WHITE PAPER

TRAVEL DEMAND MANAGEMENT AND HOV SYSTEMS

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INTRODUCTION

Travel Demand Management and High Occupancy Vehicle systems are intensely mutually supportive. TDM counts on HOV systems as a major strategy. HOV systems are undergirded by the ridesharing enhancement of practically all TDM activities. Major HOV systems today already benefit from TDM, much of it put in place before the term "Travel Demand Management" was coined, and a lot more can be done. HOV without TDM is like rail rapid transit without feeder bus lines or station parking.

This White Paper describes and examines TDM in brief. It then addresses the synergy of TDM and HOV working together. It closes by looking at future directions, recognizing that HOV systems are a here and now example of "manageable infrastructure;" infrastructure that is friendly to TDM and the broader concept of Transportation Management as a whole.

TRAVEL DEMAND MANAGEMENT IN BRIEF

Travel Demand Management, or TDM, focuses on measures that nudge travel behavior toward choices that increase transportation efficiency.[1] It is the demand-side partner of Transportation Systems Management, or TSM, which is being definitionally narrowed to focus on supply-side operational efficiencies. By addressing both supply and demand, TSM and TDM together offer promise of the most efficient use of existing and future transportation facilities.

Travel Demand Management may be characterized in terms of distinctive types of actions:

- Improved Alternatives: Supplying improved travel alternatives that are attractive and competitive with driving alone in the private (single occupant) auto.

- Incentives and Disincentives: Encouraging use of alternatives to driving alone through various bonuses, penalties and compensatory actions which impact the cost, time or ease of travel.

- Impediment Removal: Elimination of barriers to use of alternatives, particularly lack of information and real or perceived needs that keep travelers "captive" to the single occupant auto.

- Travel Time Management: Inducing shifts of travel to less congested times of the day, or reduction in the number of days travel to the job site is required.

An alternative categorization of TDM actions is to separate those which are employer-based from those which are sponsored by area-wide organizations, typically government. Employer-based strategies have excellent potential, but their effectiveness is highly dependent on the degree of employer participation. Employer participation and other factors in TDM effectiveness are examined immediately after the following examples of different types of TDM actions.

Improved Alternatives

It is unrealistic and unreasonable to expect that travelers will switch from single occupant auto driving unless suitably attractive alternatives are made available. Availability of viable options is generally required for imposition of disincentives and mandatory requirements to be politically acceptable. In any case, the bettered travel times, costs and convenience of significantly improved alternatives will in themselves act as incentives for more transportation-efficient behavior.

Transit is the traditional alternative to the automobile. It is at its most effective when the travel market involved is radial to a central business district. Conventional transit is placed at a disadvantage by suburbia's typical lack of development concentration at either the residence or workplace. Dispersed travel does not provide the critical mass for the advantages of mass transit to manifest themselves, making it difficult to provide competitive door-to-door travel times and adhere to realistic cost recovery standards.

New service designs more attuned to dispersed travel markets include direct express services between those residential and business concentrations which may exist, timed-transfer networks, subscription or "buspool" services to take repeat-user groups directly to their destinations, and linkages between business concentrations and parking facility/staging areas, either near the destination area or at more remote park/ride locations.

The option of obtaining transit service from providers other than the regional transit operator, including employers themselves, may entail fewer restrictions and come at lower cost. At the other extreme, high capital options such as rail services, bus transitways, and advanced technology circulators surely fit within the transit improvement menu, but require evaluation in the context of regional major-capital-investment decisionmaking.

Vanpooling is an alternative that strikes a balance between the door-to-door convenience of carpooling and the vehicle capacity of transit. Because vanpooling is a subscription service, pickup and distribution can be systematized and made convenient to the needs of the particular group. Vanpools are most commonly offered, promoted and subsidized by employers, but some programs are run by certain transit agencies and other parties, including individuals. Vanpools are

sometimes entrusted to join transit in using HOV facilities deemed inappropriate for general carpool use.

Carpooling offers door-to-door convenience that approaches that of the single occupant auto, particularly in suburban settings. It requires as few as two passengers with common schedules and geography to form an effective unit. The primary user disadvantage is imposition of workplace arrival and departure time constraints.

Unless travelers are willing and able to make arrangements on their own, carpooling requires providing information on acceptable matches. Both regional and employer-based efforts are used in supplying matching assistance. Employer-based programs have advantages even beyond that of offering match possibilities structured around a common destination. An employer can put corporate support behind a carpool program, including marketing and promotion, flexibility with work hours, and rewarding carpooling with employer-based incentives.

HOV systems in all their various manifestations are, as already stated, a major TDM strategy. They, in combination with the transit, vanpooling and carpooling given preference by each particular HOV facility, constitute alternatives to driving alone that offer inducements of travel time savings and avoidance of congestion-induced travel uncertainties. Integration of Travel Demand Management and HOV systems is covered in the next section of this paper.

Walking and bicycling is a legitimate TDM alternative to single occupant auto use. Public interest in exercise activities offers new potential for non-motorized travel if proper facilities are provided at the destination for bicycle storage and change of attire, and enroute in the form of suitable bikeways/walkways and sidewalks. Moreover, walking is an important distribution and circulation mode for those who arrive as a transit or van/carpool passenger.

Modal interconnectivity can make combinations of single occupant auto use, carpooling, transit and non-motorized travel attractive to travelers who cannot be accommodated by one mode operating in isolation. Low capital modal interconnectivity strategies include park/ride staging areas for carpools, vanpools and transit services; integration of bicycling or walking with either line-haul or local circulator transit services; enhancement of opportunities for "instant carpools" through provision of enroute carpool formation facilities, and linkage of employer-provided transit or ridesharing services with regional transit services.

Incentives and Disincentives

The configuration of cities today, particularly the shape of the suburban environment, and current costs from which the auto is exempt, make it difficult to produce alternatives that can stand alone as fully competitive alternatives to single occupant auto use. For many travelers, it will be necessary to provide inducements to overcome residual advantages of the single occupant auto. Inducements can be incentives (carrots) which make alternatives more attractive, or disincentives (sticks) which make auto driving less attractive. The most powerful inducements are incentives and disincentives working together.

Introduction of new disincentives tends to be politically feasible only when paired with both acceptable alternatives and compensatory incentives.

Transit/HOV Cost Incentives can be provided by employers through provision of direct subsidy payments to transit and van and carpool users. Even though public transit fares are already subsidized and van/carpoolers realize savings by sharing costs, driving alone has the cost advantage of being heavily subsidized as well. Most employers provide free or heavily subsidized parking even though parking is not free to them. Direct subsidies to users of alternatives helps to level the playing field.

A common method of subsidizing transit fares is for the employer to buy prepaid transit passes and resell them to employees below cost. Of course, if the site is not adequately served by transit, the effort will accomplish little. Vanpools may be subsidized in many ways, including assistance with van purchase financing, insurance and maintenance. One company, State Farm in Southern California, subsidizes carpooling by handing out chits at the parking lot which are cashed in at paycheck time.[2] Unfortunately, any employee transit/HOV subsidy over $15/month is subject to federal income tax, whereas parking subsidy is not.

Time and Convenience Incentives at employment sites and activity centers are best provided to transit users at the time of site design, by ensuring that buildings are placed close to transit stops and sidewalks, and not set back in a sea of parking. Time and convenience incentives for van and carpoolers are provided with preferential HOV parking; special spaces which are reserved, close-in and sheltered if possible. Figure 1 illustrates a suburban job site design incorporating these features. Both transit and van/carpools can also gain time savings if special business park and activity center entrances and exits are provided for them.

