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# Parking and Transportation Demand Management

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# Foreword

Since 1990, the Task Force on Transportation Demand Management has provided a focus and a forum within TRB on transportation demand management (TDM) and has sought to promote a better understanding of the demand management concept within the transportation profession. As part of its activities, the task force has sponsored or cosponsored a number of sessions at the TRB Annual Meetings. The first several papers in this volume are from TDM-related sessions at the 1994 TRB Annual Meeting and cover a wide variety of topics related to TDM. Readers with an interest in experience gained from TDM programs will find papers related to TDM program evaluations, TDM case studies, employee commute options, telecommuting, ridesharing, and the impact of mandated TDM programs on working women.

Readers with an interest in parking management and practice will find papers concerning the assessment of parking demand versus supply.

The papers presented in this volume are sponsored by the TRB Committee on Transportation System Management and the Task Force on Transportation Demand Management.

# Seeing the Trees and Missing the Forest: Qualitative Versus Quantitative Research Findings in a Model Transportation Demand Management Program Evaluation

CRAIG JESUS POULENEZ-DONOVAN AND CY ULBERG

Following the traditional procedural methodology of modern research using "objective," quantitative designs for understanding and planning transportation systems, transportation researchers from a number of disciplines, including psychology, sociology, planning, engineering, organizational behavior, and others in 20 years of studies have sought to measure and understand the human factor and apply the results to planning and public policy formation. Such quantitative evaluations on whether a program achieved a statistically significant effect are frequently misleading and often of little value to decision makers. They neglect by design the relationship between what was desired and what was delivered, the relationship between official programmatic goals and the goals of the users, and the differences between the various stakeholders, each of whom has a unique interest in the program. Qualitative methods, as part of an overall evaluation design, thus have an important and overlooked place in transportation research. A conjoint, multimethod quantitative and qualitative study of a model transportation demand management program is described in which the favorable findings of the typical quantitative work are in conflict with the larger issues of importance to program users and nonuser stakeholders as discovered in the qualitative study.

For a number of years, the dominant mode of thinking and the research conducted in transportation planning have been based on a linear, regression type of model emphasizing travel time and cost factors to explain an individual's travel behaviors and choices. On the basis of such thinking, linear quantitative methods were used and linear behavioral explanations were suggested: "If a cost disparity did not exist, just as many commuters would be seen riding in carpools, vanpools, and buses as driving alone to work" (*1*, p. 16).

In the last several years, the need to increase the scope of research factors by adding more personal variables has been addressed by a number of authors (*2,3*). However, the inclusion of individual psychological factors in and of themselves cannot deal with problems whose roots are in the methodologies used to study, understand, and plan in transportation research.

Study after study in the field is based on results gathered from some type of objective "black box" survey research (*4*) that measures reports of actual behaviors or relevant attitudes toward certain policies or procedures, or both. Within the realm of transportation demand management (TDM), surveys are typically taken of actual single-occupant-vehicle (SOV) and multiple-occupant-vehicle (MOV) usage. They are then compared with the program incentives and disincentives to SOV travel to determine relative "measures of effectiveness." The number of such studies is large and growing (see, for example, nos. 1203, 1212, and 1321 in the *Transportation Research Record* series). Generally the conclusions, although not completely uniform, tend to report some variation of the finding that "the monthly charge for employee parking on site was found to be the single most influential factor for determining the percent of employees that drive alone to work" (*5*, p. 109).

On occasion, people's attitudes toward various SOV and MOV options are surveyed as well. The world of the survey, however, is bounded by the perspectives and goals of the survey writers. The survey restricts not only the question frame but the answer frame as well, anticipating the important issues and questions and the responses.

This type of survey usually begins with a statement about the importance of "psychological factors" in traveler behavior and goes on to measure the predefined factors that the survey writers have determined to be of importance. Not infrequently, these psychological factors turn out to be important "intervening variables in understanding individual behaviors and decisions."

To overcome this predirection, some studies have included focus groups in their work to better understand the factors that are a part of decision making [see, for example, Polena and Glazer (*6*)]. Although the focus group can overcome the closed-end nature of the survey, it contains its own limitations, not the least of which are the drive for normative responses within the group and the lack of confidentiality. The latter can be especially important when asking about positives and negatives regarding the policies and personnel of one's employer.

One major reason for the omnipresent use of the quantitative methodology is the linguistic framing that occurs in describing it. Such methods are described as objective. Qualitative methods that seek to understand and gather participants' perceptions and beliefs are labeled subjective. With modern researcher norms, it is understandable that there is a strong level of support for methods that are described as objective.

Although there can be no doubt that the researcher needs to be free of presupposition and bias (observer objective), subjective beliefs and behavior on the part of those being studied (by the same objective observer) is the heart of qualitative research and is a legitimate and vital part of scientific work. Qualitative research is also vital to understanding the complexity of transportation behavior, which rests upon the subjective beliefs and behaviors of the individual person.

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A direct outcome of this automatic methodological response choice has been to direct efforts away from qualitative work when this technique would prove useful in understanding personal variables and their roles in transportation behavior. The framing of the issue as one of objective versus subjective work has meant that only quantitative research is seen as objective and hence as "scientific." Little wonder then that researchers have avoided these not just subjective but also "unscientific" studies and methods.

> The hope which originally inspired [quantitative] methodology was the hope of finding a method of inquiry which would be both necessary and sufficient to guide the scientist unerringly to truth. This hope has died a natural death. (*7*)

After the first flush of success in measuring social programs in terms of their quantified usage, a number of researchers recognized that whatever the results of such reports, they failed to answer the critical question of why. Without such knowledge "failing" programs could not be corrected and successful programs could not be transferred to other locations (*8*). Managers, politicians, and planners frequently report that such evaluation studies fail to provide them with needed information and often are not used in decision making (*9*).

The management sciences have come to recognize that even the best organizational procedures administered by the most competent staff cannot replace the need for a more fluid and dynamic hands-on contact to keep in touch with what is going on. This is usually referred to as "management by wandering around" (*10*).

## METHOD

Charged with evaluating a new and model TDM program for a major government employer, the organization used a typical methodology: a quantitative survey questionnaire. The actual survey was based on forms used by other governmental agencies. The questionnaire asked employees about means of commuting to work (eight options) each of the previous 5 work days, whether the prior week's commuting pattern was typical for their normal commute, the number of miles they commute to work from their home one way, and about level of satisfaction with the program.

Recognizing the problems in "research as usual" and trying to overcome them, the author used an additional and different approach: a multimethod combination of traditional quantitative research and a detailed, systematic, qualitative study: "research by wandering around."

In addition to the standard survey and numbers design, a qualitative research methodology was used involving one-on-one, semi-structured interviews. Interviews were conducted with more than 250 participating and nonparticipating employees at three work locations during a 4-month period. Each interview lasted from 10 min to ½ hr or more.

Each interview addressed issues involving the employee's commuting patterns and choices, the reasons for those patterns and choices, as well as his or her knowledge about and attitudes toward the organization's TDM program. The content of early interviews guided questions in later interviews. Data collection and analysis followed the process described by Kram (*11*, p. 254):

> As interviews are conducted, initial insights emerge about the phenomenon that is being studied. These new insights influence the kinds of questions that seem important to ask in subsequent interviews. This inductive process is characterized by continuous movement between data and concepts . . . to explain what has been observed.

The results of these interviews provided some unexpected and disturbing information on peoples' perceptions of TDM. These results are presented to show what individuals thought was important—not simply their ratings of what the researchers thought a priori was important.

The overarching purpose of this work was to search out what people were seeing, hearing, and feeling; to look at them and listen to them in their own words; to compare the results and findings of the two methods; and ultimately to generate clearer discussion and direction for future research. Detailed descriptions and analyses of qualitative versus quantitative research methodology are beyond the scope of this paper. It is also not the primary purpose to provide an analysis of the organization in question. Thus, identifying details of the organization have been excluded from this report.

## DESCRIPTION OF ORGANIZATION

The organization in question is a moderate-sized governmental entity. It has approximately 550 full-time employees. The three work sites are of roughly equal size and accommodate approximately equal numbers of employees. The northernmost site is approximately 10 mi north of the other sites, which are within 3 mi of each other.

The northernmost and southernmost sites are staffed primarily by unionized service employees along with a small complement of nonunionized support staff and various managers. The central site functions as the organizational headquarters and, as such, it is primarily home to management and support staff.

All locations are close to and have easy access to major freeways and highways and have ample free parking. The central location has very good transit access, whereas the north and south locations do not.

## DESCRIPTION OF PROGRAM

The program was designed to serve as a model for other public- and private-sector employers in the area. The focus of the program was on incentives. The organization subsidizes employees who commute to work in other than SOVs through a direct reimbursement for out-of-pocket costs.

Employees who wish to ride a local public-transit vehicle to work are given an annual pass allowing them to ride free. Those who must take other public transit out of the local area are reimbursed up to \$46.00/month on the basis of the distance traveled. The organization requires that other-than-SOV commuting to work occur at least 75 percent of the time per month for eligibility for such a reimbursement.

Because the hours of many of the workers are so widespread, carpooling plays an important role in the TDM program efforts. The program reimburses carpool drivers also up to \$46.00/month on the basis of the distance traveled. Carpoolers also receive preferential parking at each of the work sites, which consists of reserved parking in spots closest to entrances.

A carpool was defined here as a two-occupant vehicle. The second carpool occupant does not need to be an employee of the organization but must be an adult commuting to or from work. In this way the organization feels that it is contributing to the overall work-related trip reductions in the local area. A ridematching service exists both within the organization and regionally.

One group the organization did not want to overlook was the non-reimbursable participants. The organization has employees who commute to work by riding local transit, riding bicycles, walking, and of course carpooling. One incentive that was offered to them, as well as to the reimbursable participants, was a monthly cash drawing. Each month, six $50.00 cash prizes, two at each location, were awarded from the names of all monthly participants by a random drawing.

## RESULTS

The mandated survey showed that there was a 21 percent decrease in the numbers of employees who drove alone to work in the 2-year period the program had been in effect. The program was declared a success. The interviews indicated, however, four main areas of concern: individual/psychological factors, social factors, organizational factors, and external/economic factors.

### Individual/Psychological Factors

The existence of an American "love affair" with the car is a common concept. According to Angell and Ercolano (*12*), for example, "Despite a relative wealth of options . . . commuters . . . have developed an attachment to their automobiles that transcends convenient transportation and has become almost an obsession." Although the numbers clearly show that people to date have overwhelmingly chosen the SOV for commuting, an inherent love of the car or even of driving per se is not the reason given. Of 253 individuals interviewed, only 5 mentioned any sort of love affair with driving or with their cars. Moreover, this was from people who had chosen to carpool or vanpool and had abandoned the SOV. Their remarks centered on missing the comforts of their more luxurious cars compared with the vehicles they rode in for pooling purposes.

