Integrating TSM into the Overall Transportation Planning Process

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In one of the overview papers for this conference, Lee and Meyer distinguish between "strategic" and "tactical" transportation system management (TSM) planning:

> "Strategic" planning can be defined as that characterized by a focus on systemic intermodal effects and the achievement of regional goals and objectives. "Tactical" planning is that characterized by the solution of localized, intramodal problems.

They conclude that, with a few exceptions, the focus of TSM has remained tactical. This paper will briefly sketch an approach that is strategic, tactical, and integrated within an overall process that unifies regional versus subregional demands, long-range versus short-range needs, and capital-intensive versus low-cost improvements, actions, policies, and combinations of such. Although this may seem overly ambitious, such an approach is overdue if we are to survive the babel of current requirements, funding conditions, and methodologies. Moreover, the North Central Texas Council of Governments (NCTCOG) in the Dallas-Ft. Worth area is well on its way to implementing such an approach in a program that relates TSM actions to improvements in areawide air quality.

This approach has, basically, three stages:

1. Establishment of a regional context within which detailed subregional (corridor) plans can be developed, including assessment of growth in population and employment and identification of regional TSM actions that could be implemented and of committed transportation facilities that will be in place;
2. Development of subarea (corridor) transportation policies and plans within the constraints of regional growth and transportation actions; and
3. Synthesis of an overall regional transportation plan from the policies and plans developed for each of the subareas of the region.

This approach could represent a major breakthrough in the planning process. It has been made possible by the development of simulation software that permits focusing on an area of interest while simultaneously dealing with the remainder of the region and of sketch-planning software that permits estimation of regionwide effects. The simulation software has the additional advantage of being able to handle finely detailed networks and very small zones at a subarea level so that impacts that might be lost in the regional approach may be simulated and evaluated. By applying this approach to all of the subareas of an entire region, a set of subarea plans can be developed.

The major activities or tasks in each of the three stages are summarized in Table 1.

The layout of these stages of the process is simple, but the content is ultimately complex. Clearly, successful linkage of regional and local actions requires activities that to some extent occur in sequence. In reality, however, many subprocesses occur simultaneously. That there is a need for a regional plan, however, is indisputable. The transportation facilities that serve the region must be a system. Major highways must connect with each other. Public transportation systems must cross jurisdictional boundaries and the service on different lines must be coordinated. As the above approach suggests, however, a regional plan must evolve through a synthesis and integration of local plans that considers both regional demand and local supply.

ESTABLISHMENT OF A REGIONAL CONTEXT: AREAWIDE TSM-AIR-QUALITY ANALYSIS

The three-stage planning process described above requires that detailed corridor plans (stage 2) be developed within the context of overall regional conditions (stage 1). This regional context includes employment and population forecasts for future years by small areas (e.g., regional zones), transportation improvements that are committed, and regional TSM-air-quality-related actions that can be assumed to be in place. This regional analysis must be carried out and completed before the actual testing of alternatives at the corridor level can begin.

The advantages of conducting an areawide TSM-air-quality program include the following.

1. Improvement of air quality as required by the Clean Air Act as amended 1977: It is necessary to isolate and reach agreement on areawide TSM-air-quality strategies in order to take positive steps toward improving air quality before the completion of all of the subarea analyses in the region. The areawide program will partially fulfill the requirements specified in the Clean Air Act as amended 1977. The planning agency [i.e., the metropolitan planning organization (MPO)] would integrate the areawide TSM program into an implementation plan to ensure attainment of the national ambient air quality standards.
2. Ensurance of consistency of regional inputs into subarea analysis: A consistent regional context is necessary to ensure that all subsequent corridor analyses will use the same assumptions regarding network, population and travel, and areawide TSM-air-quality strategies.

Table 1. Major activities or tasks in each stage of planning process.