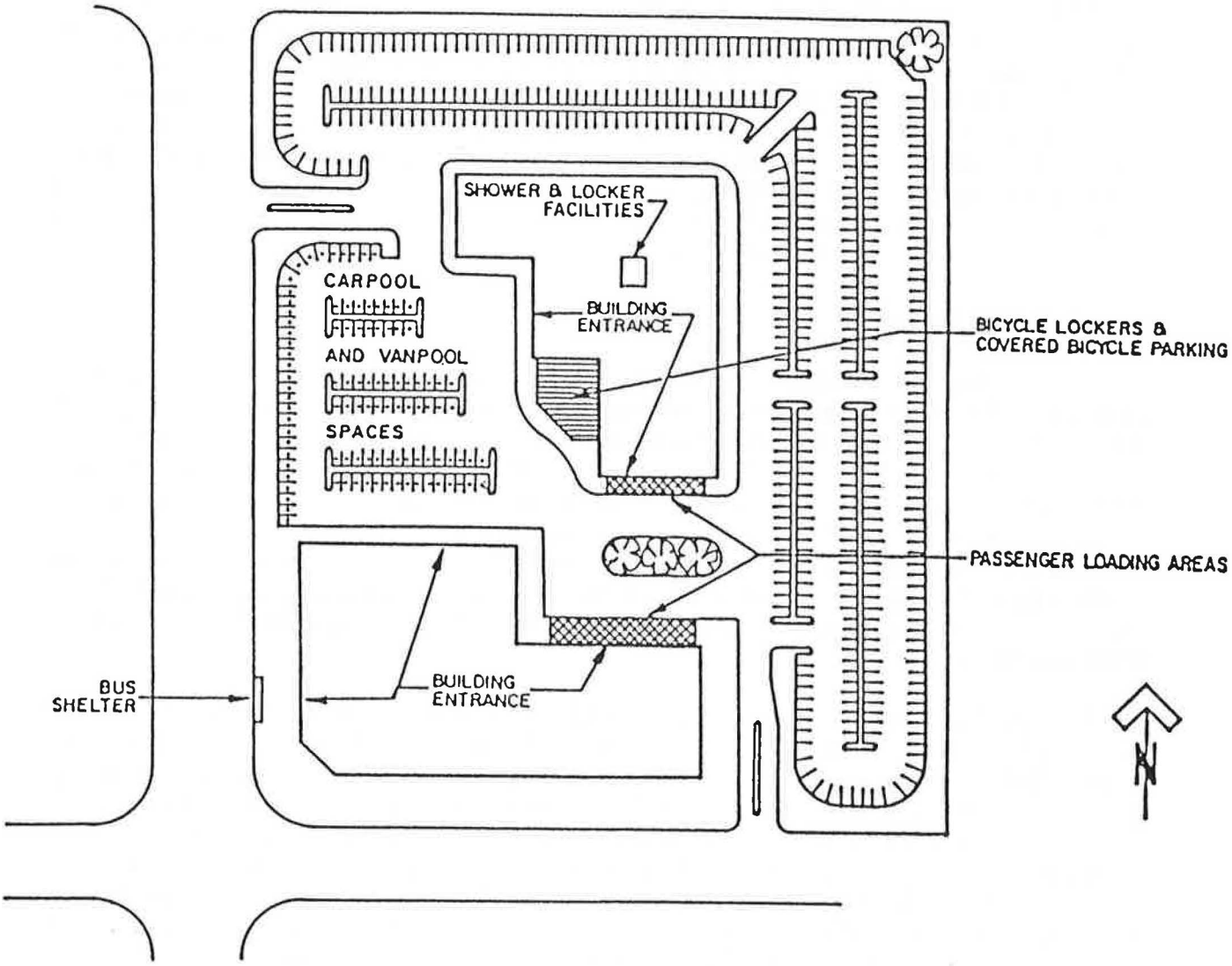
The effectiveness of preferential HOV parking depends on the relative advantage to van and carpoolers as compared to single occupant auto drivers, which in turn is a function of parking facility size. Where the parking facility is small, the most effective approach is to allow HOV parking on-site, and shift single occupant vehicle parking off-site.

Parking Management encompasses parking pricing programs, parking supply and location programs, and related incentive programs.[3] Parking pricing programs include elimination of subsidies so that commuters pay free market rates, and institution of parking charges where there are none. Parking supply and location programs include the preferential parking strategies discussed above, plus overall restraint on parking availability. Incentive programs associated with parking pricing include applying differential parking rates to lower charges as auto occupants increase in number.

The beneficial effect on transit use and ridesharing of parking cost occurs whether the cost is imposed by a parking facility operator or an employer. However, employers play a crucial role, because they generally influence whether or not, and how much, their employees have to pay. Posted pay-parking fee schedules do not reflect what the average employee pays, even in central business districts. In Washington, D.C., for example, half of all employees receive or find free parking;

Figure 1

EXAMPLE OF SUBURBAN JOB SITE WITH IMPROVED SITE DESIGN



in Los Angeles, more than half of downtown office workers who drive receive subsidized parking.

As quantified later in the section on TDM effectiveness experience, parking management is the hallmark of higher impact TDM programs. Unfortunately, provision of free parking as an employee benefit is a deeply ingrained practice, sometimes even written into union contracts. It is regarded as an aid to employee recruitment and retention, and as a perk that may disgruntle employees if taken away. Landowners fear that elimination of free parking will lower the desirability of their property and therefor property values. Any program of parking management, to gain acceptance, must address these concerns satisfactorily.

Transportation Allowance programs offer an incentive package specifically designed to balance imposition of parking pricing from the perspective of affected employees. The transportation allowance is a fringe benefit remuneration scaled to the parking cost the employee must pay with parking subsidy eliminated. If the employee continues to drive alone, he or she incurs no net financial gain or loss. If the employee uses transit or rideshares, financial gain is obtained. Current tax law, which makes any such allowance in excess of $15 a month non-taxable when applied to other than parking, is an undesirable complication, but not a prohibition. The solution under present conditions is to compute the tax cost to the employee and increase the transportation allowance accordingly.

Impediment Removal

Improved alternatives, and complementary incentives and disincentives, all serve to present the traveler with a set of choices in which transit and ridesharing offer enhanced travel time, cost and convenience relative to single occupant auto use. Mode choice modeling and related travel behavior studies have well established that relative travel time, cost and convenience among modal options influence travel decisions in significant and rational way. However, if there are barriers to giving up driving alone, travel time, cost and convenience improvements will be correspondingly limited in their effectiveness. As barriers are identified, TDM actions are being devised to help travelers become less "captive" to the single occupant auto.

Marketing/Brokerage focuses on providing information on alternatives to driving alone and on actively matching travelers with appropriate options; i.e., brokering alternative transportation. Marketing/brokerage seeks to break down barriers of ignorance about options, address needs for van and carpool matches, and form a line of communication between travelers with specific requirements and parties in a position to respond. An example of a party in position to respond might be a Transportation Management Association of employers and transportation agencies that could effect service changes. Employment site resource persons assigned to assist in marketing/brokerage functions through direct employee contact are known as On-Site Transportation Coordinators.

Guaranteed Ride Home programs address the concerns that a potential transit user or van/carpooler may have that an unexpected need to work late, or leave

early to tend to a family/personal emergency, may leave him or her stranded. Such programs provide an alternative mode such as a taxi at no extra cost or a company car. Indications are that the impediment to transit and van/carpool use thus removed is significant even though the backup mode is seldom actually used.