There were even a number of individuals who described themselves as hating their car but being a "car captive" and, hence, an SOV user and not a TDM participant. Although the individual reasons for such feelings differed, the core of the responses was based on lifestyle needs that required wide diversity in trips. Child care, geographically diverse errands, and split-schedule jobs, among other needs, placed people in a position of wanting to use an MOV option but feeling constrained from doing so because of, for example, geographic spread arising from land use and zoning around their homes.

In terms of individual differences in TDM participation and nonparticipation, there was a continuum of people along the line of introversion/social facilitation. Dedicated, no-chance-of-change nonparticipants generally preferred being alone and saw their commute times as positive, private moments. For example, "If I don't want to spend my lunch having to be with, and talking to other people, why should I want to be forced to [do so] every morning and every afternoon?"

Under such a set of beliefs and needs a number of alternatives to explain SOV love affairs can be created. One such possibility is the level of privacy or control, that the SOV provides, or is seen to provide, relative to other MOV options. Individuals with such high privacy or control needs were making decisions on the basis of a multiplicative—not an additive—decision model. If individual privacy or levels of control were considered insufficient, no other positive factor could make up for it because each factor was multiplied (not summed) together; hence, any factor with a weight of 0 led to a total MOV mode evaluation of 0.

Although many people who used MOV described some positive feelings toward reducing pollution, congestion, and the like, MOV use for these goals would clearly be a desirable option only for those who seek out or at least do not object to the company of others during their commute times. For this type of person, resistance to MOV is more a function of psychological comfort zones and desired relaxation time than a linear economic decision or one of psychosexual sublimation.

Another factor involved various individual biases. In a confidential setting, talking with a trusted confederate, many admitted to having a number of preferences about whom they did or would find acceptable (and unacceptable) as commute companions. These biases included gender, race, age, social status and class, and occupational status.

Most organizations are highly class and status bound. People most frequently expressed more reluctance toward commuting with those who were above or below themselves in terms of job status than toward any of the more common biases: that is, they did not wish to ride with people at the levels of either their supervisors or their employees.

Because such attitudes are held in negative esteem and are a source of conflict in our culture, the existence of such attitudes is rarely examined and when it is questioned by researchers, it is rarely acknowledged by subjects. These feelings may also represent general deep-seated values that have been seen as being antecedent to or even causative of specific attitudes and behaviors (*13*) and as such are functioning at a subconscious level not touched upon by multiple-choice/scaled-response questions.

TDM also represents an intrusion into people's nonwork time. Although individuals recognized the necessity of interacting on the job with people whom they would otherwise not associate with, commute time was clearly seen as "my time, not the company's." Freedom to associate or not associate and freedom to select a mode on their own time were sensitive issues and ones not addressed in most traditional efforts.

All of the above argues strongly against the success of the typical work site, or even the general regional model of seeing people as interchangeable and matchable primarily on the basis of origin and destination points and times (*14*).

### Social Factors

Whether the mode was buses, carpools, vanpools, or rail, the social factors of who was in the group and how to act toward them came up often. "I'm never quite sure how to behave in my carpool. What's OK to talk about, what isn't. At least in an elevator I know what to do—keep quiet and stare at the ceiling!"

Clearly we lack social norms for the general social interactions of most TDM alternatives. For some people this is trivial; to others it is daunting.

We also lack norms and comfort zones for dealing with the many social problems that MOV can bring. "I quit my carpool because I couldn't deal with the stress of having to pressure a coworker with being on time. We'd have words in the morning, then we would have to work together off and on during the day, then came the long ride home . . . "

A number of researchers have discussed cultural norms towards individual competition and group cooperation (*15,16*). An MOV group represents just such a cooperative group effort. In a typical TDM program a brochure may describe how to form a carpool or perhaps even how to deal with some of the conflicts that arise. An on-site program coordinator may be available (as was the author), but people wanted and needed more. "I'm just a shy person. I don't like calling or talking to strangers . . . and none of my friends worked out for a carpool . . . so I just dropped the whole thing." Contrast the above with the comfort zone of individuals who are willing participants in another phenomenon—the casual carpool. In a number of areas, such as suburban Washington, D.C., and San Francisco, casual carpools have arisen in which total strangers drive and ride with others to form "on demand," "instant," or "casual" carpools to get the benefits of localized highway TDM incentives such as the use of HOV lanes, waiving of bridge tolls, and the like (*17*).

For some individuals such as one worker in the sample, a casual carpool may be an acceptable solution to choosing an MOV precisely because the temporary nature of the carpool decreases the need for social interaction and feelings of social responsibility that are based on being in an ongoing group. "You don't have to worry what they think [of you] 'cause you know you're probably never going to see them again."

The bus, but not the train/light rail vehicle, was also seen as a low-social-status vehicle—one fraught with "too many people, with too little hygiene, packed too close together." Among managers and professionals there was a social/organizational fear factor that riding public transit could hinder promotions and future opportunities. For them, riding the bus involved a great deal more than just getting to and from work: "I wouldn't mind riding the bus to work but, when I see [the CEO] or even just my own boss giving up their company car and riding public transit, that'll be the day I'd give it a try."

### Organizational Factors

The existence of an organizational policy supporting TDM was a necessary but not sufficient condition to determine actual TDM behavior. For most workers, occupational class was a critical factor.

As in most work environments there were three broad classes of employees: the hourly worker, the salaried professional, and the salaried manager. Total MOV use was highest among the former and lowest among the latter. In part this simply reflects the overall difference in the total numbers of the three groups. But there is much more going on.

For the hourly worker, the individual manager was the largest factor in whether an interested employee used an MOV or stopped using one: it was not the chief executive officer, the program coordinator, or the program itself. This finding supports the results reported by Freas and Anderson (*18*) about use of variable work hour programs. The hourly workers knew this and often resented it.

TDM brought to the forefront a number of the occupational class differences that exist in the traditional, hierarchial workplace. Whereas the hourly workers felt the highest internal desire as a group to use MOVs, they noted with some anger that it was the salaried workers who were in the best position to actually use MOVs. "They can adjust their work schedules, be a few minutes early or late as long as their work gets done, and they aren't living hand to mouth where buying a monthly [MOV] pass or parking permit really hurts."

Whereas the overall company TDM policy was uniform and supportive, the individual managers made or broke the program. "Sure I could take the bus, but I couldn't leave at 4:55 to catch the express. I had to wait till precisely 5:00, which meant a 30-minute wait for the next local bus that I could use."

Hourly workers also reported receiving the most pressure to use MOV. Although there were managers who made it difficult if not impossible for a worker to select an MOV option, the opposite was true of managers who wanted high TDM program usage for their sections. "If we drove our own car to work, we were supposed to drop in and explain why we hadn't taken the [MOV]. And there was never an acceptable reason."

### External/Economic Factors

Although there were none at any of the three work sites, disincentives, particularly parking charges, had been discussed as a possibility. Disincentives are the major lever discussed in most research for changing SOV travel behavior (*19*).

A number of people recognized and described the typical parking charge as a "regressive" and "discriminatory" fee. Whether the fee is $5.00 or $50.00/month, a flat fee is more burdensome on the lower wage earners.

Clearly equality does not equal equity. However, threatening workers who earn $15,000/year with a parking fee of $50.00/month (equal to more than 4 percent of annual gross income) will likely be effective in driving them out of their cars. The perception was that "they [salaried workers] get company cars and expense accounts." "No matter what you charge it won't come out of their pocket but it [parking fees] means my family having less each month."

One intriguing suggestion was to "charge everyone who drives to work alone, in a company car or their own private car, the same percentage of their monthly salary—no exceptions, no company reimbursements. And give those who [don't use an SOV] an equal percentage of salary amount in a bonus . . ." This suggestion was from a senior accountant (and a salaried manager).

## DISCUSSION AND CONCLUSIONS

Clearly these accounts from people do not replace quantifiable research and they are not intended to. At the same time, they point out that there are more factors involved interacting in more complex patterns than planners and researchers have generally acknowledged.

The results of the standard TDM survey (Figure 1) indicated that there was a gain in the use of MOV options as a result of the TDM program. Rankings of the overall program were also found to be generally satisfactory. This leads to the typical report of a "successful" TDM program.

At the same time, the qualitative efforts conducted over time in a confidential and trusting relationship (Figure 2), to understand the overall perspectives on the TDM program and SOV versus MOV, generally provided a very different reaction. Many truisms were found to be inaccurate or badly distorted. A number of factors were raised against traditional TDM implementation and programs that could block the success of such programs even in the face of reported "successful" quantitative research findings.

Work Location: TOTAL As of July 10, 1991

How do you presently commute to work? (vs as of August 1989 before TDM program started)

| Pre | Post | | Pre | Post | | Pre | Post |
|---|---|---|---|---|---|---|---|
| 317 | 243 | drive alone | 0 | 3 | vanpool | | |
| 11 | 11 | company car | 4 | 17 | heavy rail | | |
| 12 | 13 | bus | 2 | 11 | bicycle | | |
| 1 | 3 | walk | 1 | 7 | other | | |
| 4 | 6 | motorcycle | 1 | 37 | carpool | | |
| 0 | 2 | light rail | | Total = 353 | | | |

93% 72% SOV usage

**FIGURE 1 TDM survey: quantitative results.**

In terms of using qualitative methodology, it is not enough to simply pull out such factors from individuals or focus groups and place them into the standard survey. The question of how satisfied one is with A, B, or C begs the question, "Compared with what?" Asking how likely one is to use X, Y, or Z leaves out the question, "But what real choices do I have?"

People who use an MOV as a part of a TDM effort may report being satisfied with their new commute mode and yet still may be disturbed by the fundamental nature of the overall program. By pressuring workers into riding with others and by using equal but inequitable incentives and disincentives, individual programs and legislative actions may breed further antagonism toward company management, government, and public policy organizations.

Concerns raised:

Individual/Psychological

- Loss of comfort in MOV as compared to SOV.
- Individual car captivity due to external factors including land use/planning.
- Preference for privacy/private time.
- Preference for high level of control vis-a-vis SOV.
- Biases over who to commute and not commute with, especially organizational class/status.
- Intrusion by business/government into non-business time.

Social

- Discomfort in creating a new social group.
- Discomfort being a part of a social group.
- Discomfort dealing with positive/negative behaviors in an MOV.
- Lack of clear social norms for MOVs.
- Low social/work status in using MOVs.

Organizational

- Lack of support for MOV usage by individual managers.
- Pressure to use MOV's by individual managers.
- Resentment towards schedule flexible salaried workers by hourly wage workers.