Stage	Activity or Task
1: Establishment of regional context	Classification of TSM actions: Subarea (corridor) versus areawide
	Specification of candidate actions and policies to be tested at the regional level
	Development of goals and goal-performance measures
	Estimation of impacts and effects of candidate actions and policies: 1982 and 1987
	Development of cost estimates of candidate actions and policies
	Evaluation and selection of candidate actions and policies: 1982 and 1987
	Presentation of areawide actions and policies to appropriate agencies and discussion to secure approval
2: Development of subarea (corridor) policies and plans	Establishment of base-year validation
	Establishment of future projections
	Identification of goals and objectives of the subarea (corridor)
	Specification of candidate TSM and air quality actions to be tested at the subarea level
	Determination of a reasonable time frame for implementation of actions and policies
	Development of packages of alternative TSM actions
	Estimation of impacts of alternative TSM-air-quality packages in subarea
	Analysis of subarea capital improvements
	Development of cost estimates of TSM-air-quality packages
	Evaluation and selection of subarea plan
	Presentation of corridor plan to appropriate agencies and citizens and discussion groups to secure approval
3: Synthesis of regional plan	Reassessment of regional actions, policies, and requirements given implementation of corridor plans
	Synthesis of corridor TSM actions and policies and capital improvements into a regional plan for 10-year and 20-year futures
	Adjustment and reconciliation of corridor plans and presentation to appropriate jurisdictions for approval
	Staging and coordination of elements of regional and corridor plans

3. Improvement of the efficiency and reduction of the cost of corridor planning: By making commitments to the implementation of areawide TSM-air-quality actions, it will be possible to reduce the number of alternative tests necessary in the subarea work (which otherwise would increase the time, cost, and complexity of the planning effort).

4. Expansion of awareness and understanding of air quality issues: The analysis undertaken in this phase can provide input to the technical staffs of jurisdictions, to elected officials, and to citizens groups and others interested and active in improving air quality through transportation-related programs.

Although there are a wide variety of possible TSM actions that can be considered, only a limited number can be dealt with in an areawide approach. From among these possible areawide actions, candidate actions must be selected for testing and review of their impacts within an evaluation framework. The costs of these candidate actions and policies must be estimated and integrated into the evaluation, and a selection of actions must be made. Finally, the proposed actions must be presented to and discussed with the appropriate agencies and other groups to obtain approval and move toward the implementation of the areawide plan.

Classification of TSM Actions: Subarea (Corridor) Versus Areawide

The list of potential TSM-air-quality actions must be classified according to whether a particular action should be analyzed and implemented at the regional, areawide, or subarea level. There are several bases for the hierarchical classification of such actions.

Modal Versus Jurisdictional

This approach suggests that actions and policies can be identified according to their involvement of one or more transportation modes and of one or more local governments (1, pp. 2-7 to 2-8). The different classifications of actions include the following:

Class No.	Type of Action	Description
1	Routine internal administrative or operational actions	Actions that have known consequences, fall within the scope of authority of the traffic engineer or the transit operator, and can be implemented immediately at little or no cost
2	Jurisdictional-level actions	Actions that fall within the area of responsibility of the traffic engineer or the transit operator but require management or jurisdictional budget approval and some degree of project analysis and justification
3	Local multimodal actions	Actions that fall within a single jurisdiction but require coordination among the traffic engineer, transit operator, and other; budget approval; and project analysis and justification
4	Interjurisdictional actions	Actions that affect one mode only but are regional or interjurisdictional in nature, and require coordinated budgeting and areawide analysis and justification
5	Regional multimodal actions	Actions that require regional coordination among jurisdictions and modes, areawide project analysis and justification, and coordinated budgeting

Air Quality Versus Mobility

A second approach groups actions according to their effects on transportation supply and demand (measured by speed of travel and vehicle kilometers of travel, respectively) in the context of two goals—air quality and mobility (1, pp. 3-3 to 3-5). The different classifications of actions include the following:

Class Letter	Type of Action	Description
A	Actions that shift the demand curve downward [reduce vehicle travel (VT) demand]	Actions that induce travelers to shift from lower-occupancy to higher-occupancy vehicles or to nonmotorized travel modes, thereby decreasing

Class Letter	Type of Action	Description
		VT demand without affecting highway supply
B	Actions that shift the highway supply curve downward (reduce travel time)	Actions that use a wide range of traffic engineering and control measures to reduce the disutility of highway travel experience at given levels of VT demand
C	Actions that shift the demand curve downward and the supply curve upward (reduce VT demand and increase travel time)	Actions primarily aimed at inducing travelers to shift from lower-occupancy to higher-occupancy vehicles or to nonmotorized travel modes but to do so by increasing the disutility of highway travel
D	Actions that shift both the supply and the demand curves downward	Actions that simultaneously decrease the disutility of highway travel for given levels of VT and induce travelers to shift from lower-occupancy to higher-occupancy vehicles

Direct Versus Indirect Impact on Supply or Demand

This criterion identifies effects on supply or demand as direct or indirect: e.g., a new highway facility has a direct effect on supply and, by a presumed increase in travel, an indirect effect on demand.

