct-demand model used in this case for forecasting total travel demand and mode split among five different modes represents a modification of the DODOTRANS package undertaken by CALTRANS (12). The 1995 multimodal demand forecasts were made for 20 of the initial modal-improvement alternatives (packages) and four refined improvement alternatives. A total of about 40 full modeling runs were made over a time span of 6 months after model calibration was completed (these included additional runs made to account for adjustments of input data).

Both the direct-demand and multimodal features of the demand model are particularly significant for intercity analysis. In the direct-demand approach, as noted above, the three fundamental steps in demand estimation—trip generation, trip distribution, and mode split—are performed simultaneously rather than sequentially, which ensures that both total amount of travel and amount and geographic distribution of travel attracted by each mode are directly related to the supply of transportation provided by each mode. Thus the concept of induced travel—that increase in travel demand that can be related to an increase in the level of service provided by any particular mode—can be represented. The multimodal nature of the model permits the competitive effect of varying levels of service among modes to be tested in each modeling run.

For modeling purposes the San Diego-Los Angeles Corridor Study area was divided into 141 zones: 107 in the Los Angeles area, 31 in the San Diego region, and 3 in Tijuana, Mexico. Relatively coarse transportation networks were then developed for highway, bus, rail, and air routes in relation to this zonal system, both for current conditions, as input to model calibration, and for the 1995 forecast of modal-improvement alternatives as part of the first-stage evaluation. For the nonhighway public modes, terminal-to-terminal matrices were developed for scheduled travel times, fares, and service frequencies. Business and nonbusiness trip purposes were considered. In the second-stage evaluation, 1985 networks for selected alternatives were also developed.

Table 1. Alternative modal service characteristics.

Mode	1995 Improvement Level	Number of Routes	Route Length[a] (km)	Access Points or Terminals[b]	Maximum Speed (km/h)	Daily One-Way Frequency
Automobile-highway	0	6	126	394	88.5	Unlimited
	1	5	266 to 282	473 to 482	88.5	Unlimited
	2	3	292	482	88.5	Unlimited
	3[c]	3	240 to 490	490 to 519	88.5	Unlimited
Intercity bus	0	3	177 to 202	15	88.5	2 to 34
	1	3	177 to 226	16	88.5	6 to 34
	2	4	177 to 250	21	88.5	18 to 31
	3	7	177 to 258	53	88.5	15 to 45
Intercity rail	0	1	207	7	145	5
	1	1	207	7	145	6
	2	1	207	7	177	8
	3	1	202 to 207	7	177	10
	4	1	198	3	323	21
Air	0	5	123 to 195	10	645	5
	1	5	123 to 195	10	387 to 645	6 to 46
	2	3	139 to 171	6	387	5
	3	6	137 to 205	12	290 to 387	5 to 10
Water	1	1	145 to 161	2	84	3
	2	2	145 to 181	3	84	3
	3	3	145 to 194	4	84	2 to 3

Note: 1 km = 0.62 mile.

[a] Total route kilometers are given for the automobile mode; individual route kilometers are given for all other modes.
[b] Double counting is used for bus, air, and water modes if a terminal may be served by more than one route.
[c] Comprises two alternatives for analysis purposes.

The large-zone system developed for the study was quite coarse in nature. Conventional travel-demand analyses in the Los Angeles area are conducted at a 1285-zone level. The sketch-planning framework of the corridor study obviously greatly reduced the work of network preparation as well as computer processing time for model application. The much quicker turnaround time for individual modeling runs and the ability to test several modal improvement alternatives in rapid succession made it possible to examine a large number of alternative multimodal transportation systems spanning the entire corridor study area [250 km (155 miles) in length]. Although a large number of shorter intrazonal trips were eliminated, the large-zone site used in the analysis primarily eliminated only the many shorter trips that were not likely to compete for capacity on interregional transportation facilities (with the exception of some automobile-highway routes). The large-zone system was thus compatible with the longer trips typical of interregional travel demand.

EVALUATING ALTERNATIVES

Because a significant increase in the number of alternatives to be evaluated can greatly increase the amount of information to be processed during the evaluation phase, using some systematic cost-effectiveness framework for plan evaluation is essential (5). Such a framework should connect the evaluation of alternatives to transportation goals and objectives established for the corridor, region, or multiregion study area (17). The objectives should in turn be expressed in some measurable way, wherever possible, by specific quantitative or qualitative criteria. In any case, procedures must be designed for the subjective comparison of alternatives at a significant level, either by assigning weights among goals or by assessing trade-offs among the impacts of various alternatives (9).