External/Economic

- Flat fees for SOV usage seen as regressive and discriminatory.
- Ability of high income/status individuals to pass along to company/gov't any increased costs.

**FIGURE 2 TDM survey: qualitative results.**

Methodologies are just tools. They may be appropriate or inappropriate in a given setting. However, when the only research tool one has (or will use) is a (quantitative) hammer, then all research questions look like nails. Naturalistic research based on qualitative methods helps to better explore and understand the various stakeholders' concerns, needs, and feelings rather than just their behaviors.

There are many stakeholders present in an organizational or social environment, including senior management, program implementers, and individual users. Such flexible methods provide rich, firsthand knowledge of how a program is being implemented, the real-world problems of the implementors and users, and the complex interactions between the groups.

The qualitative method is neither a panacea nor a replacement for the quantitative method per se. It is useful when the full range of issues is unknown or cannot be fully clarified before the evaluation program begins, where there are a large number of diverse stakeholders to be considered, and especially when there is a need for information about processes and not just outcomes. What is most effective is a dynamic, multiplistic approach that is designed to use multiple methods and investigate multiple and interactive issues and that involves the views of the full spectrum of relevant stakeholders.

Ultimately it is the individual who must judge the desirability, convenience, and the safety of mass transit, carpooling, and other alternatives to the SOV. Although surveying behavioral changes—even surveying attitudes and attitudinal changes—lets one see and count the "trees," it is no substitute for understanding (and meeting) the diverse concerns and feelings of all the individuals whose behaviors the various programs seek to influence.

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*This paper reflects the views of the authors, who are responsible for the facts and accuracy of the data presented herein. The paper does not necessarily reflect the official views of the University of Washington, the Washington State Transportation Commission, Department of Transportation, FHWA, or any other organization. This paper does not constitute a standard, specification, or regulation.*

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# Transportation Demand Management: Case Studies of Medium-Sized Employers

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The effects of various transportation demand management (TDM) strategies on single-occupancy-vehicle (SOV) mode split are explored. Fourteen innovative and effective TDM programs that have been implemented by medium-sized employers (100 to 450 employees) in several areas of the western United States are described. Employers are found to practice a wide range of TDM strategies, including high-occupancy-vehicle incentives, such as transit pass subsidies, and SOV disincentives, such as parking charges. Parking charges are found to be the most effective TDM strategy in urban areas where transit service is good and where parking is often expensive and scarce. On the other hand, in suburban areas, where transit access is often poor and where parking is usually plentiful and free of charge, generous alternate mode travel allowances are found to be necessary ingredients in successful TDM programs.

Air quality degradation is a pressing issue, especially in urban areas, where much of the air pollution is caused by automobile emissions. To reduce the impact of excessive automobile use, some U.S. employers, often under legal requirements, have begun to practice transportation demand management (TDM). TDM reduces roadway demand by creating single-occupancy-vehicle (SOV) disincentives, such as parking charges, and high-occupancy-vehicle (HOV) incentives, such as transit pass subsidies and carpool parking discounts.

The purpose of this paper, which is based on a recent study for the Washington State Transportation Commission (*1*), is to survey and assess the TDM programs of selected medium-sized employers (100 to 450 employees). Most government and academic research on TDM has focused on large corporations (*2,3*). This focus may be because large organizations themselves are more prominent or because their programs tend to be better funded and, thus, more elaborate. Start-up costs for TDM programs may be significant; large companies are often better able to absorb these costs. Moreover, related economies of scale allow them to offer more attractive benefits at a lower cost per employee.

In focusing on medium-sized employers, this paper addresses a gap in the literature. It surveys the components of TDM programs implemented by 38 employers and assesses their effects. Detailed information on 14 of the 38 individual case studies is presented herein. These case studies represent TDM programs that the authors consider most successful or innovative.

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## CASE SELECTION AND ORGANIZATION

The first step in selecting cases was to find jurisdictions that had issued transportation demand reduction ordinances or policies. The Puget Sound region in Washington State and the South Coast area in southern California were identified for presentation in this paper. The original research also included Maricopa County, Arizona; Silver Spring, Maryland; and the San Ramon area in northern California. Representative employers in these areas were then selected on the basis of the following criteria: size (from 100 to 450 employees); SOV rate (at or below that of the surrounding area); and the availability of current, accurate, employer-specific mode split data.

The case studies are organized geographically. A brief description of each area's population, existing roadways and transit services, and transportation-related ordinances and policies precede the individual case studies from that area. Each case study is divided into four sections: employer description, TDM strategies, program assessment, and transportation mode split. Each of these divisions is described in this section.

Employer description covers the number of employees, type of business, land use, and location. Land use designates the type of activity (e.g., office use or manufacturing), whereas location is used to distinguish among urban centers, suburban centers, urban areas, and suburban areas. Urban centers are the downtown area of a region's major city; the rest of the city is defined as urban. Downtown areas of cities other than the region's center are defined as suburban centers. All other areas are described as suburban. (The case studies do not include any rural locations.) Also included in the employer description is the approximate number of employers in the building and in the surrounding area; this information reflects land use density.

TDM strategies encompass the supply and cost of employee parking as well as the other components of the organization's TDM program, which may range from parking charges to paid time off for alternate mode users.

Program assessment analyzes the organization's overall TDM program. Distinctive program features are highlighted, obstacles related to location or business type are noted, and in some cases suggestions for mode split improvement are offered.

Transportation mode split quantifies employee commute travel by mode (e.g., SOV, carpool, transit). Employee transportation coordinators (ETCs) were surveyed for mode split information in summer 1992; most based their estimates on data from the same year. Areawide SOV mode split averages are provided for comparison. In some areas, average vehicle ridership (AVR), as opposed to mode split, is the relevant unit of measurement. In such cases, ETCs were asked to estimate the SOV mode split.

The paper concludes with some general observations on the relative effectiveness of various TDM program components.

## PUGET SOUND REGION, WASHINGTON STATE

Seven case studies are drawn from the Puget Sound region in western Washington. Represented are the cities of Seattle, Bellevue, Kirkland, and Lynnwood. With a population of 500,000, Seattle is the state's biggest city. The region has three Interstate highways and four state highways. Most of the employers surveyed have access to Metro Transit, the ninth-largest bus system in the country. The region does not have a major rail system.

Seattle is the nation's seventh-most-congested city (*4*). To address this congestion, as well as poor air quality, the state legislature passed the Commute Trip Reduction Law in 1991. The law requires that organizations with 100 or more employees in eight counties take action to reduce SOV commutes. The base year against which progress is judged is 1992. Employer plans must accomplish the following:

- Reduce the number of SOVs by 15 percent by 1995, 25 percent by 1997, and 35 percent by 1999; and
- Reduce the number of vehicle miles traveled by 15 percent by 1995, 25 percent by 1997, and 35 percent by 1999.

The following case studies demonstrate how several medium-sized employers addressed this new law.

### Johnson & Higgins

| *Description* | | *Transportation Mode Split* | |
|---|---|---|---|
| *Characteristic* | *Information* | *Mode* | *Percentage* |
| No. of employees | 182 | SOV | 23 |
| Business type | Brokerage firm | Transit | 70 |
| Land use | Office | Carpool | 2 |
| Location | Urban center | Other | 5 |
| | | Area SOV | 43 |

Johnson & Higgins is a single-site employer located in downtown Seattle. Environmental concerns prompted Johnson & Higgins to initiate a TDM program. The program has been in place for 2 years. ETC support averages 2 hr/week.

#### *TDM Strategies*

The company's parking supply is tight, and the charge is $180/month. Johnson & Higgins employees benefit from the following:

- Bus pass subsidy: $10 per month;
- Motorpool: vehicles available free of charge to employees for business trips;
- Guaranteed ride home: employer-provided fleet car or taxi fare reimbursement; and
- Flextime: variable start times; core hours between 8:30 a.m. and 4:30 p.m.

#### *Assessment*

The tight parking supply and very high parking cost appear to be the primary factors in this company's low SOV mode share. Good transit access and other TDM strategies may also contribute to the high transit mode share.

### William M. Mercer, Inc.

| *Description* | | *Transportation Mode Split* | |
|---|---|---|---|
| *Characteristic* | *Information* | *Mode* | *Percentage* |
| No. of employees | 120 | SOV | 33 |
| Business type | Employee benefits | Transit | 64 |
| Land use | Office | Carpool | 3 |
| Location | Urban center | Area SOV | 43 |

William M. Mercer is a multisite consulting firm located in downtown Seattle. The company's motivation for beginning a TDM program was to provide employee benefits. The program has been in place for 11 years. ETC support averages 2 hr/week.

#### *TDM Strategies*

Parking is adequate, and the charge is $130/month. William M. Mercer's employees benefit from the following:

- HOV parking discount: $39/month,
- Bus and ferry pass subsidy: 100 percent,
- Preferential parking: preferential HOV treatment,
- Motorpool: vehicles available free of charge to employees for business trips,
- Guaranteed ride home: employer-provided fleet car or taxi fare reimbursement, and
- Flextime: employees work their choice of hours.

#### *Assessment*

William M. Mercer, Inc., supports alternate modes in a variety of ways, but its most effective strategy appears to be a 100 percent subsidization of transit passes coupled with a high parking charge.

### Puget Sound Blood Center

| *Description* | | *Transportation Mode Split* | |
|---|---|---|---|
| *Characteristic* | *Information* | *Mode* | *Percentage* |
| No. of employees | 200 (day shift) | SOV | 34 |
| Company | Blood bank/center | Transit | 60 |
| Business type | Office (service) | Other | 6 |
| Location | Urban | Area SOV | 59 |

Puget Sound Blood Center is a multisite medical facility located on First Hill, adjacent to downtown Seattle. It is surrounded by many businesses, primarily medical, and is the only employer in the building. Puget Sound Blood Center's motivation for beginning a TDM program was to address a severe parking shortage. The program has been in place for 6 years. ETC support averages 2 hr/week.

#### *TDM Strategies*

The Puget Sound Blood Center has a 7-year waiting list for parking, which costs $50/month. Employees at this organization benefit from the following:

- HOV parking discount: $25/month for established 3+ carpools;
- Bus pass subsidy: 50 percent discount;
- Bicycle facilities: bicycle racks, showers, and lockers;
- Compressed work week and flextime: choice of many shifts;
- Guaranteed ride home: Metro-provided taxi ride home;
- Parking pass program: alternate mode users may park free of charge 1 day/month; and
- Private/public transit service: employers in the area cooperate to pay for additional transit service.

*Assessment*

Puget Sound Blood Center's transit mode split is very high. This is because of a combination of extremely scarce parking and a customized transit program tailored to employee travel patterns. Under this program, area employers cooperate to pay for additional express and regular transit service.