Local Versus Regional Effects

An action or a policy can be local or regional in its application or effect. However, this dimension is complicated by the ambiguity of the terms local and regional. For example, they could refer to geography, but that is further complicated by the possibility of extending a local action (such as paratransit service or intersection improvement) throughout the region. Alternatively, local and regional could refer to population subgroups, e.g., the elderly and the handicapped.

Immediate Versus Long-Range Impacts

An action or policy can be immediate or long range in both implementation and effect. Most actions or policies are easy to classify on the dimension of implementation (given reasonable definitions of immediate and long range), but difficult assumptions regarding the duration of effect are required and the rapidity of effect (the time to reach equilibrium) is difficult to agree upon. Is it reasonable, for example, to assume that the effects of a ride-sharing program will continue for 20 years?

Capital Costs

A traditional way to identify TSM projects has been the extent to which they are either capital or operating cost intensive. The assumption has always been that capital-intensive projects are not management oriented and therefore not TSM.

The primary objective in classifying TSM (and other) policies and actions is the practical one of determining which should be evaluated on a regionwide basis and which on a local basis. As can be expected, however, there is no one criterion that can be used to make this determination, which thus requires consideration along several dimensions.

The criteria for regionwide actions and policies that appear most useful include whether the action or policy (a) is not site specific, (b) does not involve a design element, and (c) can be evaluated by using sketch-planning techniques. Thus, by using these criteria, one can identify the following actions as being regionwide:

1. Promotion of ride sharing (carpooling and vanpooling),
2. Promotion of transit use [advertising, perhaps uniformly reduced fares—any action that could be undertaken regionwide that would not vary from location to location (as improved service might)],
3. A vehicle inspection and maintenance program (for continued compliance with vehicle standards for emissions control devices),
4. Conversion of a vehicle fleet to less-polluting or more-energy-efficient (or both) vehicles, and
5. Work rescheduling, either to staggered hours or to a four-day workweek (or both).

Alternatively, actions that would be analyzed and evaluated at the subarea level include

1. Express bus service and park-and-ride lots,
2. Local transit route and schedule improvements,
3. Paratransit systems,
4. Bicycle and pedestrian facility improvements,
5. General traffic engineering (the wide range of traffic regulation and control and minor design improvements aimed primarily at reducing travel time),
6. Freeway traffic management (including incident surveillance and response, ramp control, and driver advisory information aimed at upgrading freeway performance),
7. Truck restrictions and enhancements (those actions aimed at reducing the conflict between truck and automobile operations and facilitating the curbside pickup and delivery operations of trucks),
8. Preferential treatment for high-occupancy vehicles (exclusive lanes),
9. Automobile-restricted zones (ARZs),
10. Parking supply reductions (off-street parking restrictions),
11. Preferential treatments (exclusive lanes), and
12. On-street parking restrictions.

The final product of this classification is the identification of those TSM-air-quality actions that should be analyzed on a regional basis to provide input into subarea analysis and of those for which no firm decision or commitment, on an areawide basis, can be made until a subsequent, detailed subarea analysis is performed.

Specification of Candidate Actions and Policies to Be Tested at the Regional Level

Although candidate actions may not fall neatly into a regional versus local dichotomy, some bases for classification have been described. After candidate actions have been categorized by level of analysis, those to be tested at the regional level must be specified. The feasibility of implementation of a policy could be an important consideration in choosing the strategies to be tested, as would be the potential impact of a strategy and the availability of appropriate analysis tools. At the areawide scale, for example, detailed traffic simulation will not be used for estimating the impacts of candidate TSM-air-quality actions. Maximum use will be made of the available sketch-planning methodologies.

Another consideration in action selection is that, because these actions can be combined, it is also necessary

to review their anticipated impacts in terms of compatibility. A policy directed at air quality, such as, for example, increased carpooling, might be encouraged in several ways:

1. By reducing parking supply,
2. By increasing parking costs,
3. By reducing parking charges per vehicle as the number of occupants increases,
4. By increasing fuel costs,
5. By establishing vehicle toll charges,
6. By establishing park-and-ride fringe lots for carpoolers,
7. By establishing preferential or exclusive lanes for high-occupancy vehicles, and
8. By establishing carpool-matching programs at places of employment.

Each of these alternatives, and combinations thereof, should be considered.

Development of Goals and Goal-Performance Measures

The evaluation of candidate actions must take place within a specified goal structure, but a basic problem in evaluation has been that our goal system always contains conflicts. Dealing with trade-offs between goals—whether objectively or subjectively—is a difficult and time-consuming step in choosing between alternatives, and one cannot gloss over the process and hope it will disappear. Unless it is attacked early on and with citizen participation as well as jurisdictional decision making, the planning process can become mired in wrangling or, worse yet, litigation.