On-Site Services are being planned for and provided as a strategy to reduce real or perceived need for a car enroute or at midday to accomplish errands or secure day care for children. This action requires employment sites to be planned or retrofitted with restaurants, day care centers, and retail services such as dry cleaning and banking outlets.

Travel Time Management

Variable work hours, variable work weeks and alternative work arrangements are all travel time management strategies intended to shift the timing or frequency of travel in such a manner as to reduce travel peaks. Whereas other TDM strategies have as their primary objective reduction of the vehicle trips required to accommodate a given amount of travel, travel time management strategies are primarily attuned to shifting trips of whatever travel mode from the most congested times to times when more capacity is available, or, in some cases, the elimination of trips altogether. Examples include:

Flexible Work Hours, whereby an employer gives employees a degree of freedom to vary arrival or departure times, to either avoid peak travel conditions or allow flexibility to use an alternative mode.

Staggered Work Hours, a fixed scheduling of different work hours designed to get away from a sharp concentration of employee arrivals and departures by spreading employee starting and quitting times over a wider band of time.

Modified Work Week, the institution of a 4-day or other non-traditional work week that both eliminates an entire trip to work once each week or two, and, because of the longer workday, spreads arrival and departure times into off-peak periods.

Telecommuting, the substitution of advanced telecommunications equipment and networking for travel by allowing certain types of job functions to be performed off-site, at home or at a satellite work center, eliminating the need for daily commute travel or shortening trips.

Employer Participation

Some non-conventional transit services, a majority of van and carpooling programs, certain non-motorized travel and modal interconnectivity programs, most applications of incentives, disincentives and impediment removal actions, and all travel time management strategies, are employer based TDM measures. At the site of a single employer, TDM effectiveness is a function of individual program success, including the rate of employee participation in the options offered. However, in an employment area as a whole, a corridor, or a region, TDM effectiveness is heavily reliant on employer participation.

Without substantial employer participation, the vehicle trip reduction benefit of individual programs can be lost in a sea of status quo vehicular travel. Employer participation can be purely voluntary, influenced by incentives, or mandatory.

Rates of employer participation in carpooling programs, where participation is actively encouraged but still voluntary, appear to average about 4% for firms with less than 100 employees, and 35-40% for larger firms. Roughly half of all employees work for firms with less than 50 employees in a typical metropolitan area.[4] For offices, voluntary employer participation in the more common travel time management programs is similar.[5] Voluntary participation in subsidized transit pass programs appears to be only about 1/5 the participation in carpooling and variable work hours programs, probably indicative of the situation for voluntary incentive/disincentive programs as a whole.

More substantial employer participation appears to require mandatory employer involvement. The following approaches have been employed to require private sector cooperation with TDM objectives:[6]

Conditional Development Approval allows local governments to require private sector involvement as a condition of individual land development project approvals. The requirements are usually imposed on developers at the subdivision or preliminary site plan approval stage, with applicable elements passed down to individual employers through sale or lease agreements. Most TDM agreements reached as a condition of development approval set targets in terms of allowable vehicle trip generation for the development as a whole or per employee, but leave developers wide latitude as to means used for achieving the target.

TDM requirements placed on new development enforce employer participation by new and expanding firms, but leave other employers with no requirement for other than voluntary involvement. They are thus most applicable in the case of newly urbanizing areas that do not yet experience high levels of congestion. Some conditional development approval requirements apply only for a fixed time period, such as 10 years, and what happens afterward is yet to be seen.

Trip Reduction Ordinances, or traffic mitigation ordinances, can cover existing as well as new employers. They generally apply to all present employers over a given size, such as 50 or 100 employees, plus all future development. Typically they establish target vehicle trip generation rates, set to represent a reduction from pre-existing ambient conditions. Many, but not all, ordinances require annual surveys as a way of monitoring progress. In virtually all cases to date, failure to reach a target is not treated as a punishable offense, so long as the employer has demonstrated good faith efforts toward complying.

Both traffic congestion and air quality concerns have served as impetus for trip reduction ordinances. Traffic mitigation is the most common objective, but the most far reaching trip reduction ordinance to date is "Regulation XV" of the South Coast Air Quality Management District in southern California.

Transportation Management Districts are something of a hybrid between an assessment district and a trip reduction ordinance. They encompass and focus responsibility for action on all commercial entities of a designated area, and are specifically intended to create a collective public/private response to an areawide problem. Attainment standards are developed for the area, in terms of level of service or measures of effective use of transportation, and then a program of combined public and private actions is devised to bring the area into compliance.

The concept is quite new. At issue is whether such a district has legal authority to impose requirements on existing as well as new employment, require monitoring of conformance, impose penalties for non-compliance or non-performance, levy fees to encourage performance, and raise capital for transportation programs. The two such districts which have been formed, the Silver Spring, Maryland Transportation Management District and the Coastal Transportation Corridor in southern California, were created by a public entities under legislative action.

A Transportation Management District could logically evolve out of a Transportation Management Association, but there is a major distinction between the two. Transportation Management Associations are cooperative partnerships of private and public interests that have a shared interest in the satisfactory resolution of an impact area transportation problem, operating primarily in the realm of voluntary participation in any travel demand management actions. Transportation Management Districts would have legal power to involve key actors and institute key actions, and thus would operate in the realm of mandatory participation.

Factors in TDM Effectiveness

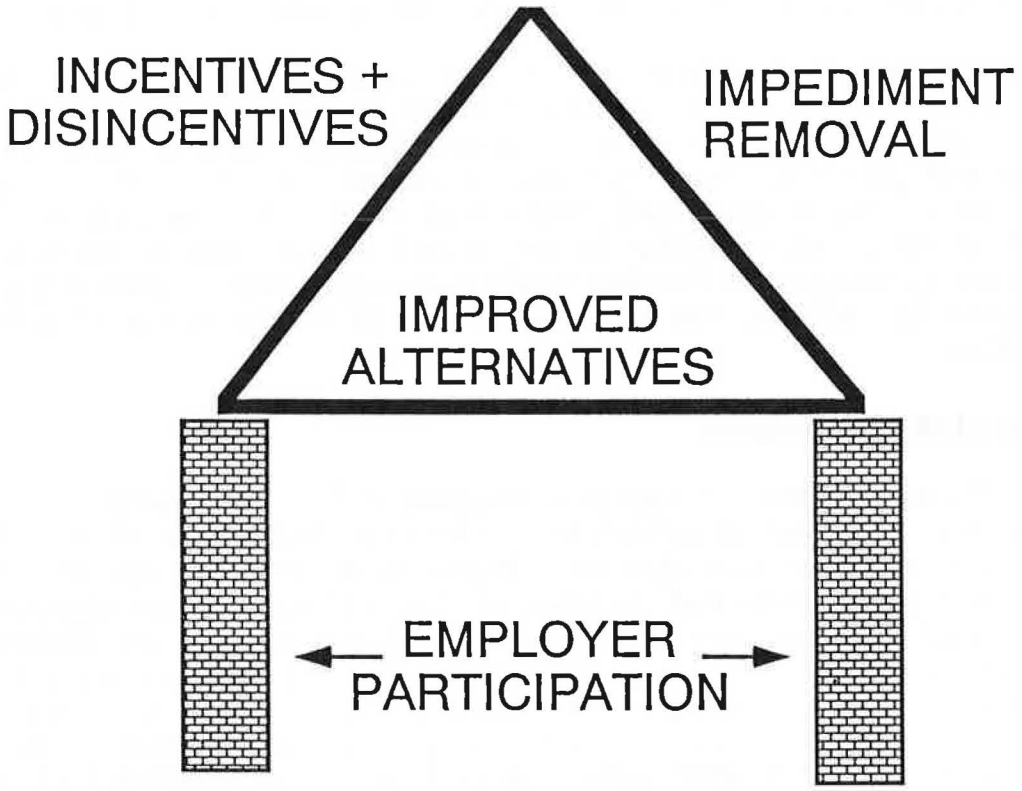
Effective Travel Demand Management requires a full complement of strategies encompassing improved alternatives, incentives and disincentives, barrier removal, and employer participation. Improved alternatives are essential to provide travel times, costs and convenience that will help attract travelers from single occupant auto use, and make imposition of certain auto use disincentives and mandatory requirements acceptable. Incentives and disincentives are needed to reinforce the attractiveness of alternatives, and to make auto driving less attractive. Removal of barriers that keep certain travelers "captive" to the single occupant auto will allow alternatives, incentives and disincentives to reach a broader clientele. Ensuring substantial employer participation will join individual employer efforts with those of others to ensure area-wide TDM effectiveness.