The mode split achieved by this agency reflects the commute patterns of the day shift only; those who work at night are encouraged to drive for reasons of personal safety.

### Bonneville Power Administration

| *Description* | | *Transportation Mode Split* | |
|---|---|---|---|
| *Characteristic* | *Information* | *Mode* | *Percentage* |
| No. of employees | 100 | SOV | 52 |
| Business type | Public power agency | Transit | 20 |
| Land use | Office | Carpool | 13 |
| Location | Urban | Vanpool | 5 |
| | | Other | 10 |
| | | Area SOV | 74 |

The Bonneville Power Administration is a multisite agency located in the lower Queen Anne Hill area, adjacent to downtown Seattle. The agency is surrounded by many businesses, but it is the only employer in the building. The Bonneville Power Administration's motivation for beginning a TDM program was to promote environmental and energy awareness. The program has been in place for 4 years. ETC support averages 2 hr/week.

*TDM Strategies*

The agency's parking supply is tight, and monthly charges range from $25 to $40. Some free, on-street parking is available. Bonneville Power Administration employees benefit from the following:

- Bus pass subsidy: $21/month;
- Bicycle facilities: bicycle racks;
- Compressed work week: flexible work schedules; employees keep track of their hours and may take time off when they reach 80 hr over a 2-week period;
- Flextime: variable start times; core hours between 8:30 a.m. and 3:00 p.m.;
- Ridematching: regional, computerized system available on site; and
- Vanpools: two Metro-supplied vehicles.

*Assessment*

The Bonneville Power Administration is located near the Seattle Center complex, which offers relatively inexpensive parking for an urban area. However, the employer-provided parking supply is tight, which discourages employees from driving alone. Bus pass subsidies, ridematching, vanpools, and the program environment encourage employees to use alternate modes. The resulting mode split is excellent for an urban area.

### $CH_2M$ HILL

| *Description* | | *Transportation Mode Split* | |
|---|---|---|---|
| *Characteristic* | *Information* | *Mode* | *Percentage* |
| No. of employees | 420 | SOV | 52 |
| Business type | Engineering | Transit | 19 |
| Land use | Office | Carpool | 9 |
| Location | Suburban center | Other | 20 |
| | | Area SOV | 81 |

$CH_2M$ HILL is a multisite consulting firm located in downtown Bellevue. It is surrounded by other businesses, and there are other employers in the building. $CH_2M$ HILL's motivation for beginning a TDM program was to provide employee benefits and to respond to concerns about traffic congestion and limited parking. The program has been in place for 6 years. ETC support averages 6 hr/week.

*TDM Strategies*

The company's parking supply is adequate, and the charge is $56/month. $CH_2M$ HILL employees benefit from the following:

- Travel allowance: $40/month to all employees;
- Bus pass subsidy: $15/month;
- Carpool subsidy: $15/month;
- On-site facilities: automatic bank withdrawals for payment of bus, vanpool, and parking fees;
- Motorpool: vehicle available free of charge to employees for business trips and on a rental basis for personal use;
- Compressed work week: 9/80 work week, all employees participate;
- Flextime: variable start times, core hours between 9:00 a.m. and 4:00 p.m.;
- Guaranteed ride home: Metro-provided taxi ride home; and
- Ridematching: on-site vanpool and carpool postings.

*Assessment*

The $40/month travel allowance is an important component of $CH_2M$ HILL's innovative TDM plan. $CH_2M$ HILL introduced the travel allowance to soften the impact of the concurrent $40 parking charge. The parking charge has since been raised to $56/month. $CH_2M$ HILL's plan has resulted in a remarkably low SOV mode split for a suburban center.

### Kirkland City Hall

| *Description* | | *Transportation Mode Split* | |
|---|---|---|---|
| *Characteristic* | *Information* | *Mode* | *Percentage* |
| No. of employees | 287 | SOV | 68 |
| Business type | Government agency | Transit | 3 |
| Land use | Office | Carpool | 22 |
| Location | Suburban | Other | 7 |
| | | Area SOV | 85 |

The city of Kirkland is a multisite agency; the city hall is located in Kirkland, a Seattle suburb. There are few employers in the area, and the agency is the only employer in the building. The motivation for initiating a TDM program was to provide area leadership in transportation management. The program has been in place for 4 years. ETC support averages ½ hr/week.

*TDM Strategies*

The agency's parking supply is adequate because of the TDM program, and there is no charge. Employees benefit from the following:

- Alternate mode travel allowance: $25/month for employees who carpool, vanpool, use transit, bicycle, or walk to work;
- Telecommuting: home-based work options available to employees on a limited basis;
- Bicycle facilities: bicycle racks, showers, and lockers;
- Flextime: flexibility for alternate mode users only;
- Ridematching: on-site postings; and
- Guaranteed ride home: employer-provided taxi fare reimbursement.

*Assessment*

Despite the fact that parking at the city hall is adequate and free of charge, this organization has achieved an SOV mode split well below the area average. The alternate mode travel allowance, active management support, and additional TDM strategies contribute to a low SOV mode split for a suburban area.

### Pacific Pipeline

| *Description* | | *Transportation Mode Split* | |
|---|---|---|---|
| *Characteristic* | *Information* | *Mode* | *Percentage* |
| No. of employees | 138 | SOV | 69 |
| Business type | Book distribution | Transit | 2 |
| Land use | Manufacturing | Carpool | 24 |
| Location | Suburban | Other | 5 |
| | | Area SOV | 85 |

Pacific Pipeline is a single-site company located in Kent, a Seattle suburb. The company is in an industrial park, and there is one other employer in the building. Pacific Pipeline's motivation for beginning a TDM program was to address environmental concerns, a lack of parking, and the CTR law. The program has been in place for about 1 year. ETC support averages 1 hr/week.

*TDM Strategies*

The company's parking supply is tight, but there is no parking charge. Pacific Pipeline employees benefit from the following:

- Alternate mode travel allowance: $24/month for employees who use alternate modes at least 60 percent of the time;
- Preferential parking: preferential HOV treatment;
- Ridematching: on-site postings; and
- Guaranteed ride home: employer-provided taxi fare reimbursement.

*Assessment*

The tight parking supply, coupled with a $24/month travel allowance, results in a very high carpool rate. The SOV mode split achieved by this company is very low for a suburban area.

## SOUTH COAST, CALIFORNIA

The cities of Glendale, Irvine, La Habra, and Los Angeles provide five case studies from the South Coast area of southern California. Los Angeles has a population of approximately 3 million, which makes it one of the biggest cities in the country. The South Coast area has 7 Interstate highways and about 20 state highways. It features 26 mi of light rail and a commuter rail system; however, none of the employers surveyed have access to the rail network.

Los Angeles is the most congested city in the country, and its air quality is the poorest (*4*). Because the region's air quality does not meet federal standards, four counties in the area adopted Regulation XV in 1987. The South Coast Air Quality Management District (SCAQMD) is the governing agency. The regulation requires that affected employers submit trip reduction plans designed to achieve specific AVR targets. Employers having 100 or more employees who report to work between 6:00 and 10:00 a.m. are affected. Regulation XV's requirements include the following:

- Employers in high-density areas are to have an AVR of 1.75, those in medium-density areas an AVR of 1.5, and those in low-density areas an AVR of 1.3.
- Employers are not to be fined for failing to reach AVR goals; however, they can be fined if they fail to submit a plan or if they fail to demonstrate a good-faith effort to implement an approved plan.
- Employers are to update their plans biennially; if no significant progress is made in reaching AVR targets then the SCAQMD may require them to adopt more aggressive measures.

Since adoption of Regulation XV, the following improvements have been documented (*5*):

- The urban center AVR has increased from 1.34 to 1.40.
- The urban area AVR has increased from 1.21 to 1.24.
- The suburban center AVR has increased from 1.16 to 1.20.
- The SOV rate has decreased from 76 to 71 percent.
- The carpool rate has increased from 14 to 18 percent.

### Commuter Transportation Services

| *Description* | | *Transportation Mode Split* | |
|---|---|---|---|
| *Characteristic* | *Information* | *Mode* | *Percentage* |
| No. of employees | 117 | SOV | 58 |
| Business type | Transportation | Transit | 17 |
| Land use | Office | Carpool | 20 |
| Location | Urban | Other | 5 |
| | | Area SOV | 74 |

Commuter Transportation Services, located west of downtown Los Angeles, is surrounded by other businesses. Many other employees share the same building. This private, nonprofit consulting firm works with employers to develop TDM programs. Thus, its primary motivation for beginning a program of its own was to model TDM strategies. The program has been in place for 16 years. ETC support averages 4 hr/week.

*TDM Strategies*

The company's parking supply is plentiful, and the charge is $60/month. Commuter Transportation Services employees benefit from the following:

- Travel allowance: $40/month for all employees;
- Bus pass subsidy: subsidization of bus pass costs not covered by the travel allowance;
- Alternate transportation bonus: $20/month for those who use an alternate mode 4 to 10 times a month; $40/month for those who use an alternate mode 11 or more times a month;
- Ridematching: on-site, regional computerized system;
- Guaranteed ride home: employer-provided personal ride home, taxi fare reimbursement, or rental car;
- Flextime: variable start times; core hours between 9:00 a.m. and 4:00 p.m.;
- Telecommuting: home-based work options used by 12 percent of employees and generally available; and
- Compressed work week: schedule options; 18 percent of employees participate.

*Assessment*

The $40/month travel allowance is an important component of this company's innovative TDM plan. The travel allowance softens the impact of a parking charge that is high for an urban area. The additional alternate mode allowance further encourages transit and HOV use. In an area where the SOV is the primary means of transportation, this organization has achieved a low SOV mode split.

### Gotcha Sportswear

| *Description* | | *Transportation Mode Split* | |
|---|---|---|---|
| *Characteristic* | *Information* | *Mode* | *Percentage* |
| No. of employees | 175 | SOV | 60 |
| Business type | Sportswear | Other | 40 |
| Land use | Manufacturing | Area SOV | 91 |
| Location | Suburban center | | |

Gotcha Sportswear is a single-site company in downtown Irvine. Surrounded by other businesses, it is the only employer in the building. It began a TDM program to comply with Regulation XV. The program has been in place for 6 years. ETC support averages 3 hr/week.

*TDM Strategies*

The company's parking supply is plentiful, and there is no charge. Gotcha Sportswear employees benefit from the following:

- Time off: 1/2 day off per quarter for employees who use an alternate mode 60 percent of the time; 1 full day off per quarter for employees who use an alternate mode 95 percent of the time;
- Guaranteed ride home: employer-provided personal ride home up to 3 days/year;
- Ridematching: personalized attention;
- Compressed work week: schedule options; 23 percent of employees participate; and
- Flextime: flexibility for alternate mode users only.