This issue will be addressed in greater detail below, but it appears that a narrower framework of evaluation of TSM-air-quality strategies should be used in the regional analysis, i.e., these strategies should be evaluated solely in terms of their effectiveness in improving air quality. This analysis of effectiveness should include appraisals of the cost-effectiveness of the actions and also present a measure of their impacts on energy consumption. However, this need not be a conflict requiring a trade-off between air quality and energy conservation because most actions affect both of these objectives positively. A saving in energy consumption through encouraging ride sharing will also result in improved air quality. Should an energy crisis require, the major emphasis of these regional strategies might shift to energy conservation with air quality improvements tagging along.

Estimation of Impacts and Effects of Candidate Actions and Policies: 1982 and 1987

For each candidate action, policy, or package of actions, it will be necessary to estimate impacts in terms of the goal-performance measures for the years 1982 and 1987 to be consistent with the objectives of the Clean Air Act Amendments. At this stage of the analysis, the impact estimation will be at a macro or sketch-planning level of detail, rather than at a level of fine-grained simulation techniques. This effort will provide the data base of impact measures to serve in the subsequent evaluation and selection of the final package of strategies. The procedural steps for estimating impacts are as follows:

1. Select the candidate action or policy to be analyzed—for example, use of ride sharing to increase vehicle occupancy and thereby reduce VT demand.
2. Identify any ongoing ride-sharing programs within the metropolitan area and any recent prior programs that attempted to encourage ride sharing. For each such program, obtain information on its sponsor, area of coverage, measures of impact, cost, and any additional information relevant to its success or failure.
3. Identify relevant and similar programs in other metropolitan areas and obtain the same data as in step 2.
4. From the data collected in steps 2 and 3, analyze the impact in terms of changed vehicle-occupancy levels and reduced VT demand to the extent possible. These impact estimates are an attempt to determine the extent of impact of actual programs.
5. Estimate the regional impact of the candidate action in terms of the goal-performance measures selected earlier (e.g., before-and-after air quality performance, energy consumption, VT demand levels). For example, if the motivation to be used to encourage high vehicle occupancy is reduced parking rates for each additional passenger in a vehicle, estimate the reduction in the number of vehicle trips that might occur under such a program and calculate the reduction in VT demand that would be associated with that shift in vehicle occupancy. First, analyze those packages representing actions or containing policies that are currently implemented and under way for the target year 1982. Where appropriate, policy variables should be input at levels consistent with specific activity levels. For example, transit fares should be input at levels consistent with those forecast for 1982 by individual transit operators. The results of this analysis will indicate whether or not it will be possible to attain air quality standards by 1982, given no new implementation but continued support of existing TSM-air-quality activities.

Second, make an additional analysis by using the variables set at their maximum reasonable level to determine to what extent air quality objectives could be achieved, given added emphasis and additional support for the strategies already under way.

Finally, analyze selected candidate packages for the 1987 time frame to include the travel changes expected by then to determine the extent to which an areawide TSM-air-quality program could achieve the specific air quality objectives.

Development of Cost Estimates of Candidate Actions and Policies

Because costs represent such a critical issue in the selection process and because the costs of TSM actions and policies have not been carefully identified and enumerated in prior studies, it is important to make careful estimates before proceeding to the subarea analysis stage.

First of all, the cost components of the candidate TSM action must be identified. Does the action require capital investment such as new buses, the construction of a bus-only or a high-occupancy-vehicle lane, new signal equipment? or Will there be ongoing operating or maintenance (or both) costs? Will there be special one-time costs? Will there be marketing or advertising costs? Will special personnel be required to implement and maintain the action? These costs can be estimated by using some broad rules of thumb on equipment, personnel, and operating costs, and such estimates should be made (2). However, to the extent feasible, costs of similar programs should also be reviewed.

For each candidate action, a complete cost estimate should be performed, including amortization period and interest used for each capital expenditure.

Evaluation and Selection of Candidate Actions and Policies: 1982 and 1987

After the development of the impact and cost estimates, it will be possible to compare the candidate actions and policies and begin to select specific proposals. This comparison should stress cost-effectiveness in improving air quality, but measures of other impacts (such as mobility, travel time, and energy) should also be provided so that effects will be known as decisions are made. This is basically a three-level process, as follows:

1. Prepare a summary matrix of the candidate actions. Each candidate action will be a row in such a matrix, and the impact criteria will be shown as columns. These criteria might fall in the following order:

   a. Program cost,
   b. Percentage improvement in air quality,
   c. Cost per 1 percent improvement in air quality,
   d. Percentage improvement in energy use,
   e. Cost per 1 percent improvement in energy use,
   f. Mobility score.