Staging is especially critical in the plan-evaluation phase. Because large amounts of information are generated not only for travel demand impacts but for social, economic, and environmental impacts as well, it may be best to examine only a selected set of most significant impacts during the first stage of plan evaluation, when the largest number of alternatives must be reviewed. After this initial range of alternatives has been screened and a smaller number of most promising options have been identified, a more complete set of objectives and criteria is available for subsequent evaluations. The alternatives themselves can also be further refined with regard to such details as cost characteristics, operating scenarios, and route and station locations.

Many methodological options can be applied in the plan-evaluation process (17). The structures of cost-effectiveness evaluation matrices and the range and description of goals and objectives can vary; wide variation can also be expected in the types of criteria applied and in the extent to which the community and the decision makers get involved in plan evaluation (including the extent to which goal-weighting exercises are conducted). Selection of an appropriate sequence of plan-evaluation methodologies thus depends on the unique circumstances of the study area as well as the agency, decision-maker, and community participants involved. Because what works in one area may not work in another, we emphasize the illustrative nature of the evaluation procedures used in the San Diego-Los Angeles Corridor Study, a brief description of which is given below (2, 3).

The five broad goals and 25 objectives that guided the case study corridor project are summarized in Table 2. These goals and objectives were synthesized from local, regional, and statewide goal and policy statements based on current plans and on interviews with transportation and land-use planning agencies. The five goals cover overall transportation problems; multimodal balance; social, economic, and environmental consequences; interregional transportation demands; and local and neighborhood impacts. The 25 objectives reflect both regional and local concerns and involve both direct and indirect consequences of transportation improvements.

The goals and objectives given in Table 2 are also grouped under three basic issues: economic feasibility, nonuser impacts, and user benefits. These three issues formed the backbone for plan-evaluation trade-off analyses. At least one evaluation measure or criterion was defined for each objective, as indicated in Table 2. Twenty-seven of the more significant measures (for 14 objectives) were applied during the first phase of evaluation; all were applied during the second phase. Most of these criteria are quantitative, e.g., costs and revenues, air pollutant emissions, service frequencies, and ridership levels. Qualitative measures reflecting judgmental assessments by the study team in such areas as aesthetics, tax-base impacts, and support of the California coast environmental plan were used in a few cases. In addition to the travel-demand and associated cost and revenue analyses, the study team estimated the impacts of many of the objectives in Table 2 by using a variety of environmental and land-use impact analyses.

During each phase of the evaluation, goal achievement was assessed by using a three-step process. First, an impact-analysis matrix was completed for each set of alternatives to compare the levels of modal improvement. Table 3 gives the results of the various feasibility, impact, and benefit analyses conducted by the study team for the intercity bus alternatives tested in phase 1. These impact measures were then converted to relative rankings, according to least negative impact or most positive impact, within each mode. This made comparing the alternatives easier and represents a crude form of normalizing—converting all measures to a common percentage score over a high-low range of impact values for a particular criterion (Table 3). A subjective comparison and a trade-off analysis were then made among the three basic categories of impact: economic feasibility, nonuser impacts, and user benefits. (In Table 3 it would be possible to add information to assign relative weights to objectives and to calculate a single weighted summary score for each alternative, but this was avoided because it was felt that a single summary score would tend to oversimplify the evaluation process and obscure some important differences among the alternatives.) Tables 4 and 5 give a summary of the results of this subjective procedure for the first and second evaluation phases respectively. A judgmental ranking of alternatives in the three basic issue areas is given based on a comparative assessment of goal-achievement evaluations such as that given in Table 3. Although such a subjective procedure may be criticized, it does force each evaluator to reflect carefully on the results of impact analyses and to compare the relative performance of alternatives.

Judgmental rankings permitted a reduction from 21 to 7 basic multimodal alternatives in the first evaluation phase and then a reduction from 7 alternatives to one recommended multimodal combination, as indicated in Table 5. During the first phase of the evaluation only within-mode comparisons were made (Table 3). For example, only the different bus alternatives were compared to identify the most promising initial set of bus alternatives. In the second-stage evaluation, however, comparisons were made between modes, and the 7 final alternatives, as well as an expanded list of evaluation criteria, were listed within single impact-analysis and goal-achievement

Table 2. Criteria for goal-achievement evaluation.

