TECHNICAL ASSISTANCE REPORT

# EFFECTIVENESS OF TRANSPORTATION CONTROL MEASURES: AN OVERVIEW OF THE STATE OF THE PRACTICE


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# EFFECTIVENESS OF TRANSPORTATION CONTROL MEASURES: OVERVIEW OF THE STATE OF THE PRACTICE

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## INTRODUCTION

Transportation control measures, or TCMs, are transportation measures or strategies intended both to reduce vehicle miles of travel (VMT) and to make those traveled more efficient. Although the term *TCM* has its origins in air quality and emissions reductions, TCMs encompass many of the elements or strategies in transportation systems management (TSM) and transportation demand management (TDM). In practice, overlap among the three concepts is considerable, and the terms *TCM, TSM,* and *TDM* are often used interchangeably. Table 1 presents a typology of TCMs based primarily on that developed by the Environmental Protection Agency (EPA).[1]

**Table 1**
**Traffic Control Measures Typology[1]**

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**Trip Reduction Ordinances**

**Employer-Based Transportation Management Programs**
HOV Shuttle Services Between Company Facilities
Centralized Vanpool/Carpool Matching Service
Rideshare/Transit Marketing and Information Programs
Designated Transportation Coordinator
HOV Priority Parking
Vanpool/Subscription Bus Financing
Vanpool/Subscription Bus Programs
Midday and Park-and-Ride Shuttles
Guaranteed Ride Home Program
Alternative Mode (Bicycle/Walking) Incentives
Subsidize Transit Use
Provide Transportation Allowance
Eliminate Employee Parking Subsidies
Charge for Drive-Alone Parking

**Work Schedule Changes**
Telecommuting
Teleconferencing
Staggered Work Hours
Flextime
Compressed Work Week

**Area-Wide Rideshare Incentives**
Carpool Matching Programs
Vanpool Programs
Shared Ride Taxi
Guaranteed Ride Home Programs
Transportation Management Associations (TMA)
Tax Incentives and Subsidy Programs (incl. reduced tolls)
Public Information on Rideshare/Transit

**Improved Public Transit**
System/Service Expansion
System/Service Operational Improvements (e.g., feeder bus service, express bus service, improved transfers, schedule coordination, bus traffic signal preemption, simplified fare collection)
Demand/Marketing Strategies (e.g., information programs, peak/off-peak fares, reduced fares, monthly passes, uniticket programs, passenger amenities)

**HOV Facilities**
Freeway Mainline
Freeway Entrance Ramp
Arterials

*continues*

**Table 1 (cont.)**

Other (e.g., tunnel, bus street, parking facilities)

**Traffic Flow Improvements**
Coordinated Signal Systems
Other Signal Improvements (e.g., hardware/software upgrades, retiming, removal)
Other Traffic Control Devices Improvements (e.g., pavement markings, signing)
Intersection and Roadway Widening
One-Way Streets
Intersection Improvements (e.g., channelization, turn lanes, signing, bus stop relocation)
Turning Movement and Lane Use Restrictions
Reversible Lane Systems
Arterial Access Management
Providing Additional Lanes w/o Widening (e.g., shoulder use or lane narrowing)
Incident Detection/Management Systems or Programs
Traffic Surveillance/Control Systems
Motorist Information Systems (e.g., diversion and advisory signing)
Integrating Freeway/Arterial Surveillance and Control Systems
Traffic Management Teams
Ramp Metering
Enforcement
Traffic Management Programs during Highway
Reconstruction/Major Improvements Projects
Prohibiting Maintenance/Repairs on Major Routes during Peak Traffic Hours
Goods Movement Management (incl. parking management and use restrictions for trucks/delivery vehicles)

**Parking Management (area-wide basis)**
Differential Parking Rates (pricing strategies)
Preferential Parking for HOVs
Governmental Control of Supply and Location
On-Street Parking Controls (e.g., curb parking restrictions, residential parking controls, peak hour ban, enforcement)
Parking Requirements in Zoning Codes
Park-and-Ride/Fringe Parking
Dedicated Lot
Joint-Use Lot
Parking at Major Transit Stations
Amenities at Lots

**Alternative Modes of Transportation**
Bicycles
Pedestrians (walking)

**Special Events**

**Vehicle Use Limitations/Restrictions**
Route Diversion (e.g., auto-restricted zones, pedestrian malls, traffic controls)
No-Drive Days (including voluntary and required)
Road/Congestion Pricing

**Avoiding/Controlling Demand Growth**
Growth Management by Public
Policy/Ordinance/Planning
Designing Multi-Use Sites to Minimize Traffic (e.g., on-site services)
Requiring Congestion-Reduction Strategies for
Proposed Development (e.g., reduced trip generation, transit options, rideshare programs)

**Accelerated Retirement of Vehicles**

**Activity Centers**
Design Guidelines/Regulations
Parking Regulations and Standards
Mixed Use Development Ordinances and Zones
Site Plan Review Ordinances

**Extended Vehicle Idling**
Controls on Drive-Through Facilities
Limitations on Idling of Heavy-Duty Vehicles
Vehicle Modifications

**Extreme Low-Temperature Cold Starts**
Vehicle Modifications
Parking Facility Electrical Outlets
Transit Use Incentives
No-Drive Days
Vehicle Fleet Operations

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The Clean Air Act Amendments of 1990 (CAAA) set standards for emissions reductions and required states to formulate and carry out state implementation plans (SIPs). Further, the act identified TCMs expected to provide emission reduction benefits and, in some cases, mandated their evaluation. In addition, the Intermodal Surface Transportation Efficiency Act of 1991 (ISTEA) created a Congestion Mitigation and Air Quality Improvement Program (CMAQ) that implements projects and programs to attain the National Ambient Air Quality Standards. Key elements of CMAQ include TCMs. Accordingly, state air quality boards, metropolitan planning organizations, and state planning agencies need to be aware of either the effectiveness of the various TCMs or methodologies for assessing their effectiveness.

## PURPOSE AND SCOPE

The purpose of this report was to provide an overview of the state of the practice regarding the effectiveness of TCMs. Two main areas were investigated: the known effectiveness of TCMs based on case study information, and methodologies available to evaluate their effectiveness.

The scope was limited to a literature review, personal contact with state and national professionals involved with TCMs, and a summary and compilation of key existing documentation.

## FINDINGS

### Known Effectiveness of TCMs

Although referred to by different names, many TCMs have been used for several years to solve transportation-related problems. Their first formal use was probably in the Traffic Operations Program to Improve Capacity and Safety (TOPICS), in which a number of low-cost, easily implemented highway projects were undertaken to improve the efficiency and safety of highways. Thereafter, many were recognized and used as energy-saving measures in the era of fuel shortages. Recently, many TCMs have been used as congestion-reducing measures.

Accordingly, a significant amount of case study information is available on the effectiveness of particular TCMs. A number of studies have attempted to compile this information both qualitatively and quantitatively. Appendices A through N provide excerpts from several of these studies. Such information can be used as default values in many TCM evaluation methods, allows the analyst to assess the validity of their results, and can possibly be applied directly to other areas with similar characteristics.[2]

On the other hand, caution must be exercised in using such information. Both the EPA and the various authors of the excerpts recommended that readers not use the documented effectiveness in a direct application. The effectiveness will vary depending on a variety of factors, e.g., extent of prior transportation controls implemented, nature of traffic congestion and network configuration, availability of transit services, trends in business, and population growth.[3] Thus, the information should be used in the context of relative and potential order-of-magnitude effectiveness when considering the implementation of TCMs or reviewing the output of sketch planning models.

Based on research at the Texas Transportation Institute (TTI),[2] the four TCMs most frequently implemented are traffic flow improvements, high-occupancy vehicle (HOV) lanes, employer-based transportation management, and vehicle use limitations/restrictions. Except for the last, the TCMs most often implemented also have the most travel impact information. Very little data exist on the emissions impact of TCMs; the most available data are for traffic flow improvements and HOV lanes.

## General Method for Determining the Effectiveness of TCMs

The EPA has defined a four-step process for calculating the effectiveness of TCMs for a given area.[3] (See Figure 1.)

*Step 1: Screen measures from both a technical and institutional framework to select those that warrant further in-depth evaluation for a given area.* Screening should identify those measures that are best for a given air quality problem, can potentially relieve specific traffic congestion problems and thus improve air quality, and are appropriate for the area's demographics and transportation infrastructure.

*Step 2: Evaluate the traffic effects of each TCM chosen in Step 1.* As appropriate, the effects measured may include vehicle miles traveled (VMT), number of trips, time of day of the trip, mode of travel, and speed of travel.

*Step 3: Evaluate the emission changes that result from the traffic effects determined in Step 2.* Procedures differ for regional analysis and intersection analysis.

*Step 4: Evaluate the air quality change based on EPA-approved models.*

More detailed information on applying this four-step methodology is presented in the full EPA report.

## Specific Methods for Determining the Effectiveness of TCMs

Researchers at TTI categorized the methods of determining the effectiveness of TCMs as follows: comparative empirical data, network-based modeling, and sketch planning tools.[2] The

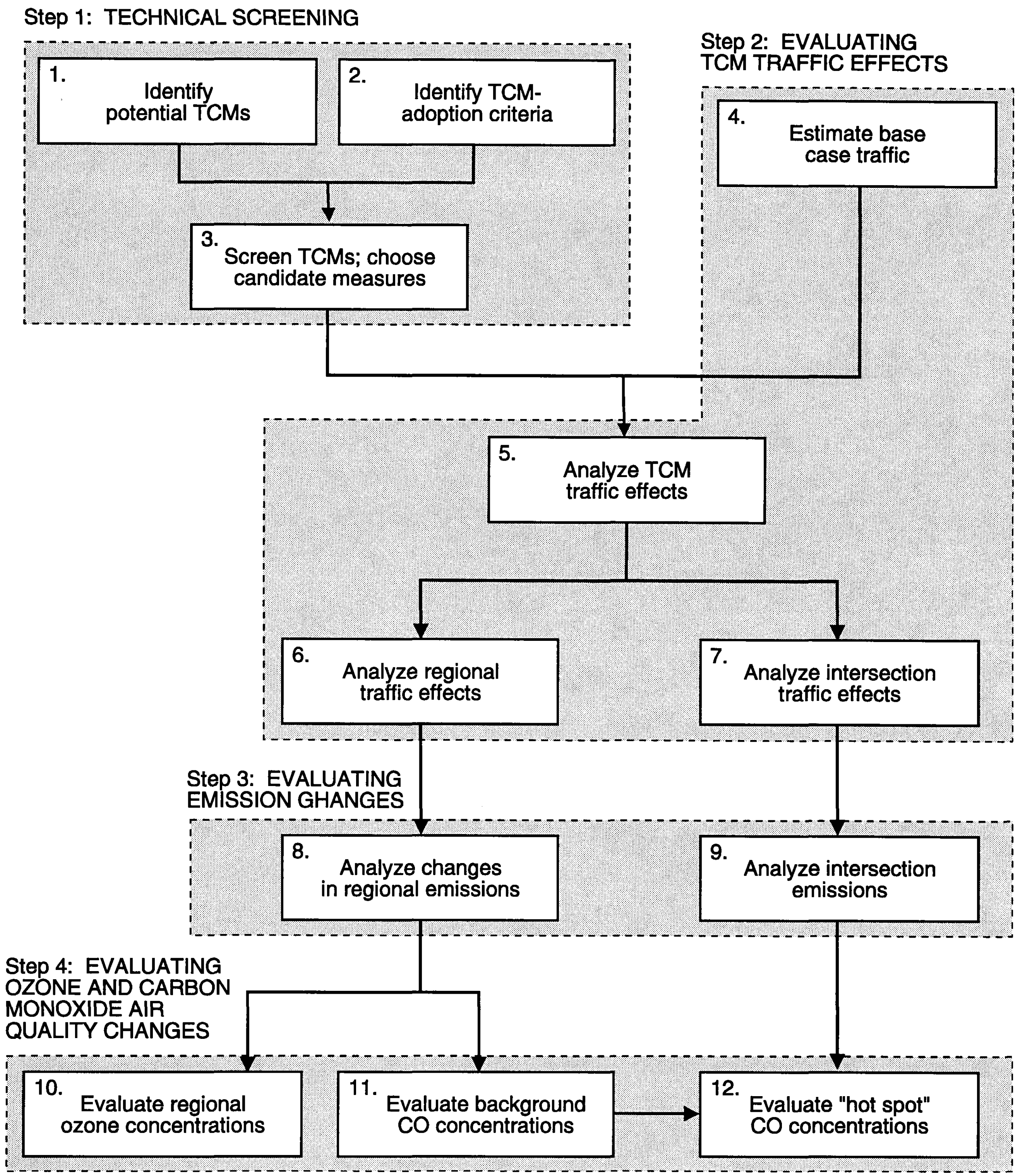


**Figure 1. Overview of Technical Analyses to Be Performed and Their Relationship to the Four Steps Described in the Guidance Document**

following overview of these methods was excerpted from the cited reference, and the reader should refer to the complete document for further detailed information.

### Comparative Empirical Data

The simplest method for estimating the impacts of a planned TCM is probably to use empirical data from the observed performance of TCMs in similar locations. This method has simplicity as its major advantage. Appendices A-N provide input for this method, but noting the caveats mentioned when using the data is important.

### Network-Based Modeling

Network-based models include traffic simulation and travel demand models. Both types are typically very large programs that require considerable expertise in applying and a significant amount of data input. Further, they typically do not contain features that enable a straightforward analysis of TCM impacts. Simulation models can be effectively used for analyzing TCMs related to traffic flow, but they do not work well with TCMs that modify demand, such as trip frequency, mode choice, destination choice, and route choice. Travel demand models can accommodate these TCMs, but surrogate variables must often be used to represent their impacts indirectly. Finally, traditional travel demand models are designed to study regional and corridor level impacts, whereas TCMs are frequently applied to much smaller areas and have relatively small impacts.

### Sketch Planning Tools

Because of the limitations and disadvantages of using comparative empirical data and network-based modeling, recent practices have focused on the refinement and development of sketch planning tools. These models employ simplified evaluation procedures that produce gross estimates of the impacts, may be available in either manual or computerized applications, and generally measure the travel and emission impacts more directly. Input is often obtained from regional travel demand models. A significant disadvantage is that the models currently available are limited to the analyses of specific TCMs, and some TCMs are not included in any of them. However, since sketch planning tools are often computerized, relatively simple to use, and typically appropriate for the accuracy of the input data, they are currently the most promising approach available for analyzing the effectiveness of TCMs. Following is a description of several of the latest and best known sketch planning tools.

*TDM Evaluation Model*

The TDM model is an analytical tool that provides information on the probable impact of various TDM strategies. The user can review a wide range of possible TDM actions, alone or in combination. It appears to the user as a system of worksheets on which the user enters different assumptions about the measures being evaluated. Allowable strategies include the following:[4]

- alternative work schedules
- incentives and disincentives
- regulatory requirements
- transit, carpool, or vanpool support and informational programs
- transit service improvements
- HOV priority lanes
- market-based pricing measures.

The model was designed for application primarily at an area-wide level, but it can be applied at individual sites. It predicts changes in travel measures such as modal split, vehicle occupancy, VMT, and number of person or vehicle trips. The output must then be used with other models or estimating procedures to develop emission impacts. The TDM model was developed by COMSIS Corporation and R. H. Pratt, Consultant, Inc., for the Federal Highway Administration (FHWA) and Federal Transit Administration. The reader is referred to References 2, 4, and 5 for further information.

*TCM Tools*

TCM Tools (also commonly known as the SANDAG method) is a spreadsheet-based program that estimates the travel, emissions, and cost-effectiveness of individual TCMs. A transportation module estimates the effect of the selected measure on trips, VMT, and speeds. The emissions module combines output from the transportation module with output from an air quality model to produce estimates of reductions in reactive organic gases (ROG), carbon monoxide (CO), nitrogen oxide ($NO_X$), and particulates (PM). The air quality model is California based, but FHWA is funding an effort to revise it to reflect EPA's MOBILE emissions model. A cost-effectiveness module uses the output of the transportation and emissions modules, in combination with user-specified information, to estimate the costs and cost-effectiveness of the TCM being evaluated. Depending on the version of the model, between 25 and 30 predetermined TCMs can be analyzed, including the following:[6]

- growth controls
- jobs/housing balance
- densification
- mixed use

- transit service increases
- park-and-ride lots
- bicycle improvements
- ridesharing
- VMT tax
- pedestrian improvements
- traffic signal improvements
- telecommuting
- flextime
- staggered work hours
- compressed work week
- delivery timing
- capacity increases
- HOV lanes
- trip reduction ordinances
- employee transit pass subsidy
- parking management
- gas tax/cost increase
- motorist information
- incident management and response.

The model was developed by Sierra Research and JHK & Associates under a grant from the California Department of Transportation to the San Diego Association of Governments. The reader is referred to References 2, 5, 6, 7, and 8 for further information.

*SAI Method*

The SAI method provides a step-by-step manual procedure for estimating travel and emission impacts of individual TCMs and the combined impacts of several measures. Equations are provided for calculating trip reductions, VMT, and speed increases. The emission analysis methodology then calculates total mass emission changes resulting from these travel characteristics. The procedures focus on the EPA's MOBILE emission model and produce estimates of hydrocarbons (HC), $NO_X$, and CO. Specific TCMs that can be analyzed include the following:[6]

- telecommuting
- flextime
- compressed work week
- ridesharing
- transit improvements
- HOV lanes
- parking management.

The procedures described for these measures could potentially be used to develop similar estimates of travel and emissions impacts for other TCMs. The SAI method was developed for the EPA. The reader is referred to References 2, 6, and 8 for further information.

*TCM Analyst*

The TCM Analyst combines elements of the TCM Tools and SAI method into one spreadsheet-based evaluation tool. It estimates the travel and emissions effects of selected TCMs and evaluates their cost-effectiveness. Although general guidance is provided on analyzing a TCM program, the TCM Analyst evaluates only individual measures. Specific TCMs included in the program are the following:[9]

- telecommuting
- flextime
- compressed work week
- ridesharing
- transit fare decrease
- transit service increase
- transit plazas
- parking management
- HOV lanes
- traffic signalization
- intersection improvements.

The travel module calculates changes in trips, VMT, and speeds. The emissions module is based on EPA's MOBILE model and estimates changes in CO, HC, and $NO_X$. A cost-effectiveness module develops cost estimates from the output of the first two modules. Estimates are based on a regional, not a microscale, level. The TCM Analyst also includes three additional analysis tools: a trend analysis, a sensitivity analysis, and a detailed analysis. The program was developed by researchers at TTI. Readers are referred to Reference 9 for further information.

*TTI CM/AQ Evaluation Model*

This model advances the previously described models by also determining the eligibility of projects for CMAQ funding and then weighting the overall effectiveness of projects being evaluated to derive a relative rating. The first step is to apply an eligibility module based on the information in Table 2.[11] Cost-effectiveness is then derived from a travel module that calculates

**Table 2. Project Eligibility for CMAQ Funding**

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**Fundamental Prerequisites**

All projects and programs eligible for CM/AQ funds must come from a conforming transportation plan and TIP and be consistent with the conformity provisions contained in Section 176(c) of the Clean Air Act. The project must also comply with National Environmental Policy Act (NEPA) requirements.

**Eligible Projects/Programs and Restrictions**

*Transportation Activities in an Approved SIP*

*Transportation Control Measures Included in the CAAA of 1990*
Public transit
HOV facilities
Employer-based transportation management plans, including incentives
Trip-reduction ordinances
Traffic flow improvement programs that achieve emission reductions
Park and ride facilities
Programs to limit or restrict vehicle use in congested areas
Programs for shared-ride services
Programs to limit roads and areas to nonmotorized use
Bicycle facilities
Programs to control extended idling of vehicles
Programs to permit flexible work schedules
Programs and ordinances to facilitate nonautomobile travel
New construction and reconstruction of paths for nonmotorized transportation

*Other Bicycle and Pedestrian Facilities and Programs*
Nonconstruction projects related to safe bicycle use
Establishment and funding of state bicycle/pedestrian coordinator positions
Provision of bicycle amenities must primarily be used for transportation

*ISTEA Management Systems*
Eligible if projects are required to develop and establish three ISTEA management systems (traffic congestion, public transportation facilities and equipment, and intermodal transportation facilities and systems).

*New Traffic Monitoring, Management and Control Operations*
Operating expenses are eligible for a period of only three years from the inception of the new or additional service.

*New Emission Inspection and Maintenance Programs*
Eligible only for new or expanded programs, satisfies EPA requirements, and funding does not displace existing funding.
If for operating expenses, eligible only for three years.

*Transit Project Funding Limitations*
In general, the capital costs of system/service expansions are eligible, and transit operating and maintenance costs are not eligible. In limited cases, operating costs for new transit service are eligible for CM/AQ funding. The main criterion is that the project must be for new service which supports a discrete, new project or program having documented air quality benefits. CM/AQ funds cannot be used to replace existing funding sources for transit operations and cannot be used to further subsidize existing operations.

*continues*

**Table 2 (cont.)**

*Highway and Transit Maintenance and Reconstruction Project Ineligible*
Routine maintenance on existing facilities is ineligible since it merely maintains and does not improve air quality.

*Planning and Air Quality Monitoring Projects*
Projects planning activities that lead directly to construction of facilities or new services and programs that have an air quality benefit, such as preliminary engineering or environmental documents.

*Public/Private Initiatives*
Initiatives that are owned, operated, or under the primary control of the public sector. If privately owned or operated, they must be shown to be cost-effective; and the state is responsible for protecting the public interest and investment, and must normally be a public sector responsibility.

*Limitation on Construction of Single-Occupant Vehicle Capacity*
Eligible if the project consists of an HOV facility only available to single-occupant vehicles at off-peak travel times.

*Employer Trip Reduction Ordinances*
Vehicle purchases for a private firm must be excluded from the program.

*Alternative Fuels Incentives*
If a vehicle conversion program, then it must respond to a specific Clean Air Act requirement or be specifically identified in the SIP as an emission reduction strategy.

*PM-10 Reduction Measures*
All CO and ozone nonattainment parties must be satisfied with the program.

*Telecommunications*
Project can be a planning, technology, or feasibility study; or it can be for training, coordination or promotion, plus
The project must exclude physical establishment of telecommuting centers, computer/office equipment purchases or related activities.

*Other Transportation Projects*
Projects based on promising technologies and feasible approaches to improve air quality will also be considered for funding if AQ benefits can be demonstrated and have concurrence of Federal and State transportation agencies and MPOs.

*Outreach Activities*
Eligible if project is a communication service that is critical to successful implementation of transportation measures. May be funded for an indefinite period.

*Rideshare Programs*
New or expanded rideshare programs are eligible and may be funded for an indefinite period if the project is an outreach program.
Vanpool activities must be for new or expanded services.
Operating expenses are eligible for only three years.
Not eligible for public services that would be in direct competition with and impede private sector initiatives.

*Establishing/Contracting with TMAs*
Establishment of TMAs and start-up costs for three years and must be sponsored by a public agency.

*continues*

**Table 2 (cont.)**

*Attainment Deadline Restrictions*
Projects (or phases thereof) programmed in the first two years of the TIP that is in effect at the time of redesignation.

*Maintenance Areas*
Projects (or phases thereof) programmed in the first two years of the TIP that is in effect at the time of redesignation.

*Fare/Fee Subsidy Programs*
Eligible if offered as a component of a comprehensive, targeted program to reduce SOV use.

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changes in trips, VMT, speed, and idling and an emissions module that calculates changes in CO, volatile organic compounds (VOC), $NO_X$, and particulate matter (PM-10). Finally, a criteria-weighting module develops a rating for each project being evaluated to derive a relative ranking. The criteria and weighting factors include travel impacts, 30; emission impacts, 30; cost-effectiveness, 30; and early project effectiveness, 10. Each of the first three criteria contains multiple components, and an intermediate weighting factor that can be changed to fit a specific area's needs is assigned to each component. An example of this scheme is shown in Table 3.[11]

## Other Issues Concerning the Effectiveness of TCMs

The implementation of TCMs will not typically have major impacts on regional air quality. For example, a report by the General Accounting Office (GAO) to Congress[10] indicated that, based on a nationwide survey of 119 metropolitan planning organizations, reviews of federal and state air quality studies, and discussions with transportation and air quality experts, traditional TCMs are projected to reduce region-wide HC and CO emissions from 0 to 5 percent. There was a consensus that TCMs are complementary programs that will supplement improvements in emissions technology, cleaner fuel, and vehicle inspection and maintenance programs. TCMs have traditionally been used for congestion reduction and energy conservation and will likely continue to play a growing role in an area's transportation planning efforts as funding and enforcement provisions encourage their implementation.

The same GAO report[10] found a strong consensus that market-based TCMs (those that impose financial disincentives on the use of automobiles) may be the most effective means of changing travel behavior. Examples are increased gasoline taxes, highway congestion pricing, and emissions fees. Implementing these measures would be difficult, as the public's resistance to them is expected to be significant. One reason the effectiveness of TCMs is so low is that they are dependent on the size of the market affected. Many TCMs focus on home-based work trips, and these trips typically comprise only 20 to 30 percent of the travel in an area. However, work trips are an important component of an area's travel. They are the most recurring and concentrated set of trips, employers can have an influence over the trips, and TCMs have the additional benefit of reducing congestion and conserving energy.