Figure 2 illustrates these relationships with the analogy of a structure that will be severely weakened or collapse without all four components. Such is the structure of Travel Demand Management.

To assess the likely impact of a TDM program on regional transportation system efficiency, it is necessary to understand the factors that impose a degree of dissipation on the effect that is observed at an individual employment site with

Figure 2

STRUCTURE OF EFFECTIVE TRAVEL DEMAND MANAGEMENT



TDM. Relative to effectiveness in work trip reduction for large participating employers in the office land use category, the dissipation elements are:[7]

- Inclusion of small employers along with large ones. Overall, small firms exhibit lower TDM effectiveness than medium to large firms, and have a much lower employer participation rate. (Half of all employees work for firms of under 50 people, on average.)

- Inclusion of non-office employers along with office employers. Some TDM actions are impractical for non-office employers, for example, work hours management has little application to retail employees, who tend not to arrive and depart in peak hours anyway.

- Inclusion of non-participating employers. This is a much more serious factor in a voluntary program that in a fully mandatory program.

- Inclusion of non-work travel. Few TDM measures directly address non-work travel, except those which seek to reduce "captivity" to the single occupant auto by introducing on-site services.

- Inclusion of travel not generated by TDM-area employment. Such unaffected travel will include residence-based travel if not included in the program, and all travel between areas not included.

The degree of dissipation potentially involved can be illustrated with TDM effectiveness estimates that have taken all such factors into account. Probably the first such estimate was that prepared for the 1987 I-494 Corridor Study in Minneapolis.[8] In this study, workplace based TDM actions were estimated to reduce peak hour vehicle trips at the largest participating office employers by 33% (Low Scenario) to almost 50% (High Scenario). These "ideal employer" results were shown to equate to peak hour vehicle trip reductions at the average workplace of 4% to 10%, respectively, after taking into account smaller employers, non-office employers, and non-participating employers. This in turn translated into peak hour vehicle trip reductions of 1% to 3% on the I-494 segment under study, after accounting for inclusion of non-work travel, and travel from land uses and areas not included in the corridor TDM program.

This study did not assess mandatory participation, except for new development under the "High Scenario." It also faced the most difficult set of circumstances; a circumferential highway running through an entirely suburban residential and employment area, with no TDM programs assumed in areas beyond the suburban corridor segment under study. When the workplace TDM actions were combined with HOV lanes and ramps, and ramp meter bypass lanes, the "High Scenario" TDM estimates projected a 9% peak hour vehicle trip reduction potential for I-494.

TDM Effectiveness Experience

A major TDM research effort currently underway, under contract to the Traffic Operations Division of FHWA, is presently beginning the process of synthesizing current TDM experience. It has been possible to draw some TDM information

from literature assembled for that project, but much of the experience presented here is necessarily from earlier compilations. Unless otherwise footnoted, all 1970s data is from the FHWA handbook *Traveler Response to Transportation System Changes,*[9] and all 1980s data is developed from the FHWA report *Evaluation of Travel Demand Management Measures to Relieve Congestion.*[10]

Insofar as possible, all examples are presented in terms of percentage reduction in the number of vehicle trips per traveler, as compared to prior conditions, or to control areas without the TDM strategy or strategies in place. In many instances this has required application of person trip per vehicle trip assumptions for specific modes. For consistency with FHWA case studies, assumptions of 2.5 persons per carpool, 12 persons per vanpool, and 30 persons per bus have been used.

Transit improvements in the suburbs of a conventional nature are perhaps typified by the 1987-1988 restructuring of bus service in the suburban Bellevue, Washington CBD, which was accompanied by added transit service hours and introduction of service from exurban areas. Transit usage by Bellevue CBD employees overall increased by 38%, to a mode share of 11%,[11] producing a $1^1/_2$% reduction in vehicle trips per CBD employee.

Expansion of bus service by 32% in the I-35W corridor of Minneapolis, through the introduction of express routes to the CBD, gave a 12% increase in ridership in 1972-1974, and increased the AM peak period corridor-wide transit mode share to 19%. The corresponding reduction in corridor-wide vehicle trips per traveler was $1^1/_2$%. However, measured in terms of AM peak period corridor travel to the Minneapolis CBD, the transit mode share increased by 18%, producing a 39% mode share, accompanied by a 10% reduction in vehicle trips per CBD-destined traveler.

A program of multifaceted improvements of alternatives, implemented by the Tennessee Valley Authority at their Knoxville headquarters in the context of a pre-existing pay parking disincentive, gave a 1973-1974 reduction in vehicle trips per TVA employee of 27%. The part attributable to a targeted express bus service focused on TVA's downtown offices was a vehicle trip reduction per TVA employee of 15%. After addition of transit fare subsidies as part of an overall incentives strategy, the total 1973-1977 reduction was 58%, still the standing record for TDM programs. The part attributable to the targeted express bus service was a vehicle trip reduction per TVA employee of 37%.

Vanpooling, as a part of the TVA program example, can be attributed a vehicle trip reduction per TVA employee of 3% prior to implementation of vanpool subsidies as one of several transit and ridesharing incentives, and 9% after incentive program implementation. The 3M Company vanpool program at their St. Paul, Minnesota headquarters was credited with a 9% reduction in vehicle trips per employee in 1977. The 3M program was not yet at its peak in 1977, but was fairly close to more recent (1985) performance. Cost and convenience incentives are part of the 3M program.

Carpooling programs that specifically involve employer carpooling assistance and encouragement were found in the National Ridesharing Demonstration Program to reduce vehicle trips per employee by 5% to 8% as measured at the site of participating employers. The higher rate is for programs with proactive measures such as in-house matching and special incentives, and to some extent includes the effect of vanpooling as well.[12] In the TVA example, carpooling can be attributed a vehicle trip reduction per TVA employee of $8^1/_2$% prior to implementation of reduced parking fees for carpools, as part of their total ridesharing and bus incentives package, and 9% after incentive implementation. The disincentive imposed by pay parking on driving alone applied in both periods.