Issue	Goal	Objective[a]	Evaluation Measure	Application
Economic feasibility	Improve multimodal balance	Ridership levels	Number of weekday person trips Weekday mode-split percentage	Phases 1 and 2 Phases 1 and 2
		Revenue-cost viability	Annual revenue to operating cost ratio	Phases 1 and 2
		Investment efficiency	Annual operating cost/passenger·km Annual capital cost/passenger·km	Phases 1 and 2 Phases 1 and 2
		Implementation feasibility	1985 revenue to operating cost ratio 1985 revenue to total cost ratio	Phase 2 Phase 2
		Geographic balance	Modal improvement costs by county	Phase 2
		Modal coordination	Number of multimodal terminals Judgmental rating of improvement staging	Phase 2 Phase 2
	Effectively meet interregional travel demands	Multimodal rights-of-way	Bimodal route distance Trimodal route distance	Phase 2 Phase 2
		Collection-distribution interfaces	Judgmental ratings by mode	Phase 2
		Capacity-demand balance	Volume-capacity ratios on peak links (public modes)	Phase 2
Nonuser impacts	Minimize undesired social, economic, and environmental impacts	Coastal environment	Judgmental ratings by mode	Phases 1 and 2
		Open space resources	Designated open space and parks consumed (hm^2)	Phases 1 and 2
		Ecological and historical resources	Number of intrusions on historical or archaeological sites	Phases 1 and 2
		Agricultural resources	Agricultural land consumed (hm^2) Vacant land consumed (hm^2)	Phases 1 and 2 Phases 1 and 2
		Transportation noise	Noise level at 15-m (dBA) Maximum frequency of service	Phases 1 and 2 Phases 1 and 2

Note: 1 hm^2 = 2.5 acres; 1 m = 3.3 ft.
[a]Only the basic factor involved is given. The appropriate verb should be supplied; e.g., improve, increase, preserve, reduce, minimize.

tables. Various multimodal combinations of service levels could also be examined, e.g., automobile 1, bus 2, rail 2, air 1 (a possible total of eight combinations). This was partly accomplished in the demand analysis.

CONCLUSIONS

The San Diego-Los Angeles Corridor Study has made some first steps in accommodating a larger number of alternatives in interregional transportation planning. Improvement is needed, however, in the following areas in developing planning methods that will make multiple alternatives more meaningful in the planning process. Needed improvements in travel-demand modeling have been adequately addressed elsewhere (6) and are not included here.

Design of Alternatives

1. A more varied mix of modes is needed. Alternatives tended to be developed one mode at a time; for example, a combined interregional bus-rail alternative was not examined. At the regional system planning level mixed-technology transit alternatives may be especially relevent.
2. Increased short-range emphasis is needed. While minimum-level improvement alternatives (level 0) could be interpreted as short range in nature, additional low-capital-intensive options in transportation system management should be defined. These will tend to become more detailed and local in nature, but must somehow still be contained within a sketch-planning framework.
3. More emphasis should be given to the staging of alternatives. In the case study, recommendations were developed for the single preferred multimodal alternative, in terms of a three-stage series of improvements, and the first 5-year stage was emphasized. Thus it appeared that the staging options themselves could be made a part of the basic alternatives, particularly if more emphasis were given to short-range alternatives (10).
4. More careful attention should be given to the identification of key decision points. In blending short-range with long-range alternatives, decisions that foreclose future options, especially technology choices, should be clearly identified, perhaps in the form of a decision tree indicating those options that remain open at each successive stage of decision making.
5. More direct participation is needed by community groups and individuals as well as decision makers. Generating significant levels of community or decision-maker participation was difficult in the San Diego-Los Angeles Corridor Study mainly because interregional transportation needs were only a small proportion of overall regional travel needs. Increased participation focused on the design of alternatives should be vigorously pursued at smaller scale regional and corridor transportation planning levels.

Evaluation of Alternatives

1. Methods for trade-off comparisons and judgmental matching of alternatives should be more systematic and explicit, especially when they concern impact or issue conflicts. Judgment cannot be eliminated, but the kinds of subjective trade-offs illustrated in Tables 5 and 6 should be more clearly explained, e.g., by more detailed tabular or graphic summaries.
2. Some form of goal weighting, although not essential, may be desirable. Goal weighting, especially in support of more systematic trade-off comparisons, could simplify the comparison process by permitting the calculation of performance indexes for alternative plans (20). A variety of techniques exist for goal weighting.
3. Better procedures must be developed for incorporating the results of parametric analyses in the evaluation process. Parametric analyses can greatly increase

Table 3. Impact estimates and improvement rankings for intercity bus alternatives.