**Table 3**
**Factors Used in Criteria Weighting Module**

| Criteria/Components | Intermediate Factors | Weighting Factors |
|---|---|---|
| **Travel Impacts** | | **30** |
| Percent VMT reduction | 35 | |
| Percent speed increase | 40 | |
| Percent idling reduction | 25 | |
| **Emissions Impacts** | | **30** |
| Percent CO reduction | 20 | |
| Percent VOC reduction | 20 | |
| Percent $NO_x$ reduction | 20 | |
| Percent PM10 reduction | 10 | |
| CO Hot spot/Hot grid | 20 | |
| PM10 Hot spot/Hot grid | 10 | |
| **Cost-Effectiveness** | | **30** |
| CO cost per kg reduced | 30 | |
| VOC cost per kg reduced | 20 | |
| $NO_x$ cost per kg reduced | 30 | |
| PM10 cost per kg reduced | 10 | |
| **Early Project Effectiveness** | | **10** |

Note: These factors can be updated, although the same factors should be used for the project ratings in any given analysis year. Each set of intermediate factors and the weighting factors most total 100.

**Table 4**
**Strategies Included in the TTI CMAQ Evaluation Model**

**Improved Public Transit**
Increased Transit Service
Express Buses
Paratransit Programs
Light Rail
Bus Signal Preemption
Activity Center Shuttles
Transit Advanced Traveler Information System
Transit Shelters

**HOV Facilities**
Freeway HOV Lanes
Arterial HOV Lanes
Ramp Meter Bypass for HOVs

**Employer-Based Strategies**
Transit Pass Subsidy
Employee Transportation Coordinator
Education/Information Dissemination

*continues*

**Table 4 (cont.)**

Guaranteed Ride Home
Trip Reduction Ordinances

**Traffic Flow Improvements**
Traffic Signal Timing & Coordination Improvements
Traffic Operations Center
Courtesy Patrol
Other Incident Detection & Response Programs
Motorist Information
Intersection Improvements (widening)
Ramp Metering
Reversible Lanes

**Park-n-Ride Lots**
Transit-oriented
Car/Vanpool-oriented
Bike to Park-n-Ride Program

**Auto/Truck Restrictions**
Restricted Times for Goods Delivery
Auto Restricted Zones

**Congestion Pricing**
VMT Tax
Tolls

**Rideshare Programs/Services**
Regional or Neighborhood Based Rideshare Program
Transportation Management Associations
Vanpool Programs

**Non-Motorized Facilities**
Pedestrian Improvements
Bicycle Lanes, Paths
Bicycle Amenities (lockers, showers, secure storage)

Public Education Campaign
Bicycle/Pedestrian Coordinator Positions

**Vehicle Idling Controls**
Drive-thru restrictions
Curb-side idling restrictions
Vehicle idling restrictions by buses and trucks

**Alternative Work Schedules**
Compressed Work Week
Flexible Work Hours
Staggered Work Hours

**Alternative Fuel Incentive Programs**
Public Fleet Compressed Natural Gas
Reformulated Gasoline/Diesel

**PM10 Reduction Measures**
Enhanced Street Sweeping
Road Sanding/Salting Alternatives
Diesel Control Programs

**Telecommuting**
Home-based Telecommuting
Satellite Work Centers
Teleconferencing

**Parking Management**
Restricted Parking Supply
Parking Charges (commute and all trips)
Preferential Parking for Carpools and Vanpools

**Other Transportation Projects**
Promising Technologies
Feasible Approaches
Projects not in strategy listing

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There is generally a direct and positive relationship between the traffic impacts of a TCM (e.g., change in VMT, number of trips, speed) and the change in emissions, but the relationship may not be 1:1. For example, a TCM may have the potential of reducing VMT by 10 percent, but a like reduction is emissions will not necessarily follow.

The effectiveness of individual measures may not be directly additive in computing the impacts of a package or program of TCMs. Jointly implemented TCMs may complement each other or may, in fact, detract from their individual effectiveness.[3] This relationship can be further categorized as:[7]

- *Directly additive.* Measures are essentially unrelated while affecting different segments of the travel market.

- *Sequentially additive.* Measures affect essentially the same market but not in a supportive role. Impacts of one are calculated, a new baseline market is determined, and then the impact of the second is determined sequentially based on the lower market. Effect is less than directly additive.

- *Synergistic.* Measures affect essentially the same market in a supportive role. Impacts of one are calculated, a new baseline market is determined, and then the impact of the second is determined sequentially based on the higher market. Effect is more than directly additive.

- *Conflicting.* Measures provide conflicting incentives, thus reducing individual effectiveness.

Appendices O and P contain excerpts from the cited references that depict the packaging effects of TCMs.

Work is continually ongoing to improve the base knowledge about the effectiveness of TCMs. One important effort in the national arena is Project 8-33 of the National Cooperative Highway Research Program entitled *Quantifying Air Quality and Other Benefits of Transportation Control Measures.* It is currently scheduled for completion at the end of 1997. Appendix Q provides an overview of the scope of work for the research.

## CONCLUSIONS

The following conclusions were reached for this study:

- Significant work is underway regarding TCMs, mostly in the development and refinement of sketch planning tools that allow for a quick and reasonably accurate assessment of their effectiveness. Practitioners should stay abreast of these ongoing efforts to evaluate as accurately as possible the effectiveness of such measures in their area.

- The impacts of TCMs on regional air quality are relatively small and should be regarded as incremental, supportive measures that supplement other approaches, such as emissions technology and cleaner fuels. The additional impacts of TCMs on reducing congestion and saving energy should also be recognized in assessing their worth.

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## APPENDIX A

## POTENTIAL EFFECTIVENESS OF TCMs

Source: *Methodologies for Quantifying the Emission Reductions of Transportation Control Measures.* Prepared for the San Diego Association of Governments by Sierra Research, Inc., with support from JHK & Associates, October 1991.

Table 7-1

Potential Effectiveness
of Transportation Control Measures

| Control Measure | Emission Reduction Potential | Rate of Reduction |
|---|---|---|
| Land Use Management | | |
| Jobs/Housing Balance | Low | Slow |
| Densification | Medium | Slow |
| Mixed Use | High | Slow |
| Growth Controls | High | Slow |
| Pedestrian Improvements | Low | Slow |
| Traffic Flow Improvements | | |
| Traffic Signal Improvements | Low - Medium | Fast |
| Capacity Increases | Low | Slow |
| Transit Improvements | | |
| Service Increases | Low | Fast |
| Employee Transit Pass Subsidy | Low | Fast |
| Park-and-Ride Lots | Low | Fast |
| High Occupancy Vehicle Lanes | Low | Slow |
| Bicycle Improvements | | |
| Bicycle Improvements | Low | Fast/Slow |
| Demand Management | | |
| Trip Reduction Ordinances | High | Fast |
| Ridesharing | Medium | Fast |
| Parking Management | Medium | Fast |
| Telecommuting | High | Slow |
| Alternative Work Schedules | | |
| Flexible Work Hours | Low | Fast |
| Staggered Work Hours | Low | Fast |
| Compressed Work Week | Low | Fast |
| Pricing | | |
| Gas Tax | High | Fast |
| VMT Tax | High | Fast |
| Freeway Management | | |
| Motorist Information | Low | Fast |
| Incident Management and Response | Low | Fast |
| Goods Movement | | |
| Delivery Timing | Low | Fast |
| Loading Facility Improvements | Low | Fast |

# APPENDIX B

## TDM SOLUTIONS

Source: Jeffrey Zupan. Transportation Demand Management: A Cautious Look. *Transportation Research Record 1346,* 1992.

TABLE 2 TDM SOLUTIONS

| Strategy | Area Suitability | Travel Impacts: SOV Reduction | Travel Impacts: Peak Trip Reduction | Travel Impacts: VMT Reduction | Travel Impacts: Transit Impact | TDM Costs: Employee Cost | TDM Costs: Employer Cost | TDM Costs: Public Capital Cost | TDM Acceptance: Employee | TDM Acceptance: Employer | TDM Acceptance: Municipal | TDM Acceptance: Political | Ease of Implementation Index |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Alternate Work Schedules** | | | | | | | | | | | | | |
| Staggered | U,S | none | high | none | none | same | higher | none | high | low | high | high | 3 |
| Flex-time | U,S | negative | high | negative | negative | same | higher | none | high | low | high | high | 4 |
| 4 day week | U,S | medium | medium | high | highly neg | lower | unknown | none | medium | low | high | medium | 3 |
| Telecommuting | U,S | positive | positive | positive | highly neg | lower | unknown | none | unknown | unknown | high | medium | unknown |
| **Carpools** | S | high | medium | medium | negative | lower | varies | none | low | medium | high | high | 3 |
| **Vanpools** | S | medium | low | low | negative | lower | higher | none | low | low | high | high | 2 |
| **Subscription Buses** | S | low | low | low | positive | lower | higher | none | low | low | high | medium | 2 |
| **Parking Management** | | | | | | | | | | | | | |
| Preferential Pkng | S | low | low | low | none | same | higher | none | low | low | high | high | 2 |
| Parking pricing | U,S | medium | medium | medium | low | higher | same | none | negative | low | negative | negative | 1 |
| Parking ratios | U,S | medium | medium | medium | positive | same | lower | none | negative | unknown | negative | negative | 2 |
| Park - Rides | U,S | medium | medium | medium | positive | varies | n.a. | higher | medium | medium | varies | high | 4 |
| **Preferential HOV lanes** | U,S | medium | medium | medium | positive | same | n.a. | higher | varies | varies | high | varies | 4 |
| **Congestion Pricing** | U,S | medium | high | medium | positive | varies | n.a. | lower | low | low | unknown | negative | unknown |
| **Transit** | | | | | | | | | | | | | |
| Transitchek | U,S | medium | medium | medium | medium | lower | same | none | high | medium | high | high | 5 |
| Employer sponsored | U,S | low | low | low | low | varies | higher | none | medium | low | high | high | 4 |
| Employer subsidized | U,S | low | low | low | low | varies | higher | none | medium | low | high | high | 5 |
| **Land Use - Zoning** | | | | | | | | | | | | | |
| Higher densities | S | medium | medium | high | high | n.a. | varies | lower | n.a. | n.a | negative | negative | 2 |
| Transit - Friendly Design | S | medium | medium | medium | medium | same | same | lower | medium | low | varies | positive | 4 |
| Mixed Use Development | S | unknown | unknown | medium | unknown | lower | unknown | lower | unknown | unknown | varies | positive | 4 |
| Growth management | S | unknown | unknown | unknown | unknown | same | unknown | lower | unknown | unknown | varies | varies | 3 |
| **Trip Reduction Ordinances** | S | high | high | high | low/medium | varies | higher | n.a. | low | negative | varies | varies | 4 |
| **Transportation Mgmt Assoc** | U,S | varies | varies | varies | unknown | same | higher | n.a. | n.a. | varies | n.a. | positive | n.a. |

Suitability index U - Urban Areas S - Suburban Areas N A not applicable
Ease of Implementation Index 1 (difficult) to 5 (easy) N A not applicable

## APPENDIX C

## POTENTIAL EFFECTIVENESS OF TCMs IN THE WASHINGTON, D.C., METROPOLITAN AREA

Source: National Capital Region Transportation Planning Board, Metropolitan Council of Governments. *Conformity Determination of the Constrained Long Range Plan and the FY 96-20001 Transportation Improvement Program fort the Washington Metropolitan Region with the Requirements of the 1990 Clean Air Act Amendments.* July 9, 1995.

*Transportation Control Measure Analysis (for the Washington Region's 15 Percent Rate of Program Plan).* Metropolitan Planning Techical Report No. 5. Federal Highway Administration, February 1995.

# SHORT LIST OF TCMs FOR CONFORMITY OF THE FY 96-01 TIP & CLRP

| | | NOx REDUCTION tons by 2001 | COST PER TON | TOTAL COST IN MILLIONS | | |
|---|---|---|---|---|---|---|
| | | | | FY96 TIP | FY96-01 TIP | DC/MD/VA |
| **COMMUTE ALTERNATIVE PROGRAMS** | | | | | | |
| M-47a | Employer Outreach (Level 2) | 0.51 | 12,900 | 0.88 | 9.86 | 30/35/35 |
| M-47b | Employer Outreach (Level 2)/$10 Guaranteed Ride Home (combination) | 1.14 | 15,000 | 1.55 | 16.34 | 30/35/35 |
| | Employer Outreach (Level 2)/$25 Guaranteed Ride Home (combination) | 1.05 | 13,100 | 1.46 | 14.53 | 30/35/35 |
| M-70a | Bicycle Parking (regionwide) | 0.01 | 5,100 | 0.13 | 0.40 | 20/40/40 |
| M-77 | Vanpool Incentives | 0.21 | 19,000 | 1.03 | 6.20 | 0/40/60 |
| M-93 | Improve Pedestrian Facilities - Transit Stations/Suburban Retail Cntrs | 0.02 | 95,000 | 2.65 | 8.00 | 0/48/52 |
| M-100 | Guaranteed Ride Home ($10/participant) | 0.65 | 22,400 | 0.70 | 6.86 | 30/35/35 |
| | Guaranteed Ride Home ($25/participant) | 0.55 | 17,800 | 0.60 | 4.73 | 30/35/35 |
| **VEHICLE REPLACEMENT PROGRAM** | | | | | | |
| M-98 | Alternative Fueled Vehicles (conversions) | 0.01 | 69,000 | 1.50 | 1.50 | 20/40/40 |
| M-99a | Bus Replacement (based on 50 buses per year, FY 1996-2001) | 0.27 | 106,900 | 15.00 | 90.00 | TBD |
| M-103 | Taxicab Replacement (50 alt. fueled taxicabs/yr as a continuing program) | 0.40 | 10,300 | 1.23 | 6.15 | TBD |

# OTHER POTENTIAL TCMs FOR CONFORMITY OF THE FY 96-01 TIP & CLRP

| | | DAILY EMISSION REDUCTIONS (Tons by 1999) | | COST PER TON ($) | | ANNUAL COST IN MILLIONS FY 96 | DC/MD/VA % SHARE |
|---|---|---|---|---|---|---|---|
| | | VOC | NOX | VOC | NOX | | |
| **I. ADDITIONAL TCMs UNDER CONSIDERATION** | | | | | | | |
| M-04 | Cash For Clunkers, Remote Sensing ** | 0.98 | 0.12 | 8,000 | 62,500 | 1.9 | |
| M-10 | 75¢ per Gallon Gasoline Tax | 2.25 | 4.28 | * | * | * | N/A |
| M-11 | Congestion Pricing - LOVs @ 20¢ | 0.19 | 0.25 | * | * | * | N/A |
| M-14 | 1/2 Price Off Feeder Bus Service | 0.06 | 0.12 | 204,000 | 107,000 | 3.0 | |
| M-15 | Mileage Tax | 0.63 | 1.22 | * | * | * | N/A |
| M-26 | Increase Commuter Rail Frequency in Virginia | 0.07 | 0.14 | 370,000 | 176,000 | 12.7 | 0/0/100 |
| M-27 | Existing Timed Transfer | 0.00 | 0.00 | 0 | 0 | 0.0 | 0/0/0 |
| M-32 | Improve Bus Speeds on Selected Routes | 0.03 | 0.06 | | | | |
| M-44 | Standard ECO Program | 1.04 | 2.10 | 580,000 | 287,000 | 151.0 | |
| M-55 | Employers Provide 1 Bicycle per 100 Employees | 0.03 | 0.03 | 73,600 | 73,600 | 2.3 | |
| M-71 | $20/month Parking Charge - All Spaces | 1.40 | 2.93 | * | * | * | N/A |
| M-75 | Balanced ECO Program | 4.29 | 8.57 | 0 | 0 | 0.0 | 0/0/0 |
| M-78 | Increase Bus Frequency on Select Routes | 0.04 | 0.08 | | | | |
| M-90 | Extend Current 12% Parking Tax To All Market Rate Spaces in D.C. | 0.18 | 0.36 | * | * | * | 100/0/0 |
| M-89 | Increase D.C. Commercial Lot Parking Tax From 12% to 42% | 0.25 | 0.49 | * | * | * | 100/0/0 |
| **II. TCMs REQUIRING FURTHER STUDY** | | | | | | | |
| M-36 | Introduce 7 ATMS/ATIS Systems in the Region | *Under Development* | | | | | |
| M-40 | 10 Day Care Centers Near Rail Stations/P&R Lots | *Under Development* | | | | | |
| M-70 | Bicycle & Pedestrian Incentives | *Under Development* | | | | | |
| M-73 | Student "Cash-Out" Transit Program | *Under Development* | | | | | |
| M-76 | Formation of TMOs | *Under Development* | | | | | |
| M-91 | Volunteer ECO Proposal | *Under Development* | | | | | |
| M-101 | Mass Media Campaign | *Under Development* | | | | | |

* = Net Revenue

The results of the analysis are summarized in table 5 and table 6. Table 5 presents the vehicle trip and vehicle miles of travel reduction/increase and the corresponding volatile organic compound reduction in tons/day. Table 6 arrays the emission reduction potential of the TCMs against their cost effectiveness.

**Table 5: Summary Table of Transportation Impacts and Emission Reduction of TCMs**

| NO. | SHORT DESCRIPTION (page #) | VT REDUCED | VMT REDUCED | VOC REDUCED (tons/day) |
|---|---|---|---|---|
| M-04 | Cash for Clunkers (43) | N/A | N/A | 1.00 |
| M-07 | Mandatory Cash-Out Subsidy for Transit/HOV (44) | 555,300 | 7,166,500 | 6.82 |
| M-08 | Single Price Public Transit Services (50) | 129,700 | 2,114,700 | 1.86 |
| M-09 | "Pollution Fee" for Gasoline-Powered Motor Vehicles (53) | 56,200 | 1,027,700 | 0.87 |
| M-10 | Increase Gasoline Taxes by $0.75 Per Gallon (56) | 52,500 | 973,400 | 0.83 |
| M-11 | Congestion Pricing on LOVs (Max. 20¢/mile) (60) | 29,400 | 108,600 | 0.20 |
| M-12 | Employee Parking Space Tax Outside Metro Core (64) | 154,500 | 2,063,100 | 1.94 |
| M-13 | Employee Parking Space Tax in Metro Core (68) | 147,100 | 1,954,500 | 1.84 |
| M-14 | Half price fares on feeder bus service to metrorail (71) | 41,600 | 453,200 | 0.46 |
| M-15 | Graduated Tax on Vehicle Mileage (74) | 13,600 | 286,500 | 0.23 |
| M-16 | Market-based Parking Charges for Federal Facilities (77) | 44,100 | 597,200 | 0.56 |
| M-17 | Congestion Pricing on LOVs (Max. 10¢/mile) (80) | 18,400 | (108,600) | 0.02 |
| M-18 | Free Rail Fares Between 10am and 3pm Weekdays (84) | 6,300 | 50,900 | 0.06 |
| M-19 | Free Parking for Carpools and Vanpools (87) | 3,700 | 108,600 | 0.08 |
| M-20 | Congestion Price Low Occupancy Vehicles (Min./$0.10) (89) | 3,700 | (217,200) | (0.12) |
| M-23 | Graduated Additional Vehicle Registration Fee (93) | 60,600 | 1,054,100 | 0.91 |
| M-24 | Increased Adherence to the 55 MPH Speed Limit (97) | N/A | N/A | 0.7 |
| M-25 | Increase the Frequency of Existing Transit Service (99) | 72,100 | 1,153,300 | 1.02 |
| M-26 | Increase the Frequency of Commuter Rail (102) | 8,100 | 221,400 | 0.17 |
| M-27 | Timed Transfer Service with Exten. Suburban Coverage (105) | 18,900 | 274,500 | 0.25 |
| M-28 | Improve Pedestrian Facilities Near Rail Stations (108) | 1,900 | 17,000 | 0.02 |
| M-29 | Provide Bike Racks and Lockers at All Transit Stations (112) | 2,000 | 22,800 | 0.02 |

| NO. | SHORT DESCRIPTION (page #) | VT REDUCED | VMT REDUCED | VOC REDUCED (tons/day) |
|---|---|---|---|---|
| M-30 | Flashing Yellow in Predominant Direction, Midnight-5am (114) | N/A | N/A | 0.06 |
| M-31 | Highway Ramp Metering (117) | 0 | 18,300 | 0.01 |
| M-32 | Increase Bus Speeds in High Volume Bus Corridors (119) | 4,100 | 49,500 | 0.05 |
| M-33 | Develop Pedestrian/Bike Access to Commercial Centers (122) | 190 | 570 | 0.001 |
| M-35 | Build New P&R Lots Associated With HOV Facilities (124) | (2,400) | 41,600 | 0.015 |
| M-36 | Implement Advanced Trans. Management Systems (127) | N/A | N/A | 0.50 |
| M-37 | Complete Bike Element of LRP within 10 years (129) | 71,600 | 84,300 | 0.37 |
| M-38 | Right Turn on Red throughout D.C. (131) | N/A | N/A | 0.39 |
| M-39 | P&R Lots Near Selected Major Highway Intersections (133) | (730) | 63,500 | 0.04 |
| M-41 | Mandatory Employee Commute Options (137) | 415,600 | 6,135,000 | 5.60 |
| M-42 | Regional Voucher Program (140) | 172,800 | 2,388,800 | 2.20 |
| M-43 | Monthly Transit Passes/Regional Fare Media (143) | 45,900 | 597,500 | 0.57 |
| M-44 | On-site Employer Trip Reduction Programs (146) | 95,600 | 1,411,600 | 1.28 |
| M-45 | Flexible Work Week/Four Day Work Week (149) | 66,200 | 977,300 | 0.89 |
| M-46 | Financial Incentives for Telecommuting Programs (151) | 62,500 | 868,700 | 0.81 |
| M-47 | Integrated Ridesharing Measures (154) | 15,500 | 381,800 | 0.30 |
| M-48 | Shorter Distances from Bus Stops to Buildings (157) | 6,400 | 67,500 | 0.07 |
| M-49 | Regional Vanpool Insurance Pool (160) | N/A | N/A | * |
| M-50 | Convenience Commercial Centers in Residential Areas (161) | 4,770 | 14,310 | 0.03 |
| M-52 | Build HOV Network in the Freeway System (163) | 34,900 | 684,100 | 0.57 |
| M-53 | Control Student Parking at High Schools (165) | 16,000 | 86,000 | 0.12 |
| M-54 | Free Transit Passes for Students (167) | 10,000 | 50,000 | 0.07 |
| M-55 | Employer-Provided Bicycles (169) | 4,500 | 13,500 | 0.03 |
| M-56 | Control of Extended Idling (171) | N/A | N/A | 0.39 |
| M-57 | Restrict New Parking Construction (172) | 53,400 | 776,500 | 0.71 |
| M-58 | Telecommuting Centers in Outlying Areas (177) | 19,000 | 1,083,400 | 0.74* |

* Full emission benefits

# Table 6: TCM Emission Reduction vs Cost Effectiveness

| EMISSIONS REDUCTION (tons per day) | REVENUE PRODUCING | $0 - $49K/ton | $50K - $99K/ton | $100K - $249K/ton | $250K - $499K/ton | More than $500K/ton |
|---|---|---|---|---|---|---|
| Less than 0.5 | M-11 Cong. Price (20¢) (60)<br>M-15 Mileage Tax (74)<br>M-17 Cong. Pricing (10¢) (80)<br>M-20 Cong. Pricing (min) (89)<br>M-30 Flashing Yellow (114) | M-29 Bicycle Racks/Lockers (112)<br>M-38 RTOR in D.C. (131)<br>M-50 Conv. Ctrs @ Resident.(161)<br>M-53 Control Student Parking(165)<br>M-56 Control Extend. Idling (171) | M-37 Bike Element in 10 yrs (129)<br>M-39 P&R Lots at Intersect (133)<br>M-47 Ridesharing (154) | M-14 1/2 Price Feeder Bus (71)<br>M-27 Timed Transfer (105)<br>M-32 Increase Bus Speeds (119)<br>M-55 Employer provides Bikes (169) | M-26 Increase Commuter Rail (102<br>M-33 Ped/Bike Access to Ctrs (122)<br>M-35 New P&R Lots (HOV) (124)<br>M-48 Short. Dist to Bus Stop (157) | M-18 Free off-peak Rail (84)<br>M-19 Free Pool Parking (87)<br>M-28 Pedestrian Facilities (108)<br>M-31 Ramp Metering (117)<br>M-54 Free Transit for Student (167) |
| 0.5 - 0.99 | M-09 Pollution Fee (53)<br>M-10 Gasoline Tax (56)<br>M-16 Market Park. for Feds (77)<br>M-23 Veh. Registration Fee (93)<br>M-45 Flex Work Schedule (149)<br>M-57 Restrict New Parking (172) | M-24 Speed Limit Adherence (97)<br>M-36 A.T.M.S. (127) | | M-43 Transit Passes (143)<br>M-58 Telecommute Cntrs. (177)* | M-46 Incentives to Telecomm. (151) | M-52 Freeway HOV System (163) |
| 1.0 - 1.49 | | M-04 Cash for Clunkers (43) | | M-25 Increase Existing Transit (99) | M-44 ETR Program (146) | |
| 1.5 - 1.99 | M-12 Parking Tax (non-core) (64)<br>M-13 Park Tax (core) (68) | | | M-08 Single Price Transit (50) | | |
| 2.0 - 2.49 | | | | | | M-42 Regional Voucher (140) |
| 2.5 - 2.99 | | | | | | |
| 3.0 - 3.49 | | | | | | |
| 3.5 - 3.99 | | | | | | |
| 4.0 - 4.49 | | | | | | |
| 4.5 - 4.99 | | | | | | |
| 5.0 - 5.49 | | | | | | |
| 5.5 - 5.99 | | | | M-41 Mandatory ECO (137) | | |
| 6.0 + | | | | | | M-07 Cash-Out (44) |

* Emission benefits by 1996

## APPENDIX D

## EFFECTIVENESS OF CONGESTION-REDUCING MEASURES IN VIRGINIA

Source: E.D. Arnold, Jr. *An Evaluation of Congestion-Reducing Measures Used in Virginia.* VTRC 93-R7. Charlottesville: Virginia Transportation Research Council, November 1992.