Incentives have their effectiveness illustrated in most of the preceding examples. The high-end vehicle trip reduction percentages for each category of improved alternatives reflect inclusion of incentives in the TDM program package. The importance of incentives is further demonstrated by a final look at the TVA program example. From 1973 to 1974, improved alternatives reduced vehicle trips per TVA employee by 27%. From 1974 to 1977, with addition of cost and certain time and convenience incentives, vehicle trips per employee were reduced by 42%. TVA's express bus and vanpool alternatives were obviously further improved in the latter period in response to greater usage, so it cannot necessarily be concluded that incentives were more important than improved alternatives, but it is clear that they both played major roles.

A unique incentive program was introduced in 1989 by State Farm Insurance in Orange County, California. Each employee, upon arrival each day, is given a coupon worth 50¢ if he or she came via 2-person carpool, $1.00 if via 3-person carpool, and $1.50 if via 4-or-more-person carpool, bus, bicycle, or walking. When added along with vanpool subsidies to what had been a largely passive carpool program, these incentives produced an immediate 22% reduction in vehicle trips per employee. Compared to other firms in their area, State Farm produced 30% less vehicle trips per employee.

Parking Management, which introduces the disincentives to driving alone of pay parking and constrained parking, offers demonstrably superior trip reduction potential. Of 11 top individual TDM programs evaluated recently by the Federal Highway Administration, 8 out of 11 have some measure of restricted parking, and 7 out of 11 charge for employee parking. Of the top 6 as measured by trip reductions achieved, 4 charge for employee parking; of the 6 with the lowest number of vehicle trips per employee, all charge for parking.

Most TDM programs with parking management also include other TDM actions, making it difficult to quantify parking management's undeniably major role. The experience of 20th Century Insurance in the San Fernando Valley of Los Angeles is helpful. Their initial effort at TDM, offering preferential carpool parking space locations and a $15 per month subsidy for vanpools and transit users, produced negligible impact. Institution of a $30 per month parking charge with carpools exempted, enhanced with impediment removal in the form of an on-site

transportation coordinator and a guaranteed ride home, netted a 25% reduction in vehicle trips per employee.[13]

The 11 TDM programs evaluated by FHWA ranged in effectiveness from 6% to 48% reductions in vehicle trips per employee. These were single employer, not areawide, programs. The 3 programs without any measure of restricted parking ranged from 10% to 30% reductions, and averaged 18% ($11^1/_2$% without State Farm, described above). The 8 programs with restricted or pay parking ranged from 6% to 48% reductions, and averaged 27%.

The full range of TDM measures employed by the better of these programs is illustrated by the engineering firm of CH2M Hill in Bellevue, Washington, which achieved a 26% vehicle trip reduction. This firm gave a $40 per month compensation increase as a transportation allowance while instituting a parking charge of $40 per month. They continue to give transit users a $15 monthly pass discount, and carpoolers a free parking space, both in addition to the transportation allowance.

Impediment Removal effectiveness is only now beginning to be quantified, very tentatively. Analysis of time-series surveys in the Seattle area suggests that use of transportation coordinators in conjunction with offering a guaranteed ride home and other complementary programs has a beneficial employee trip reduction impact on the order of 1% over a one-year period, and maybe 3% or more over a 2-year period.[14] Modeling studies done with the same data set give preliminary indication that transportation coordinators and the guaranteed ride home are of roughly equal importance, at least for transit users.[15] Trip generation surveys in Minneapolis-St. Paul have been used to suggest that placement of offices in developments with mixed land use may offer vehicle trip reduction potential on the order of 5% as compared to monolithic office developments.[16]

Travel Time Management that focuses on variable work hours programs such as flexible work hours and staggered work hours has been found to average a peak hour reduction in trips per employee of 22% as measured at the site of participating employers.[17] As might be expected, results are highly variable. At individual downtown San Francisco firms in 1978, for example, the peak hour trip reduction achieved with variable work hours ranged from 4% to 49%. Such programs, as previously noted, do not eliminate vehicle trips per se; they spread them into less traveled hours. If critical transportation system elements are equally crowded in the hours next to the peak, variable work hours programs offer no benefit.

Employer Participation rate data were given earlier in the section on that topic. Areawide TDM effectiveness is a function of both employer participation and effectiveness of the individual programs encompassed. There are four areawide efforts for which there is sufficient data presently available to judge overall TDM affectiveness in scenarios covering multiple employers.

A voluntary program in downtown Hartford, in which individual companies have used parking management and other strategies to achieve employee vehicle trip

reductions on the order of 25%, has yielded a $2^1/_2$% employee vehicle trip reduction overall. The overall reduction is measured across the downtown as a whole, between 1981 and 1987. The Bellevue, Washington suburban CBD has 17% fewer vehicle trips per employee as compared to other Seattle suburban employment areas. This is the result of mandatory TDM participation by new development since 1983; individual employer programs encompassing parking management, with employee vehicle trip reductions as high as 48%; and a built environment with offices placed close to sidewalks and transit stops, along with mixed land use.

Hacienda Business Park in Pleasanton, California, is covered by an ordinance that requires TDM participation by new and old employers, and multi-tenanted buildings. The Pleasanton approach to TDM places heavy emphasis on peak hour trip reduction through variable work hours. Business park employees generate 4% fewer vehicle trips per employee than Pleasanton as a whole. In Pleasanton as a whole, the drive alone rate actually increased between 1985 and 1988. Peak hour employee vehicle trips were down 9%, however, thanks to shifting trips out of the peak hour.

Bishop Ranch business park, also in Northern California, has a program run by a Transportation Association which, although not covered by ordinance until recently, is dominated by three major employers. Bishop Ranch employees in 1988 generated 17% fewer vehicle trips per employee than adjacent suburbs. This was accomplished without parking management, but may not be sustainable without stronger TDM actions, as vehicle trips per employee increased 16% in the 1986-1988 period of project maturation.

TRAVEL DEMAND MANAGEMENT AND HOV

With TDM supportive of HOV system effectiveness, and HOV systems as a major TDM strategy, how then do TDM and HOV work together in practice? Evidence is that HOV systems and TDM are both major players, and that when system design is developed from this perspective, the best results will be secured.

Transit and HOV

Transit service is the senior partner of HOV systems. The first major HOV facilities were opened 20 years ago as busways or exclusive bus lanes, with van and carpools introduced more recently to those facilities which can accommodate them. Even today, with greater emphasis on van and carpooling, the majority of passengers on HOV facilities are bus passengers.

Table 1 lists in descending order, for 33 HOV facilities in freeways or separate rights-of-way, the 1989 a.m. peak hour percentages of all passengers (including all van and carpool occupants) that are bus passengers. All North American HOV facilities and lanes are covered, except for five for which data is not available.[18] The average is 63% bus passengers, the median is 41%, and the average excluding 6 facilities which allow only buses, or buses and vanpools, is 35% bus passengers.