			Improvement Level							
			0		1		2		3	
Issue	Objective[a]	Criterion	Estimate	Ranking	Estimate	Ranking	Estimate	Ranking	Estimate	Ranking
Economic feasibility	Ridership levels	No. of person trips (000)	4	4	5.6	3	6.8	2	8.6	1
		Mode split (%)	3.2	4	4.4	3	5.3	2	6.6	1
	Cost-revenue viability	Revenue to operating cost ratio	1.8	1	1.7	1	1.4	2	1.2	3
		Revenue to total cost ratio	1.8	1	1.5	1	1.2	2	1	3
	Investment efficiency	Operating cost/ passenger·km ($)	0.028	1	0.029	2	0.033	3	0.037	4
		Annual capital cost/ passenger·km ($)	0	1	0.002	2	0.006	3	0.007	4
Social, economic, and environmental nonuser impacts	Coastal environment	Judgmental rating (support of California coastal plan)	2	2	2	2	2	2	3	1
	Open space resources	Open space, parks, ecological preserves, wildlife habitats consumed (hm^2)	0	1	0	1	0	1	0	1
	Ecological and historical resources	No. of intrusions on historical or archaeological sites	0	1	0	1	0	1	0	1
	Agricultural resources	Agricultural land consumed (hm^2)	0	1	0	1	0	1	0	1
		Vacant land consumed (hm^2)	0	1	1.2	2	2.4	3	5.2	4
	Transportation noise	Noise level at 15-m (dBA)	75 to 85	1	75 to 85	1	75 to 85	1	75 to 85	1
		Maximum frequency of service	88	1	116	2	134	3	284	4
	Neighborhood disruption	No. of community areas severed	0	1	0	1	0	1	0	1
		No. of residential units displaced	0	1	0	1	0	1	7	2
		Residential land consumed (hm^2)	0	1	0	1	0	1	1.6	2
		No. of businesses displaced	0	1	0	1	11	2	18	3
		Commercial and industrial land consumed (hm^2)	0	1	0	1	8	2	5.2	3
	Air quality	CO/passenger·km (g)	0.33	1	0.33	1	0.33	1	0.39	2
		HC/passenger·km (g)	0.06	1	0.06	1	0.06	1	0.07	2
		NO_x/passenger·km (g)	0.12	1	0.12	1	0.12	1	0.12	1
	Energy consumption	No. of automobile trips (000)	105.4	2	104.8	1	104.8	1	106.1	3
		Kilojoules/passenger·km	696	1	430	1	430	1	430	1
User benefits	Modal availability	No. of access points	56	2	56	2	61	1	62	1
		Daily one-way frequency of service	44	4	58	3	67	2	142	1
		Los Angeles to San Diego line-haul travel time (min)	140	1	140	1	140	1	140	1

Note: 1 km = 0.62 mile; 1 hm^2 = 2.5 acres; 1 m = 3.3 ft; 1 g = 0.035 oz; and 1 J = 0.000 94 Btu.
Alternatives are ranked according to least negative impact (9 objectives) or most positive impact (4 objectives), and best performance rating receives a ranking of 1.

[a]Only the basic factor involved is given. The appropriate verb should be supplied, e.g., improve, increase, preserve, reduce, minimize.

Table 4. Phase 1 evaluation of modal alternatives.

	Ranking by Goal									
	Economic Feasibility			Nonuser Impacts			User Benefits			
Alternative	First	Second	Third	First	Second	Third	First	Second	Third	Preferred Alternatives
Automobile-highway	—	—	—	0	1	2	3A	3B	2	1, 2
Intercity bus	1	2	0	1	0	2	3	2	1	1, 2
Intercity rail	1	0	2	1	0	2	4	3	2	1, 2
Rail extension[a]	TJ 3	—	—	TJ 3	—	—	TJ 3	—	—	TJ 3
Air	1	0	2	0	1	2	3	2	1	1

[a]Tijuana only.

Table 5. Phase 2 evaluation of modal-improvement alternatives.

	Ranking by Goal				Ranking by Goal		
Alternative	Economic Feasibility	Nonuser Impacts	User Benefits	Alternative	Economic Feasibility	Nonuser Impacts	User Benefits
Automobile-highway				Rail			
1B	—	5	2	1	2	2	4
2	—	6	2	2	3	3	3
Bus				Air 1	—	4	1
1	1	1	4				
2	2	1	4				

Note: The preferred combination is bus 1, rail 1, air 1, automobile-highway 1B.

the amount of information available on the performance of alternatives. Ranges of performance or impact might be consistently associated with each alternative, or some means might be used to attach probabilities to different consequences.