STATE SURVEY RESULTS
EFFECTIVENESS (TOTAL RESPONSES)

| 0 | 1 | 2 | AVG | CATEGORY | MEASURE |
|---|---|---|---|---|---|
| 0 | 6 | 20 | 1.8 | I.B.5 | PROVIDING HIGHWAY GRADE SEPARATIONS |
| 2 | 11 | 39 | 1.7 | I.B.1 | CONSTRUCTING NEW HIGHWAYS |
| 0 | 5 | 11 | 1.7 | I.B.7 | CHOOSING TOLL-BASED FINANCING TO EXPEDITE CONSTR OF NEW FACILITIES |
| 1 | 1 | 7 | 1.7 | I.B.4 | CONSTRUCTING HOV LANES |
| 2 | 13 | 35 | 1.7 | I.A.20 | PROHIBITING MAINTENENCE/REPAIRS ON MAJOR ROUTES DURING PEAK TRAFFIC HOURS |
| 3 | 18 | 37 | 1.6 | I.B.2 | RECONSTRUCTING HIGHWAY W/IMPROVED DESIGN |
| 0 | 27 | 35 | 1.6 | I.A.8 | COORDINATED SIGNAL SYSTEMS |
| 0 | 4 | 5 | 1.6 | I.A.2 | TRAFFIC SURVEILLANCE/CONTROL SYSTEM |
| 1 | 10 | 14 | 1.5 | I.B.6 | PROVIDING RAILROAD GRADE SEPARATIONS |
| 2 | 18 | 25 | 1.5 | I.B.3 | WIDENING BY ADDING GENERAL PURPOSE LANES |
| 2 | 16 | 16 | 1.4 | I.A.7 | PROVIDING ADDITIONAL LANES W/O WIDENING (SHOULDERS, NARROWER LANES) |
| 0 | 5 | 3 | 1.4 | I.A.5 | INTEGRATED FREEWAY AND ARTERIAL/SURVEILLANCE CONTROL SYSTEM |
| 2 | 40 | 26 | 1.4 | I.A.12 | INTERSECTION IMPROVEMENTS, INCL. CHANNELIZATION, TURN LANES, SIGNING, BUS STOP RELOCATION |
| 4 | 37 | 24 | 1.3 | I.A.10 | OTHER SIGNAL IMPROVEMENTS, INCL. HARDWARE, UPGRADES, RETIMING, REMOVAL |
| 1 | 5 | 4 | 1.3 | II.A.10 | IMPLEMENTING/IMPROVING RAIL TRANSIT OR COMMUTER RAIL SERVICES |
| 1 | 6 | 4 | 1.3 | I.A.6 | CONVERTING EXISTING FACILITIES TO HOV FACILITIES |
| 1 | 1 | 2 | 1.3 | II.B.2 | AUTO-RESTRICTED ZONES |
| 4 | 26 | 15 | 1.2 | I.A.14 | ONE-WAY STREETS |
| 9 | 29 | 21 | 1.2 | I.A.16 | REMOVING/RESTRICTING ON-STREET PARKING |
| 1 | 6 | 3 | 1.2 | I.A.15 | REVERSIBLE TRAFFIC LANES ON ARTERIALS |
| 3 | 12 | 7 | 1.2 | II.A.9 | IMPLEMENTING EXPRESS BUS SERVICES |
| 2 | 6 | 4 | 1.2 | II.B.5 | REQUIRING CONGESTION-REDUCTION STRATEGIES, REDUCED TRIP GEN, OR TRANSIT CONSIDERATIONS FOR PROPOSED DEV |
| 4 | 18 | 9 | 1.2 | II.A.1 | DAILY FLEXIBLE WORK HOURS (STAGGERED/FLEXTIME) |
| 1 | 5 | 2 | 1.1 | I.A.3 | MOTORIST INFORMATION SYSTEM |
| 6 | 20 | 10 | 1.1 | II.A.14.b | PARK AND RIDE LOTS |
| 2 | 7 | 3 | 1.1 | I.A.4 | TRAFFIC MANAGEMENT TEAM |
| 5 | 29 | 8 | 1.1 | II.B.1 | GROWTH MANAGEMENT BY PUBLIC POLICY/ORDINANCE/PLANNING |
| 0 | 13 | 1 | 1.1 | I.A.1 | INCIDENT DETECTION/MANAGEMENT SYSTEM/PROGRAM |
| 8 | 31 | 11 | 1.1 | I.A.11 | IMPROVING OTHER TRAFFIC CONTROL DEVICES |
| 6 | 5 | 7 | 1.1 | I.A.17 | ARTERIAL ACCESS MANAGEMENT |
| 3 | 12 | 4 | 1.1 | II.A.14.a | CAR/VANPOOL PREFERENTIAL PARKING |
| 9 | 33 | 11 | 1.0 | I.A.13 | TURN PROHIBITIONS |
| 10 | 34 | 12 | 1.0 | I.A.19 | TRAFFIC MANAGEMENT DURING HIGHWAY RECONSTRUCTION OR OTHER MAJOR IMPROVEMENTS |
| 7 | 14 | 8 | 1.0 | II.A.7.a | COMMUTER MATCHING SERVICES |
| 0 | 2 | 0 | 1.0 | II.B.4 | ROAD/CONGESTION PRICING (EXCL. TRADITIONAL TOLL CONSTRUCTION) |
| 3 | 13 | 2 | 0.9 | II.B.3 | DESIGNING MULTI-USE SITES TO MINIMIZE TRAFFIC (E.G., ON-SITE SERVICES) |
| 4 | 17 | 1 | 0.9 | II.A.2 | ALTERNATIVE WORK HOURS - COMPRESSED WORK WEEK |
| 8 | 16 | 4 | 0.9 | II.A.13 | SUBSIDIZING TRANSIT USAGE |
| 1 | 6 | 0 | 0.9 | I.A.9 | RAMP METERING |
| 3 | 9 | 1 | 0.8 | II.A.12 | REDUCING TRANSIT FARES |
| 2 | 10 | 0 | 0.8 | II.A.5 | COMMUNICATION IN LIEU OF TRAVEL-TELECOMMUTING |
| 3 | 7 | 1 | 0.8 | II.A.7.e | TAX INCENTIVES FOR VANPOOLS |
| 9 | 19 | 3 | 0.8 | II.A.8 | IMPLEMENTING/IMPROVING TRANSIT FIXED-ROUTE SERVICES |
| 6 | 10 | 2 | 0.8 | II.A.4 | COMMUNICATION IN LIEU OF TRAVEL-TELECONFERENCING |
| 5 | 11 | 1 | 0.8 | II.A.6 | IMPLEMENTING TRANSPORTATION MANAGEMENT ASSOC OR ORGANIZATIONS |
| 14 | 18 | 5 | 0.8 | II.A.7.c | PROVIDING PUBLIC INFORMATION ON RIDESHARE/TRANSIT |
| 4 | 7 | 1 | 0.8 | II.A.7.b | REDUCED TOLLS |
| 11 | 13 | 3 | 0.7 | II.A.3 | PROMOTING NON-VEHICULAR ALTERNATIVES TO AUTO USAGE |
| 3 | 6 | 0 | 0.7 | I.A.18 | GOODS MOVEMENT MANAGEMENT |
| 3 | 5 | 0 | 0.6 | II.A.14.c | DIFFERENTIAL PARKING RATES |
| 13 | 13 | 2 | 0.6 | II.A.11 | IMPLEMENTING/IMPROVING PARATRANSIT SERVICES |
| 4 | 5 | 0 | 0.6 | II.A.14.d | GOVERNMENTAL CONTROL OF SUPPLY AND LOCATION |
| 10 | 2 | 1 | 0.3 | II.A.7.d | GUARANTEED RIDE HOME PROGRAM |

Note: Effectiveness Rating Scale

0 = measure has minimal effect on decreasing congestion
1 = measure has average effect on decreasing congestion
2 = measure has maximum effect on decreasing congestion

Columns 1 through 3 indicate the number of responses received for each rating.

# APPENDIX E

## ASSESSMENT OF TRAVEL REDUCTION OPTIONS

Source: Paul M. Schonfeld and Himmat S. Chadda. An Assessment of Urban Travel Reduction Options. *Transportation Quarterly,* July 1995.

TABLE I—ASSESSMENT OF TRAVEL REDUCTION OPTIONS

| Options | *Effectiveness in Reducing:* 1. *Vehicle miles* | 2. *Energy conservation* | 3. *Environmental impacts* | 4. *Parking regulations* | 5. *User costs* | 6. *Overall costs* | *Potential applicability* | *Implementation Problems and Requirements* |
|---|---|---|---|---|---|---|---|---|
| Ridesharing | | | | | | | | |
| Carpooling | M | M | L | M | L | L | H | Promotion and matching program desirable. |
| Vanpooling | H | H | M | H | L | L | M | Government or employer information and incentives. |
| Subsidization | M | M | M | M | L | L | L | Program funding more difficult than preferential treatment. |
| Trip Chaining | | | | | | | | |
| Chaining shopping trips | M | M | L | L | M | H | M | Education, land use planning, activity scheduling. |
| Combining shopping with other trips | M | M | L | L | M | H | M | Education, land use planning, activity scheduling. |
| Public Transportation | | | | | | | | |
| Fixed route service (bus, rail, etc.) | H | H | M | H | L | L | H | Adequate route density and frequency require substantial subsidies. |
| Taxi | L | L | L | H | L | M | M | Reduced barriers to entry in taxi business. |
| Subscription services | H | H | M | H | L | M | M | Transit management practices. |
| Dial-a-Ride | M | M | L | M | L | L | M | Employer initiatives, good management, adequate demand density, vehicle operating cost. |
| Car rental | L | L | L | L | L | L | L | Vehicle redistribution, vandalism. |
| Activities Scheduling | | | | | | | | |
| Staggered work hours | L | L | L | L | M | M | M | Possible government intervention. |
| Flexible work hours | L | L | L | L | M | L | M | May sometimes reduce ridesharing. |
| More part-time jobs | L | L | L | L | L | L | L | More management. |
| Extended workdays for service firms | L | L | L | M | M | M | M | Cost of overtime or extra shifts. |
| Restrictions on peak period freight deliveries | L | L | M | L | L | L | L | Cost of overtime or night pay. |
| Home deliveries and pick-ups | H | M | L | H | H | M | M | Demand density, willingness to pay extra cost based on trip savings. |

TABLE I—Con't

| Options | 1. Vehicle miles | 2. Energy conservation | 3. Environmental impacts | 4. Parking regulations | 5. User costs | 6. Overall costs | Potential applicability | Implementation Problems and Requirements |
|---|---|---|---|---|---|---|---|---|
| | *Effectiveness in Reducing:* | | | | | | | |
| Parking Controls | | | | | | | | |
| Higher parking prices | M | M | L | M | L | M | H | Easier for private sector. |
| Restricted supply of parking | M | M | L | M | L | L | M | Political difficulty, risk to downtown stores. |
| Reduced accessibility of parking | M | M | L | M | L | L | M | Political difficulty, risk to downtown stores. |
| Park and ride facilities at transit station | M | M | L | L | M | M | M | Shift parking requirements to outlying areas. |
| Fringe parking with transit shuttles | M | H | L | M | L | M | M | Find parking lots and fund transit services. |
| Rate and/or accessibility differential for: | | | | | | | | |
| a) long- and short-term parking | L | L | L | M | L | M | M | Enforcement. |
| b) peak, off-peak, and night periods | M | M | L | L | L | M | M | Inflexible street meters. |
| c) higher occupancy vehicles | M | M | L | M | L | L | M | Larger lots, enforcement. |
| d) smaller vehicles | L | M | L | L | L | L | M | Larger lots, enforcement. |
| Roadspace Allocation | | | | | | | | |
| Exclusive lanes for buses | M | M | L | H | L | L | L | Corridor with sufficient bus demand. |
| Exclusive lanes for HOVs | L | L | L | M | L | M | M | Enforcement, sufficient HOV demand. |
| Contraflow lanes for buses | M | M | L | H | L | L | L | Directional imbalance in volumes. |
| Contraflow lanes for HOVs | L | L | L | M | M | L | L | Safety problems for cars. |
| Reversible lanes for mixed traffic | L | L | L | L | M | M | H | Doubtful reduction in vehicle miles traveled. |
| Bicycle lanes (on existing roads) | M | M | M | M | L | L | M | Weather, safety, and user acceptance problems. |
| Wider sidewalks (on existing roads) | M | M | H | M | L | L | M | Doubtful net benefits. |
| Pedestrian malls | L | L | M | L | L | L | L | Vehicles and impacts shifted elsewhere. |
| On-street parking restrictions | L | L | L | L | L | L | M | Depend largely on volumes and other local conditions. |
| On-street truck loading restrictions | L | L | L | L | L | L | L | Enforcement problems, higher cost to shippers. |
| Auto-free zones | M | M | H | M | L | L | M | Limited experience. |
| Barriers on local streets | L | L | M | L | L | L | M | Doubtful net benefits, political antagonism. |
| Preferential Treatment for HOVs | | | | | | | | |
| Bypass lanes at metered ramps | L | L | L | L | M | M | L | Cost and availability of extra lanes. |
| Signal pre-emption by buses | L | L | L | L | M | M | L | Difficult in coordinated signal systems. |
| Auto Disincentives | | | | | | | | |
| Road tolls | M | M | L | M | H | H | M | Toll collection technology. |
| Fuel taxes | M | M | L | M | M | M | H | Political acceptability. |
| Registration and excise taxes | L | L | L | L | L | L | H | Current levels are insignificant. |
| Speed limits | L | M | L | L | M | L | H | Doubtful net benefits. |
| Land-Use Planning to Achieve More Compact Cities | | | | | | | | |
| Mix commercial, office and residential use | M | M | M | L | H | M | M | Difficult even in long term for transportation professionals; not a short-term option. |
| Encourage bicycle and walk trips | H | H | M | H | L | L | M | May require unpopular decisions on roadspace allocation, parking restriction. |
| Improved Telecommunications | | | | | | | | |
| Shopping from home | H | H | L | H | H | H | H | Potential increases with advances in technology. |
| Teleconferencing | H | H | M | M | H | H | M | Potential increases with advances in technology. |
| Decentralization of major employees | H | H | M | H | M | M | M | Potential increases with advances in technology. |
| More work at home | H | H | M | H | H | M | L | Conceivable for many desk workers but productivity may suffer. |
| Diversified education services on Cable TV | H | H | M | H | H | H | M | Potential increases with advances in technology. |

## APPENDIX F

## IMPACTS OF TCMs ON VMT AND EMISSIONS

Source: John F. DiRenzo. Travel and Emissions Impacts of Transportation Control Measures. *Transportation Research Record 714,* 1979.

**Table 1. Impacts of selected individual transportation control measures on vehicle kilometers of travel and emissions.**

| Control Measure | Percentage Reduction: Vehicle Kilometers of Travel[a] | Percentage Reduction: Emissions | Area | Reference |
|---|---|---|---|---|
| Inspection and maintenance | | 8.1—HC[b] | Washington | 5 |
| | | 4.7—HC[b] | Baltimore | 6 |
| | | 6.4—8-h CO | | |
| | | 6—CO | Urban area in New York | 7 |
| | | 1—HC | | |
| Improved transit service | | | | |
| 10 percent increase in bus service | 0.02 | | Albany | 7 |
| 10 percent ($0.05) decrease in fares | 0.22 | | Albany | 7 |
| $0.10 decrease in fares | 0.70[b] | 0.3—HC[b] | Baltimore | 5 |
| Increased frequency of service to CBD | 0.1 | | Washington | 8 |
| Express bus service to CBD combined with increased frequency | 0.3 | | Washington | 8 |
| Increased frequency of service and extended coverage | 1.1-2.2 | | San Diego | 9 |
| HOV preferential lanes | 2.5[c] | | Albany | 7 |
| HOV lane on freeway | 0.2[b] | 0.1—HC[b] | Baltimore | 6 |
| | 0.6 | | Washington | 8 |
| Carpool or vanpool | | | | |
| Major employer-based carpool or vanpool program | 1.5 | 1.3—HC | >500 000 population | 4 |
| | | 1.3—CO | | |
| Carpool matching and promotion | 0.4 | | Washington | 8 |
| Carpool cost subsidy | | | | |
| $0.016/passenger kilometer | 0.3 | | Washington | 8 |
| $0.031/passenger kilometer | 0.7 | | | |
| Vanpooling | 1.2 | | Washington | 8 |
| Carpool locator | 0.4[b] | 0.2—HC[b] | Baltimore | 6 |
| Major employer matching | 1.0 | | Chicago | 10 |
| Meet and ride program | 1.0 | | Chicago | 11 |
| Major employer matching | 1.2 | | Numerous areas | 11, 12 |
| Areawide programs | 0.12 | | Numerous areas | 11, 12 |
| Automobile-restricted zones | | | | |
| Automobile-restricted zone | 0.4 | | Washington | 8 |
| One-day-a-week driving ban | 8.8 | | Washington | 8 |
| Parking management | | | | |
| $1.00 parking surcharge | 0.8[b] | 0.3—8-h CO | Baltimore | 6 |
| | | 0.3—HC[b] | | |
| $2.00 parking surcharge | 1.5[b] | 0.7—8-h CO | Baltimore | 6 |
| | | 0.8—HC[b] | | |
| Outlying parking cost | 4.8[b] | 1.5—8-h CO | Baltimore | 6 |
| | | 2.7—HC[b] | | |
| Preferential parking for carpools | 0.6 | | Washington | 8 |
| Areawide parking cost increase | | | | |
| $1.00 | 0.8 | | Washington | 8 |
| $2.00 | 1.7 | | Washington | 8 |
| $3.00 | 2.5 | | Washington | 8 |
| CBD parking cost increase | | | | |
| $1.00 | 0.3 | | Washington | 8 |
| $2.00 | 0.6 | | Washington | 8 |
| $3.00 | 0.9 | | Washington | 8 |
| Reduced parking supply in CBD | 0.5 | | Washington | 8 |
| Increased parking costs in seven high-density areas | | | | |
| Commercial rates | 14—subareas | | Washington | 13 |
| Commercial rates + $1.00 | 29—subareas | | Washington | 13 |
| Commercial rates + $2.00 | 30—subareas | | Washington | 13 |
| Park-and-ride lots and fringe parking | | | | |
| Six park-and-ride lots | 0.8[c] | | Syracuse | 7 |
| Six peripheral park-and-ride lots | 0.5[c] | | Syracuse | 7 |
| Pedestrian malls | 0.3—region[c] | | Syracuse | 7 |
| | +1.9—CBD[c] | | Syracuse | 7 |
| Staggered work hours | | | | |
| Flexible working hours | 3.7[b] | 2.0—HC[b] | Baltimore | 6 |
| | 4.0[b] | | Washington | 5 |
| Pricing strategies | | | | |
| Increase gasoline prices $0.05/L | 1.5[b] | | Baltimore | 6 |
| Double gasoline prices | 5.1 | | Washington | 8 |
| Triple gasoline prices | 9.7 | | | |
| Quadruple gasoline prices | 13.8 | | | |
| Tolls for single-occupancy automobiles to CBD | | | | |
| $0.50 | 0.2 | | Washington | 8 |
| $1.00 | 0.4 | | | |
| Vehicle ownership tax | | | | |
| $100/vehicle | 0.1 | | Washington | 8 |
| $200/vehicle | 0.2 | | | |
| $400/vehicle | 0.4 | | | |
| Carpool tax rebates | | | | |
| $250/year | 0.05 | | Washington | 8 |
| $500/year | 0.1 | | | |
| Idling controls | | 3.4—CO | Upstate New York | 7 |
| | | 1.5—HC | | |
| Traffic flow improvements | | | | |
| Preferential traffic control | 0.1 | 1—HC[b] | Washington | 8 |
| Progressive signalization to increase speeds by 1 percent | | 1—8-h CO | Washington | 5 |
| Retrofits | | | | |
| Light-duty vehicle | | 9.3—8-h CO | Baltimore | 6 |
| | | 3.2—HC[b] | | |
| Light-duty trucks | | 0.3—8-h CO | | |
| | | 0.2—8-h HC | | |
| Heavy-duty gasoline-powered trucks | | 6.3—8-h CO | | |
| | | 1.6—HC[b] | | |

Notes: 1 km = 0.62 mile; 1 L = 0.26 gal.

[a] Percentages apply to weekday areawide vehicle kilometers of travel, except where noted. [b] Peak period. [c] Peak hour.

Table 2. Summary of estimated impacts of the localized prototype scenarios.

| Prototype Scenario | Impact on Morning Peak-Hour Corridor Vehicle Volume[a]: Base Peak-Hour Volume | Impact on Morning Peak-Hour Corridor Vehicle Volume[a]: Change (%) | Impact on Morning Peak-Hour CO Concentration at Reference Receptor, from Affected Facility Emissions ($\mu g/m^3$)[b] — Typical, Good Dispersion[d]: Base Value | Typical, Good Dispersion[d]: Change (%) | Typical, Poor Dispersion[d]: Base Value | Typical, Poor Dispersion[d]: Change (%) | Program Costs[c] ($000s): Capital (One-Time Implementation)[e] | Program Costs[c] ($000s): Operating per Year[f] |
|---|---|---|---|---|---|---|---|---|
| 1. Expanded express bus service in mixed freeway traffic; favorable impacts | 19 667 | -1.47 | 5756 | -2.4 | 8210 | -2.5 | 3168-4788 | 1447 |
| 2. Freeway lane reserved for buses and carpools; favorable impacts | 19 667 | -6.30 | 5756 | -11.4 | 8210 | -9.3 | 3720-5350 | 1839 |
| 3. Ramp metering and bus bypass lanes; favorable impacts | 19 667 | -3.06 | 5756 | -6.7 | 8210 | -6.5 | 5224-6844 | 1703 |
| 4. Reserved bus and pool lane, ramp metering, and bus bypass lanes; modest impacts | 19 667 | -3.97[d] | 5756 | -[g] | 8210 | -[g] | 4862-6482 | 1751 |
| 5. Reserved bus and pool lane, ramp metering, and bus bypass lanes; favorable impacts | 19 667 | -6.98 | 5756 | -8.7 | 8210 | -10.1 | 6248-7868 | 2266 |
| 6. Contraflow freeway lane reserved for buses; favorable impacts | 14 750 | -1.69 | 4798 | +4.7 | 6759 | +3.4 | 962 | 541 |
| 7. Contraflow bus lane, expanded express bus service, and park-and-ride lots; favorable impacts | 14 750 | -3.72 | 4798 | +2.3 | 6759 | +1.5 | 3668-5288 | 1818 |
| 8. Contraflow bus lane, expanded express bus service, and lots; assuming 70%-30% directional split; favorable impacts | 13 500 | -4.07 | 4066 | | 5748 | -2.7 | 3668-5288 | 1818 |
| 9. Reserved arterial median lane for express buses; favorable impacts | 3 750 | -15.47 | 4964 | -15.7 | 6485 | -15.3 | 3594-4134 | 1130 |
| 10. Contraflow curb lane for local buses on pair of one-way arterials; favorable impacts | 5 000 | -4.40 | 3992[h]<br>3349[i] | -13.3[h]<br>+10.9[i] | 4992[h]<br>4793[i] | -13.7[h]<br>+9.9[i] | 468 | 123 |

Note: 1 $\mu g/m^3$ CO = 870 ppm.

[a] Volume is for freeway or arterial segments approximately 0.6 km (1 mile) out from the CBD (adjacent to the CBD in the case of scenario 10).
[b] CO concentration 15 m (50 ft) from downwind edge of primary corridor facility, based on vehicular emissions from affected facilities only; uninterrupted traffic flow conditions are also assumed.
[c] Costs are in 1976 dollars.
[d] This value includes the vehicles originally using the corridor freeway, but estimated as being unable to pass through during peak hour because of flow breakdown caused by congestion.
[e] The two capital cost entries represent the range in costs depending on whether existing parking facilities (e.g., shopping center) or newly constructed facilities are required for park-and-ride lots.
[f] Represents incremental operating costs.
[g] CO concentration impacts for scenario 4 could not be reliably estimated.
[h] Inbound arterial.
[i] Outbound arterial.