*Assessment*

Gotcha Sportswear's SOV mode split is relatively low; the employee transportation coordinator believes that this is due to its location in a suburban center with good transit connections and a program that allows employees to earn up to 4 paid days off per year on the basis of alternate mode use frequency.

### Heller Financial

| *Description* | | *Transportation Mode Split* | |
|---|---|---|---|
| *Characteristic* | *Information* | *Mode* | *Percentage* |
| No. of employees | 253 | SOV | 65 |
| Business type | Financial services | Transit | 4 |
| Land use | Office | Carpool | 27 |
| Location | Suburban center | Other | 4 |
| | | Area SOV | 81 |

Heller Financial is a multisite business located in Glendale, a suburb north of Los Angeles. The company is surrounded by many businesses, and there are 20 other employers in the building. Heller Financial's motivation for beginning a TDM program was to comply with Regulation XV. The program has been in place for 2 years and ETC support averages 5 hr/week.

*TDM Strategies*

The company's parking supply is plentiful, and the charge is $55/month. Heller Financial employees benefit from the following:

- HOV parking discount: 100 percent coverage for established 3+ carpools;
- Carpool subsidy: $20/month for established 3+ carpools;
- Time off (Program A): 12 hr of time off per quarter for frequent (at least 5 days/week) alternate mode users;
- Time off (Program B): 1 day off for infrequent (less than 3 days/week) alternate mode users; once employees have used an alternate mode for 32 days, they receive 1 day off;
- Bicycle facilities: bicycle racks;
- Ridematching: on-site, computerized system;
- Guaranteed ride home: taxi fare reimbursement; and
- Flextime: flexibility for alternate mode users only.

*Assessment*

The parking charge, HOV discount, and carpool subsidy work together for a relatively favorable SOV mode split. The innovative early-leave strategy, which allows employees to earn up to 48 hr of time off per year, may also be a significant factor in the high carpool rate.

Occasional alternate mode users may earn 1 paid day off after 32 days of alternate mode use. Strategies that encourage occasional alternate mode users are often neglected, but they can be effective in reducing total vehicle miles traveled.

### City of La Habra

| *Description* | | *Transportation Mode Split* | |
|---|---|---|---|
| *Characteristic* | *Information* | *Mode* | *Percentage* |
| No. of employees | 123 | SOV | 60 |
| Business type | Government | Other | 40 |
| Land use | Office | Area SOV | 85 |
| Location | Suburban | | |

The City of La Habra is a multisite agency located in a suburb 100 mi north of Los Angeles. There are other employers in the area, but the City of La Habra is the only employer in the building. The agency's motivation for beginning a TDM program was to comply with Regulation XV. The program has been in place for 3 years. ETC support averages 15 hr/week.

#### *TDM Strategies*

The company's parking supply is adequate, and there is no charge. City of La Habra employees benefit from the following:

- Compressed work week: schedule options only for those employees who use alternate modes; almost half participate;
- Guaranteed ride home: employer-provided use of fleet car or personal ride home;
- Ridematching: on-site, computerized system combined with personal attention;
- Telecommuting: home-based work options available to employees on a limited basis;
- Flextime: flexibility for alternate mode users only;
- Bicycle facilities: bicycle racks, showers, and lockers;
- Bicycle loan program: city-provided loans of bicycles for commute purposes; and
- On-site services: bus pass sales at work, lunch delivery, and personal check cashing services.

#### *Assessment*

Without offering any financial incentives or imposing parking charges, the City of La Habra has achieved a remarkably low SOV mode split. The employee transportation coordinator believes that the primary factor in this low SOV mode split is the compressed work week program, which is available to alternate mode users only. The fact that almost half of the employees participate indicates that this program is valued highly.

### Shur-lok Corporation

| *Description* | | *Transportation Mode Split* | |
|---|---|---|---|
| *Characteristic* | *Information* | *Mode* | *Percentage* |
| No. of employees | 174 | SOV | 78 |
| Business type | Aerospace | Other | 22 |
| Land use | Manufacturing | Area SOV | 91 |
| Location | Suburban | | |

Shur-lok Corporation is a single-site business in Irvine. The company is surrounded by other businesses and is the only employer in the building. Shur-lok Corporation began a TDM program to comply with Regulation XV. The program has been in place for 4 years. ETC support averages 7 hr/week.

#### *TDM Strategies*

The company's parking supply is plentiful, and there is no parking charge. Employees benefit from the following:

- Bus pass subsidy: $21/month;
- Carpool subsidy: 8 to 12 times/month, $10; 13 to 17 times/month, $15; and 18 or more times/month, $20;
- Bicycle/walk subsidy: 8 to 12 times/month, $15 gift certificate; 13 to 17 times/month, $20 gift certificate; and 18 to 20 times/month, $25 gift certificate;
- Vanpool subsidy: 50 percent or $25/week;
- Ridematching: a regional, computerized system;
- Guaranteed ride home: employer-provided fleet car or taxi fare;
- Flextime: flexibility for alternate mode users only;
- On-site services: home grocery delivery, dry cleaning delivery, and shoe repair service; and
- Bicycle facilities: bicycle racks.

#### *Assessment*

Shur-lok Corporation recognizes that many commuters need their automobiles for grocery shopping and errands during the work day. To reduce the need for a vehicle, the company reimburses the delivery costs of groceries, dry cleaning, and shoe repair. Shur-lok also provides additional alternate mode incentives. These creative strategies help lower SOV use for companies with free and plentiful parking.

## VENTURA COUNTY, CALIFORNIA

Two case studies are drawn from Ventura County, which is 40 mi northeast of Los Angeles. The cities of Simi Valley and Ventura are represented. Ventura is the biggest city in the county; its population is about 150,000. The county has access to one U.S. highway and seven state highways. A commuter rail system links Simi Valley with downtown Los Angeles.

Air pollution in the county exceeds federal ozone standards by 50 percent and state standards by 100 percent. The county adopted Rule 210 in 1989 and designated the Ventura County Air Pollution District (APCD) as the governing agency. Rule 210 requires that organizations with 50 or more employees submit trip reduction plans designed to obtain an AVR of 1.35. In 1994, the AVR level will increase to 1.5 for organizations with 100 or more employees. Specific provisions of the law require that employers do the following:

- Designate an employee transportation coordinator and send that person to a Rule 210 training session conducted by APCD;
- Survey employees who arrive at work between 6:00 and 10:00 a.m. to determine their commute patterns;
- Develop and file a trip reduction plan that specifies measures to encourage employees to alter their commute patterns;

• Carry out the approved trip reduction plan to reach the AVR target; and

• File an updated report with APCD each year documenting results and listing further steps to be taken if the required AVR has not been achieved.

### City of Simi Valley: Public Services Center, Municipal Utilities

| *Description* | | *Transportation Mode Split* | |
|---|---|---|---|
| *Characteristic* | *Information* | *Mode* | *Percentage* |
| No. of employees | 150 | SOV | 48 |
| Business type | Government | Other | 52 |
| Land use | Office; | Area SOV | 85 |
| Location | Suburban | | |

The City of Simi Valley is a multisite agency; its Public Services Center is located outside the city in a suburban area. This center is the only employer in the vicinity. The city's motivation for beginning a TDM program was to comply with the county ordinance. The program has been in place for 2 years. ETC support averages 20 hr/week.

#### *TDM Strategies*

The parking supply is plentiful, and there is no charge. Employees benefit from the following:

• Alternate mode travel allowance: $3/day or $2/day if carpooling in a city-owned vehicle;

• Transit subsidy: an additional 50 percent or $0.75/day;

• Time off: 1 day off after 70 days of alternate mode usage within a 6-month period;

• Ridematching: regional, computerized system;

• Guaranteed ride home: employer-provided fleet car, personal ride home, taxi fare reimbursement, or rental car;

• Compressed work week: schedule options; 90 percent of employees participate;

• Flextime: flexibility for alternate mode users only;

• Bicycle facilities: bicycle racks, showers, and lockers;

• Equipment allowance: reimbursement for 25 percent of equipment costs (mainly bicycle related); up to $200 per 6-month period; and

• Motorpool: clean-fuel vehicles available free of charge to employees for business trips.

#### *Assessment*

This TDM program offers an unusual variety of monetary incentives, including alternate mode travel allowances, transit subsidies, and an equipment allowance, resulting in very low SOV use. In addition to the financial incentives, employees may earn time off for using alternate modes. Although this case study indicates that a variety of generous incentives may be necessary in suburban or semirural areas to achieve SOV rates comparable with those of urban centers, it also indicates that low SOV mode splits are possible in suburbs.

### Kinko's Service Corporation

| *Description* | | *Transportation Mode Split* | |
|---|---|---|---|
| *Characteristic* | *Information* | *Mode* | *Percentage* |
| No. of employees | 283 | SOV | 70 |
| Business type | Photocopying | Other | 30 |
| Land use | Office | Area SOV | 88 |
| Location | Suburban | | |

Kinko's Service Corporation (KSC) is a multisite business whose corporate headquarters is located in Ventura. KSC is surrounded by other businesses but is the only employer in the building. Its primary motivation for beginning a TDM program was to comply with the county ordinance. The program has been in place for 2 years. ETC support averages 20 hr/week.

#### *TDM Strategies*

The company's parking supply is plentiful, and there is no charge. KSC employees benefit from the following:

• Ridematching: on-site, computerized system;

• Guaranteed ride home: employer-provided fleet car, personal ride home, or taxi fare reimbursement;

• Preferential parking: preferential HOV treatment;

• Bicycle facilities: bicycle racks and clubhouse showers and lockers; and

• On-site services and facilities: bus pass purchases, clubhouse, day care, dry cleaning, car wash, and mail services.

#### *Assessment*

KSC's SOV rate is substantially lower than that of the surrounding area. Although this cannot be clearly attributed to a single component, the most noteworthy features appear to be the on-site facilities, including day care, and the substantial amount of time (20 hr/week) the ETC spends encouraging employees to use alternate modes.

## EVALUATION

It is difficult to evaluate the case studies collectively because so many disparate factors affect mode split. Nonetheless, a few conclusions about the effectiveness of selected TDM strategies can be made. But before turning to the TDM strategies themselves, a brief discussion of location, an important contextual variable, is in order.

### Location

Among the organizations surveyed, SOV rates generally rose as the distance from the urban center increased. Organizations located in urban centers generally have lower SOV rates than their suburban counterparts for two main reasons. First, parking in urban centers is usually scarce and is often quite expensive. Second, transit service in urban areas is generally much better than in the suburbs. When these factors are combined with urban congestion, many commuters find HOV modes more attractive than driving alone.