4. Participation by affected groups and by responsible decision makers is crucial. At regional, subarea, and corridor levels of planning, it is even more important to ensure that all significant needs and impacts are addressed.

5. More effective communication devices are needed, including graphs, charts, pictograms, and color-coded maps and tables that effectively display the differences among alternatives and present increasingly large amounts of information in a form that has meaning for most decision makers. This may be one of the most important research areas in plan evaluation.

REFERENCES

1. San Diego/Los Angeles Corridor Study: Phase IIA, Improvement Alternatives. Barton-Aschman Associates, Inc.; California Department of Transportation; Southern California Association of Governments; and San Diego Region Comprehensive Planning Organization, Aug. 1975.
2. San Diego/Los Angeles Corridor Study: Phase IIB, Travel Demand Analysis. Barton-Aschman Associates, Inc.; California Department of Transportation; Southern California Association of Governments; and San Diego Region Comprehensive Planning Organization, Feb. 1976.
3. San Diego/Los Angeles Corridor Study: Phase III, Final Report. Barton-Aschman Associates, Inc.; California Department of Transportation; Southern California Association of Governments; and San Diego Region Comprehensive Planning Organization, draft, April 1976.
4. P. Benjamin, J. Barber, C. Heaton, G. Paules, and D. Ward. Urban Transportation Alternatives: A Macro Analysis. Transportation Systems Center, U.S. Department of Transportation, Dec. 1974.
5. R. J. Bouchard, E. L. Lehr, M. J. Redding, and G. R. Thomas. Techniques for Considering Social, Economic, and Environmental Factors in Planning Transportation Systems. HRB, Highway Research Record 410, 1972, pp. 1-7.
6. D. Brand and M. L. Manheim, eds. Urban Travel Demand Forecasting. HRB, Special Rept. 143, 1973.
7. Dual-Mode Transit Planning Case Study. Cambridge Systematics, Inc., and Barton-Aschman Associates, Inc.; Urban Mass Transportation Administration, U.S. Department of Transportation, April 1976.
8. R. E. Engelen and D. G. Stuart. New Directions in Urban Transportation Planning. American Society of Planning Officials, Planning Advisory Service Rept. 303, 1974.
9. G. Hall and R. Breuer. User and Community Benefits in Intercity Freeway Corridor Evaluation. HRB, Highway Research Record 399, 1972, pp. 27-39.
10. R. J. Hocking. Time-Stage Strategy in the Transportation Planning Process. TRB, Transportation Research Record 491, 1974, pp. 24-39.
11. W. G. Hansen and S. Lockwood. Metropolitan Transportation Planning: Reforming the Process. TRB, Transportation Research Record 582, 1976, pp. 1-13.
12. M. L. Manheim and E. R. Ruiter. DODOTRANS I: A Decision-Oriented Computer Language for Analysis of Multimode Transportation Systems. HRB, Highway Research Record 314, 1970, pp. 135-163.
13. M. H. Rapp and C. D. Gehner. Criteria for Bus Rapid Transit Systems in Urban Corridors: Some Experiments With an Interactive Graphic Design System. HRB, Highway Research Record 455, 1973, pp. 36-48.
14. J. C. Rea. Designing Urban Transit Systems: An Approach to the Route-Technology Selection Problem. HRB, Highway Research Record 417, 1972, pp. 48-59.
15. J. W. Schmidt, R. K. Arnold, and S. Levy. Specification and Evaluation of Alternative Feeder and Local Transit Systems in a Suburban Area. HRB, Highway Research Record 417, 1972, pp. 37-47.
16. J. B. Schneider and J. W. Clark. Designing Bus Rapid Transit Systems: Exploratory Investigation. TRB, Transportation Research Record 606, 1976, pp. 30-36.
17. J. L. Schofer and D. G. Stuart. Evaluating Regional Plans and Community Impacts. Journal of the Urban Planning and Development Division, ASCE, March 1974.
18. An Analysis of Incentives and Disincentives for Automobile Management in the SCAG Region. Southern California Association of Governments, draft, Oct. 1975.
19. M. Wachs, B. M. Hudson, and J. L. Schofer. Integrating Localized and Systemwide Objectives in Transportation Planning. Traffic Quarterly, April 1974.
20. J. C. Yu and R. C. Hawthorne. Assessing Urban Transit Systems: A Goal Programming Approach. TRB, Transportation Research Record 574, 1976, pp. 35-47.

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