Include in this matrix the agency that would have the responsibility for implementation of the candidate action.

2. Assemble alternative packages showing the total percentage improvements in air quality, cost, and such, as in step 1 above. This assembly of alternative packages should consider the achievements of the candidate action on the several performance criteria as reported above and also whether or not the candidates are reinforcing or self-canceling. This assessment may require some testing of groups (packages) of candidates by using sketch-planning methodology.
3. Prepare the recommendation of regional actions to be submitted to the agency having approval authority.

It is critical that this process thoroughly document all of the work. Particular care should be taken to ensure that a clear record of the actions that were eliminated is maintained, including the basis for that elimination, e.g., to be tested at the subarea level, not cost-effective, not capable of implementation.

Presentation of Areawide Actions and Policies to Appropriate Agencies and Discussion to Secure Approval

The work described above will produce a package of areawide TSM-air-quality actions. During the course of the preparation of the package, it is important to obtain input from citizen groups and local government representatives as to the possibility of acceptance and feasibility of implementation of the specific actions being considered. It is anticipated that detailed discussions between the MPO and the approval body will be required in order to adopt a program of actions for the entire region. To facilitate this discussion and the review by the designated body, an overview briefing paper should be prepared that summarizes the areawide process, the TSM-air-quality impact analysis, and the recommendations. This overview briefing paper should be backed up by detailed working papers to be made available on request. In addition, a formal presentation should be designed that draws on and is keyed to the overview paper. This presentation and the discussions should lead to the adoption of an approved areawide TSM program. It is this program that will be input into the stage 2 subarea planning process.

DEVELOPMENT OF SUBAREA (CORRIDOR) TRANSPORTATION POLICIES AND PLANS

After an areawide context has been developed as described above, more-specific subarea planning can proceed. This section describes the conceptual approach to planning for a subarea (corridor) that will be used by NCTCOG.

A computer-based simulation and assignment model will be used to evaluate TSM and other actions within the corridor. In developing, testing, and evaluating alternative transportation programs in a subarea, a substantial number of subarea simulations will be required. The transportation analysis process and the transportation information system developed for NCTCOG make use of hierarchical zone and network structures that eliminate zone and network details unrelated to the user's area of interest (the subarea) and thus provide an economical assignment having the potential for greater precision than is found in traditional assignment procedures (3, 4). Although the computer programs are fast and economical, it is still necessary to limit the number of simulations to a reasonable level.

The four analysis components of the subarea process that use traffic simulation and associated traffic-impact measures are summarized in step A of Table 2.

1. Base-year calibration: This simulation will be used to demonstrate that the simulation (traffic-assignment) process yields link traffic volumes, vehicle kilometers of travel, average speeds on links, and such measures that correspond to actual observations in the subareas.
2. Baseline projections: These estimates of future travel over a transportation system that includes currently committed facilities and incorporates an areawide TSM program will be used as the base against which to consider subarea TSM actions and capital improvements.
3. Subarea TSM analysis: This series of runs will be used to diagnose, test, and evaluate subarea TSM actions.
4. Subarea capital-improvements analysis: This series of runs will be used to diagnose the need for subarea capital improvements within a complementary program of TSM actions. Specific proposals will be tested and evaluated for selection.

For each simulation, traffic performance measures must be calculated and compared with those for other runs in terms of relative levels of performance (step B of Table 2). The performance measures are important for diagnosing need, as well as for the testing and evaluation of proposals.

Based on these analysis tools, the steps leading to the development of a subarea plan are as described below.

Establishment of Base-Year Validation

This step will be used to establish that the methodology being used to test and evaluate the alternative transportation actions is capable of replicating the base-year traffic in the subarea. This basic validation run will utilize the existing network in the base year, the travel associated with the distribution of population and nonresidential activities in the subarea and, at a broader scale, the entire region.

In addition to a good description of the existing network and travel, accurate ground-count data within the subarea are also needed. It is these data that must be replicated before the process can be considered valid. Moreover, failure to validate the process will jeopardize

Table 2. Traffic assignment and evaluation runs.