Table 3. Summary of estimated impacts for the regional prototype scenarios.

| Prototype Scenario[a] | Change in Regional Weekday Vehicle Kilometers of Travel: Percentage of Total | Change in Regional Weekday Vehicle Kilometers of Travel: Percentage of Work Trip | Change in Regional Weekday Highway Emissions: HC (%) | Change in Regional Weekday Highway Emissions: CO (%) | Change in Annual Highway Fuel Consumption (L000 000s) | Program Costs[b] ($000 000s): Capital (One-Time Implementation) | Program Costs[b] ($000 000s): Incremental Operating per Year |
|---|---|---|---|---|---|---|---|
| 11. Carpool or vanpool program, medium-sized city; favorable impacts | -1.5 | -5.0 | -1.2 | -1.3 | -9.8 | - | 76 |
| 12. Carpool or vanpool program, large-sized city; favorable impacts | -1.5 | -5.0 | -1.4 | -1.3 | -43.9 | - | 404 |
| 13. Reserved bus or pool lanes, ramp metering, and bus bypass lanes on all appropriate freeways; modest impacts | -0.25 | -0.8 | -0.1 | +0.1 | +5.7 | 14 586-19 446 | 5253 |
| 14. Reserved bus or pool lanes, ramp metering, and bus bypass lanes on all appropriate freeways; favorable impacts | -0.44 | -1.5 | -0.4 | -0.4 | -10.2 | 18 744-23 604 | 6798 |
| 15. Reserved median lane for express buses on appropriate radial arterials; modest impacts | -0.23 | -0.8 | +0.4 | +0.8 | -6.1 | 18 868-21 704 | 5984 |
| 16. Reserved median lane for express buses on appropriate radial arterials; favorable impacts | -0.38 | -1.3 | -0.1 | +0.2 | -11.0 | 18 868-21 704 | 5984 |
| 17. Carpool or vanpool program and freeway reserved lanes; modest impacts | -1.0 | -3.3 | -0.4 | -0.6 | -27.3 | 9 804-14 664 | 5408 |
| 18. Carpool or vanpool program and freeway reserved lanes; favorable impacts | -1.9 | -6.3 | -1.8 | -1.7 | -53.4 | 11 190-16 050 | 5921 |
| 19. Carpool or vanpool program, reserved lanes, ramp metering, and bus bypass lanes; modest impacts | -1.0 | -3.3 | -0.8 | -0.6 | -27.6 | 14 586-19 446 | 5957 |
| 20. Carpool or vanpool program, reserved lanes, ramp metering, and bus bypass lanes; favorable impacts | -1.9 | -6.5 | -0.8 | -1.8 | -53.8 | 18 744-23 604 | 7202 |

Note: 1 L = 0.26 gal.

[a] All scenarios except 11 are for a large-sized city 1 000 000 + standard metropolitan statistical area (SMSA) population. Scenario 11 is set in a medium-sized city (500 000-1 000 000 SMSA population).
[b] Costs are in 1976 dollars.

## APPENDIX G

## PAST EXPERIENCE AND POTENTIAL RULES OF THUMB ASSOCIATION WITH TCM EFFECTIVENESS

Source: *Transportation Control Measures: State Implementation Plan Guidance.* Prepared for the U.S. Environmental Protection Agency and Pacific Environmental Services, Inc., by Systems Applications, Inc., and Institute of Transportation Studies, September 1990.

# PAST EXPERIENCE AND POTENTIAL RULES OF THUMB ASSOCIATED WITH TCM EFFECTIVENESS

## Overview

One of the principal points this guidance attempts to convey is: TCM effectiveness varies substantially from region to region depending upon a wide range of factors (e.g., extent of prior transportation controls implemented, nature of traffic congestion and network configuration, availability of transit services, trends in business and population growth). For approximately a dozen TCMs, the guidance identifies the factors that contribute to the successful implementation of a particular measure; information sources are referenced so analysts can research additional measures and the factors contributing to their success. This information is provided to assist the guidance user in evaluating how applicable a measure is to his or her own urban area, and then to allow analysts to judge for themselves, based on these factors, how effective a measure might be.

Although independent analysis of the potential effectiveness of individual measures is recommended, insights can and should be drawn from TCM implementation experiences to-date. This appendix summarizes broad observations on the reported effectiveness of TCMs. To gain a complete understanding of the information provided, users should refer to the original documentation for a more complete description of the basis for these observations (references cited are mostly from those listed in Table 3-4--recommended information sources mentioned in the TCM descriptions section of this guidance). For example, data on the effectiveness of park and ride lots also reflect synergistic effects of rideshare promotion activities--synergistic effects such as these are not detailed in the guidance's descriptive information section. The observations in this appendix are provided as a "common sense" check--if your analyses do not seem to agree with the results profiled below, your assumptions and analytical methodologies may need a second review. These observations should not be an analytical starting point; a review of these findings should be part of your overall approach.

The findings cover nine broad TCM categories:

Pooling and bus service priority facilities
Vanpools and buspools

Employer-sponsored rideshare programs
Pool/transit fringe parking
Variable work hours
Transit improvements
Traffic flow improvements
Parking management
Pricing strategies

## Findings

1. Pooling and Bus Service Priority Facilities

(from Pratt and Copple, 1981)

a. Various priority programs mean an average of a doubling in bus on-time performance.

b. Mode shifts attributable to priority systems are often small, but transit market share increases of up to 50 percent can occur over an entire metropolitan corridor (even with substantial prior transit service).

c. Facilities offering moderate time advantages often realize increases of 100 to 300 pooling vehicles per hour in the peak period.

d. Bypass lanes on metered freeway ramps have increased HOVs an average 25 percent.

e. Highway person-volume increases of 8 to 15 percent have been typical with freeway and medium distance arterial HOV facilities; vehicle volumes have increased 5 percent or less, or decreased.

f. Person-volumes declined with "take a lane" strategies that were later discontinued.

g. 40 to 60 percent of bus and carpool passengers on newly opened freeway and medium distance arterial facilities formerly drove alone.

h. 35 to 45 percent of the gross VMT reductions achieved through HOV use will be counterbalanced by "new" VMT from other activities.

(from CSI, 1986)

i. Area-wide ridesharing programs resulted in annual work trip VMT reductions of from 0.03 to 3.6 percent, 0.3 percent on average (1.2 percent on average for programs with "before and after" evaluations).

j. Average daily VMT reduction per carpooler was 10.8 percent (44 percent of the roundtrip length).

k. Area-wide rideshare programs account for between 2 and 5 percent of total carpoolers in five urban areas.

l. Vehicle volume per person reductions achieved with HOV lanes averaged 6 percent during peak-period commutes (data through 1985); highest reductions achieved were 18 percent in the morning peak period and 33 percent in the afternoon peak period.

m. HOV lanes physically separated from other lanes have the potential to reduce peak period corridor vehicle trips and VMT by 10 percent; maximum reductions appear to be 5 percent on HOV lanes not physically separated from routine traffic.

(from Levinson et al., 1987)

n. HOV ramp bypasses provide travel-time savings of from 1-3 minutes per vehicle.

2. Vanpools and Buspools

(from Pratt and Copple, 1981)

a. Majority of employer-sponsored vanpool programs serve less than 5 percent of the employees (typically 1 to 2 percent); over 20 percent of programs, however, serve 10 to 58 percent.

b. Programs are most successful where one-way trip length exceeds 15 miles, where work schedules are fixed or regular, where employer size allows for matching of 10 to 12 people from the same residential area, and where congestion is a problem and transit options are inadequate.

c. About half (45 to 65 percent) of new vanpool/buspool riders formerly drove to work (except in some CBD programs); 50 to 100 percent of these former drivers drove alone; most programs do not divert transit users to pooling.

d. Rule of thumb: programs will be successful if the time spent picking up and dropping off passengers does not exceed the travel time.

e. Attendance is usually 80 to 90 percent of total participants (due to vacation, illness, need to work overtime, etc.).

(from Levinson et al., 1987)

f. An effective ridesharing program would reduce VMT an estimated 0.2 percent in suburban areas and 0.1 percent in larger cities (e.g., New York or Chicago).

3. Employer-Sponsored Rideshare Programs

(from CSI, 1986)

a. Programs with subsidized carpool parking and mandatory return of rideshare application forms achieve a switch to ridesharing in 12 to 15 percent of drive-alone employees (this translates into VMT reductions of 7 to 9 percent).

b. Programs at multi-employer sites are less successful than programs serving a single, large employer; typically, multi-employer sites achieve a decrease of 3 to 4 percent in drive-alone employees.

4. Pool/Transit Fringe Parking

(from Pratt and Copple, 1981)

a. Typical park and ride lots served by rail/rapid transit offer 400 parking spaces; all are full if the lot is free; three-quarters are full if a fee is charged.

b. Typical commuter and light rail lots are smaller; utilization varies, but tends to be high; park and carpool lots typically serve fewer than 60 vehicles (average of 20 to 30).

c. Approximately 80 to 90 percent of fringe lot users travel less than 5 miles to the park and ride service.

d. 40 to 60 percent of park and ride transit lot users previously commuted as auto drivers.

e. 60 percent of carpoolers at fringe lots drove alone prior to the parking lot's availability.

f. Peripheral lots (on the outskirts of the CBD) work only if their charges are significantly lower than downtown parking rates (cost savings of at least $0.75 per day (in 1981 dollars) appear to be necessary.

g. Park and ride/transit travel times must be no more than 10 minutes longer than drive-alone times or use will decline (total time increases over 25 minutes translate to minimal use).

(from CSI, 1986)

h. Data from several urban areas show that on average, about half of all park and ride lot users drove alone before using a park and ride lot.

5. Variable Work Hours

(from Pratt and Copple, 1981)

a. A quarter to a half of all employees in a localized area will take part in a variable-work-hours program if a major employer aggressively implements the program.

b. A large-scale program can reduce maximum 15-minute passenger and vehicle loads by 15 to 35 percent at terminal facilities (rapid transit, major parking lots); a 1 percent peak-hour volume reduction has been reported to save 0.6 to 1.2 percent in travel times.

c. The farther (geographically) the driver is from the employment source, the less is the impact/reduction in peaking volumes (program effects diminish by half on radial facilities serving an employment core).

d. In one example, a variable work hour program combined with corresponding carpooling improvements reduced VMT 14 percent (among participating employees).

e. Programs do not appear to affect overall mode choice decisions.

(from Batchelder et al., 1983)

f. Staggered work hours and flex time can yield 5 to 15 percent volume reductions during peak intervals in a major activity center with several employers; higher reductions are possible with larger, single employment centers.

6. Transit Scheduling and Frequency; Bus Routing and Coverage; Express Transit; Transit Fare Changes

(from Pratt and Copple, 1981)

a. Average response to transit improvements is a 0.5 percent gain in ridership for every 1 percent increase in service; express bus service is an exception: a 1 percent increase in express bus service to the CBD yields a 0.9 percent increase in ridership.

b. One out of every two or three new transit riders is a former auto driver.

c. New bus routes take 1 to 3 years to develop their full ridership (whole new transit systems take even longer).

d. Express buses using separate roadways (e.g., Shirley Highway in Washington, D.C.) produce travel-time savings of 10 to 30 minutes (in congested corridors).

e. Express buses using HOV freeway lanes save up to 5 minutes in travel time; large-scale programs carry from 1,000 to 11,000 passengers daily; smaller programs carry 200 to 600 morning peak-period travelers.

f. Express buses on surface street priority lanes carry 600 to 2,100 passengers daily, with some travel time savings over local bus service and auto travel.

g. Rule of thumb: ridership shrinks one-third as much in percentage terms as a fare increase (e.g., a 3 percent fare increase results in a 1 percent ridership loss); response rarely exceeds a 0.6 percent decrease in ridership per 1 percent increase in fares.

h. The larger the city and the more extensive the transit service is, the less responsive ridership is to fare increases.

i. One out of every two to three new transit riders attracted by a fare reduction is a former auto driver.

(from CSI, 1986)

j. Since transit typically accounts for a small (less than 10 percent) share of total regional trips, emissions reductions from short-range transit improvements are limited--major increases in transit ridership result in only small region-wide VMT reductions.

k. Greatest VMT reductions are associated with transit service expansions.

(from Levinson et al., 1987)

l. For transit fare or service changes (or changes in parking costs), general elasticity factors can help assess the impacts; a 100 percent increase in fares, headways, population coverage, or bus miles may result in transit ridership changes of the following (approximate) orders:

(1) 100% fare increase: 40% ridership decrease
(2) 100% headway increase: 40-60% ridership decrease
(3) 100% coverage increase: 60-90% ridership increase
(4) 100% bus miles increase: 70-100% ridership increase

Note that these estimates are highly dependent upon initial operating conditions, fares, the degree to which transit improvements carefully match potential markets, and service coverage (geographic) and frequency.

m. This reference includes a "look up" table to estimate the effects of reduced traffic congestion or frequency of stops on bus travel times and speeds.

n. Bus malls provide travel-time savings of from 2-5 minutes per mile.

o. Bus lanes on city streets provide travel-time savings of from 1-5 minutes per mile.

p. Bus lanes on freeways provide travel-time savings of from 0 to 1.2 minutes per mile.

q. Bus lanes around major queues provide travel-time savings of from 3-5 minutes per mile.

7. Traffic Flow Improvements

(from CSI, 1986)

a. Signal timing projects in 11 cities yielded estimated average annual impacts, on a per-intersection basis, of (1) a decrease of 15,470 vehicle hours of delay, (2) 455,921 fewer stops, (3) a savings of 10,524 gallons of fuel (results were computed by TRANSYT-7F).

b. Field surveys show signal timing projects reduce delay time 10 percent in p.m. and noon peak-periods, 26 percent during the a.m. peak period, and 34 percent during the off-peak period (fuel consumption reductions ranged from 4 to 13 percent).

c. A California signal timing program (also in 11 cities) yielded travel time reductions (over the whole system) of 6.5 percent; stops and delays were reduced more than 14 percent, and fuel consumption dropped 6 percent.

d. In six cities implementing freeway ramp metering, average traffic speeds increased nearly 30 percent--from 30 to 38.9 mph (taking delays at the ramp meters into account, average speed increases were about 22 percent, to 36.5 mph).

(from Levinson et al., 1987)

e. General traffic improvements result in person and vehicle roadway capacity gains of between 10-20 percent.

f. Traffic signal improvements provide travel-time savings of from 0.4 to 1.6 minutes per mile.

g. Auto restricted zones result in up to a 20 percent reduction in VMT across the screenline.

8. Parking Management

(from Levinson et al., 1987)

a. On street parking controls result in person and vehicle roadway capacity gains of between 50-100 percent.

b. On-street parking controls provide travel-time savings of from 0.2 to 2.4 minutes per mile.

9. Pricing Strategies

(from Levinson et al., 1987)

a. Bridge and tunnel tolls result in a 2 to 5 percent reduction in VMT per affected crossing.

b. Gas tax increase of $0.10 per gallon results in a 2 percent area-wide reduction in VMT.

## APPENDIX H

## EFFECTIVENESS OF TCMs: LITERATURE REVIEW

Source: *Methodologies for Quantifying the Emission Reductions of Transportation Control Measures.* Report No. SR91-10-03. Prepared for the San Diego Association of Governments by Sierra Research, Inc., with support from JHK & Associates, October 1991.

TCM #1 - JOBS/HOUSING BALANCE

Although it is extremely difficult to separate out effects of this TCM from other factors such as roadway improvements or larger economic trends, trip length reductions of two to six percent have been reported where increases in local hiring have been achieved. (Sierra Research, 1990)

TCM #2 - DENSIFICATION

Although some studies report that the potential emission reduction as a result of densification is small, other studies have shown that increased residential density accounts for the greatest increase in transit use in comparisons of transit use among various cities or urban sub-areas.

TCM #3 - MIXED USE

Decreases in average trip lengths of ten percent can be obtained regionally with a mixed use strategy. This would result in a corresponding ten percent reduction in the region's VMT. The studies reviewed did not explicitly note changes in mode of travel or number of trips.

TCM #4 - GROWTH CONTROLS

Although implemented in a variety of cities, assessments of the effectiveness of growth controls as a TCM have not been performed in detail.

TCM #5 - PEDESTRIAN IMPROVEMENTS

Some cities grade-separate sidewalks and roads (using either tunnels or bridges) to provide safer walking and fewer delays to vehicular traffic. The City of San Jose is undertaking a program of shoulder widening and curb cuts to upgrade many of its thoroughfares for pedestrians and cyclists. (MTC, 1984)

TCM #6 - TRAFFIC SIGNAL IMPROVEMENTS

According to Wagner (1980), adding timing plan improvements, interconnected signals, and a computerized signal system to a basic situation (pretimed signals with minimal or no interconnection and old timing plans) resulted in an average improvement of twenty-five percent in speed or travel time (range of seven to thirty percent). Timing plan improvements to interconnected signals yielded average improvements of between twelve and sixteen percent in speed or travel time, Wagner reported. Adding left turn signals has resulted in up to thirty percent reduction in intersection accident frequency. Studies of effects on intersections in many United States cities have been performed, including Los Angeles, Macon (GA), Washington (D.C.), Columbus (OH), Minneapolis (MN), and Toronto.

## TCM #7 - CAPACITY INCREASES

Impacts in a number of United States cities have been documented. For arterial improvements, an increase in hourly capacity of five to fifty percent can lead to an increase in speed of five to twenty percent (three to ten mph), a decrease of twenty to sixty percent in accidents related to turning movements, a reduction of up to thirty percent in delay, and up to a thirty-five percent reduction in peak period vehicle emissions. For freeways, significant increases in capacity of up to thirty percent can lead to increases in peak period hourly volumes for some segments of ten to twenty-five percent and a reduction of up to thirty-five percent in peak period vehicle emissions.

## TCM #8 - TRANSIT SERVICE INCREASES

A study by the U.S. Environmental Protection Agency found that the ability of transit service improvements to attract motorists to transit is limited, but can be enhanced where high levels of transit service are used in conjunction with automobile disincentive measures. (EPA, 1978)

Transit service improvements alone were found to have a limited ability to reduce regional VMT in the Denver CBD. However, operational improvements have been found to be more effective than fare reductions. Non-work or off-peak trips have been found to be more sensitive to transit service improvements than work or peak period trips. (DRCG, 1979)

Findings from a number of studies include:

- Off-peak free fare was estimated to reduce total areawide VMT by two percent in a Denver urban area. (DRCG, 1979)

- A study of free transit service has estimated that eliminating fares in the Boston area would increase ridership by about twenty-eight percent. (Charles River Associates, Inc., 1968)

- Roughly seven to eight percent of the population in Commerce, California, uses that city's small free transit service daily compared to a national average of four percent for towns for comparable size. (Kemp, 1975)

## TCM #9 - EMPLOYEE TRANSIT PASS SUBSIDY

Several schools and businesses in the Bay Area sell BART passes, either with no subsidy or with a subsidy. The city of San Francisco requires on-site transit pass sales at most major developments built in the last five years. In Berkeley, the city's commute alternatives program sells transit tickets and passes at its downtown Transportation Store, and encourages employers to subsidize transit users. (Eisinger, et.al., 1989)

Varian in Palo Alto sells tickets at a subsidized price (twenty-five percent subsidy for all tickets, for a total annual cost of $34,000). As a result of this program, the number of employees that use public transit increased by nine percent. Bank of America-Concord and First Interstate-Fremont also have fare-subsidy programs for their employees. Clorox, with a work force of 800 employees in downtown Oakland, sells over 300 BART tickets monthly. (Bourgart, 1986)

In New York City, an organization called Transit Center prepares transit vouchers (called Transit Checks) that business offices can distribute to their employees. The Transit Checks are worth up to $15 towards a monthly transit pass, and allows the employees to take advantage of the federal government's $15 per month tax-free transit fringe benefit program. (Soffian, et.al., 1988)

The Massachusetts Bay Transportation Authority instituted one of the earliest employer-based pass programs by offering passes through a payroll deduction. Payroll deductions make it easier to subsidize the cost of a pass and take advantage of the $15 per month tax benefit. (CSI, 1989)

TCM #10 - PARK-AND-RIDE LOTS

A study by the U.S. Department of Transportation on park-and-ride lots found that:

- The commuters use park-and-ride facility for more than four-round trips per week.
- A significant percentage (sixty to ninety percent) of park-and-ride lot users live within six miles of the mode change facility.
- The typical user travels three to four miles to reach the park-and-ride facility and shares a ride for an additional ten to twenty miles.
- The median one-way travel times for U.S. workers in large metropolitan areas are 19.6 minutes for drivers, 22.7 minutes for auto passengers, and 39.5 minutes for transit riders. Park-and-ride lot users spend an average of thirty-five minutes commuting from home to final destination.

A park-and-ride lot's service area can be defined as the area surrounding the park-and-ride site within which residents would be willing to travel out of their way to the lot. In Georgia, the service area was felt to extend no more than ten to fifteen minutes from the lot, because commuters were reluctant to go more than three or four minutes out of their way to get to the lot. (Tanner, et.al., 1973)

TCM #11 - HIGH OCCUPANCY VEHICLE LANES

In general, public reaction has been found to be favorable to the exclusive lane concept only when the project adds a new clearly-defined separate lane for HOVs and does not take a lane away from general traffic. Taking a mixed-flow lane results in an increase in congestion and vehicular emissions in the remaining lanes. (CSI, 1986) A study in Denver found that the construction of a new HOV lane on a freeway was estimated to reduce total areawide VMT by 0.2

percent and resulted in a decrease of work trip emissions of 0.9 percent of HC, 0.9 percent of CO, and 0.3 percent of $NO_x$. (DRCG, 1979)

A study on HOV-exclusive facilities in Pittsburgh, Houston, Los Angeles, Washington, D.C., and Ottawa-Canada, by the Institute for Transportation Engineers found that the HOV lanes have been credited with moving one-third or more of all peak hour freeway travelers. It was also estimated that HOV facilities were carrying at least fifty percent more peak-hour person trips than those of freeway lanes. (Eisinger, et.al., 1989)

## TCM #12 - BICYCLE IMPROVEMENTS

A study performed for the Detroit area found that one percent of all the auto trips not exceeding six miles, potentially could be replaced by bicycle trips. Assuming that the average auto occupancy is 1.5, this will result in 200,000 bikes replacing 130,000 vehicles. If the average trip length is three miles, the replacement of vehicles by bikes will lead to a reduction of 390,000 vehicle-miles. (CSI, 1980)

On the basis of the experience in Detroit, Phoenix planners projected one percent of all trips less than six miles as being replaced by bicyclists; the same study also noted that Los Angeles planners project one percent of all trips less than three miles being replaced by bicyclists. (MAG, 1987)

In Santa Clara County, California, several companies provide bicycle facilities resulting in seven percent to twenty percent of employees bicycling to work. The highest bicycle use is at Xerox Research Center in Palo Alto, where twenty percent of their employees bicycle to work. (MTC, 1984) In a separate study, it was estimated that aggressive bicycle programs in Santa Clara County, and in the cities of San Jose and Palo Alto, have resulted in 13,000 commuters using bicycles in the county. (CSI, 1986)

## TCM #13 - TRIP REDUCTION ORDINANCES

TROs are applied in a variety of ways, depending upon the needs of a particular locality. The emphasis of these ordinances have been on encouraging socially beneficial travel choices rather than controlling traveler behavior. Most TROs, therefore, offer a range of travel options, but the individual traveler's choice is voluntary. The measure of effectiveness used in individual TROs varies between localities, depending upon the needs of the area.

In Pleasanton, California, a performance standard has been set that limits peak-hour drive alone trips to fifty-five percent of the daytime workforce. This program has been successful in attaining its goal. The measure most often used by the employers is staggered work hours, while carpooling and vanpooling have been only moderately successful. Because there is not a significant reduction of VMT, rather there is a shift from the peak to the off-peak, there is probably not a significant emissions reduction. (CSI, 1989)

Regulation XV was implemented in the Los Angeles area to reduce the impact of congestion on air quality. The regulation applies to all employers with 100 or more employees and sets a goal of increasing AVR to between 1.3 and 1.75, depending upon the specific location. A preliminary analysis by the South Coast Air Quality Management District of seventy-four employers has been performed after one year of program implementation. It was found that these employers had achieved an AVR twenty-three percent closer to their target. A further study of seventy-one of these employers found an average shift in AVR of 1.22 to 1.30, which equates to an annual decrease of 81,224 two-way commute trips. This results in an increase in CO emissions of 29.3 per year and of $NO_x$ emissions of 3.1 tons per year. (SCAQMD, 1991)

## TCM #14 - RIDESHARING

Employer-based vanpooling programs have been successfully implemented at a number of large firms. The best documented program is at the 3M Company in St. Paul. Eleven percent of the employees commute by van, and the resulting reduction in daily VMT has been estimated at 5,500. (EPA, 1972)

Special parking spaces for vanpools are provided by Caltrans in San Francisco. 480 spaces are reserved for vanpools near the fringe of the San Francisco business district, and approximately sixty-five percent are utilized. (DOT, 1981)

Reduction in annual work VMT is in the 0.3% to 3.6% range in thirty-eight areas reported by U.S. Department of Transportation (Wagner, 1978). A separate study of VMT and emissions impacts was performed for twenty-one cities and thirty-two counties in 1984. Ridesharing resulted in an annual reduction of over 6.5 million total VMT, 15.7 tons HC, 149 tons CO, and 20.8 tons $NO_x$. (CSI, 1986)

TCM #15 - PARKING MANAGEMENT

Since 1971, Boston has instituted a number of parking management measures, including a downtown parking freeze, residential permit parking programs, and reductions in downtown on-street parking supply. In 1980, a study found that the impacts were 7,000 fewer parking spaces, a decrease of 131,250 VMT (equals an annual savings of 160 tons of HC and 1652 tons of CO emissions), and an annual savings of 2.2 million gallons of gasoline. (CSI, 1981)

The Portland Planning Bureau conducted a study of Downtown Parking and Circulation in 1980. Annual areawide emissions reductions attributable to parking management were 132 tons of HC and 1809 tons of CO. (Portland Planning Bureau, 1980)

Washington, D.C., implemented an aggressive parking management program. Between 1977 and 1980 the VMT decreased about two percent, average auto occupancy from 1.44 to 1.49, and the transit trips increased from twenty-seven percent to thirty-four percent. (Peat, Marwick, Mitchell & Co., 1981)

San Francisco implemented a parking policy such that the number of parking spaces in 1984 is limited to the number existing. The number of parking spaces only increased by approximately 1200 spaces between 1977 and 1985 and the traffic volume on the major corridors has not increased by a great deal. The transit system was able to handle a significant increase in number of trips due to the completion of the regional rail system, BART. (Dagang, 1990)

TCM #16 - TELECOMMUTING

A. U.C. Davis study of a pilot telecommuting program implemented by the State of California provides the following findings:

- Telecommuting reduces peak-period trips by more than seventy-five percent in the morning peak an by more than sixty percent in the afternoon peak.