One-half of the organizations surveyed located in urban centers have SOV rates of under 49 percent. Only one organization in an urban center had an SOV rate exceeding 70 percent; transit service to this area is poor.

Organizations located in suburban areas have the highest SOV rates because of their geographical isolation, poor transit access, and parking that is plentiful and free of charge. Most of the organizations with SOV rates exceeding 80 percent are located in suburban areas.

Because of its relationship to transit access and the supply and cost of parking, location is an important variable that should be taken into account whether one is studying TDM programs or putting one into place. Although parking charges alone may be enough to deter SOV commutes in urban centers, suburban employers may have to offer sizable financial incentives to encourage alternate mode use.

### Parking

Parking, which raises the cost of SOV commuting directly, affects mode choice much more than does any other factor. In fact, parking costs and SOV rates, are, by and large, inversely related. The charge must be quite high to reduce SOV rates. Data from this study indicate that relatively low charges have only modest effects. It is not uncommon for employers to impose parking charges for SOVs in conjunction with parking discounts for HOVs; this strategy creates an SOV disincentive and an HOV incentive at the same time.

Four ETCs reported that parking scarcity, in and of itself, is also a factor in reducing SOV rates. However, the sample size in this study is too small to make any conclusive determinations about its effect on mode split.

Parking charges are most effective in urban areas and centers and in suburban centers, where parking is typically scarce and where charges are customary. This strategy is much less effective and less frequently practiced in suburban areas, where parking is generally plentiful and free of charge.

### Travel Allowances

There are basically two types of travel allowances: those given to all employees, regardless of how they get to work, and those restricted to alternate mode users. Alternate modes include transit, carpools, vanpools, walking, and cycling. Some organizations simply pay all employees a set monthly stipend to defray travel costs, including SOV parking charges. Such allowances may reach \$60/month. Other organizations make monthly or quarterly payments to employees who use non-SOV modes at least part of the time. Another variation is to give daily payments to non-SOV commuters, or variable payments, on the basis of the number of times alternate modes are used each month.

Travel allowances have two benefits: they provide an excellent method of introducing a parking charge, and they subsidize alternate mode use. However, this study indicates that travel allowances that are given to all employees, regardless of mode choice, diminish the impact of parking charges. Those who wish to continue to commute in SOVs simply use the money to pay the parking charges. For this reason, restriction of travel allowances to alternate mode users may be desirable.

Alternate mode travel allowances can be quite effective in suburban areas, where, as noted, parking charges are not generally viable. Like parking charges, alternate mode travel allowances have a direct effect on the commuter's pocketbook and are helpful in reducing the SOV mode split. For example, one suburban company achieved an SOV rate of just 48 percent by offering alternate mode users \$3/day.

### Transit, Carpool, and Vanpool Subsidies

Many of the organizations surveyed offer some type of transit subsidy regardless of the quality of transit service to the work site. However, only those organizations with good transit service and access, such as those in central business districts, had high transit mode splits. Such subsidies may include HOV parking discounts, direct payment to carpools, and gasoline reimbursement.

Carpool subsidies are more viable in areas not well served by transit. In fact, carpooling is the preferred alternate mode in many suburban areas. The highest carpool rates in this study were those associated with significant cost savings for the employees. For example, one company achieved a carpool mode split of 24 percent with a substantial alternate mode travel allowance, and another achieved a carpool mode split of 30 percent with an HOV parking discount.

Although they are the most cost-effective and energy-efficient means of transportation per person trip, vanpools are uncommon (*6*). Expensive to obtain and service, vanpools require considerable administrative effort. Although vanpools often receive the same parking discounts as carpools, their mode split is much lower. The pros and cons of vanpools, as well as strategies for facilitating their use, would be a fruitful topic for further research.

### Alternate Work Hours

Most alternate work-hour programs focus on reducing vehicle miles traveled rather than reducing SOV rates directly. Although the effects of parking charges and travel allowances are clearly visible, it is more difficult to assess the effectiveness of alternate work-hour programs. They are not as common, and comparisons are problematic because they can take so many different forms. Telecommuting, flextime, compressed work week, and time-off programs all fall into this category.

In addition, results from the few that have been implemented are mixed. At one organization the employees have enthusiastically embraced a time-off program, and almost half have shifted to alternate modes to earn additional time off. On the other hand, several ETCs reported that the alternate work-hour programs offered at their organizations have had little or no effect on mode split. More research in this area is needed.

### Ridesharing

Ridesharing programs are the single most common TDM strategy. They are often inexpensive, and many employers believe them to be a significant factor in determining mode choice. A total of 66 percent of the organizations surveyed offer ridematching services, ranging from simple bulletin boards to computerized programs and, in some cases, personal assistance from an ETC.

ETCs reported that regional computerized programs are often inadequate because employees prefer to carpool with people who work in the same building; regional systems based on zip codes do not provide such specific service. This study could find no direct correlation between ridesharing programs and lower SOV rates. However, these services may encourage a higher use of alternate modes when combined with other TDM strategies.

### Management Support

What role does management support play in determining mode choice? Such support may be demonstrated in several ways, chief among them creation of an ETC position (or, where such a position is already in place, dedication of additional resources).

Management support may also be communicated through internal publications, statements by top executives, and new employee orientations. In addition, employers may foster alternate mode use by installing transit information centers at the workplace, by disseminating brochures and other printed materials, and by sponsoring special events, such as transportation fairs, drawings, or parties for alternate mode users.

Although some ETCs reported that their efforts encourage carpool formation and maintenance and that a lack of management support prevents organizations from achieving lower SOV rates, this study was unable to discern exact relationships among alternate mode promotion, management support, ETC effort, and SOV rate reduction. One's impression is that the effects of marketing, support, and "promotion" are minor compared with strategies that have concrete economic components.

### Net Effects of Financial Incentives and Disincentives on SOV rates

Figure 1 shows the relationship among financial HOV incentives, SOV disincentives, and SOV rates. A variety of factors affect an employee's choice of a specific alternate mode; therefore, to simplify the analysis, for Figure 1 only economic incentives that apply to all employees were used to calculate the net HOV incentive. Parking charges and alternate mode travel allowances are both counted as HOV incentives, whereas a general travel allowance is assumed to decrease the HOV incentive of a parking charge. Therefore, if a company offers both a parking charge and a general travel allowance, the allowance is subtracted from the parking charge to derive the net HOV incentive. This may not be a true reflection of commuter behavior because they may spend the allowance on anything; that is, it is not like an offer of free parking.

Although HOV incentives are significant, they are not the only effective TDM strategy. Some case studies in Figure 1 have achieved very low SOV rates, beyond what one would expect given their relatively low parking charges. What accounts for these successes? One organization has a 7-year waiting list for parking space; another enjoys excellent transit service and fully subsidizes the cost of passes; two others offer alternate work schedules to non-SOV commuters only. The data shown in Figure 1 represent only part of the picture in terms of what influences TDM success; clearly much more study, including statistical analysis, is needed.

Linear regression analysis on all 38 cases included in the main study (*1*) indicates that net economic incentives account for 54 percent of the variability in SOV rates ($r^2 = 0.54$). The following statistics were also obtained:

- Coefficient of fit, −0.27;
- Constant of fit, 74.32;
- Standard error, 0.04; and
- *t*-test, −6.21.

The absolute *t*-test value, 6.21, suggests that one can be 99 percent certain that HOV incentives are a significant indicator of SOV rates.

## CONCLUSION

As demonstrated herein, case studies can reveal a great deal about the success of TDM programs. The culture of various organizations often decides what the TDM program will be. The finding that high parking costs and good transit result in less SOV use is not new and

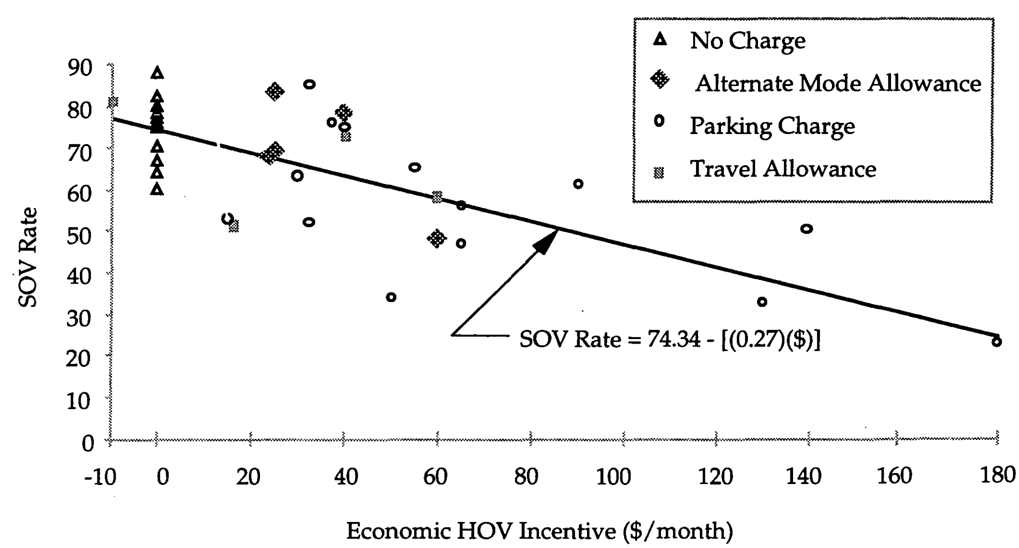


**FIGURE 1 Effect of economic incentive structures on SOV rates.**

is only reinforced in this paper. The success of TDM programs in the suburbs is less well understood but very important given today's development patterns and the increase in TDM-related policies and regulations.

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# Creating Transportation Demand Management Solutions for Honolulu: Use of a Joint Public-Private Task Force To Address Transportation Issues

MARK R. WILLEY

With the failure of the Honolulu City Council to provide a local funding agreement for the proposed fixed guideway rail project in the fall of 1992, the burden to develop a direction for future transportation planning on the island of Oahu shifted from the city administration to the city council. To meet this public expectation, the council established the joint public-private Task Force on Traffic and Transportation Management, whose goal was to develop economically reasonable nonrail alternatives to help alleviate congestion in Honolulu. The processes used by the task force's Subcommittee on Employee Commute Options for developing transportation demand management strategies applicable to Honolulu and the subcommittee's recommendations are discussed.

The defeat of Honolulu's light-rail initiative by the city council in 1992 resulted in the end to 30 years of rail planning and left Honolulu with no cohesive plan for dealing with traffic congestion. With worsening traffic problems becoming a political liability, the city council turned to the private sector for help and established a joint private/public sector task force on transportation and traffic management planning. The goal of this 60-member task force was to develop recommendations that would provide, within the constraints of public funding, sufficient nonrail transportation alternatives to ensure adequate mobility for Oahu's citizens.