Network Supply	Travel Demand	TSM Policies: Existing	Proposed Areawide	Proposed Subarea and Areawide
Step A: Basic Simulation Analyses				
Existing	Present	Base-year calibration		
Committed	Future		Baseline projections	Subarea TSM analysis
Subarea capital improvements plus committed	Future			Subarea capital improvements analysis
Step B: Typical Diagnostic Runs				
Existing	Present		Disgnosis of short-range TSM problems	
	Future	Null: to scale problems if no action is taken		
Committed	Future		Diagnosis of mid-range TSM problems	
Step C: Runs to Estimate TSM-Air-Quality Impacts for Subarea				
Existing	Present	Base year	Diagnosis of short-range TSM approaches	ARZs, parking supply reductions, traffic engineering, preferential lanes, transit improvements
	Future	Null		
Committed	Future		Baseline projections	ARZs, parking supply reductions, traffic engineering, preferential lanes, transit improvements
Step D: Analysis of Combined TSM and Capital Improvements for a Subarea				
Existing	Future	Null		
Committed	Future		Baseline projections	ARZs, parking supply reductions, traffic engineering, preferential lanes, transit improvements
Subarea capital improvements plus committed	Future		Rail rapid transit, additional freeway capacity, exclusive bus lanes	Combined (1, 2, and 3)

the resulting plans by leaving the methodology to stand on purely theoretical, rather than on empirical, grounds. The data needed include the following:

1. VT demand within the subarea,
2. Transit line volumes,
3. Transit central business district counts,
4. Link volumes (sample),
5. Average link speeds (sample),
6. Volumes at corridor crossings,
7. Peak-hour link volumes (sample),
8. Peak-hour speeds (sample),
9. 24-h screen-line volumes, and
10. Peak-hour screen-line volumes.

Establishment of Future Projections

This step will be used to establish the traffic conditions expected at future baselines. Years 1980, 1990 and, for some analyses, 2000 baselines are required. These baseline projections are made by using the committed network additions expected to be in place by the year being considered. The travel estimates should also take into account the future locations of population and nonresidential activities. Finally, these baseline projections should incorporate the areawide TSM program developed in stage 1.

Identification of Goals and Objectives for the Subarea (Corridor)

As noted above, goals often conflict with each other—mobility versus energy or safety versus economy. Clearly, trade-offs must be made, and the process to be pursued in analyzing alternative actions affecting transportation in a corridor is designed both to measure progress toward attainment of the identified goals and to identify the trade-offs in goal attainment inherent in any action or policy.

For purposes of this discussion, a goal is an ideal or abstract state that can be described but that cannot always be measured without further specificity. As shown in Table 3, goals include such factors as general welfare, health, economy, and stability. But, because goal attainment is difficult to measure, some people prefer to use objectives (which are tangible, attainable, recognizable and, in most cases, measurable). A measure expresses the specific term(s) in which the goal or objective is to be expressed and in which progress toward attaining it is to be measured. Finally, it is useful to avoid confusing actions or plans with objectives. Actions or plans are the ways by which objectives are attained. A moving sidewalk is an action. Whether it is a good action depends on its performance with respect to the goals and objectives of the region.

The critical point for the subarea analysis is to recognize that a number of goals and objectives will be affected by each proposed action—TSM or long-range, capital cost intensive or operating cost intensive, localized or regionwide. A single goal or objective may be identified for emphasis in a given context, but the effects of any given policy, action, or group of policies and actions must be recognized for all of the objectives.

In the discussion of the regional analysis process, primary emphasis was placed on analyzing the regionwide actions and policies in terms of the attainment of desired air quality objectives. Despite the suggestion that regionwide policies be evaluated in the context of only one or two objectives (air quality and cost), it is important to recognize that complete reliance on a single measure of performance as the figure of merit for evaluation of alternative packages can produce misleading results. For example, assume that the measure selected is person hours of travel (as a measure of the ob-

Table 3. Goals, objectives, and performance measures.