Table 1

1988 AM PEAK HOUR, PEAK DIRECTION, BUS AND VANPOOL RIDERSHIP ON ON HOV FACILITIES IN FREEWAYS OR SEPARATE RIGHTS-OF-WAY

Location	HOV Facility	AM Peak Hour Inbound Passengers			Percent
		Bus	Van/Carpool	Total	Bus
Union City, NJ/NY	Rt. 495	34,685	0	34,685	100
Ottawa, Ontario	O-C Transitway	11,000	0	11,000	100
Pittsburgh, PA	East Busway	5,892	0	5,892	100
Pittsburgh, PA	South Busway	2,098	0	2,098	100
Vancouver, B.C.	H-99	1,080	0	1,080	100
Denver, CO	US 36-Boulder Tpk.	1,000	0	1,000	100
New York, NY	Gowanus Expy.	8,686	173	8,859	98
New York, NY	Long Island Expy.	7,838	214	8,052	97
Houston, TX	I-45N (pre-carpools)	2,810	416	3,226	87
Seattle, WA	SR 520	3,140	498	3,638	86
Seattle, WA	I-90	1,250	229	1,479	85
Seattle, WA	I-5	2,605	1,105	3,710	70
Fort Lee, NJ/NY	I-95	1,800	919	2,719	66
San Francisco, CA	US 101	1,995	1,490	3,485	57
Hartford, CT	I-84	600	604	1,204	50
Pittsburgh, PA	I-279	485	498	983	49
Houston, TX	I-10 (Katy)	1,820	2,595	4,415	41
Los Angeles, CA	San Bernadino	2,750	4,352	7,102	39
Washington/No. VA	I-395 (Shirley)	5,621	9,483	15,104	37
Houston, TX	I-45S (Gulf)	840	1,598	2,438	34
Minneapolis, MN	I-394 (interim)	455	942	1,397	33
San Francisco, CA	Oakland Bay Bridge	3,535	8,273	11,808	30
San Jose, CA	Rt. 237	630	1,720	2,350	27
Fairfax Co., VA	I-95	1,226	5,336	6,562	19
Houston, TX	US 290 (Northwest)	600	3,248	3,848	16
Washington/No. VA	I-66	398	2,278	2,676	15
Miami, FL	I-95 (1985 data)	350	2,460	2,810	12
San Jose, CA	Rt. 101	105	803	908	12
San Diego, CA	I-15	350	2,686	3,036	12
Seattle, WA	I-405	20	435	455	4
L.A./Orange Co., CA	I-405	120	3,705	3,825	3
L.A./Orange Co., CA	Rt. 55	50	2,687	2,737	2
L.A./Orange Co., CA	Rt. 91	0	3,112	3,112	0
TOTAL, all facilities		105,834	61,859	167,693	63
TOTAL, facilities open to carpools		33,555	61,472	95,027	35
Median percentage bus passengers relative to total passengers					41

A comparable summary for arterial HOV facilities is not available, but a majority of arterial facilities are for buses only.

Transit improvements, including reroutings, establishment of new express services, and increases in service levels have accompanied most HOV facility openings, especially those with heavy transit usage. Clearly transit and transit improvements are crucial to the success of many HOV systems. In turn, the travel time savings offered by HOV systems make transit much more attractive to potential users and offer operating efficiencies. Transit travel time reductions achieved with individual HOV treatments have ranged from nothing to 30 minutes, depending on characteristics of the applications, and reliability increases have similarly ranged from marginal to more than a tripling of buses arriving on time or early.[19]

The Shirley Highway Busway (I-95) through Northern Virginia into Washington, D.C. served buses only from partial opening in 1969 until van and carpools were admitted in 1974. The inbound a.m. peak period reduction in vehicles per person, as measured for all travelers crossing a 4-mile wide corridor (including 7 other arterials), was reduced by 5% in the all-bus 1970-1973 period, and 16% after introduction of van and carpools in 1974.[20] (This reduction was helped along by gas shortages, but has apparently held over the years.) In 1988 the 2-lane reversible facility carried 160 buses during the a.m. peak one hour, and 2,300 van and carpools.

Transit will not perform as well in all corridors. Like any transit operation, the viability of bus lines on HOV facilities is a function of both service and geographic characteristics. HOV facilities radial to a region's CBD are much more likely than any other to provide the travel time savings, and encounter the trip densities and destination parking costs, that make conventional transit successful. The only facility in Table 1 that carries over 500 transit riders in the peak hour, peak direction without being radial to the region's CBD is California Rt. 237. Located in the vicinity of San Jose, Rt. 237 serves the "Silicon Valley" employment area. New transit service designs intended for dispersed travel markets may hold the most promise for non-radial HOV facilities.

Carpooling/Vanpooling and HOV

Transit service may be the senior partner of HOV systems, but van and carpooling is the fastest growing component of system users. Looking at Table 1 from the van and carpooling perspective, 65% of all a.m. peak hour passengers on 27 HOV facilities in freeways or separate rights-of-way which allow van and carpools are van and carpool occupants. Van and carpooling are much more suited to dispersed travel patterns than transit service, but do require enough concentration of trip origins and destinations to allow carpools to be formed in sufficient numbers.

TDM carpooling/vanpooling programs have a double benefit for those HOV facilities which may be a bit ahead of their time or otherwise marginally used. By helping increase the use of HOV facilities in the vicinity, TDM van and carpooling

programs not only increase their efficiency, they also increase the perception of their usefulness by making the facilities appear less empty. This can be an important factor in successful implementation; an additional argument for coordinated TDM and HOV development.

Like the Shirley Highway Busway, the San Bernadino Busway from El Monte to Los Angeles along I-10 was open to buses only for its first 4 years of operation. In 1976-77 it was opened to van and carpools. The inbound a.m. peak period reduction in vehicles per person, in addition to what had been achieved by the bus operation, was 4% as measured on I-10, or 2% as measured on both freeways (about 3 miles apart) in the corridor.[21] In 1988 the inbound lane carried 1,400 van and carpools during the a.m. peak one hour, in addition to 70 buses. TDM programs in central Los Angeles will increasingly contribute to San Bernadino Busway usage as South Coast Air Quality District regulations continue to be implemented.

Incentives, Disincentives and HOV

Just as TDM incentives and disincentives support reduction in use of the single occupant auto, they play an important role in amplifying use of HOV systems by both transit passengers and van/carpoolers. Synergistically, even as TDM incentives and disincentives are providing time and cost reasons for transit use and ridesharing, the HOV systems add their own time savings (and sometimes toll savings) to the equation.

Development of mode- and occupancy-choice models in the Shirley Highway corridor, for purposes of improved HOV forecasting, has helped provide a clue as to the importance of carpool programs and incentives.[22] To quantify effectiveness in inducing ridesharing, several measures of TDM activity were expressed in terms of their equivalent in minutes of time savings for HOV users. Two surrogates for carpool programs and encouragement, employment of the traveler in the federal government or a by large employer, were found to be equivalent to 12.5 and 8.1 minutes of HOV user time savings in explaining who chooses to rideshare. Parking incentives at the worksite were equivalent to an 8.0 minute HOV time savings. Flexible work hours were equivalent to 2.7 minutes of time savings in enhancing ridesharing, but similar studies in the Seattle suburbs are in conflict; Seattle results suggest flexible work hours may be detrimental.[23]

Given that HOV facility time savings are in the range from nil to 30 minutes, it follows that the importance of TDM actions is of the same order of magnitude as the importance of HOV time savings in encouraging use. An HOV system not paired with TDM is performing with one hand tied behind its back.