- An estimated total of four trips can be reduced in a five-day work week if a worker telecommutes twice per week.
- Total travel distance can be reduced by an average of forty miles every telecommuting day.
- Telecommuters generated an average of 1.17 non-work trips on telecommuting days, and 1.71 non-work trips on commuting days. (Kitamura, et.al., 1990)

A study conducted by the Southern California Association of Governments projected transportation, energy, and air quality impacts on work-related travel for the year 2000 in the Los Angeles urbanized area. This study estimated an areawide 3.4 percent reduction of VMT. CO emissions were forecast to decrease by 4.3 percent. (SCAG, 1985)

## TCM #17 - FLEXIBLE WORK HOURS

A study by Cambridge Systematics, Inc., found that a ten to fifty percent reduction in peak-period (i.e., fifteen-minute to one-hour peak period) employee arrivals occurred with flextime. In the City of Berkeley, flextime reportedly reduced overtime costs by $18,000 and reduced sick leave by $26,000 annually. (Brittle, et.al., 1984)

## TCM #18 - STAGGERED WORK HOURS

There was an improvement over a two year period in the transit system operated by the Golden Gate Transit due to a staggered work hour program, with an eleven percent reduction in peak hour bus operation while total bus patronage increased by 4.7 percent. (Dagang, 1990)

A study in Toronto found that thirty-one percent of employees participating in a staggered work hours program benefit from an average travel time savings of eleven minutes. (CSI, 1986)

TCM #19 - COMPRESSED WORK WEEK

Lockheed in Sunnyvale implemented an aggressive "find-a-rideshare-replacement program" along with its staggered work hours plan; since work schedule changes can disrupt ridesharing arrangements, the replacement program helped to maintain rideshare level as work hour changes occurred. (MTC, 1985)

A study in the late 1970s indicated over twelve percent of the U.S. private sector businesses with fifty or more employees had alternative work schedule options, with approximately six percent of all employees adopting alternative hours. (Nollen, 1978)

Denver participated in a federal employee compressed work week experiment in 1978. The findings from this experiment in terms of travel-related impacts included a fifteen percent reduction in the total weekly work trip VMT and a fourteen percent decrease in the total travel times among participating employees. It was estimated that the average CO and HC emissions for employees were reduced by 16.4 percent. (CSI, 1980)

TCM #20 - GAS TAX/COST INCREASE

For a study in San Diego County, a decrease in VMT of between four and five percent resulted when an eighty-eight percent increase in gasoline price from $1.13 per gallon to $2.13 per gallon was modeled (Sierra Research, Inc., 1990). The same study noted that this benefit was more probable for the short and medium term, because actions by consumers to offset the price increase, such as purchasing more fuel efficient vehicles, would be likely over the long term.

TCM #21 - VMT TAX

In the late 1970s, potential federal demonstration projects in Berkeley (CA), Madison (WI), and Honolulu (HI) were blocked by public opposition and lack of political support (Institute of Transportation Engineers Technical Committee 6A-26, 1985). A congestion pricing scheme succeeded in reducing congestion in Singapore using the type of monitoring that would be used for VMT taxing. The Singapore project was suspended due to drivers' privacy concerns. Up to 1991, no location in the United States had implemented a VMT tax.

TCM #22 - MOTORIST INFORMATION

In combination with accident and incident detection systems, motorist information systems resulted in a reduction of five percent in non-recurrent freeway delay due to accidents and incidents. Non-recurrent freeway delay accounts for fifty percent of all freeway delay. (CSI, 1988)

TCM #23 - INCIDENT MANAGEMENT AND RESPONSE

Where incident management and response systems have been implemented on freeway segments, sixty percent of segments showed a ten to forty-five percent decrease in travel time and operating speed increases of ten to twenty miles per hour to free flow status. This type of TCM would be applicable to about thirty percent of major urban freeway miles. (Institute of Transportation Engineers, 1989)

Incident management and response, in connection with motorist information systems, resulted in a reduction of five percent in non-recurrent freeway delay. Non-recurrent freeway delay accounts for fifty percent of all freeway delay. (CSI, 1988)

TCM #24 - DELIVERY TIMING

In a study for Caltrans, it was estimated that thirty percent of large companies could shift shipping and receiving activities to night hours (Cambridge Systematics, 1988). During the Olympic Games in Los Angeles, an average reduction of five percent in truck traffic on freeways during peak hours, in combination with a reduction of other traffic, resulted in a forty-two percent decrease in truck-related freeway incidents and accidents. Because as much as fifty percent of all non-recurring freeway congestion in urban areas has been estimated as being due to truck-related incidents and accidents, this could mean a decrease of approximately twenty percent in non-recurring freeway congestion during peak hours with a six percent reduction in truck presence during peak hours. (Institute of Transportation Engineers, 1989)

TCM #25 - LOADING FACILITY IMPROVEMENTS

Providing improved loading facilities that would reduce lane blockages due to parking maneuvers or double-parking by trucks can be expected to decrease surface street congestion significantly. An effective ban on curb parking by trucks during peak hours can increase roadway capacity by twenty to sixty percent. For example, a twelve-minute lane blockage such as would be caused by one double-parked delivery truck along a six-hundred-foot block with three lanes moving in each direction was found to cause between 380 and more than 1000 minutes of incremental delay to traffic. (FHWA, 1979)

## APPENDIX I

## CHARACTERISTICS OF EMPLOYER TDM PROGRAMS

Source: Richard Kuzmyak and Michael D. Meyer. *Implementing Transportation Demand Management Programs.* An ITE Educational Foundation Seminar, February 26, 1993.

# FIGURE 1--CHARACTERISTICS OF EMPLOYER TDM PROGRAMS

| Program | Vehicle Trip Reduction | Travel Base | Type Area[1] | Preferential Reserved Parking | Restricted Parking | Parking Charges | Employer Support Level: Transit | Employer Support Level: Carpool | Employer Support Level: Vanpool | Legal Requirement | Employee Modal Split[2]: SOV | Employee Modal Split[2]: Transit | Employee Modal Split[2]: Carpool | Employee Modal Split[2]: Vanpool |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Travelers | 47.9% | 10,000 | CBD | Yes | Yes | Yes | High | High | High | No | 33% | 36% | 19% | 8% |
| US West | 47.1 | 1,150 | SBD | Yes | Yes | Yes | Low | High | None | Yes | 26 | 13 | 60 | -- |
| NRC | 41.6 | 1,400 | ISI | Yes | Yes | Yes | Medium | Medium | None | Yes | 42 | 28 | 27 | -- |
| GEICO | 38.6 | 2,500 | SBD | Yes | Yes | Yes | High | High | High | Yes | 40 | 31 | 20 | 8 |
| $CH_2M$ Hill | 31.2 | 400 | SBD | No | Yes | Yes | High | High | None | Yes | 64 | 17 | 12 | -- |
| State Farm | 30.4 | 980 | SBP | No | No | No | None | High | Medium | Yes | 66 | -- | 31 | 2 |
| Pacific Bell | 27.8 | 6,900 | SBP | Yes | Yes | No | High | High | Medium | Yes | 63 | 2 | 22 | 11 |
| Hartford Steam Boiler | 26.5 | 1,100 | CBD | No | Yes | Yes | High | High | High | No | 40 | 38 | 21 | 1 |
| Swedish Hospital | 26.1 | 2,500 | ISI | No | Yes | Yes | High | Medium | Medium | Yes | 33 | 44 | 23 | -- |
| Bellevue City Hall | 25.8 | 900 | ISI | Yes | Yes | Yes | Medium | High | Medium | No | 52 | 7 | 29 | 4 |
| San Diego Trust & Savings | 22.7 | 500 | CBD | No | Yes | Yes | High | Medium | None | Yes | 44 | 37 | 14 | -- |
| Pasadena City Hall | 21.0 | 350 | SBD | No | Yes | Yes | High | High | High | Yes | 58 | 7 | 27 | 2 |
| TransAmerica | 20.0 | 2,700 | CBD | Yes | Yes | Yes | Medium | Medium | High | Yes | 45 | 14 | 21 | 10 |
| ARCO | 19.1 | 2,000 | CBD | No | Yes | Yes | Medium | High | High | Yes | 46 | 20 | 20 | 14 |
| Varian | 17.7 | 3,200 | SBP | No | Yes | No | Medium | Low | Low | Yes | 62 | 8 | 21 | 3 |
| AT&T | 13.4 | 3,890 | SBP | Yes | Yes | No | Low | Medium | Medium | Yes | 71 | 2 | 22 | 3 |
| Ventura County | 13.0 | 1,950 | OSI | No | No | No | Medium | Medium | None | Yes | 69 | 2 | 23 | -- |
| COMSIS | 10.5 | 250 | SBD | No | Yes | Yes | Medium | Medium | None | Yes | 54 | 18 | 28 | -- |
| 3M | 9.7 | 12,700 | OSI | No | No | No | Low | Low | High | No | 83 | 2 | 14 | 0 |
| Allergan | 7.0 | 1,250 | SBP | Yes | No | No | Medium | Medium | High | Yes | 78 | 1 | 14 | 7 |
| UCLA | 6.5 | 18,000 | ISI | No | Yes | Yes | High | Low | High | Yes | 74 | 8 | 10 | 5 |
| Chevron | 3.7 | 2,300 | SBP | Yes | No | No | High | Medium | High | Yes | 82 | 1 | 11 | 5 |

[1] Key: CBD = Central Business District; OSI = Outer Suburb, Isolated; SBD = Suburban Business District; SBP = Suburban Business Park; ISI = Inner Suburb, Isolated

[2] May not sum to 100% because of walk, bike, other.

## Table 3.2-3
## Characteristics of Employer TDM Programs

| Program | Vehicle Trip Reduction | Travel Base | Type Area[1] | Employer Support Level | | | Employee Modal Split[2] | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | *Transit* | *Carpool* | *Vanpool* | *SOV* | *Transit* | *Carpool* | *Vanpool* |
| Travelers | 47.9% | 10,000 | CBD | High | High | High | 33% | 36% | 19% | 8% |
| US West | 47.1 | 1,150 | SBD | Low | High | None | 26 | 13 | 60 | -- |
| NRC | 41.6 | 1,400 | ISI | Medium | Medium | None | 42 | 28 | 27 | -- |
| GEICO | 38.6 | 2,500 | SBD | High | High | High | 40 | 31 | 20 | 8 |
| $CH_2M$ Hill | 31.2 | 400 | SBD | High | High | None | 54 | 17 | 12 | -- |
| State Farm | 30.4 | 980 | SBP | None | High | Medium | 66 | -- | 31 | 2 |
| Pacific Bell | 27.8 | 6,900 | SBP | High | High | Medium | 63 | 2 | 22 | 11 |
| Hartford Steam Boiler | 26.5 | 1,100 | CBD | High | High | High | 40 | 36 | 21 | 1 |
| Swedish Hospital | 26.1 | 2,500 | ISI | High | Medium | Medium | 33 | 44 | 23 | -- |
| Bellevue City Hall | 25.8 | 600 | ISI | Medium | High | Medium | 52 | 7 | 29 | 4 |
| San Diego Trust & Savings | 22.7 | 500 | CBD | High | Medium | None | 44 | 37 | 14 | -- |
| Pasadena City Hall | 21.0 | 350 | SBD | High | High | High | 58 | 7 | 27 | 2 |
| TransAmerica | 20.0 | 2,700 | CBD | Medium | Medium | High | 45 | 14 | 21 | 19 |
| ARCO | 19.1 | 2,000 | CBD | Medium | High | High | 46 | 20 | 20 | 14 |
| Varian | 17.7 | 3,200 | SBP | Medium | Low | Low | 62 | 8 | 21 | 3 |
| AT&T | 13.4 | 3,890 | SBP | Low | Medium | Medium | 71 | 2 | 22 | 3 |
| Ventura County | 13.0 | 1,850 | OSI | Medium | Medium | None | 69 | 2 | 23 | -- |
| COMSIS | 10.5 | 250 | SBD | Medium | Medium | None | 54 | 18 | 25 | -- |
| 3M | 9.7 | 12,700 | OSI | Low | Low | High | 83 | 2 | 14 | 8 |
| Allergan | 7.0 | 1,250 | SBP | Medium | Medium | High | 76 | 1 | 14 | 7 |
| UCLA | 5.5 | 18,000 | ISI | High | Low | High | 74 | 6 | 10 | 5 |
| Chevron | 3.7 | 2,300 | SBP | High | Medium | High | 82 | 1 | 11 | 5 |

[1] Key: CBD = Central Business District; SBD = Suburban Business District; ISI = Inner Suburb, Isolated; OSI = Outer Suburb, Isolated; SBP = Suburban Business Park

[2] May not sum to 100% because of walk, bike, other.

Table 3.2-3 (continued)
Characteristics of Employer TDM Programs

| Program | Vehicle Trip Reduction | Preferential Reserved Parking | Restricted Parking | Parking Charges | Subsidies | | | Legal Requirement |
|---|---|---|---|---|---|---|---|---|
| | | | | | *Transit* | *Carpool* | *Vanpool* | |
| Travelers | 47.9% | Yes | Yes | Yes | Yes | Yes | Yes | No |
| US West | 47.1 | Yes | Yes | Yes | No | Yes | Yes | Yes |
| NRC | 41.6 | Yes | Yes | Yes | Yes | No | No | Yes |
| GEICO | 38.6 | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| $CH_2M$ Hill | 31.2 | No | Yes | Yes | Yes | Yes | Yes | Yes |
| State Farm | 30.4 | No | No | No | No | Yes | Yes | Yes |
| Pacific Bell | 27.8 | Yes | Yes | No | No | No | No | Yes |
| Hartford Steam Boiler | 26.5 | No | Yes | Yes | Yes | Yes | Yes | No |
| Swedish Hospital | 26.1 | No | Yes | Yes | Yes | Yes | Yes | Yes |
| Bellevue City Hall | 25.8 | Yes | Yes | Yes | Yes | Yes | Yes | No |
| San Diego Trust & Savings | 22.7 | No | Yes | Yes | Yes | Yes | No | Yes |
| Pasadena City Hall | 21.0 | No | Yes | Yes | Yes | Yes | Yes | Yes |
| TransAmerica | 20.0 | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| ARCO | 19.1 | No | Yes | Yes | Yes | Yes | Yes | Yes |
| Varian | 17.7 | No | Yes | No | Yes | Yes | Yes | Yes |
| AT&T | 13.4 | Yes | Yes | No | No | No | No | Yes |
| Ventura County | 13.0 | No | No | No | Yes | Yes | Yes | Yes |
| COMSIS | 10.5 | No | Yes | Yes | Yes | Yes | No | Yes |
| 3M | 9.7 | No | No | No | No | No | Yes | No |
| Allergan | 7.0 | Yes | No | No | Yes | No | Yes | Yes |
| UCLA | 5.5 | No | Yes | Yes | No | No | No | Yes |
| Chevron | 3.7 | Yes | No | No | No | No | Yes | Yes |

[1] Key: CBD = Central Business District; SBD = Suburban Business District; ISI = Inner Suburb, Isolated; OSI = Outer Suburb, Isolated; SBP = Suburban Business Park

[2] May not sum to 100% because of walk, bike, other.

# APPENDIX J

## POTENTIAL IMPACTS OF CONGESTION MANAGEMENT MEASURES

Source: *Congestion Control and Demand Management.* A Report prepared by an Organization for Economic Cooperation and Development Scientific Expert Group, International Road Research Documentation, IRRD No. 865266, 1994.

Table II.3. **Potential impacts (objective) of demand-side congestion management measures**

| TYPES | STRATEGY CLASS | MEASURES | IMPACTS | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | REDUCE NEED TO MAKE TRIP | REDUCE LENGTH OF TRIP | PROMOTE NON-MOTORIZED TRANSPORT | PROMOTE PUBLIC TRANSPORT | PROMOTE CARPOOLING | SHIFT PEAK HOUR TRAVEL | SHIFT TRIPS AWAY FROM CONGESTED LOCATIONS | REDUCE TRAFFIC/ TRAVELLER DELAYS |
| DEMAND - SIDE | LAND USE & ZONING | Land Use & Zoning Policy | X | XX | XX | XX | X | X | X | X |
| | | Site Amenities & Design | XX | XX | XX | XX | XX | X | | X |
| | TELE-COMMUNICATIONS SUBSTITUTES | Telecommuting | XX | XX | X | X | | | X | X |
| | | Tele-Conferencing | XX | XX | | | | | | |
| | | Tele-Shopping | XX | X | | | | | | |
| | TRAVELLER INFO SERVICES | Pre-Trip Travel Information | X | X | X | XX | XX | XX | XX | X |
| | | Regional Rideshare Matching | XX | | | XX | XX | X | X | X |
| | ECONOMIC MEASURES | Congestion Pricing | X | X | X | XX | XX | XX | XX | XX |
| | | Parking Pricing | X | X | X | XX | XX | XX | XX | X |
| | | Transportation Allowances | | | X | XX | XX | X | | X |
| | | Transit & Rideshare Financial Incentives | | | | XX | XX | X | | X |
| | | Public Transport Pass Programme | | | | XX | | X | | X |
| | | Innovative Financing | | | | XX | XX | | | X |
| | ADMINISTRATIVE MEASURES | Transp. Partnerships | | | X | XX | XX | X | X | X |
| | | Trip Reduction Ordinances & Regulations | XX | | X | XX | XX | X | X | XX |
| | | Alternative Work Schedules | X | | | XX | XX | XX | | X |
| | | Auto Restricted Zone | XX | | XX | XX | | | XX | |
| | | Parking Management | X | | X | XX | XX | X | X | X |

**Note:** XX - Significant Impact, X - Some Impact, (Blank) - No Impact

| TYPES | STRATEGY CLASS | MEASURES | IMPACTS | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | REDUCE NEED TO MAKE TRIP | REDUCE LENGTH OF TRIPS | PROMOTE NON-MOTORIZED TRANSPORT | PROMOTE PUBLIC TRANSPORT | PROMOTE CARPOOLING | SHIFT PEAK HOUR TRAVEL | SHIFT TRIPS AWAY FROM CONGESTED LOCATIONS | REDUCE TRAFFIC/ TRAVELLER DELAYS |
| SUPPLY - SIDE | ROAD TRAFFIC OPERATIONS | Entrance Ramp Controls | | | | XX | XX | X | XX | XX |
| | | Traveller Information Systems | | X | | X | X | XX | XX | XX |
| | | Traffic Signalization Improvements | | | | X | | | X | XX |
| | | Motorway Traffic Management | | X | | X | X | X | X | XX |
| | | Incident Management | | | | | | | XX | XX |
| | | Traffic Control at Construction Sites | | | | X | X | X | XX | XX |
| | PREFERENTIAL TREATMENT | Bus Lanes | | | | XX | | X | X | X |
| | | Carpool Lanes | | | | X | XX | X | X | X |
| | | Bicycle & Pedestrian Facilities | | | XX | | | | | |
| | | Traffic Signal Pre-Emption | | | | XX | | | | X |
| | PUBLIC TRANSPORT OPERATIONS | Express Bus Services | | | | XX | | | | X |
| | | Park & Ride Facilities | | | | XX | XX | | X | X |
| | | Service Improvements | | | | XX | | | | X |
| | | Public Transport Image | | | | XX | | | | X |
| | | High Capacity Public Transport Vehicles | | | | XX | | | | X |
| | FREIGHT MOVEMENTS | Urban Goods Movement | | | | | | X | X | XX |
| | | Inter-city Goods Movement | X | | | | | X | X | XX |

**Note:** XX - Significant Impact, X - Some Impact, (Blank) - No Impact

## APPENDIX K

## COST-EFFECTIVENESS OF TDM MEASURES

Source: Deborah Dagang. *Transportation Demand Management Cost-Effectiveness Model for Suburban Employees.* Transportation Research Record 1404, 1993.

TABLE 2 Results of Cost-Effectiveness Analysis: Alternative 1A

| TDM Measure | Average Daily Cost per Daily Trip Reduced | Ranking | Average Daily Cost per Peak-Period Trip Reduced | Ranking |
|---|---|---|---|---|
| Commute Information Program | $0.42 | 7 | $0.53 | 7 |
| Ridematching Services In-House | -$0.23 | 4 | -$0.28 | 3 |
| Transit Pass Subsidies | $4.63 | 13 | $5.79 | 13 |
| Employee Transportation Coordinator | $5.15 | 14 | $6.44 | 14 |
| Home-Based Telecommuting | $100.87 | 15 | $126.09 | 15 |
| Compressed Work Hours | -$0.59 | 3 | -$0.01 | 5 |
| Reduction of Employer-Subsidized Parking | -$6.48 | 1 | -$8.10 | 1 |
| Preferential Parking | $0.15 | 6 | $0.18 | 6 |
| Bicycle Lockers and Showers | $4.40 | 12 | $5.50 | 12 |
| Guaranteed Ride Home | -$0.14 | 5 | -$0.18 | 4 |
| Shuttle to Transit Stations | $3.84 | 9 | $4.80 | 9 |
| Vanpool Program | $4.04 | 11 | $5.06 | 11 |
| Reduction of Parking Supply | -$0.87 | 2 | -$1.09 | 2 |
| Direct Monetary Incentives | $4.02 | 10 | $5.02 | 10 |
| Transportation Allowance | $1.01 | 8 | $1.26 | 8 |

*Note: Ranking among measures with a negative cost per trip reduced may be misleading and should all be considered highly cost-effective.*

## APPENDIX L

## COSTS AND EFFECTIVENESS OF TCMs

Source: *Costs and Effectiveness of Transportation Control Measures (TCMs).* Prepared by Apogee Research, Inc., for the National Association of Regional Councils, January 1994.

## TABLE 2.
## TRAVEL IMPACT ESTIMATES:
## RANGE OF DAILY REGIONAL REDUCTIONS (in percent)[a]
## (Based on literature review)[b]

| TCM[c] | VMT | Trips |
|---|---|---|
| Employer trip reduction | 0.2% - 3.3% | 0.1% - 4.1% |
| Area-wide ridesharing | 0.1 - 2.0 | 0.5 - 1.1 |
| Transit improvements | 0.0 - 2.6 | 0.6 - 2.5 |
| HOV lanes | 0.2 - 1.4 | 0.5 - 0.6 |
| Park-and-ride lots | 0.1 - 0.5 | 0.0 |
| Bicycle/pedestrian facilities | d | d |
| Parking pricing | | |
| work | 0.5 - 4.0 | 0.4 - 4.0 |
| non-work | 3.1 - 4.2 | 3.9 - 5.4 |
| Congestion pricing | 0.2 - 5.7 | 0.4 - 4.2 |
| Compressed work week[e] | 0.0 - 0.6 | 0.0 - 0.5 |
| Telecommuting[e] | 0.0 - 3.4 | 0.0 - 2.8 |
| Land use planning[e] | 0.0 - 5.2 | 0.0 - 5.2 |
| Signal timing | ( d ) | ( d ) |
| Incident management | (0.1) - 0.0 | (0.1) - 0.0 |
| Emissions/VMT Tax | 0.2 - 0.6 | 0.1 - 0.9 |
| Buy-backs of older cars | N/A | N/A |

Notes:
(a) Numbers in parentheses represent increases in VMT or trips.
(b) Numerical estimates have been converted from the literature into common units and rounded to the nearest tenth of a percent. The estimates reflect the specific parameters for the case studied or the assumptions in any predictive model -- all from existing literature. Actual impacts in specific regions will depend on the level of implementation and local circumstances.
(c) See text for discussion of TCMs, including assumptions made in the literature. Appendix II provides a detailed summary of the TCM travel impact estimates in the literature.
(d) Impact is less than 0.1 percent.
(e) No literature reported impact as low as 0; literature indicated that the potential impact of this measure is highly speculative, and we have therefore reported a range starting at 0. (Conversely, the upper end of the range may exceed that reported here.)