Goal	Objective	Performance Measures
General welfare	Mobility	Vehicle hours of travel, vehicle kilometers of travel, person hours of travel by highway, person kilometers of travel by highway, person hours of travel by transit, person kilometers of travel by transit, vehicle hours of travel by transit, vehicle kilometers of travel by transit, average travel speed, vehicle hours delay, kilometers of facility by volume-to-capacity class, kilometers of facility, number of transit lines, transit line kilometers, transit seat kilometers, seat kilometers per square kilometer, use measure(s) per supply measure(s), automobile ownership per household, no. of person trips by purpose and by mode
	Opportunity	Accessibility, trips per household by automobile, trips per household by transit, vehicle kilometers of capacity, accessibility to transit, accessibility to highway, automobile ownership per household, person trips to CBD, vehicle trips to CBD, median household income
	Equity	Mobility measures on a per capita basis
	Development potential	Accessibility
Health	Air quality	Percentage of trips served by transit, percentage of person kilometers of travel by transit, emissions—highway, emissions—transit
	Safety	Accidents—transit, accidents—highway
Economy	Least annual dollar cost	Capital cost, operating cost, supply measures per cost unit, use measures per cost unit
	Energy consumption	Percentage of trips served by transit, percentage of person kilometers of travel by transit, liters per joule consumed, patronage (various measures) per unit of energy
Stability	Disruption	Land dedicated to transportation, households relocated, businesses relocated, jobs relocated

jective of mobility) and that a higher value of this measure is associated with improved mobility. Assume further that, in (a hypothetical) case 1, there are 1 000 000 daily person trips at an average speed of 36 km/h (20 mph) and an average length of 8.8 km (5.5 miles). Compare this with case 2, in which there are 800 000 person trips at an average speed of 16 km/h (10 mph) and an average length of 6.4 km (4.0 miles).

Clearly the second case is less desirable. The residents of the region are engaging in less travel, which represents a loss in opportunity and activity for them, the travel is slower (and time spent in travel is, itself, nonproductive, so this represents a loss in utility), and the average area in which they travel and from which they make their choices for shopping, work, recreation, and so forth is diminished from 250 km^2 (95 $miles^2$) to 130 km^2 (50 $miles^2$). Yet a simple calculation shows that case 1 produces 275 000 person hours of travel while case 2 produces 320 000. Thus, on the basis of person hours of travel alone, case 2 would be judged superior! But there is nothing to recommend it, given the characteristics used in the example.

In this phase of the analysis, therefore, all objectives must be considered—mobility, safety, cost, energy consumption, development, and so forth—given, at least, no degradation in air quality and, at best, further improvement in it.

Specification of Candidate TSM and Air-Quality Actions to Be Tested at the Subarea Level

At the subarea level, the areawide TSM-air-quality program determined in stage 1 is assumed to be in place. The conditions or problems these actions will address would have been determined in (a) a simulation-evaluation run using the present network and the base-year travel demand and assuming the areawide TSM-air-quality program as having been implemented; (b) a run using the committed network, future travel, and assumed areawide TSM-air-quality program; and (c) the null case (future travel over the current network).

These candidate actions or packages will be tested by using simulation-evaluation runs in which the specific candidate effect is reflected in the travel assigned, the network to which the travel is assigned, or both. The primary objectives of specifying these actions or policies are to determine (a) the extent to which the short-range subarea transportation problems can be solved by a combination of areawide TSM programs and specific TSM-air-quality actions within the subarea and (b) the extent to which the midrange subarea problems can be solved by a combination of the capital improvements scheduled for the region (including the subarea), the areawide TSM-air-quality programs, and specific subarea TSM actions. No recourse to new capital improvements is to be considered in this analysis.

Determination of a Reasonable Time Frame for Implementation of Actions and Policies

To consider the possible transportation actions and policies in any rational way, it is necessary to answer the question, What is the earliest date by which a specific action or policy could be in place if the decision to do it were made now? This information is needed to introduce the action into the analysis at the appropriate time. Some actions require 5-10 years lead time; other policies can be put into effect next week.

Development of Packages of Alternative TSM Actions

The variety and number of TSM-air-quality actions and policies require some packaging or grouping of them because of the cost and time that can be consumed in evaluating all the potential combinations and permutations. The objective in packaging the policies and actions (in addition to reducing the cost of evaluation) is to group those policies that (a) have the same (or similar) effects relative to the objectives and (b) reinforce those effects, rather than canceling each other, relative to the objectives.

The preliminary process described below can be used for grouping the policies and actions.

1. Estimate the effect of each individual policy or action on each of the objectives. Whenever possible, make these estimates by using simulation or sketch-planning techniques. A realistic application should be used, although hypothetical applications are acceptable if necessary. Manual techniques or general estimates of effects may be considered as a last resort.
2. Group the candidate actions according to their effects on each of the objectives. This process is similar to that recommended by the Urban Mass Transportation Administration (2), but should not be limited to two objectives only and should be supported by the relatively more rigorous analysis in step 1.
3. If the results of step 2 require further analysis, assemble groups of two or three projects into prelimi-

nary packages and analyze their combined effects.