Members of the task force, invited to participate by the chair of the Council Committee on Transportation, included representatives of state and county transportation agencies, private corporations and agencies, local private transit and taxi groups, and special interest groups, such as the antirail Committee on Sensible Transit, Hawaii's Thousand Friends, and the League of Women Voters.

The task force structure consisted of four subcommittees, coordinated by a 12-member executive committee, representing various aspects of the transportation management picture:

1. Highway capacity changes,
2. Public and private transit and paratransit opportunities,
3. Employee commute options, and
4. Pricing strategies and other incentives/disincentives.

This paper focuses on the process utilized by the Subcommittee on Employee Commute Options in developing transportation demand management (TDM) strategies and outlines the subcommittee's TDM recommendations for Oahu.

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## SUBCOMMITTEE ON EMPLOYEE COMMUTE OPTIONS

The Subcommittee on Employee Commute Options consisted of six individuals: five private-sector members and the head of the state's rideshare program. The private-sector members had varied backgrounds; included were a transportation planner, the director of the local Chamber of Commerce, an architect, a construction manager, and a hospital employee. Except for its own expertise, the subcommittee received no technical assistance from the sponsoring government. Deliberations were free flowing, and decision making was done by consensus, reflective of local Hawaiian customs and culture.

In considering TDM options for Oahu, the subcommittee examined several factors. First, although mandatory programs can increase the participation rate among employers (*1*), members did not believe that the general public perceived that congestion levels were high enough to create the political atmosphere necessary for passage of any mandatory trip-reduction ordinance. Also, Oahu is an air quality attainment area and does not fall under the mandatory trip-reduction regulations included in the 1990 Clean Air Act Amendments.

Second, members felt that various types of employers, that is, government versus private, large versus small, as well as employer location—central business district (CBD) versus non-CBD—could play a part in both the effectiveness of various TDM components and their attractiveness to employers.

Third, implementing a voluntary private-sector program on a wide basis could be accomplished only if

- Government led the way with its own comprehensive programs;
- Private employers could see benefits to their businesses from the TDM program;
- Private employers had options to pursue and to tailor to their own environment—not mandated options that may be inappropriate to their situation;
- Private employers could see the effectiveness of their programs on congestion, either at their work site or on an areawide basis;
- Government removed legislative barriers to TDM implementation in the private sector; and
- Government provided tax credits or other incentives for successful private-sector programs.

Given the various factors involved, the subcommittee defined its overall task as a two-tiered challenge: (a) how to encourage employees to change their commuting habits and (b) how to enroll employers in voluntarily adopting policies that would encourage their employees to change their behavior.

## EFFECTIVENESS AND ATTRACTIVENESS OF ALTERNATIVES

In developing recommendations for TDM programs, the subcommittee used an achievement matrix ranking system that considered both the effectiveness and attractiveness of various options to different employer groups. Employers were categorized into the following groups reflecting their makeup, location, and commute demands placed on their employees:

- State government (including school employees),
- City and county of Honolulu government,
- Federal military facilities,
- Federal civilian agencies located in the CBD,
- Large employers located in the CBD (100 or more employees),
- Large employers located outside the CBD (suburban),
- Small employers located in the CBD,
- Small employers located outside the CBD,
- Waikiki hotels,
- Existing businesses,
- New businesses,
- Relocating businesses,
- Businesses with a large number of shift workers, and
- University of Hawaii (staff and students).

The effectiveness of various TDM options and the attractiveness to the employer were then estimated. The following scale was used to score each TDM option according to the various employer types: 1 = minimally effective, 2 = marginally effective, and 3 = very effective.

Blanks were left when members felt they lacked sufficient information or when they felt an option did not apply to a particular employer. These rankings were averaged across the subcommittee members and summed. Given the 14 employer groupings and a possible score from 1 to 3, the maximum amount possible for an option was 42 points. The rankings for the estimated effectiveness of each TDM option are given in Table 1.

Measures that limit parking or provide parking surcharges were considered most effective in stimulating the movement toward alternative modes of transportation, receiving 42 and 38 points, respectively. Also, ride matching, financial incentives, and optional work hour arrangements were considered an effective way of providing the alternative modes for employee use, although their scores were somewhat lower (between 29 and 33 points). Conversely, allowing employers to set their own goals was not considered very effective; programs that consisted only of information and marketing strategies also were not considered effective.

Table 1 also indicates which options may be most appropriate for each employer group. Again, restricting parking availability was considered most effective for all employer groups. However, parking surcharges were not viewed as effective for employers outside the urban area because of the availability of free parking near work sites. In addition, the lack of consistent bus service and routes outside the urban core lowered the expected effectiveness of supplying transit passes or vouchers.

From the employer's standpoint, however, the attractiveness of an option may not stem from its overall effectiveness, but from its overall cost. Table 2 indicates that low-cost programs, such as information and marketing, and those that are revenue generators, such as parking surcharges, are considered to be much more attractive than more cost-intensive measures, such as a guaranteed ride home program or an available vehicle fleet for carpools or vanpools. The subcommittee did not find that the type of employer group caused a significant variance in the attractiveness of TDM options.

Examination of Tables 1 and 2 indicates that measures containing elements of parking restrictions and increased parking costs, in conjunction with increased commuting alternatives, either through subsidized transit or ridematching for carpools and vanpools, can create an effective, attractive TDM program on Oahu. Thus, the

**TABLE 1 Estimated Effectiveness on Oahu of Various TDM Options by Employer Group**

| | State | City & County | Military | Fed. Civil. | CBD > 100 | Non-CBD > 100 | CBD < 100 | Non-CBD < 100 | Resort Hotels | Exist. Bus. | New Bus. | Reloc. Bus. | Shift Work | Univ. of Haw. | Totals |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Restricted Parking Availability | 3.00 | 3.00 | 3.00 | 3.00 | 3.00 | 3.00 | 3.00 | 3.00 | 3.00 | 3.00 | 3.00 | 3.00 | 3.00 | 3.00 | 42.00 |
| Employers Develop Own TDM Program | 3.00 | 3.00 | 2.75 | 3.00 | 3.00 | 2.75 | 2.75 | 2.50 | 3.00 | 2.75 | 2.75 | 2.75 | 2.50 | 3.00 | 39.50 |
| Parking Surcharges | 3.00 | 3.00 | 2.67 | 3.00 | 3.00 | 2.67 | 2.67 | 2.33 | 3.00 | 2.67 | 2.67 | 2.67 | 2.33 | 3.00 | 38.68 |
| Ridematching | 2.75 | 2.75 | 2.50 | 2.75 | 2.75 | 2.00 | 2.00 | 1.75 | 2.25 | 2.33 | 2.33 | 2.50 | 1.75 | 2.67 | 33.08 |
| Telecommuting Option | 2.50 | 2.50 | 2.25 | 2.50 | 2.50 | 2.25 | 2.25 | 2.00 | 2.50 | 2.25 | 2.25 | 2.00 | 2.00 | 2.33 | 32.08 |
| Transportation Allowances | 2.33 | 2.33 | 2.33 | 2.33 | 2.33 | 2.33 | 2.33 | 2.33 | 2.33 | 2.33 | 2.33 | 2.00 | 2.33 | 2.00 | 31.96 |
| Vehicles Available for Work-Related Trips | 2.50 | 2.50 | 2.25 | 2.50 | 2.50 | 2.25 | 2.25 | 2.00 | 2.50 | 2.00 | 2.00 | 2.25 | 3.00 | 2.33 | 32.83 |
| Guaranteed Ride Home | 2.50 | 2.50 | 2.25 | 2.50 | 2.50 | 2.25 | 2.25 | 2.00 | 2.50 | 2.25 | 2.25 | 2.00 | 2.00 | 2.00 | 31.75 |
| Transportation Coordinator | 2.33 | 2.33 | 2.00 | 2.33 | 2.33 | 2.00 | 2.00 | 1.67 | 2.33 | 2.00 | 2.00 | 2.00 | 1.67 | 2.00 | 28.99 |
| Alternative Work Hours | 2.25 | 2.25 | 2.00 | 2.25 | 2.25 | 2.00 | 2.00 | 1.75 | 2.25 | 2.00 | 2.00 | 1.75 | 2.00 | 2.33 | 29.08 |
| Employer-Provided Bus Passes | 2.25 | 2.25 | 2.00 | 2.25 | 2.25 | 2.00 | 2.00 | 1.75 | 2.25 | 2.00 | 2.00 | 2.00 | 1.75 | 2.00 | 28.75 |
| Preferential Parking | 2.25 | 2.25 | 2.00 | 2.25 | 2.25 | 2.00 | 2.00 | 1.75 | 2.25 | 2.00 | 2.00 | 2.00 | 2.25 | 2.00 | 29.25 |
| Employers Set Own Goals | 2.00 | 2.00 | 1.75 | 2.00 | 2.00 | 1.75 | 1.75 | 1.50 | 2.00 | 1.75 | 1.75 | 1.50 | 1.50 | 1.33 | 24.58 |
| Vehicles Available for Car/Vanpools | 1.67 | 1.67 | 1.67 | 1.67 | 1.67 | 1.67 | 1.67 | 1.67 | 1.67 | 1.67 | 1.67 | 1.67 | 2.00 | 2.00 | 24.04 |
| Information and Marketing Provided | 1.75 | 1.75 | 1.50 | 1.75 | 1.75 | 1.50 | 1.50 | 1.25 | 1.75 | 1.50 | 1.50 | 1.25 | 1.25 | 1.00 | 21.00 |
| Bike Racks, Showers, Lockers Provided | 1.50 | 1.50 | 1.50 | 1.50 | 1.50 | 1.33 | 1.50 | 1.33 | 1.33 | 1.33 | 1.33 | 1.50 | 1.33 | 1.33 | 19.81 |