Modal Interconnectivity and HOV

Transit use of non-arterial HOV systems consists primarily of express bus routes, often serving relatively low density residential markets. For such routes, park-ride facilities are an essential ingredient, providing modal interconnectivity between the auto as a passenger collection and transit access mode, and transit as the trunk line and distribution mode. Van and carpooling use of HOV systems is

similarly enhanced by park/pool lots, which supplement home pickup of passengers by allowing van and carpool members from scattered locations to drive to the park/pool lot, leaving all but the pool vehicle there. In Houston, where there are four major HOV "transitway" facilities, there is one car parked at park-ride lots for every three round trips via transitway bus or van/carpool. Houston's two matured transitway facilities have achieved 23% and 14% reductions in vehicles per person, as measured on the freeways traversed by the transitways (not the corridor as a whole).[24]

Modal interconnectivity between an HOV facility, a parking management system, and a pedestrian system is featured in the design of I-394 in Minneapolis, now under construction. Eleven miles total of concurrent flow diamond lanes and reversible HOV facility are being linked with three new parking garages, two via direct ramps. Van and carpoolers from I-394 are eligible for reduced rates in these garages. The garages, and I-394 bus terminal facilities which they contain, will be connected by skyway to adjacent buildings that are on the downtown Minneapolis skyway system, a network of weather-protected grade-separated pedestrian walkways.[25]

An interim I-394 HOV lane is in use during construction, and has been operating in conjunction with two downtown parking lots opened by Minnesota Rideshare to provide free parking for registered carpools. The combination has resulted in a 9% reduction in vehicles per person, as measured on the facility. The percentage traveling in van and carpools increased by over 12% without detriment to transit usage. An HOV time savings averaging 8 minutes, combined with the parking pricing incentives, has achieved this result even with interim conditions of lane discontinuity and traffic signal control.[26]

HOV modal interconnectivity with bus transit -- carried to its logical conclusion -- can, under appropriate circumstances, provide a rapid transit service that is quite economical. Modal interconnectivity allows buses in rapid transit service to have the flexibility to use any combination of running on busways, lanes reserved for buses or for all HOV's, freeways in mixed traffic, and/or streets in mixed traffic. The more expensive options need only be used for those portions of a transit route where they are critical to bypass congestion and bring service close to high-activity centers. Wherever HOV system elements can accommodate van and carpools, costs can be shared between the transit and highway system.[27]

Using modal interconnectivity and HOV systems to provide bus rapid transit is beyond what is commonly considered as travel demand management, and moves into the realm of multi-modal infrastructure, discussed in the section on "Future Directions." It places special demands on physical design, discussed next.

Physical Design for Synergy

The fullest advantage from joint application of HOV and TDM systems will be gained when HOV system design deliberately supports TDM improvements to alternatives to the single occupant auto. In the case of transit improvements, that means provision of special ramps where bus routes diverge from the HOV facility,

as done along the Shirley Highway Busway; on-line stations where buses can stop at major enroute passenger destinations and transfer points, out of the way of van and carpools, as provided on the El Monte Busway; and direct connections from HOV lanes into HOV facilities, like the connection from I-5 to the Seattle Bus Tunnel. For van and carpools, it means provision of exclusive ramps and interchanges at sites such as major employment centers to provide significant advantage over low occupancy vehicle access.

Obviously transit ramps and van/carpool ramps can be one and the same in many instances. Transit and van/carpools have differing needs under some circumstances, however, and to overlook this in design can detract significantly from performance. A transit vehicle that is making a stop and continuing on must be able to do so without a high time penalty. On-line stations, such as on the El Monte Busway, generally meet this need. Poorly thought-through off-line stations, particularly those that require weaving across mixed traffic and passage through mixed traffic interchanges, but also those with exclusive but circuitous access, can largely or totally negate the time advantage of the HOV facility.

Properly done, melding HOV systems and transit improvements can provide segments of true bus rapid transit. If the special needs of transit service are not dealt with appropriately, transit will remain the poor cousin of automotive transport, even though it may have been afforded some highly visible infrastructure. If transit is to be a significant component of an HOV application, as it is in so many of the more successful projects, it deserves the analysis of travel demands and planning of operations that should be done for any major transit capital investment, with follow-through in HOV facility design to ensure success.

FUTURE DIRECTIONS

The futures of travel demand management and HOV systems are -- or should be -- intertwined with each other and with provision of new infrastructure and land use decisions. This is a future that lies beyond TDM alone or HOV systems alone, and is best described as "Transportation Management."

Transportation Management

Transportation Management is the concept of solving the travel demand vs. transportation supply imbalance through systematic, coordinated efforts that encompass provision of new strategic, manageable, multi-modal infrastructure; transportation systems management; land use management; and travel demand management.[28] Actions can be "supply side" or "demand side", long term or short term, and focused on management to obtain better use of existing resources or on structural change to achieve fundamental redesign of the existing environment. Transportation Management may be thought of as a "toolbox" of actions which may be strategically and creatively applied to achieve the desired ends.

New infrastructure must be made as effective and supportive of mobility and management goals as possible, given limitations in the amount of new

transportation infrastructure that can be provided, for reasons of cost and available space. *Strategic infrastructure* seeks to meet these objectives by focusing on providing missing critical elements in the transportation system. These elements may be missing links whose omission leads to lack of system integration and flexibility, with associated travel circuity and bottlenecks, or missing classes of facility that impose traffic on routes ill-suited to it.

Manageable infrastructure goes beyond strategic infrastructure by being designed for maximum efficiency in operation and use through complementing and enhancing travel demand management. Manageable infrastructure, as best we can conceive of it today, is transportation infrastructure offering built-in emphasis on HOV, transit and pedestrian mobility. With manageable infrastructure, TDM and other programs of single occupant auto de-emphasis can build upon inherent advantages not present in conventional traffic plans.

HOV systems are manageable infrastructure in the here and now. By offering time savings to high occupancy vehicles, they help guarantee a higher ratio of person-to-vehicle usage than could be provided with the same investment in a conventional highway, and work in partnership with other travel demand management actions intended to encourage transit use and ridesharing. In the next section of this paper a hypothetical example of manageable infrastructure is presented that suggests how the concept may be further developed into a total network embodying advanced redesign of conventional transportation and land use systems.

Multi-modal infrastructure brings in the companion concept of providing multiple modal options and full integration of those options. Infrastructure planning for multiple options addresses the full range of conventional highways, HOV systems, and special transit facilities and services, with special attention to integrating their use. The options should recognize the needs of various groups of travelers in their design and location, providing viable alternatives to the single occupant auto wherever feasible.

Transportation Systems Management or TSM, as definitionally narrowed in context with TDM, focuses on supply-side operational efficiencies. It includes Traffic Engineering actions such a ramp metering, lane management, channelization improvements, access management, traffic signal system improvements, various forms of traffic restrictions, and enforcement. It also covers incident management, including monitoring of traffic conditions, motorist information systems and incident response. In the future TSM may increasingly rely on advanced traffic management systems and associated intelligent vehicle highway system technologies for added effectiveness. As an element of Transportation Management, TSM requires coordinated action to make sure that improvements in one location do not result in service degradations in other parts of the total transportation system.

Land Use Management addresses the physical environment from which travel demand patterns are formed. The potential solution to mobility problems, and the suburban mobility problem in particular, rests heavily on the shape of this environment. Achieving change in the land use environment to enhance mobility

and transportation efficiency is unfortunately a highly complex and difficult undertaking that encounters a byzantine web of economic, political, and legal forces and constraints, both public and private; individual preferences; and even lack of reliable information about which of certain land use arrangements are the most beneficial. Be that as it may, there are specific actions that could favorably impact on the current fragmented approach to shaping the physical environment.

Land use planning should identify the preferred development plan, and the transportation infrastructure should then be designed to reinforce it, thus harnessing the development shaping power of transportation access. Greater attention to achieving balanced land use, from mixed-use site development to attaining better matches in local area jobs/housing ratios at all income levels, can help reduce travel needs. Judiciously applied higher densities and improved site design can make transit and ridesharing more convenient and economical to provide, enhancing alternatives to the private auto. Land use reform and innovation, and manageable/multi-modal infrastructure, hold powerful long term potential if developed and applied together.