4. Based on the results of steps 2 and 3 and on the timing of implementation, assemble packages of actions and policies. Criteria for candidacy should include both the effects of the policy or action and the objective(s) for the action in the area under analysis. For example, as has been suggested above, the objectives emphasized in the regional analysis may differ from those of the subarea analysis. Similarly, the emphasis placed on various objectives in different subareas may vary with the conditions in the subarea.

Estimation of Impacts of Alternative TSM-Air-Quality Packages in Subarea

The simulation-evaluation models will be used to simulate system performance of each TSM-air-quality package proposed to be tested within a subarea. For example, as shown in step C of Table 2, a series of 10 runs might be made to estimate the impacts of five alternative TSM-air-quality actions. For short-term improvement, five comparisons are made—one for each of five possible subarea actions. When the impacts (on air quality, energy, VT demand, mobility, and such) are compared with those of the same measures in the base year, the improvement or degradation is indicated. When they are compared with those of the short-range diagnosis runs, the improvement over and beyond the areawide TSM program is indicated.

The comparison of future travel runs using the committed network and specific TSM proposals and the baseline projection gives an indication of system performance and impacts under a future condition that includes an areawide TSM-air-quality program. If comparisons are also made with the null case, we obtain a measure of how subarea actions improve performance compared with the improvement given by the committed network and the areawide TSM-air-quality program. Finally, the need for packaging is emphasized by the number of runs and the amount of analysis required.

Over and beyond the impact measures discussed above, it is also necessary to gauge the effects of various transportation system actions and policies on regional development potential. Recognition of the long-range development impacts of transportation improvements and policies is certainly not new. The major focus of recent efforts has been to examine the long-range impacts of major transportation improvements on settlement. For example, the planned construction of rail rapid transit systems anticipates ridges of increased residential density along the lines, clustering of work centers around transit stations, and a general buttressing of the economic vitality of the focus of these lines, the central business district. The configuration of limited-access highway systems (grid versus radial) is presumed to have influenced the settlement patterns around them. For example, in the Washington, D.C., area, the response of development to successive improvements in the Shirley Highway corridor is striking evidence of the relationship between access and land development.

Policies that limit or regulate access to parts of a region, dictate the mode of travel to be used, set aside exclusive lanes for high-occupancy vehicles, or radically change the cost of travel all can be expected to have long-range impacts on development. Therefore, in evaluating alternative strategies, in addition to considering the short-range impacts on air quality and energy, it is necessary to consider developmental impacts arising from changes in accessibility.

Analysis of Subarea Capital Improvements

After the seven steps described above have been completed, the extent to which the travel requirements of the subarea can be met through construction of already committed capital improvements, areawide TSM-air-quality programs, and specific subarea TSM-air-quality packages will be known. It is likely, however, that some problems will remain that suggest subarea capital improvements (e.g., rail transit, construction of express bus lanes, new freeway capacity including double decking). These capital improvements should be analyzed, and their performance should be reviewed against the baseline projection and the null case.

Finally, a combined set of TSM-air-quality packages that reinforces or complements proposed subarea capital improvements can be assembled as shown in step D of Table 2 for three combinations that are unspecified but labeled 1, 2, and 3 (C-3 future). These would be simulated and the impact measures would be available for selection of a final package.

Development of Cost Estimates of TSM-Air-Quality Packages

The level of detail and complexity involved in the component actions and policies included in the packages requires careful estimation of economic costs of each. This step is a logical extension of the earlier specification of candidate actions and policies in that dollar costs—for implementation, capital, and operation—must be specified with some precision for each candidate action and policy. In some instances, this may involve the determination and application of a unit cost or value for various measures derived in the simulation.

Evaluation and Selection of Subarea Alternative Packages for 1980 and 1990

The final step in the subarea analysis is the comparison and evaluation of the alternative policy and action packages and the selection of those to be implemented. Initially, this step will involve the MPO staff. However, the ultimate responsibility for the evaluation and selection will rest with a policy group and also require citizen approval. As in all planning efforts, the selling of the plan will require careful preparation of presentations, discussion papers, and an ongoing dialogue between the MPO and other concerned groups.

CONCLUSION

This paper has shown that a unified planning approach that combines TSM and more-traditional planning concepts is not only possible, but indispensable to the transportation planning process. The first two stages of this approach—(a) the regional context within which corridor planning can take place and (b) the corridor planning process itself—are being implemented in a program for the NCTCOG. The third stage—the synthesis and integration of the corridor plans into an overall plan for the region—will be developed further in future efforts.

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