**TABLE 3.**
**TRAVEL AND EMISSIONS EFFECTIVENESS:**
**ESTIMATED POTENTIAL REGIONAL DAILY REDUCTIONS (in percent)[a]**
**(Based on literature review)[b]**

| TCM[c] | VMT | Trips | Emissions (Mobile-source HC) |
|---|---|---|---|
| Employer trip reduction | 1.0% | 0.8% | 0.9% |
| Area-wide ridesharing | 0.4 | 0.3 | 0.4 |
| Transit improvements | 1.0 | 0.8 | 0.9 |
| HOV lanes | 1.4 | 0.5 | 1.1 |
| Park-and-ride lots | 0.5 | 0 | 0.3 |
| Bicycle/pedestrian facilities | d | d | d |
| Parking pricing | | | |
| work | 3.0 | 2.5 | 2.8 |
| non-work | 4.2 | 5.4 | 4.6 |
| Congestion pricing | 5.0 | 3.8 | 8.2[e] |
| Compressed work week | 0.8 | 0.7 | 0.7 |
| Telecommuting | 1.1 | 1.0 | 1.0 |
| Land use planning | f | f | f |
| Signal timing | ( d ) | ( d ) | 0.4[e] |
| Incident management | (0.1) | (0.1) | 0.8[e] |
| Emissions/VMT Tax | 0.4 | 0.7 | 4.1[e] |
| Buy-backs of older cars | N/A | N/A | 0.4[e] |

Notes:

(a) **Maximum reasonable potential** based on current information; some of these estimates do not reflect actual experience, and all depend on the level of implementation and specific local assumptions (congestion pricing, for example, assumes a 15 cents per mile charge). Estimates are percentage changes from baseline travel and emissions. Estimates are rounded to the nearest tenth of a percent. Numbers in parentheses represent increases in VMT or trips.

(b) Estimates should be treated separately: in some cases, TCM impacts may be additive; in others, the impacts are likely redundant; and for some combinations, there may be synergy among TCMs. This analysis simply reports individual impacts from the literature review.

(c) See text for discussion of TCMs, including assumptions made in the literature.

(d) Impact is less than 0.1 percent.

(e) Estimates not interpolated -- but drawn directly from literature.

(f) The best available study on land-use planning (the LUTRAQ report) reports a long-term impact of 5.2 percent trip reduction (achieved by the year 2010) as the impact of land-use planning and parking pricing (plus free work-trip transit). Material in the report indicates that the pricing measure accounts for a large proportion of the total impact, but does not allow for a clean separation of the effects. For that reason, no estimate is shown in this table.

**TABLE 4.**
**TRAVEL COST-EFFECTIVENESS ESTIMATES:**
**COST PER VEHICLE ROUND-TRIP AVOIDED (in dollars)[a]**
**(Based on literature review)**

| TCM | COST-EFFECTIVENESS |
|---|---|
| Employer trip reduction | $10.30 |
| Area-wide ridesharing | 0.60 |
| Major rail transit improvements | 10.00 |
| HOV lanes | 4.00 |
| Park-and-ride lots | b |
| Bicycle/pedestrian facilities | 10.60 |
| Parking pricing | |
| work | 1.70 |
| non-work | c |
| Congestion pricing | 2.40[d] |
| Compressed work week | c |
| Telecommuting | c |
| Land use planning | c |
| Signal timing | e |
| Incident management | e |
| Emissions/VMT Tax | f |
| Buy-backs of older cars | e |

Notes:
(a) Based on current information; some of these estimates do not reflect actual experience, and all depend on the level of implementation and specific local assumptions (congestion pricing, for example, assumes a 15 cents per mile charge). Estimates are rounded to the nearest ten cents (except for park-and-ride). Appendix V provides an explanation of these estimates.
(b) Measure does not reduce trips; it does reduce VMT at cost of $0.17 per VMT avoided.
(c) No information available on which to base a cost-effective estimate; however, TCM is potentially highly cost-effective (see text for explanation).
(d) The general consensus in the literature is that in a benefit-cost context, the traffic-flow benefits of such measures (not counting emissions effects) exceed the societal costs.
(e) Measure does not reduce trips.
(f) Cost-effectiveness not calculated; only part of effect is in travel reduction -- balance is in scrappage of high-emitting vehicles. Since costs are very low, measure would be highly cost effective.

**TABLE 5.**
**EMISSIONS COST-EFFECTIVENESS ESTIMATES:**
**COST PER TON OF HYDROCARBON (HC) REDUCED (in dollars)[a]**
**(Based on literature review)[b]**

| TCM | 1990 | 1994 | 1997 |
|---|---|---|---|
| Employer trip reduction | $227,000 | $281,000 | $365,000 |
| Area-wide ridesharing | 13,000 | 16,000 | 20,000 |
| Major rail transit improvements | 220,000 | 272,000 | 353,000 |
| HOV lanes | 88,000 | 109,000 | 141,000 |
| Park-and-ride lots | 118,000 | 146,000 | 188,000 |
| Bicycle/pedestrian facilities | 233,000 | 289,000 | 376,000 |
| Parking pricing | | | |
| work | 38,000 | 47,000 | 61,000 |
| non-work | c | c | c |
| Congestion pricing[d] | 53,000 | 66,000 | 85,000 |
| Compressed work week | c | c | c |
| Telecommuting | c | c | c |
| Land use planning | c | c | c |
| Signal timing | | | 23,000[e] |
| Incident management | | | 83,000[e] |
| Emissions/VMT Tax | near 0 | near 0 | near 0 |
| Buy-backs of older cars | 3,000[e] | | |

Notes:
(a) Based on current cost information; some of these estimates do not reflect actual experience, and all depend on the level of implementation and specific local assumptions (congestion pricing, for example, assumes a 15 cents per mile charge). Estimates are rounded to nearest thousands of dollars; 1994 and 1997 are not adjusted for inflation.
(b) Appendix IV provides an explanation of these estimates.
(c) No information available on which to base a cost-effectiveness estimate; however, TCM is potentially highly cost-effective (see text for explanation).
(d) The general consensus in the literature is that in a benefit-cost context, the traffic-flow benefits of such measures (not counting emissions effects) exceed the societal costs.
(e) Estimates drawn directly from the literature.

## APPENDIX M

## EFFECTIVENESS OF TCMs

Source: *Effectiveness of TCMs and TDM Programs in Reducing Congestion: A Review of Recent Literature.* Capital Beltway Major Investment Study, DeLeuw Cather Company, December 1995.

## II. Results of the Literature Review

For each TCM or TDM measure evaluated, a summary sheet which outlines the findings of the literature review has been prepared. Each sheet contains the following information:

**TCM/TDM Measure** = Name of congestion-reducing strategy or program.
**Description** = Brief overview of measure and applications.
**Documented Effectiveness** = Findings of research and studies conducted on the referenced measure or strategy.
**Sources for Additional Information** = Bibliographic references for more detailed information on TCM/TDM measure or specific case study.

This section also uses a number of abbreviations in describing the TCM or TDM measures and their respective effectiveness, including:

HOV = High Occupancy Vehicle
SOV = Single Occupant Vehicle
TCM = Transportation Control Measure
TDM = Transportation Demand Management
TMA = Transportation Management Association
TRO = Trip Reduction Ordinance
VMT = Vehicle Miles Travelled

**TCM/TDM Measure:** **TRIP REDUCTION ORDINANCES**

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**Description:** Local or regional regulations which require employers to achieve reductions in vehicular use by their employees. Although trip reduction ordinances are often initiated because of air quality concerns, congestion reduction is also an important objective. Most comprehensive trip reduction (or transportation demand management) ordinances require active efforts by employers, developers and property managers to reduce traffic volumes serving their respective facilities. Complete programs usually include technical assistance, monitoring and reporting requirements, and penalties for non-compliance.

In lieu of global regulations or ordinances, individual trip reduction programs or agreements with private employers or developers are used in some parts of the country. In Montgomery County, Maryland, developers commit to traffic mitigation as part of the development approval process. Failure to meet trip reduction goals can lead to the forfeiture of the money used to secure the commitment with the county. In some California cities, Phoenix and Denver, mandatory or voluntary "no-drive" days have been instituted. The goal is to reduce the total number of weekly trips (and VMT), thereby alleviating congestion, particularly during peak commuting periods.

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**Documented Effectiveness:**

- In the first year of implementation, Regulation XV in Southern California increased mode shares of carpools and vanpools by 39% and 50% respectively; SOV share dropped by 6%. (Wachs, 1991)
- In the first year of implementation, Regulation XV resulted in a reduction of .96% in daily VMT and .80% in daily trips. (National Association of Regional Councils, 1994)
- An increase of 25% in average vehicle ridership (goal of Regulation XV) would produce 2% - 3% decrease in the total number of vehicle trips and 3% - 4% decrease in daily VMT. However, these gains are likely to be quickly cancelled out by expected growth in traffic volumes. (Orski, 1993)
- The U.S. EPA found in 1986 that TROs resulted in a 5% - 25% reduction in trips for affected employees and less than 1% reduction in area-wide trips; a later study estimated an area-wide VMT reduction of .36% due to TROs. (U.S. EPA, 1986 and 1990)
- In general, employee trip reduction has had a very small impact on traffic congestion. (Lupa, 1994)
- TROs have not had major impacts on employee mode choice in most cases, at least through the first several years of operation. (Sanford and Ferguson, 1991)
- With an ordinance requiring employer or development trip reduction, developers are more likely to include preferential parking for HOVs and charge higher parking rates. No significant decrease in SOV use to date as a result of these measures. (Blankston, 1990).

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**Sources for Additional Information:**

Blankston, C. and M. Wachs. Preliminary Evaluation of the Coastal Transportation Corridor Ordinance in Los Angeles. *Transportation Research Record*, vol. 1280 (1990), pp. 39-45.

Denver Department of Public Works. *City and County of Denver Travel Reduction Program: First Year Performance Evaluation*. Denver: Denver Department of Public Works, April 1994.

Guiliano, G., K. Hwang and M. Wachs. *Mandatory Trip Reduction in Southern California: First Year Results*. Berkeley, CA: University of California Transportation Center, 1992.

Lupa, M. Feasibility of Employee Trip Reduction as a Regional Transportation Control Measure. *Transportation Research Record,* vol. 1459 (1994), pp. 46-52.

Orski, C. Employee Trip Reduction Programs--An Evaluation. *Transportation Quarterly*, vol. 47, no. 3 (1993), pp. 327-341.

Urban Mobility Corporation. Mandatory Trip Reduction Programs--How Effective Are They? *Private Sector Briefs,* vol. 4, no. 5 (May 1992).

Sanford, E. and E. Ferguson. Overview of Trip Reduction Ordinances in the United States: The Vote is Still Out on Their Effectiveness. *Transportation Research Record*, vol. 1321 (1991), pp. 135-137.

Stewart,, J., R. Young, A. Ho. et. al. *What Price Success? Regulation XV Trip Reduction Plans: Investment Patterns and Cost Effectiveness.* Commuter Transportation Services Inc., 1992.

Wachs. M. and G. Guiliano. Regulation XV: Beginning to Show Results. *ITS Review*, vol. 15, no. 1 (November 1991), pp. 4-6.

**TCM/TDM Measure: TRANSPORTATION MANAGEMENT ASSOCIATIONS/DISTRICTS**

**Description:** Groups of employers or developers which form a non-profit corporation or another type of organization to promote joint efforts to reduce traffic volumes and increase ridesharing. These associations are generally based on a specific commercial development or activity center. These voluntary TDM efforts remain the most common form of private sector involvement. The chief shortcoming is their limited scope; because most serve well-defined employment clusters, their influence on freeway and regional arterial traffic is negligible.

**Documented Effectiveness:**

**Sources for Additional Information:**

**TCM/TDM Measure:** **TDM PROGRAM/ON-SITE TRANSPORTATION COORDINATOR**

**Description:** Employers (private and public sector) can develop strategies or programs that encourage the use of SOV alternatives; in some states or regions, employer-based trip reduction is mandated by law (see "Trip Reduction Ordinances" summary). General employer support for transportation demand management can take a number of forms: a TDM Marketing Program which outlines and promotes the transportation-related services or incentives offered by the company, 2) an on-site Transportation Coordinator (full or part-time) who is responsible for implementing programs such as carpools and vanpools, 3) ridesharing-friendly location or site design, 4) on-site services such as banking, dry cleaners, and restaurants, and 5) supporting services, such as a guaranteed ride home program or employee use of fleet vehicles.

## Documented Effectiveness:

- In general, the impact of employer-based support measures is difficult to estimate quantitatively. Even more difficult is to isolate the role of a specific program or service which leads to an effective TDM program. Often, it is a combination of services and incentives/disincentives which are the key to a successful reduction in vehicle trips by workers.
- TDM marketing and promotional programs are largely ineffective alone; shifts to ridesharing resulting from informational programs is less than 3%. An on-site Transportation Coordinator can help, but only marginally. (U.S. DOT, September 1993)
- Site design and amenities which encourage ridesharing (or transit) may decrease reliance on SOV use, but there is no conclusive data to support this finding.
- On-site support services are very important to a small share of commuters, but not significant enough to force a mode shift for most workers.

## Sources for Additional Information:

Chicago Area Transportation Study and Illinois EPA. *Recommendations of the Task Force on Employee Trip Reduction.* Chicago: CATS, 1992.

Rutherford, G., S. Badgett, J. Ishimaru, and S. MacLachlan. Transportation Demand Management: Case Studies of Medium-Size Employers. *Transportation Research Record,* vol. 1459 (1994), pp. 7-16.

Schreffler, E. and R. Kuzmyak. Trip Reduction Effectiveness of Employer-Based Transportation Control Measures: A Review of Empirical Findings and Analytical Tools. Paper Presented at the 84th Meeting of the Air and Waste Management Association, June 1991.

**TCM/TDM Measure:** **TRANSPORTATION ALLOWANCES**

**Description:** Transportation or travel allowances consist of a monthly stipend from an employer which can then be used to help an employee pay for any transportation mode and parking fees. A travel allowance program may have differential subsidies based on the level of vehicle occupancy. In those cases, where the employee walks to work or receives a ride which does not park, the allowance becomes additional income.

## Documented Effectiveness:

- Previous research suggests that alone, travel allowances have a modest impact on a change in modal shares among most drivers. However, when allowances are packaged with other TCM/TDM measures (e.g. on-site transportation coordinator, information promotion, HOV preferential parking), SOV share reductions of 5% - 10% are possible. (Bhatt, 1991)
- Travel allowances combined with parking charges for SOVs or a reduction in employee parking subsidies have led to SOV share reductions as high as 30%. (U.S. DOT, 1989)

## Sources for Additional Information:

Bhatt, K. Review of Transportation Allowance Programs. *Transportation Research Record*, vol. 1321 (1991), pp. 45-50.

**TCM/TDM Measure:** **EMPLOYER TRANSIT SUBSIDIES/VOUCHERS**

**Description:** Employer-sponsored transit subsides can take a number of forms. In some cases, the employer provides "Transit Checks" which can be used to purchase multi-ride transit tickets, tokens or passes. These checks are generally purchased from the regional transportation provider at cost and provided to employees as a direct subsidy and incentive to use transit for work trips. In other cases, employers participated in subsidy matching programs sponsored by the local government or transit provider. Employers purchase multi-ride tickets or passes at a discount from the local government or transit agency and then apply a similar discount before re-selling them to its employees. Discounts or subsidies are rare for single-rides because work trips generally occur during peak periods where most transit operators charge premium fares due to the increased demand.

**Documented Effectiveness:**

- Anecdotal evidence suggests that pre-payment discounts and fare reductions do not seem to have a significant impact on transit usage, though transit subsidy matching programs appear to be more promising.
- Transit subsidy program at the University of Washington (Seattle) reduced vehicle trips by 16%, increased transit use by 35%, increased the number of carpools by 21%, and increased the number of vanpools by 250%. (Williams and Petrait, 1993)

**Sources for Additional Information:**

U.S. Department of Transportation. Federal Highway Administration. *Traveler Response to Transportation System Changes*, 2nd Edition. Prepared by Barton-Aschman Associates, July 1991.

U.S. Department of Transportation. Urban Mass Transit Administration, Office of Budget and Policy. *Employer-Based Transit Passes*. Prepared by KPMG Peat Marwick, November 1990.

Williams, M. and K. Petrait. U-PASS: A Model Transportation Management Program That Works. *Transportation Research Record,* vol. 1404 (1993), pp. 73-81.

**TCM/TDM Measure:** **EMPLOYER RIDESHARING (CARPOOL/VANPOOL) SERVICES**

**Description:** The effectiveness of area-wide ridesharing programs in reducing vehicle trips and VMT led rideshare agencies to market carpooling and vanpools through employers. Employer's role in ridesharing has also been prompted in recent years by traffic mitigation ordinances and development agreements at new office locations. Most employer-sponsored ridesharing programs include features such as SOV disincentives (parking fees) and carpooling incentives (lower cost/free parking, gas allowances, on-site ride matching, guaranteed ride home services). In some cases, employers also subsidize the formation and operation of vanpools. Overall, employer-based ridesharing is probably more effective than area-wide programs, though the level of success is largely dependent on an employer's incentive/disincentive package. Although most employers do not implement carpooling programs by themselves, past experience shows that employer-based carpooling can improve the participation rate and be an effective reducer of vehicle trips and VMT.

## Documented Effectiveness:

- Regional ridesharing not particularly effective in reducing VMT (< 1% area-wide reductions), but employer-based programs in some cases have been more successful. (Urban Transportation Monitor, 1988)
- Firm size is the most important variable in a ridesharing program's effectiveness; employees of larger firms are more likely to rideshare. (Ferguson, Transportation Research Record, 1990)
- An FHWA analysis found that 11 employer-sponsored carpooling programs reduced the number of vehicle trips from 5 - 48%. Further, the combination of employer carpools and preferential parking for HOVs can reduce the total number of vehicle trips by up to 22%. Most of the success of these programs is attributed to the incentives developed to encourage ridesharing. (U.S. DOT, 1990)
- Employer ridesharing initiatives can be expected to reduce employee vehicle trips by 5%- 15%; this figure increases to 20% if employment site parking rates are increased. (Ewing, 1993).

## Sources for Additional Information:

Ferguson, E. An Evaluation of Employer Ridesharing Programs in Southern California. *Transportation Research Record,* vol. 1280 (1990), pp. 59-72.

Ferguson, E. The Influence of Employer Ridesharing Programs on Employee Mode Choice. *Transportation*, vol. 17, no. 2 (1990), pp. 179-207

Limited Success Shown in Ridesharing. *Urban Transportation Monitor*, vol. 2, no. 15 (1988), pp. 1-9.

U.S. Department of Transportation. Federal Highway Administration. *Evaluation of Travel Demand Management Measures to Relieve Congestion.* Report FHWA-SA-90-005 Prepared by COMSIS Corporation and Katz & Associates, February 1990.

Wegmann, F. Cost-Effectiveness of Private Employer Ridesharing Programs: An Employer's Assessment. *Transportation Research Record*, vol. 1212 (1989). pp. 88-100.

**TCM/TDM Measure:** **EMPLOYER PARKING SUPPLY/PRICING**

**Description:** Effective control of parking supply and demand is a vital element of a successful employer-based trip reduction program. The availability of free parking invites commuters to drive to work alone. Research shows that adjustment of the parking supply and pricing may be the single most effective strategy to force mode shifts among SOV commuters. Employer-based parking strategies can take many forms: 1) a reduction or "cashing-out" of an employee's subsidized parking, 2) elimination of free on-site parking, 3) free/discounted parking for HOVs, or 4) parking surcharges for peak periods. While many of these strategies are most effective when the employer controls the parking supply and rate structure, they can be implemented with the cooperation of private and municipal parking operators.

## Documented Effectiveness:

- An increase in parking rates at federal government facilities in the Washington, DC area led to automobile trip reductions of 1% - 10% in the city and 2% - 4% in the suburbs. (Miller and Higgins, 1983)
- Study of San Francisco medical institutions found that an increase of $8.00 in monthly parking costs was needed to drop SOV share by 1%. (Dowling et. al., 1991)
- Elimination of employer-paid parking resulted in a reduction in the SOV share from 42% to 8% and a subsequent rise in carpooling from 17% to 50%. (Surber et. al., 1984)
- An assessment of the effect of employer-provided parking subsidies on mode share found that when employees were required to pay for on-site parking, the number of SOV drivers declined by an average of 41 %. (Willson and Shoup, 1990).

## Sources for Additional Information:

Dowling, R., D. Feltham, and W. Wycko. Factors Affecting Transportation Demand Management Program Effectiveness at Six San Francisco Medical Institutions. *Transportation Research Record*, vol. 1321 (1991), pp. 109-117.

Miller, G. and T. Higgins. *Implementing Parking Pricing Strategies*. Washington, DC: The Urban Institute, August 1983.

Shoup, D. Cashing Out Free Parking. *Transportation Quarterly*, vol. 36 (1992), pp. 35-64.

Simon, J. and A. Woodhull. *Parking Subsidization and Travel Mode Choice*. Los Angeles: Southern California Rapid Transit District, August 1987.

Surber, M., D. Shoup, and M. Wachs. Effects of Ending Employer-Paid Parking for Solo Drivers. *Transportation Research Record*, vol. 957 (1984), pp. 67-71.

U.S. Department of Transportation. Federal Transit Administration. *Parking Cash Out: A TDM Status Report*. Prepared by K.T. Analytics, February 1994.

Willson, R. Estimating the Travel and Parking Demand Effects of Employer-Paid Parking. *Regional Science and Urban Economics*, vol. 22, no. 1 (March 1992), pp. 133-145.

Willson, R. and D. Shoup. Parking Subsidies and Travel Choices: Assessing the Evidence. *Transportation,* vol. 17, no. 2 ( 1990), pp. 141-157.

**TCM/TDM Measure:** **EMPLOYER HOV INCENTIVES**

**Description:** Employers can use a number of financial and convenience-related incentives to encourage the use of HOVs, including rideshare matching, vanpool subsidies, and preferential parking. These incentive packages come in many forms and are most effective when tailored to the specific conditions associated with each employer's travel markets. A number of public and private sector employers have implemented HOV incentive program. For example, in most federal office buildings, the majority of parking is reserved for carpools and vanpools. These parkers also benefit from reduced or subsidized parking rates.

## Documented Effectiveness:

- Financial incentives alone have led to vehicle trip reductions of 8% - 18% for selected employers. (U.S. DOT, September 1993)
- Employers who develop HOV programs which combine financial incentives with SOV parking disincentives have seen vehicle trip reductions of up to 50%, though the average is about a 20% reduction. (U.S. DOT, September 1993)

## Sources for Additional Information:

Ulberg, C. and W Herman. *Analysis of Employer-Based High Occupancy Vehicle Policies in the Interstate 5 Corridor Between Seattle and Everett. Final Report.* Prepared for Washington State Department of Transportation, April 1992.

**TCM/TDM Measure:** **STAGGERED WORK HOURS/FLEX-TIME**

**Description:** This measure involves employer modification of work hour policies to adjust the time periods in which employees travel to and from work. A staggered work hours program includes varying start/finish times for employees (generally 15 minute increments); the primary impact is to spread peak-period traffic over a longer time span, alleviating the "peak of the peak" congestion. A flex-time program allows employees to set their own arrival and departure times within a two-three hour time band in the morning and afternoon. The use of flex-time often encourages employees to avoid most congested travel periods. The use of staggered work hours or flex-time affects not only peak-period traffic volumes, but also influences the likelihood of choosing SOV alternatives. However, use of staggered work hours or flex-time does not always increase ridesharing or transit use. The ultimate effectiveness of any variable work hours measure is dependent on a number of site-specific conditions, including location, size of employer, and accessibility.

## Documented Effectiveness:

- Use of staggered work hours or flex-time does not generally reduce the total number of vehicle trips or VMT. At best, this strategy can shift the timing of some trips, which may provide some general congestion relief, but may also lead to an extension of the peak period and increase air pollution.
- Modified work hours can reduce peak-hour commute trips by 20% - 50%; staggered work hours and flex-time generally produce reductions in the 15% - 40% range. (Neveu, 1980/NCHRP, 1980/Oppenlander and Booth, 1981)
- Use of staggered work hours and flex-time by employers can lead to a .1% to 1% reduction in work-trip VMT and .03% - .33% reduction in total VMT. (U.S. DOT, September 1993)
- Staggered work hours and flex-time can reduce traffic volumes by 5% - 15% during peak periods at major activity centers. (U.S. EPA, 1990)
- Total number of trips are not reduced consistently in both the AM and PM peak periods. (Ewing, 1993)
- Honolulu Demonstration Project found that staggered hours led to a 7% - 9% time savings in the daily commute. (Guiliano, 1990)
- Case study of Ventura County, California workers found that a compressed work week and flex-time led to a decrease in SOV driving from 82% to 77%, and an increase in ridesharing from 8% to 13%. (Freas and Anderson, 1991)

## Sources for Additional Information:

Freas, A. M. and S. M. Anderson. Effects of Variable Work Hour Programs on Ridesharing and Organizational Effectiveness: A Case Study, Ventura County. *Transportation Research Record*, vol. 1321 (1991), pp. 51-56.