Travel demand management was discussed at length in the first part of this paper. It can be a short term action to obtain a measure of relief from congestion today, or a long term action to protect transportation investments from tomorrow's excess demand. The more manageable/multi-modal infrastructure that can be developed, the more effective tomorrow's TDM will be.

Manageable Infrastructure and TDM

At the Stone Mountain Conference on Transportation for Suburban and Activity Center Locations sponsored by TRB in 1988, a hypothetical example of manageable infrastructure was presented to suggest how the concept may be further developed into a total network embodying advanced redesign of conventional transportation and land use systems.[29] This example is reproduced here in Figure 3 to provide an illustrated "vision" of future directions for travel demand management and HOV.

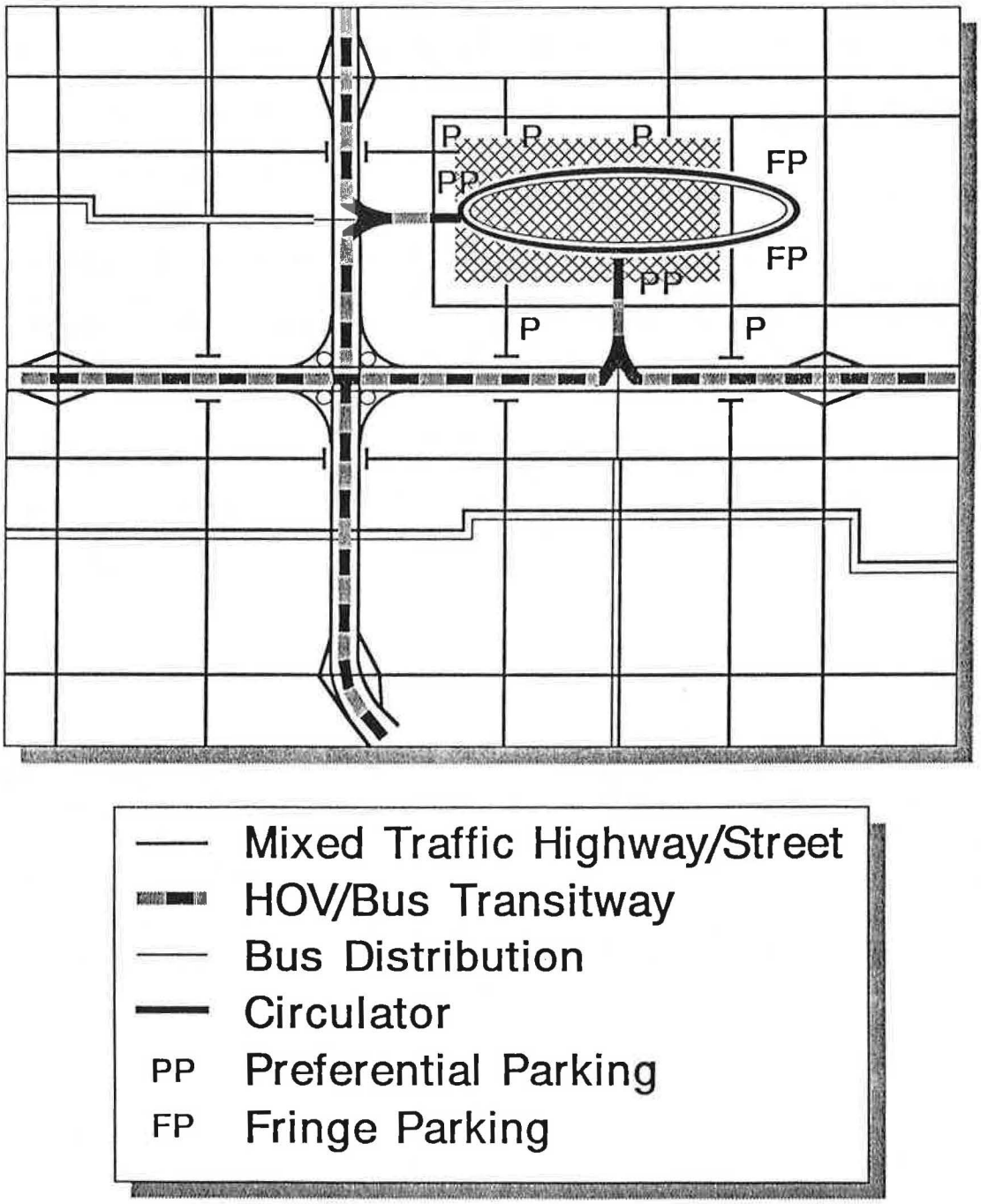
The conceptual example focuses on an activity center. The activity center itself is the crosshatched area. It is a pedestrian zone, connecting mixed land uses without auto penetration, an advanced application of land use management. An array of on-site services is assumed, to reduce midday or enroute need for an auto to the bare minimum, thereby removing an impediment to ridesharing.

Within the pedestrian precinct, internal circulation and transit/HOV passenger trip distribution is enhanced by a "circulator," shown as an ellipse for illustrative purposes. This "circulator" can be any form of pedestrian movement enhancement, including Minneapolis-St. Paul type skyways. The pedestrian zone and its pedestrian systems strengthen both walking and bicycling as auto alternatives and provide modal integration at the core of the activity center.

Carpools and vans are allowed to penetrate into preferential parking facilities located directly on the circulator, indicated by the letters "PP" in Figure 3. This

Figure 3

MANAGEABLE INFRASTRUCTURE



strong convenience and time savings incentive for HOV use is assumed to be further undergirded by parking pricing incentives.

The closest-in circulation road for mixed traffic is the rectangle around the activity center proper. General purpose mixed traffic is allowed to penetrate no further than the unrestricted use parking garages indicated by the letter "P." These garages would charge substantial rates for long term parking as part of the overall parking management program.

Low occupancy vehicles may use garages on the circulator if they drive to the fringe parking facilities located outside of the activity center, at the locations indicated by the letters "FP." The fringe parking is located on major arterials with freeway interchanges, but with less direct access than provided to carpools, vanpools and transit. Low occupancy vehicle access time disincentive is thus maintained.

Carpools, vanpools and transit are afforded direct access into the activity center, and into the preferential parking, via HOV/bus transitways. These transitways provide exclusive facilities approaching from each compass direction, the trunk line elements of HOV system and transit alternatives to single occupant auto access.

Direct access is provided local buses from surrounding areas by connecting local streets with the inner links of the transitways. This connection is by exclusive facility not open to low occupancy vehicles. By allowing carpools and vanpools from the local area to use the exclusive bus access routes in as far as the preferential parking facilities, travel time incentives can be provided even short trip HOVs.

CONCLUSIONS

TDM and HOV systems both provide here-and-now transportation management actions to increase transportation system efficiency. Working together, they are more effective than either can be alone. The importance of TDM actions is of the same order of magnitude as the importance of HOV time savings in encouraging HOV system use, and their effects are synergistic. Looking to the future, TDM and HOV systems together form part of a transportation management "vision" incorporating manageable/multi-modal infrastructure, other TDM and HOV system elements, TSM and land use management into an advanced expression of transportation efficiency and effectiveness.

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Consultant, Inc. and K T Analytics, Inc. Because of timing, information from this FHWA research is very preliminary, and along with the considerable data presented here from earlier sources, may well be superseded by the final research results. In any case, the author takes sole responsibility for anything that may be wrong with the findings and conclusions presented here.

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