Guiliano, G. and T. Golob. Staggered Work Hours for Traffic Management: A Case Study. *Transportation Research Record*, vol. 1280 (1990), pp. 46-58.

Jones, D. *Off Work Early.* Berkeley, CA: University of California, Institute of Transportation Studies, February 1983.

Jones, D. Flex-Time: A Voluntary Approach. *ITS Review*, vol. 6, no. 2

Jovanis, P. Flexible Work Hours and Mode Change: Interpretation of Empirical Findings from San Francisco. *Transportation Research Record,* vol. 816 (1977), pp. 11-19.

National Cooperative Highway Research Program (NCHRP). *Alternative Work Schedules: Impacts on Transportation*. NCHRP Synthesis No. 73. Prepared by Transportation Research Board, 1980.

Neveu, A. and K. Koeppel. Who Switches to Alternative Work Hours and Why. *Transportation Research Record*, vol. 767 (1980), pp. 7-12.

Oppenlander, J. and J. Booth. Congestion Reducing and Energy-Saving Effectiveness of Shift Staggering at Major Manufacturing Plant. *1981 Compendium of Technical Papers*. Washington. DC: Institute of Transportation Engineers, 1981.

Quon, J. and R. Valdez. *Alternative Work Schedules and Their Effects on Ridesharing: A Review of the Ridesharing Literature*, 1989.

**TCM/TDM Measure:** **COMPRESSED WORK WEEK**

**Description:** A compressed work week program allows employees to work more hours in fewer days; common examples are the 4/40 and 9/80 work periods. In both cases, the remaining day in the work week is an "off" day. The goal of this measure is twofold: 1) reduce work week VMT and 2) encourage arrivals and departures outside the normal peak periods.

**Documented Effectiveness:**

- A case study of federal employees in Denver suggests that reduction in VMT of up to 15% are possible; the observed increase in non-work trips on "off" days did not offset the work week trip reductions. (U.S. DOT, September 1993)
- Study of public sector employees in Los Angeles found trip reduction in the 40% - 50% range for participating employees. (Atherton, 1982)
- Case study of Los Angeles County worksite found that compressed work week employees made fewer overall trips and travelled fewer miles that their counterparts working a standard 5/40 work week. The highest number of trips occurred on the off-day, but most trips were short and in the off-peak periods. (Ho and Stewart, 1992)

**Sources for Additional Information:**

Atherton, T. et. al. Transportation-Related Impacts of Compressed Work Week: The Denver Experiment. *Transportation Research Record*, vol. 845 (1982), pp. 22-30.

Ho, A. and J. Stewart. Case Study on Impact of 4/40 Compressed Workweek Program on Trip Reduction. *Transportation Research Record*, vol. 1346 (1992), pp. 25-32.

**TCM/TDM Measure:** **TELECOMMUTING**

**Description:** Telecommuting represents an approach to reduce work trips by allowing employees to work at home, or alternatively, at Telecommuting Centers. These centers are generally located in outlying areas to reduce the total VMT travelled by workers. Employer participation is critical to the effectiveness of this strategy. To date. telecommuting is being tested primarily by large corporations (e.g. ATT, Control Data, and Pacific Bell) and state or federal government agencies.

**Documented Effectiveness:**

- A 1986 pilot program sponsored by the Southern California Association of Governments resulted in a reduction of 31 VMT for each day for each employee tele-commute, though employees did not telecommute every day. (SCAG, 1988)
- In the State of California Telecommuting Pilot Project, participants in the program reported a decrease in daily vehicle trips of 44% in the AM peak period and 15% in the PM peak. (Kitamura et. al., 1989/Pendyala, 1991)
- In the State of Hawaii Telework Center Demonstration Project, 93% of the participating employees reported a reduction in the total number of work trips. (Hawaii DOT, 1990)
- Direct travel impacts of telecommuting are likely to be small, and in most areas, any trip reductions due to telecommuting will be outpaced by expected growth in traffic volumes. (Handy and Mokhtarian, 1993)

**Sources for Additional Information:**

Handy, S. and P. Mokhtarian. *Technical Memo #2: Travel and Energy Impacts of Telecommuting*. University of California at Davis, Institute of Transportation Studies, May 1993.

Hawaii Department of Transportation. *Evaluation of Hawaii Telework Center Demonstration*. Honolulu: Hawaii Department of Transportation, September 1990.

Kitamura, et. al. Telecommuting as a Transportation Planning Measure: Initial Results of the State of California Pilot Project. Presented at the 69th Annual Meeting of the Transportation Research Board, January 1989.

Pendyala, R. Impact of Telecommuting on Spatial and Temporal Patterns of Household Travel. *Transportation*, vol. 18 (1991), pp. 383-409.

Southern California Association of Governments. *Evaluation Report: Telecommuting Pilot Project*. Los Angeles: Southern California Association of Governments, August 1988.

U.S. Department of Transportation. *Transportation Impacts of Telecommuting*. Washington, DC: Department of Transportation, April 1993.

**TCM/TDM Measure:** **RIDESHARE PROGRAMS**

**Description:** This measure includes the development and operation of a regional or local organization to promote and facilitate ridesharing. Most major cities in the U.S. have some sort of ridesharing organization and active programs to encourage alternatives to driving alone. They are operated by various governmental or non-profit agencies but all have a common goal of helping commuters join, form or expand carpools and/or vanpools. These agencies also provide information and promotional support for increased transit use. An effective rideshare program will include the following components: 1) accurate and updated database, 2) promotional activities, 3) quick responses to requests for services, 4) follow-up procedures for placements, 5) incentives to try ridesharing, and 6) employer commitments to encourage ridesharing (HOV preferences, transit subsidies, etc.).

**Documented Effectiveness:**

- In one study of ridesharing programs, the carpool placement rate averaged 23% and the vanpool placement rate was 4%. The actual effectiveness of specific programs is highly dependent on local conditions. (Beroldo, 1991)

**Sources for Additional Information:**

Beroldo, S. Ridematching System Effectiveness: A Coast-to-Coast Perspective. *Transportation Research Record*, vol. 1321 (1991), pp. 7-12.

Stevens, W. Improving the Effectiveness of Ridesharing Programs. *Transportation Quarterly*, vol. 44, no, 4 (October 1990), pp. 563-578.

**TCM/TDM Measure:** **CARPOOLS**

**Description:** Carpooling, the most common alternative to driving alone, consists of sharing rides in a private vehicle among two or more individuals. Most carpools are created among friends and relatives, though in most cities and metropolitan areas, a regional agency or non-profit organization sponsors an area-wide carpooling programs. These agencies serve as the primary information and marketing resource for carpooling and generally offer ride-matching services for those wishing to join a carpool. Today, some sort of area-wide carpool program is in operation in most urban areas. Carpools are also formed informally, and in some cities, an organized system of "instant carpooling" has developed to take advantage of HOV facilities. Most of the research on carpooling's effect on vehicle trips and VMT is derived from national studies conducted after the 1973 and 1979 oil crises.

## Documented Effectiveness:

- Overall, past studies have found that area-wide carpool/rideshare programs reduce peak period VMT only between 0 and 3%, but these programs influence a significant proportion of ridesharing participants to choose carpooling over other modes. (U.S. DOT, September 1993)
- A U.S. DOT study estimated that carpooling reduced total VMT by .5% - 2% and work trip VMT by 1.5% - 7%. (U.S. DOT, 1975)
- An FHWA/UMTA evaluation analyzed carpool programs in 15 cities and found a .05% - .28% reduction in all vehicle trips and a .14% - 1% reduction in work trips. (U.S. DOT, 1978)
- Review of carpool programs in 38 cities found that area-wide carpool programs have the potential to reduce work-trip VMT by an average of .3%, with a range from .1% - 3.6%. (U.S. EPA, 1986)
- The State of Virginia estimated that a statewide reduction of 6.5 million VMT was due to carpool and rideshare programs. (Virginia DOT, 1986)
- A 1989 survey by Commuter Transportation Services, Inc. found that a daily VMT reduction of 1% for all trips, and 2% -3% for work trips due to carpooling. (National Association of Regional Councils, 1994)

## Sources for Additional Information:

Booth, R. and R. Waksman. "Analysis of Commuter Ridesharing Behavior at Five Urban Sites" *Transportation Research Record,* vol. 1018 (1985), pp. 33-40.

U.S. Department of Transportation. Federal Highway Administration, Office of Highway Planning. *Evaluation of Carpool Demonstration Projects*. Prepared by Frederick A. Wagner and JHK & Associates. Washington, DC: Department of Transportation, 1975.

U.S. Department of Transportation. Federal Highway Administration and Urban Mass Transit Administration. *Transportation System Management: An Assessment of Impacts*. Prepared by Alan M. Vorhees, Inc., November 1978.

Virginia Department of Transportation. *Statewide Evaluation of Ridesharing Programs in Virginia*. Richmond, VA: Department of Transportation, 1986.

**TCM/TDM Measure:** **VANPOOLS**

**Description:** Vanpools serve as an important alternative between transit and carpools, and often appeal to a wide range of individuals, particularly those with lengthy commuting distances. Vanpools generally involve groups of 7 to 15 persons. Riders pay a fee to the driver who often assumes responsibility for the organization and management of the operation. There are many types of vanpool arrangements, including employer-sponsored, private owner-operator, and private companies offering vanpool services. Research has indicated that vanpools work best for long distance commutes, but are not widely used overall. In some cases, vanpool promotion has generated an increase in carpool placements by rideshare agencies.

**Documented Effectiveness:**

- In 1990, the U.S. DOT estimated that .3% of all work trips nationally are made in vanpools. (U.S. DOT, September 1993)
- Vanpool programs are most effective when one-way trip distances exceed 15 miles. (U.S. EPA, 1990)
- A vanpool program started as part of the reconstruction of the Ventura Freeway (Los Angeles) suggested that changes in travel behavior are price sensitive. Due to discounts for the first six months of operation, 69 new vanpools were formed; most (95%) remained in operation after the end of the construction period. (Kodama, et. al., 1991)

**Sources for Additional Information:**

Kodama, M., J. Pankratz, and M. Moilov. Ventura Freeway Vanpool Support Program. *Transportation Research Record*, vol. 1321 (1991), pp. 21-25.

Torluemke, D. and D. Roseman. Vanpools: Pricing and Market Penetration. *Transportation Research Record*, vol. 1212 (1989), pp. 83-87.

**TCM/TDM Measure:** **GUARANTEED RIDE HOME PROGRAMS**

**Description:** A guaranteed ride home program provides a way home for ridesharers in cases where they miss their regular ride home as a result of a daytime emergency or after-hours work commitments. There are six types of services commonly used in guaranteed ride home programs: 1) back-up vanpools, 2) back-up carpools, 3) subsidized taxi service, 4) company fleet car, 5) escort service to public transit terminal, and 6) subsidized public transit service. Some type of guaranteed ride home component is increasingly common in employer-sponsored TDM programs; application on the local or regional level is more limited.

## Documented Effectiveness:

- A recent study of ten guaranteed ride home programs found that the programs encouraged ridesharing but these findings are not empirically supported. However, the administrators of the programs felt they were successful in meeting the basic goals and objectives. (Polena and Glazer, 1991).

## Sources for Additional Information:

Polena, C. and L. Glazer. Examination of 11 Guaranteed Ride Home Programs Nationwide. *Transportation Research Record*, vol. 1321 (1991), pp. 57-65.

U.S. Department of Transportation. *Guaranteed Ride Home: Taking the Worry Out of Ridesharing.* Prepared by Commuter Transportation Services, Inc. Washington, DC: Department of Transportation, 1991.

**TCM/TDM Measure:** **DIFFERENTIAL PARKING PRICING**

**Description:** There are a number of options to consider when evaluating the use of parking pricing as a means of reducing congestion, including: 1) parking taxes on parking providers (private employers, commercial lot/garage operators), 2) increased rates (or taxes) on parking facilities users, 3) increased rates at municipal facilities, and 4) discounts or preferential treatment for HOV parking. In developing a parking-based TCM/TDM strategy, various issues should be reviewed:

– Where are increased fees applied?
– What proportion of the total parking supply for an area (or region) would be affected?
– What amount of price increase is needed to influence shift to HOVs or other transportation modes?
– Have issues of legality been addressed?
– Will parking providers and users accept increased taxes or fees?

## Documented Effectiveness:

- Most experts agree that parking pricing represents the best opportunity for reducing the number of vehicle trips and increasing vehicle occupancy levels.
- TDM programs which included charges for parking were more effective than those without parking charges. (U.S. DOT, September 1993)
- An increase in parking rates at federal government facilities in the Washington, DC area led to automobile trip reductions of 1% - 10% in the city and 2% - 4% in the suburbs. (Miller and Higgins, 1983)
- Study of San Francisco medical institutions found that an increase of $8.00 in monthly parking costs was needed to drop SOV share by 1%. (Dowling et. al., 1991)

## Sources for Additional Information:

Bhatt, K. and T. Higgins. Road and Parking Pricing: Issues and Research Needs. *Transportation Research Record*, vol. 1346 (1993), pp. 68-73.

Dowling, R., D. Feltham, and W. Wycko. Factors Affecting Transportation Demand Management Program Effectiveness at Six San Francisco Medical Institutions. *Transportation Research Record*, vol. 1321 (1991), pp. 109-117.

Mehranian, M., M. Wachs, D. Shoup, and R. Platkin. *Parking Costs and Choice Among Downtown Workers: A Case Study*. Los Angeles: University of California Los Angeles, August 1986.

Miller, G. and C. Everett. Raising Commuter Parking Rates: An Empirical Study. *Transportation*, vol. 11 (1982).

Miller, G. and T. Higgins. *Implementing Parking Pricing Strategies*. Washington, DC: The Urban Institute, August 1983.

U.S. Department of Transportation. Urban Mass Transit Administration. *A Preferential Parking Demonstration in Hermosa Beach, California*. Washington, DC: Department of Transportation, 1985.

**TCM/TDM Measure:** **PARKING SUPPLY MANAGEMENT**

**Description:** This measure seeks to influence the supply of available parking through parking ordinances, on-street measures (e.g. zones, meters), zoning codes or aggressive pre-development review to control the total number of parking spaces allowed in an area. Various cities have attempted to reduce the parking supply using the following methods:

- Portland, Oregon has a "lid" on the total CBD parking supply.
- Seattle limits the amount of parking at new commercial developments.
- San Francisco regulates the amount of parking to 7% of the gross floor area of new commercial development.
- Orlando allows developers to make payments to City in lieu of on-site parking; these funds are used to operate municipal parking facilities.

The control of the parking supply is largely an urban phenomenon; in suburban activity centers, where ample parking has traditionally been available, reducing the amount of is much more difficult, especially when many employment locations are either underserved, or not served at all by transit or other alternative modes.

## Documented Effectiveness:

- TDM programs which restrict the supply of parking have the greatest overall levels of trip reduction. (U.S. DOT, September 1993).
- Cities often have a difficult time setting parking requirements in support of policy objectives. Local governments should be cautious in setting parking minimums, maximums and flexible requirements; any standards should be established only after a careful assessment of the parking market. (Higgins, 1989)
- Parking rate regulation has not proven to be very effective in limited test cases and employer-subsidized parking will often negate any attempts at parking pricing.

## Sources for Additional Information:

Akán, Guzin. Parking Management in Downtown Norfolk. *Transportation Research Record.* vol. 1459 (1994), pp. 53-57.

Higgins, T. Parking Management and Traffic Mitigation in Six Cities: Implications for Local Policy. *Transportation Research Record*, vol. 1232 (1989), pp. 60-67.

Thompson, R. and E. Collins. Downtown Parking Management System. *Transportation Research Record.* vol. 1459 (1994), pp. 63-67.

**TCM/TDM Measure:** **PARK & RIDE LOTS**

**Description:** Park and ride lots, generally located in outlying areas, which serve as a central transfer point between SOVs, ridesharing and transit services. In most cases, parking at park and ride lots is free. These lots are often served by express transit to the region's central business district and can also provide a convenient staging point for commuters travelling to different parts of the region. Although the use of park and ride lots may not reduce the overall number of trips by much, they do reduce VMT and congestion, particularly on crowded arterial and freeways during peak periods.

In some areas, peripheral parking is provided in the downtown business district. It functions much like a park and ride lot (with shuttle buses linking the lots to the business district) though the potential for trip and VMT reduction is much less. However, peripheral lots have proven effective in reducing peak-hour congestion in some cities and are useful where downtown parking is limited.

**Documented Effectiveness:**

- Study of park and ride lots in New Haven and Hartford, Connecticut found daily VMT reductions of .45% (U.S. EPA, 1990).

**Sources for Additional Information:**

Baehr, G. Park and Ride: Lots of Success. *Mass Transit.* vol. 9, no. 8 (August 1992), pp. 6-7, 48-49, 54.

U.S. Department of Transportation. Federal Highway Administration. *Park and Ride Facilities: Guidelines for Planning, Design and Operation.* Washington, DC: Department of Transportation, 1986.

**TCM/TDM Measure:** **HOV FACILITIES**

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**Description:** Transportation facilities where high-occupancy vehicles are given priority treatment: separate roadways, barrier-separated lanes, non-separated lanes, and ramp/queue by-pass facilities. Depending upon the location, most HOV facilities require 2 - 4 occupants in a vehicle. Most successful applications have been along radial corridors in large metropolitan areas; HOV facilities work best when there is sufficient congestion to create significant travel delays. They are used primarily by commuters during peak periods; in some cities, HOV facilities are "reversible" so that it can be operated concurrent with the peak travel flow.

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## Documented Effectiveness:

- HOV facilities operate best when used in conjunction with other TCM/TDMs, such as transit re-routing, express transit service, carpool/vanpool support and programs, and employer incentives to use HOVs. (U.S. DOT, September 1993)
- Concurrent flow HOV lanes can reduce peak period trips by 2% - 10%; if HOV lanes are separated and level of congestion very high, trip reduction can approach 30%. (Ewing, 1993)
- Using HOV lanes in Philadelphia, regional weekday VMT was reduced .23% - .44% (1% - 1.9% with ridesharing). (National Association of Regional Councils, 1994)
- 35% - 45% of gross VMT reductions achieved through use of HOV facilities will be offset by new VMT from other activities. (U.S. EPA, 1990)
- Surveys of carpoolers on Houston HOV facilities (transitways) found that between 19% and 42% (depending on the specific transitway) would not be ridesharing if the HOV lanes were not available. Further between 45% and 61% of the carpools may have been created because of the opening of the transitways. (Bullard, 1991)
- An earlier study of the Houston transitways found that 35% to 52% of carpool trips were either new trips or former SOV trips, and that 20% to 45% of the carpools were due to the existence of the transitways. (Christiansen, 1990)
- Case study of HOV commuters in Southern California found that HOV facilities have a significant impact on carpooling behavior, particularly among those commuters who can take full advantage of the HOV lane's travel time savings (long-distance commuters). However, significant barriers to increased levels of ridesharing remain. (Guiliano, Levine and Teal, 1990)
- Surveys of users of Orange County (California) HOV facilities done in 1985 and 1987 found that carpooling had increased 65% in the morning peak period and person-trips in the CA-55 corridor had increased by 45%. (Wesemann, Duve and Roach, 1989)

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## Sources for Additional Information:

Bullard, D. Analysis of Carpool Survey Data from the Katy, Northwest and Gulf Transitways in Houston, Texas. *Transportation Research Record*, vol. 1321 (1991), pp. 73-81.

Christiansen, D. Status and Effectiveness of the Houston High-Occupancy-Vehicle Lane System, 1988. *Transportation Research Record*, vol. 1280 (1990), pp. 119-130.

Guiliano, G., D. Levine, and R. Teal. Impact of High Occupancy Vehicle Lanes on Carpooling Behavior. *Transportation,* vol. 17, no. 2 (1990), pp. 159-177

Texas Transportation Institute. *A Description of High-Occupancy Vehicle Facilities in North America.* Technical Report 925-1, July 1990.

U.S. Department of Transportation. Federal Highway Administration, Office of Research and Development. *Evaluation of Priority Treatments for High Occupancy Vehicles.* Washington, DC: Department of Transportation, 1981.

Wesemann, L., P. Duve, and N. Roach. Comparison of Travel Behavior Before and After Opening of HOV Lanes in a Suburban Travel Corridor. *Transportation Research Record,* vol. 1212 (1989), pp. 41-52.

**TCM/TDM Measure:** **CONGESTION PRICING**

**Description:** In general, road and congestion pricing measures have greater potential for reducing VMT than market-based measures, such as gasoline taxes and vehicle excise taxes. Differential pricing can take a number of forms:

*Occupancy pricing* where users of transportation facilities are charged different rates depending upon the number of occupants in the vehicle.

*Road pricing* where users are charged differential rates depending upon the day, time of day, location and level of congestion.

*Congestion pricing* where governments (or transportation authorities) impose fees for entering a congested zone (area-wide pricing), bridge, tunnel or highway (tolls).

Most of the differential pricing measures can be implemented using toll booths/collectors, automatic vehicle identification technology or special permits. All of these measures can encourage some peak period users to shift to off-peak periods, to HOV modes, or to forego certain trips.

Although market-based congestion pricing measures and taxes have been used successfully in other countries, their application in the U.S. is unlikely.

## Documented Effectiveness:

- Although wide-scale congestion pricing has not been implemented in the U.S., the concepts are gaining favor. Advances in technology are addressing many of the toll collection and vehicle identification issues, and the FHWA is soliciting proposals from cities to participate in a Congestion Pricing Demonstration Pilot Program.

- Congestion pricing mechanisms have been used in Asia (Signapore, Hong Kong) and Europe (Oslo, Stockholm) for some time and experience suggests that peak period traffic reductions of up to 30% are possible. However, any mechanism to limit traffic in one zone or roadway may only exacerbate problems on peripheral routes.

- Commuter travel demand is highly price inelastic; New York City doubled its bridge and tunnel tolls without a noticeable drop in traffic volumes. (Orski, 1990)

- Area-wide pricing programs may work in limited areas (such as a CBD), but probably will not relieve congestion levels on a region's freeway network. (Bhatt and Higgins, 1992)

## Sources for Additional Information:

Arrillaga, B. U.S. Experience with Congestion Pricing. *ITE Journal.* vol. 63, no. 12 (December 1993), pp. 39-43.

Bhatt, K and T. Higgins. Road and Parking Pricing: Issues and Research Needs. *Transportation Research Record,* vol. 1346 (1992), pp. 68-73.

Higgins, T. Road Pricing Attempts in the United States. *Transportation Research*, vol. 20, no. 2 (1986).

Hills, P. Road Congestion Pricing: When Is It Good Policy? *Journal of Transport Economics and Policy*. vol. 27, no. 1 (1993), pp. 91-105.

Orski, K. Congestion Pricing: Promise and Limitations. *Transportation Quarterly*. vol. 46, no. 2 (April 1992), pp. 157-167.

Reason Foundation. *Congestion Pricing for Southern California: Using Market Pricing to Reduce Congestion and Emissions*. Los Angeles: Reason Foundation, September 1992.

Watson, P. and E. Holland. Relieving Congestion: The Singapore Area License Scheme. Washington, DC: The World Bank, February 1978.

**TCM/TDM Measure:** **TRAFFIC FLOW IMPROVEMENTS**

**Description:** This strategy includes a number of steps that can be taken to improve the flow of traffic and operation of the local and regional roadway network. These improvements range from the simple--converting two-way streets to one-way--to the complex--establishment of "intelligent transportation systems"--to monitor and redirect traffic congestion. Traffic flow improvements can be divided into a number of categories:

- Traffic Operations Improvements: changes in the layout and operation of streets and roads
- Traffic Signalization Upgrades: improvements in signal timing and synchronization
- Traveler Information Systems: congestion warnings and alternate route information
- Incident Management Systems: "quick response" teams and traffic management plans for emergencies
- Electronic Toll Collection: automatic toll deductions using "stored value" systems and electronic sensors at toll booths.

## Documented Effectiveness:

- In general, measures to improve traffic flow do no reduce either VMT or the number of vehicle trips. However, these measures can be effective at reducing congestion and improving both roadway safety and travel times.

## Sources for Additional Information:

Ferguson, E. Intelligent Vehicle Highway Systems and Travel Demand Management. Paper Presented at the 73rd Annual Meeting of the Transportation Research Board, 1994.

**TCM/TDM Measure:** **LAND USE/ZONING CHANGES**

**Description:** This measure includes encouraging or mandating (through development agreements, planned developments, and zoning ordinances)land use patterns which promote trip reduction activities or programs. These changes can take a number of forms, including higher density suburban development, requirements for mixed-use developments, balancing commercial and office development with nearby residential development, adoption of transit and pedestrian "friendly" site design guidelines, and implementation of parking standards or restriction. Although primarily focused on employment and commercial land uses, the same principles can be applied to residential development.

## Documented Effectiveness:

- Site design and amenities which encourage ridesharing (or transit) may decrease reliance on SOV use, but there is no conclusive data to support this finding.
- This strategy is based on promoting long-term changes to traditional (and popular) land use patterns and development trends. Despite the resurgence of "traditional" planning techniques in many suburban residential development, most land use planning and zoning ordinances remains automobile-oriented
- Any trip reduction successes based on land use or zoning changes are likely to be site or location specific.

## Sources for Additional Information:

Bookout, L. Neotraditional Town Planning: Cars, Pedestrians, and Transit. *Urban Land.* February 1992.

Calthorpe Associates. *Transit-Oriented Development Impacts on Travel Behavior.* August 1992.

Cervero. R. *America's Suburban Centers: The Land Use-Transportation Connection.* Boston: Unwin-Hyman, 1989.

Cervero, R. Congestion Relief: The Land Use Alternative. *Journal of Planning Education and Research.* vol. 10, no. 2, pp. 119-128.

**TCM/TDM Measure:** **BICYCLE/PEDESTRIAN FACILITIES**

**Description:** This measure seeks to maximize access to existing development, key destinations, and activity centers through the following strategies:

- Construction of sidewalks
- Construction of bike lanes/trails
- Installation of bike racks at transit stations and key destinations
- Installation of lockers/showers at employment locations

### Documented Effectiveness:

- There is little empirical analysis of the impacts of enhanced bicycle/pedestrian facilities. However, one study found that if even the bicycle/pedestrian mode share increased from its current 1% to by 6%, it would only lead to a .2% - .4% reduction in total VMT. (U.S. DOT, September 1993)
- Study by U.S. EPA found that improved bicycle and pedestrian facilities could produce reductions of .05% - .1% in work trip VMT and .2% - .3% reductions in overall VMT. (U.S. EPA, 1986).

### Sources for Additional Information:

Everett. M. Empirical Evidence on the Determinants of Mass Bicycle Commuting in the United States: A Cross-Community Analysis. *Transportation Research Record*, vol. 912 (1983).

U.S. Department of Transportation, Federal Highway Administration. *Feasibility of Demand Incentives for Non-Motorized Modes*. Report FHWA-RD-90-048. Prepared by Barton-Aschman Associates, 1991.

U.S. Department of Transportation, Federal Highway Administration. *Reasons Why Bicycling and Walking Are Not Being Used More Extensively as Travel Modes*. Report FHWA-PD-92-041. Washington, DC: Department of Transportation, 1993.

## APPENDIX N

## EMISSION IMPACTS OF ITS

Source: *Qualitative Assessment of IVHS Emission and Air Quality Impacts.* DOT-VNTSC-FHWA-93-4. Volpe National Transportation Systems Center, September 1994.

**Table 2-1. IVHS technology bundles for an emission analysis.**

| | |
|---|---|
| ***Traffic and Incident Management Systems***<br>Traffic Signalization Systems (ATMS)<br>Freeway and Corridor Control Systems (ATMS)<br>Real Time Changeable Message Road Sign Display Systems (ATIS)<br>Incident Detection Systems (ATMS)<br>Emergency Mayday Systems (ATIS)<br>Hazardous Material Information Systems (CVO) | ***Vehicle Control Systems***<br>Radar Braking Systems (AVCS)<br>Vehicle Speed Control Systems (AVCS)<br>Automatic Headway Control Systems (AVCS)<br>Automatic Steering Control Systems (AVCS)<br>Automated Highway Systems (AVCS) |
| ***Route Guidance Systems***<br>Electronic Route Planning and Information Systems (ATIS)<br>Radio Data Systems (ATIS)<br>On-Board Navigation Systems (ATIS)<br>Externally Linked Route Guidance Systems(ATIS) | ***Commercial Vehicle Inspection Systems***<br>Automatic Credentials Checking (CVO)<br>Electronic Permitting and Payment (CVO)<br>Electronic Recordkeeping (CVO)<br>Weigh-in-Motion (CVO)<br>Automated Safety Inspections (CVO)<br>Automated Driver Data Processing (CVO)<br>Traffic Data Collection Systems (CVO) |
| ***Accident Reduction Systems***<br>SmartRamp Designs (CVO)<br>Site Specific Highway Warning Systems for Trucks (CVO)<br>Antilock Braking Systems (AVCS)<br>Intersection Hazard Warning Systems (AVCS)<br>Collision Avoidance Systems (AVCS) | ***Trip Guidance and Public Transportation Systems***<br>Ridesharing Information Systems (ATIS)<br>Traveler Information and Service Systems (APTS)<br>Traffic Management Systems (APTS)<br>Transit and Fleet Management Systems (APTS) |
| ***Enabling Technologies for Travel Fees***<br>Automatic Vehicle Identification<br>Automatic Vehicle Location<br>Automatic Vehicle Classification<br>Electronic Toll Collection (ATMS)<br>Smart Cards (APTS) | ***Emission Control Enabling Technologies***<br>Remote Sensing Devices<br>Vehicle Condition Warning Systems (ATIS) |

The functional area from which a specific system originates is presented in parenthesis. ATMS corresponds to advanced traffic management systems. ATIS corresponds to advanced traveler information systems. CVO corresponds to commercial vehicle operations. AVCS corresponds to advanced vehicle control systems. APTS corresponds to advanced public transportation systems. Appendix A provides detailed definitions of each specific system, or systems, included in a particular technology bundle.

## Table E-1. Potential short-term, corridor-level impacts of IVHS technology bundles.

| | Traffic Flow | Vehicle Trips | Trip Distance | Mode Shifts | Hydrocarbon Emissions | Carbon Monoxide Emissions | Oxides of Nitrogen Emissions |
|---|---|---|---|---|---|---|---|
| **Traffic and Incident Management Systems** | Positive | Insignificant | Insignificant | Insignificant | Uncertain | Uncertain | Uncertain |
| **Route Guidance Systems** | Positive | Insignificant | Insignificant | Insignificant | Positive | Positive | Uncertain |
| **Accident Reduction Systems** | Positive | Insignificant | Insignificant | Insignificant | Positive | Positive | Negative |
| **Vehicle Control Systems** | Positive | Insignificant | Insignificant | Insignificant | Positive | Positive | Negative |
| **Commercial Vehicle Inspection Systems** | Positive | Insignificant | Insignificant | Insignificant | Positive | Positive | Positive |
| **Trip Guidance and Public Transportation Systems** | Positive | Positive | Insignificant | Positive | Positive | Positive | Uncertain |
| **Enabling Technologies for Travel Fees** | Positive | Positive | Insignificant | Positive | Positive | Positive | Uncertain |
| **Emission Control Enabling Technologies** | Insignificant | Insignificant | Insignificant | Insignificant | Positive | Positive | Positive |

- The short term is defined in this study to be from 2000 to 2010.
- Positive impacts reflect improvements in traffic flow, reductions in vehicle trips or trip distance, or mode shifts from single occupancy vehicles to high-occupancy vehicles.
- Negative impacts reflect increases in congestion, vehicle trips, and those impacts that reflect mode shifts from high-occupancy vehicles to single occupancy vehicles.
- Insignificant impacts reflect no changes (or very small changes) in traffic flow, the number of vehicle trips, trip distance, or mode shifts.
- Uncertain impacts are those for which changes in traffic flow, tripmaking, trip distance, or mode cannot be even qualitatively assessed given the current state of knowledge.

## Table E-2. Potential short-term, regional-level impacts of IVHS technology bundles.

| | Traffic Flow | Vehicle Trips | Trip Distance | Mode Shifts | Hydrocarbon Emissions | Carbon Monoxide Emissions | Oxides of Nitrogen Emissions |
|---|---|---|---|---|---|---|---|
| **Traffic and Incident Management Systems** | Positive | Insignificant | Insignificant | Insignificant | Positive | Positive | Negative |
| **Route Guidance Systems** | Positive | Positive | Uncertain | Insignificant | Positive | Positive | Uncertain |
| **Accident Reduction Systems** | Positive | Insignificant | Insignificant | Insignificant | Positive | Positive | Negative |
| **Vehicle Control Systems** | Insignificant | Insignificant | Insignificant | Insignificant | Insignificant | Insignificant | Insignificant |
| **Commercial Vehicle Inspection Systems** | Insignificant | Insignificant | Insignificant | Insignificant | Insignificant | Insignificant | Insignificant |
| **Trip Guidance and Public Transportation Systems** | Positive | Positive | Insignificant | Positive | Positive | Positive | Uncertain |
| **Enabling Technologies for Travel Fees** | Uncertain | Uncertain | Uncertain | Uncertain | Uncertain | Uncertain | Uncertain |
| **Emission Control Enabling Technologies** | Insignificant | Insignificant | Insignificant | Insignificant | Positive | Positive | Positive |

- The short term is defined in this study to be from 2000 to 2010.
- Positive impacts reflect improvements in traffic flow, reductions in vehicle trips or trip distance, or mode shifts from single occupancy vehicles to high-occupancy vehicles.
- Negative impacts reflect increases in congestion, vehicle trips, and those impacts that reflect mode shifts from high-occupancy vehicles to single occupancy vehicles.
- Insignificant impacts reflect no changes (or very small changes) in traffic flow, the number of vehicle trips, trip distance, or mode shifts.
- Uncertain impacts are those for which changes in traffic flow, tripmaking, trip distance, or mode cannot be even qualitatively assessed given the current state of knowledge.

## Table E-3. Potential long-term, corridor-level impacts of IVHS technology bundles.

| | Traffic Flow | Vehicle Trips | Trip Distance | Mode Shifts | Hydrocarbon Emissions | Carbon Monoxide Emissions | Oxides of Nitrogen Emissions |
|---|---|---|---|---|---|---|---|
| **Traffic and Incident Management Systems** | Positive | Insignificant | Insignificant | Insignificant | Uncertain | Uncertain | Uncertain |
| **Route Guidance Systems** | Positive | Insignificant | Insignificant | Insignificant | Positive | Positive | Uncertain |
| **Accident Reduction Systems** | Positive | Insignificant | Insignificant | Insignificant | Positive | Positive | Negative |
| **Vehicle Control Systems** | Positive | Insignificant | Negative | Insignificant | Uncertain | Uncertain | Uncertain |
| **Commercial Vehicle Inspection Systems** | Positive | Insignificant | Insignificant | Insignificant | Positive | Positive | Positive |
| **Trip Guidance and Public Transportation Systems** | Positive | Positive | Insignificant | Positive | Positive | Positive | Uncertain |
| **Enabling Technologies for Travel Fees** | Positive | Positive | Positive | Positive | Positive | Positive | Positive |
| **Emission Control Enabling Technologies** | Insignificant | Insignificant | Insignificant | Insignificant | Positive | Positive | Positive |

- The long term is defined in this study to be beyond 2010.
- Positive impacts reflect improvements in traffic flow, reductions in vehicle trips or trip distance, or mode shifts from single occupancy vehicles to high-occupancy vehicles.
- Negative impacts reflect increases in congestion, vehicle trips, and those impacts that reflect mode shifts from high-occupancy vehicles to single occupancy vehicles.
- Insignificant impacts reflect no changes (or very small changes) in traffic flow, the number of vehicle trips, trip distance, or mode shifts.
- Uncertain impacts are those for which changes in traffic flow, tripmaking, trip distance, or mode cannot be even qualitatively assessed given the current state of knowledge.

## Table E-4. Potential long-term, regional-level impacts of IVHS technology bundles.

| | Traffic Flow | Vehicle Trips | Trip Distance | Mode Shifts | Hydrocarbon Emissions | Carbon Monoxide Emissions | Oxides of Nitrogen Emissions |
|---|---|---|---|---|---|---|---|
| **Traffic and Incident Management Systems** | Positive | Insignificant | Insignificant | Insignificant | Positive | Positive | Negative |
| **Route Guidance Systems** | Positive | Positive | Uncertain | Insignificant | Positive | Positive | Uncertain |
| **Accident Reduction Systems** | Positive | Insignificant | Insignificant | Insignificant | Positive | Positive | Negative |
| **Vehicle Control Systems** | Positive | Uncertain | Negative | Insignificant | Uncertain | Uncertain | Uncertain |
| **Commercial Vehicle Inspection Systems** | Insignificant | Insignificant | Insignificant | Insignificant | Insignificant | Insignificant | Insignificant |
| **Trip Guidance and Public Transportation Systems** | Positive | Positive | Insignificant | Positive | Positive | Positive | Uncertain |
| **Enabling Technologies for Travel Fees** | Positive | Positive | Positive | Positive | Positive | Positive | Positive |
| **Emission Control Enabling Technologies** | Insignificant | Insignificant | Insignificant | Insignificant | Positive | Positive | Positive |

- The long term is defined in this study to be beyond 2010.
- Positive impacts reflect improvements in traffic flow, reductions in vehicle trips or trip distance, or mode shifts from single occupancy vehicles to high-occupancy vehicles.
- Negative impacts reflect increases in congestion, vehicle trips, and those impacts that reflect mode shifts from high-occupancy vehicles to single occupancy vehicles.
- Insignificant impacts reflect no changes (or very small changes) in traffic flow, the number of vehicle trips, trip distance, or mode shifts.
- Uncertain impacts are those for which changes in traffic flow, tripmaking, trip distance, or mode cannot be even qualitatively assessed given the current state of knowledge.

## APPENDIX O

## PACKAGING CONSIDERATIONS AMONG SELECTED TCMs

Source: *Transportation Control Measures: State Implementation Plan Guidance.* Prepared for the U.S. Environmental Protection Agency and Pacific Environmental Services, Inc., by Systems Applications, Inc., and Institute of Transportation Studies, September 1990.

| | Area-wide Ridesharing | Bicycling | Employer Programs | HOV Lanes | Park and Ride | Parking Management | Road Pricing | Traffic Flow Improvements | Transit Improvements | TROs | No-Drive Days | Work Schedule Changes |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Area-wide Ridesharing | | 0 | + | + | + | + | + | — | — | + | + | ? |
| Bicycling | 0 | | + | 0 | 0 | 0 | 0 | 0 | 0 | + | 0 | + |
| Employer-based Transportation Management | + | + | | + | + | + | + | — | + | + | + | + |
| HOV Lanes | + | 0 | + | | + | + | + | — | + | + | + | ? |
| Park and Ride | + | 0 | + | + | | + | + | — | + | + | + | + |
| Parking Management | + | 0 | + | + | + | | + | 0 | + | + | + | 0 |
| Road Pricing | + | 0 | + | + | + | + | | — | + | + | + | 0 |
| Traffic Flow Improvements | — | 0 | — | — | — | 0 | — | | — | — | — | 0 |
| Transit Improvements | — | 0 | + | + | + | + | + | — | | + | + | ? |
| Trip-Reduction Ordinances | + | + | + | + | + | + | + | — | + | | + | + |
| Voluntary No-Drive Days | + | 0 | + | + | + | + | + | — | + | + | | + |
| Work Schedule Changes | ? | + | + | ? | + | 0 | 0 | 0 | ? | + | + | |

| Key | | | |
|---|---|---|---|
| + | Mutually supportive measures | 0 | Limited or no interaction |
| — | Conflicting measures | ? | Will vary with situation |

FIGURE 2-1. Example packaging considerations among selected TCMs (note these associations are general; individual cases may vary).*

* For further examples and discussion, see Rosenbloom, 1978; Wilbur Smith & Associates, 1981; Horowitz, 1977.

| Basic Package | Supplementary Package: Work-hour changes | Pricing techniques | Restricting access | Changing land use | Prearranged ridesharing | Communications substitutes | Traffic engineering | Transit treatments |
|---|---|---|---|---|---|---|---|---|
| Work-hour changes | | + | 0 | 0 | - | + | - | + |
| Pricing techniques | + | | 0 | + | - | 0 | - | + |
| Restricting access | 0 | 0 | | + | - | 0 | + | + |
| Changing land use | 0 | + | + | | 0 | + | - | - |
| Prearranged ridesharing | - | 0 | 0 | 0 | | 0 | - | - |
| Communications substitutes | 0 | + | 0 | + | - | | - | - |
| Traffic engineering | + | 0 | - | + | - | 0 | | - |
| Transit treatments | + | + | + | 0 | - | 0 | - | |

| Key | |
|---|---|
| + | Supportive |
| 0 | Neutral |
| - | Conflicting |

FIGURE 2-2. Packaging opportunities for eight measures proposed by Rosenbloom (1978).

| | Major Problem Areas | | | Special Problem Areas | |
|---|---|---|---|---|---|
| | CBD's of Large Citites | CBD's of Small Cities | Urban Freeways and Arterials | Roadways with Strong One-Directional Flow | Roadways with Limited Options for Alternative Routes |
| Work-hour changes | 5 | 7 | 5 | 5 | 5 |
| Pricing techniques | 2 | 1 | 8 | 7 | 1 |
| Access restriction | 4 | 2 | 6 | 8 | 6 |
| Land-use changes | 3 | 5 | 3 | 4 | 3 |
| Prearranged ridesharing | 6 | 6 | 4 | 3 | 4 |
| Communications substitutes for travel | 8 | 8 | 7 | 6 | 8 |
| Traffic engineering techniques | 7 | 3 | 2 | 1 | 7 |
| Transit treatments | 1 | 4 | 1 | 2 | 2 |

| Key |
|---|
| 1 = Most effective |
| 8 = Least effective |

FIGURE 2-3. Ranking of the proposed packages' applicability to five traffic congestion locations.

Source: Rosenbloom, 1978.

## APPENDIX P

## EFFECTS OF COMBINING TCMs

Source: *Methodologies for Quantifying the Emission Reductions of Transportation Control Measures.* Report No. SR91-10-03. Prepared for the San Diego Association of Governments by Sierra Research, Inc., with support for JHK & Association, October 1991.

Table 7-2
## EFFECTS OF COMBINING MEASURES

| Transportation Control Measure | Measure Number | | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 |
| 1 Jobs/Housing Balance | x | | | | | | | | | | | | | | | | | | | | | | | | |
| 2 Densification | A | x | | | | | | | | | | | | | | | | | | | | | | | |
| 3 Mixed Use | A | A | x | | | | | | | | | | | | | | | | | | | | | | |
| 4 Growth Controls | A | A | A | x | | | | | | | | | | | | | | | | | | | | | |
| 5 Pedestrian Improvements | A | A | A | A | x | | | | | | | | | | | | | | | | | | | | |
| 6 Traffic Signal Improvements | A | A | A | A | D | x | | | | | | | | | | | | | | | | | | | |
| 7 Capacity Increases | A | A | A | A | D | S | x | | | | | | | | | | | | | | | | | | |
| 8 Transit Service Increases | A | A | A | A | S | C | C | x | | | | | | | | | | | | | | | | | |
| 9 Employee Transit Pass Subsidy | A | A | A | A | S | C | C | S | x | | | | | | | | | | | | | | | | |
| 10 Park-and-Ride Lots | A | A | A | A | S | C | C | S | A | x | | | | | | | | | | | | | | | |
| 11 HOV Lanes | A | A | A | A | S | A | A | A | A | S | x | | | | | | | | | | | | | | |
| 12 Bicycle Improvements | A | A | A | A | A | A | A | A | A | A | A | x | | | | | | | | | | | | | |
| 13 TROs | A | A | A | A | S | C | C | S | S | S | S | A | x | | | | | | | | | | | | |
| 14 Ridesharing | A | A | A | A | S | C | C | A | S | S | S | A | S | x | | | | | | | | | | | |
| 15 Parking Management | A | A | A | A | S | A | A | S | S | A | A | A | S | S | x | | | | | | | | | | |
| 16 Telecommuting | A | A | A | A | D | D | D | A | A | A | A | A | A | A | A | x | | | | | | | | | |
| 17 Flexible Work Hours | A | A | A | A | A | D | D | A | A | C | C | A | C | C | C | A | x | | | | | | | | |
| 18 Staggered Work Hours | A | A | A | A | A | D | D | A | A | C | C | A | C | C | C | A | A | x | | | | | | | |
| 19 Compressed Work Week | A | A | A | A | A | D | D | A | A | C | C | A | C | C | C | A | A | A | x | | | | | | |
| 20 Gas Tax/Cost Increase | A | A | A | A | S | D | D | S | S | S | S | S | S | S | S | S | D | D | D | x | | | | | |
| 21 VMT Tax | A | A | A | A | S | D | D | S | S | S | S | S | S | S | S | S | D | D | D | D | x | | | | |
| 22 Motorist Information | A | A | A | A | D | D | D | D | D | D | D | D | D | D | D | D | D | D | D | D | D | x | | | |
| 23 Incident Management | A | A | A | A | D | D | D | D | D | D | D | D | D | D | D | D | D | D | D | D | D | S | x | | |
| 24 Delivery Timing | A | A | A | A | D | D | D | D | D | D | D | D | D | D | D | D | D | D | D | D | D | D | D | x | |
| 25 Loading Facility | A | A | A | A | D | D | D | D | D | D | D | D | D | D | D | D | D | D | D | D | D | D | D | D | x |

Legend:

A - Sequentially Additive
C - Conflicting
D - Directly Additive
S - Synergistic

# APPENDIX Q

# SCOPE OF WORK: NCHRP RESEARCH ON TCMs

**Project 8-33, FY '95**
**Quantifying Air-Quality and Other Benefits and Costs of Transportation Control Measures**

Research Agency: Cambridge Systematics, Inc.
Principal Investigator(s): Mr. John H. Suhrbier
Contract Amount: $749,957

Effective Date: 7/1/95
Original Completion Date: 12/31/97
Revised Completion Date:
Estimated Completion Date

Percent complete through 12/31/95: 30
Is project on schedule? Yes
Expenditures to date: $150,000
Are expenditures in keeping with project progress? Yes

Responsible NCHRP Staff Engineer
**B. Ray Derr - 202-334-3231**

**PROJECT DESCRIPTION**

The Clean Air Act Amendments (CAAA) of 1990 identify transportation control measures (TCMs) that are expected to provide emission-reduction benefits and, depending on the area's nonattainment status, mandate implementation of some of them. The CAAA also identifies other measures intended to modify motor vehicle use. The Intermodal Surface Transportation Efficiency Act (ISTEA) of 1991 further encourages the use of these measures by allowing federal funds, normally reserved for preserving and improving highways and bridges, to be used for TCM projects. Historically, transportation agencies have given priority to providing supply (transportation facilities) rather than managing demand through TCMs. However, states and metropolitan planning organizations (MPOs) are under increasing pressure to implement TCMs. While they are not equally effective for all air pollutants, TCMs will be used in many nonattainment areas to meet ambient air quality standards.

States and MPOs require specific, quantitative information on the benefits, costs, and expected air-quality improvements of various TCMs in order to select those that will best meet their needs. Most of the air quality information related to TCMs is expressed in terms of emissions and does not address expected impacts on air pollutant concentrations that determine the attainment status. Little information is available on other types of personal and social benefits and costs or the synergistic relationships between various TCMs. This type of information is needed so that officials can effectively communicate with the public and efficiently allocate scarce resources.

**The objective of this research is to develop a framework for analyzing the air-quality and other environmental, social, and economic effects of TCMs (as defined above). The objective will be accomplished by 1) identifying known and accepted techniques and assumptions used in the analysis of these effects, 2) identifying how existing analysis and evaluation criteria could be strengthened, 3) developing and validating the framework, and 4) packaging the framework for dissemination.**

Research includes the following tasks (1) Identify completed and ongoing research and other activities related to the effects of TCMs. Identify the users of TCM analysis techniques (e.g., state and local transportation agencies and state and local environmental agencies) as well as other stakeholders (e.g., citizen and environmental groups). Conduct a workshop to assess the knowledge and needs of current TCM analysis techniques and assumptions. (2) Identify how current analysis techniques and assumptions could be reasonably and effectively strengthened. (3) Prepare performance criteria and a preliminary outline of the analysis framework to be developed in Task 5. Prepare preliminary plans for validating the framework in Tasks 6 and 8. (4) Prepare an interim report documenting the findings of Tasks 1 through 3 and providing a revised work plan for subsequent tasks. (5) Develop a comprehensive framework that is suitable for analyzing TCMs recognizing that they are part of a total transportation system. TCMs to be analyzed include, but are not limited to, those designed to produce mode shifts, operational traffic changes, and reductions in motor vehicle usage. The framework must include the synergistic effects of employing various combinations of TCMs. Key variables will include number of trips, trip chaining, elasticity, vehicle miles traveled, delay, and vehicle modal activity (acceleration, deceleration, idling, etc.). Key outputs will be the effect on air pollutant emissions ($NO_x$, CO, PM-10, and VOC) and the social, economic, and environmental effects (including but not limited to energy conservation, greenhouse gas emissions, and preservation of open spaces). The framework should be compatible with federal requirements such as CAAA State Implementation Plans (SIPs) (claims for SIP credit should be supported) and ISTEA Management Systems. (6) Conduct a pilot validation study of the framework using the validation plan developed in Task 3 and presented in the Task 4 interim report. (7) Prepare an interim report documenting the findings of Tasks 5 and 6 and any needed changes in subsequent tasks. (8) Validate and refine the framework. The following aspects of the framework should be evaluated: ease of use, accuracy, applicability to various urban areas, data and monitoring requirements, approach to estimating synergistic effects, and cost to implement. The validation could include case studies of existing TCMs and combinations of TCMs, before-and-after studies, and hypothetical scenarios. Use of actual data for validation is preferred. (9) Prepare a user's manual. The manual should be designed to enable state DOTs and MPOs to use the analysis framework developed in this project. It should include a summary of the strengths and limitations of the methodology, guidance on the analysis of combinations of TCMs, and recommendations on communicating the results to the public and elected officials. (10) Submit a final report documenting the research effort and including the user's manual as a self-contained appendix.

**FUNDS AVAILABLE:** $750,000