**TABLE 2 Estimated Attractiveness on Oahu of Various TDM Options by Employer Group**

| | State | City & County | Military | Fed. Civil. | CBD > 100 | Non-CBD > 100 | CBD < 100 | Non-CBD < 100 | Resort Hotels | Exist. Bus. | New Bus. | Reloc. Bus. | Shift Work | Univ. of Haw. | Totals |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Information and Marketing Provided | 2.50 | 2.50 | 2.50 | 2.50 | 2.50 | 2.50 | 2.50 | 2.50 | 2.50 | 2.50 | 2.50 | 2.50 | 2.50 | 2.67 | 35.17 |
| Employers Develop Own TDM Program | 2.25 | 2.00 | 2.00 | 2.25 | 2.25 | 2.25 | 2.25 | 2.25 | 2.25 | 2.25 | 2.25 | 2.50 | 2.25 | 2.67 | 31.67 |
| Preferential Parking for Car/Vanpools | 2.33 | 2.33 | 1.67 | 1.67 | 2.00 | 1.67 | 1.50 | 2.00 | 2.00 | 2.00 | 2.00 | 2.00 | 2.00 | 2.50 | 27.67 |
| Parking Surcharges | 1.37 | 1.67 | 1.67 | 1.67 | 1.67 | 1.67 | 1.67 | 1.67 | 1.67 | 1.67 | 1.67 | 2.00 | 1.67 | 3.00 | 24.74 |
| Alternative Work Hours | 2.25 | 2.00 | 2.00 | 2.00 | 2.00 | 2.00 | 1.75 | 1.75 | 1.33 | 1.67 | 1.67 | 1.33 | 1.50 | 1.00 | 24.25 |
| Employers Set Own Goals | 2.00 | 2.00 | 1.75 | 1.75 | 1.50 | 1.50 | 1.50 | 1.50 | 1.50 | 1.50 | 1.50 | 1.75 | 1.50 | 1.67 | 22.92 |
| Ridematching | 2.00 | 1.33 | 1.33 | 1.33 | 1.50 | 1.50 | 1.50 | 1.50 | 1.25 | 1.33 | 1.33 | 2.25 | 1.33 | 2.67 | 22.15 |
| Restricted Parking Availability | 1.50 | 1.50 | 1.50 | 1.50 | 1.50 | 1.50 | 1.50 | 1.50 | 1.50 | 1.50 | 1.50 | 1.50 | 1.50 | 2.50 | 22.00 |
| Employer-Provided Bus Passes | 1.33 | 1.33 | 1.33 | 1.33 | 1.67 | 1.67 | 1.33 | 1.33 | 1.33 | 1.33 | 1.33 | 2.00 | 1.33 | 2.50 | 21.14 |
| Transportation Coordinator | 2.00 | 1.33 | 1.33 | 1.33 | 1.50 | 1.50 | 1.33 | 1.33 | 1.50 | 1.33 | 1.33 | 1.67 | 1.33 | 2.00 | 20.81 |
| Telecommuting Option | 1.33 | 1.33 | 1.33 | 1.33 | 1.50 | 1.50 | 1.33 | 1.33 | 1.33 | 1.33 | 1.33 | 1.75 | 1.33 | 2.33 | 20.38 |
| Bike Racks, Showers, Lockers Provided | 1.33 | 1.33 | 1.33 | 1.33 | 1.33 | 1.33 | 1.33 | 1.33 | 1.33 | 1.33 | 1.33 | 1.33 | 1.33 | 2.50 | 19.79 |
| Transportation Allowances | 1.33 | 1.33 | 1.33 | 1.33 | 1.33 | 1.33 | 1.33 | 1.33 | 1.33 | 1.33 | 1.33 | 1.33 | 1.33 | 1.50 | 18.79 |
| Vehicles Available for Work-Related Trips | 1.00 | 1.00 | 1.00 | 1.00 | 1.50 | 1.50 | 1.00 | 1.00 | 1.50 | 1.00 | 1.00 | 1.75 | 1.00 | 2.00 | 17.25 |
| Vehicles Available for Car/Vanpools | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.50 | 1.00 | 2.00 | 15.50 |
| Guaranteed Ride Home | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 2.00 | 15.00 |

subcommittee's findings confirm studies done across the country that have shown that carpooling support programs in conjunction with parking management programs have been the most effective in diverting single-occupant vehicle trips (*2,3*). At the same time, the relatively high ranking given to "employers developing their own TDM program," from both the effectiveness and attractiveness standpoints, recognizes the fact that employers feel they must take into account their own location and operational circumstances as well as consider the wants and needs of their own employees in developing a successful TDM program.

## TDM RECOMMENDATIONS FOR OAHU

A ranking of the estimated effectiveness and attractiveness of the various TDM components concluded that a mix of carpool-supporting and parking management measures could be the most effective in lowering peak-hour travel and most attractive to employers in either the private or public sectors. Such measures would include the following:

- Providing information and marketing for the program,
- Providing ridematching services,
- Providing preferential parking for carpool users,
- Providing alternative work hour opportunities for employees,
- Providing a guaranteed ride home for carpool users,
- Providing a transportation coordinator,
- Limiting parking availability to employees, and
- Implementing parking surcharges and fees for single-occupant vehicle use.

Private employers were seen by the subcommittee members to be more likely to implement TDM programs only after the following circumstances were established:

- Federal, state, and local governments take the lead in the development of their own programs.
- Private employers are shown the benefits to their business from TDM programs.
- Private employers are presented with sufficient options to pursue and tailor to their own environment and needs of their employees, rather than faced with legislated mandatory trip reduction measures.
- Private employers are shown the effectiveness of their programs on reduced peak-hour trips, either at their work site or on an areawide basis.

Clearly, the subcommittee believed that the burden of establishing TDM programs would lie with the state and city governments. Thus, it was felt that the state of Hawaii and city and county of Honolulu should take the initiative in encouraging TDM program development for their own employees by

- Developing comprehensive and coordinated programs for each agency that are truly effective and not merely Band-Aid solutions;
- Discontinuing TDM-contradictory government programs, such as charges for employee parking that are below the market rate;
- Encouraging the use of compressed work weeks, staggered work hours, and Saturday workdays;
- Encouraging the greater use of at-home telecommuting by developing guidelines to address supervision and liability questions;
- Encouraging greater use of government vehicles for work-related travel by revising current checkout procedures and eliminating personal vehicle reimbursements when government vehicles are available;
- Establishing an effective data base of commuting statistics by department for use in building an effective combination of TDM measures; and
- Revising and passing legislation to support the development of TDM programs in the public sector (such as charging prevailing market rates or higher for parking, changing restrictive policies concerning the use of fleet vehicles, revising transit services to provide greater coverage, and revising work hour policies, including TDM benefits in renegotiations of union contracts).

## CONCLUSIONS

The development of an effective areawide TDM program for Oahu requires a major shift in attitude of the current government institutions, especially among the members of the Hawaii legislature. This change will come about only when the general public perceives that the level of congestion requires certain sacrifices in their current commute choices.

Also, if government cannot overcome the barriers set up by years of status quo and "we-can't-do-it" mentalities, private employers will never be convinced of the need to make changes. Government must discontinue the contradictory nature of its current policies, which provide employee parking at below-market rates and discourage flextime and compressed work weeks. If this does not occur, no amount of private-employer participation will create an effective overall program. However, if government can overcome its own barriers to implementation, private enterprise will be more likely to follow its lead, and the overall effectiveness of an areawide program can be increased.

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# Integrated Traffic Concept for European Metropolitan Areas: Review of Alternative Traffic Management and Transportation Development Scenarios for the Greater Stuttgart Area

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A vital general condition for conurbations is detectable, continued growth in the number of residents and the working population. What is needed is an integrated concept with a comprehensive catalog of measures concerning structural aspects of residential accommodation, planning, administration, and political regulation, pricing, and finance. There is a need for investment and technical measures that are mutually supportive and all aim in the same direction. The questions posed in an integrated traffic investigation about environmentally oriented concepts for residential structures with regard to the Greater Stuttgart area are examined in two scenarios and compared with those of a Trend scenario. In both scenarios, various measures as part of an integrated traffic infrastructure concept are examined with and without concepts for charging road usage fees (so-called road pricing). To validate the effects of the examined concepts, a complex traffic and effect model was developed and calibrated in the study area. The analyses based on this model demonstrate that road pricing can contribute to a substantial reduction in the existing overloads in the road network. Moreover, road pricing demands considerable extension of the public transport network and comprehensive integration of roads and public transport through multifunctional P + R terminals. It also necessitates realignment of the road network. The studies relating to the integrated transport concept also revealed substantial future demand for research, in particular with regard to knowledge and impacts of new measures relating to pricing and organizational policy on the traffic and location behavior of the population and companies.

The development of road traffic shows that, regardless of political aims, mobility in the form of motorized individual traffic is increasing in the conurbation areas. Concepts to improve and maintain the environment must take into consideration this development in mobility. What is needed is an integrated concept for measures concerning structural aspects of residential accommodation, planning, and administration as well as political regulation, pricing, and finance (*1*). There is a need for investment and technical measures that are mutually supportive and that aim in the same direction. This then was the point of entry into the initial draft plan of an integrated traffic concept for the greater Stuttgart area (*2*).

The term integration implies more than the integral examination of the different segmental traffic systems. Here, integration in addition means the integral examination of all individual measures and their packaging into concepts. That is, parallel to the operative and structural measures, it is particularly important to include measures of a financial, pricing, regulatory, and technical nature. Integration means also integral examination and evaluation of these concepts, considering ecological and economical aspects.

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## ROAD PRICING AS A CENTRAL MEASURE OF AN INTEGRATED TRAFFIC CONCEPT

At the center of integrated traffic concepts are marketing instruments and pricing measures. There is general agreement that the variable costs of private motoring are too low. It has been demonstrated in the past that the previous scope for varying the price of motor fuel has had only slight effects on road usage and the choice of means of transportation. A medium- and long-term task is the development of a tool accommodating the supply-and-demand aspect, that is, road pricing or the road usage fee.

Electronic fee accounting and invoicing will be possible in a few years and can be introduced in the medium term. A road usage fee creates a new balance between supply and demand. Road pricing oriented toward shortages and scaled according to area and time would thus dampen demand and, consequently, would increase the quality of traffic flow.

In areas of agglomeration there is the opportunity to shift traffic to more environmentally friendly means of transport. However, at present there is no assured experience of road pricing on the basis of which the medium- and long-term consequences of such an area-related road usage fee can be forecast. Nevertheless, the idea of a market-oriented method of approach should be pursued further (*3*). In the Stuttgart area, parallel to the trend, two antagonistic scenarios were established.

## SCENARIOS

### Trend Scenario

The Trend Scenario describes a situation that anticipates a continuation of previous development up to 2010. This presages a continued growth in residential and working places with further dispersed growth of estates. The number of rail kilometers and the length of the road network for motorized individual traffic (MIT) will almost remain constant.

### Scenario A

Scenario A is based on the assumption that a locally compressed residential structure demonstrates ecological and traffic advantages (Figure 1). This concept is aimed at reducing the distances between places of residence and work.

Such a scenario depends on increased cooperation between the various transportation systems. The road network will be expanded and integrated into the public transport system. Also, the public transport system network will be improved and extended, and large, high-capacity P + R terminals will be erected. The infrastructural measures were supplemented by zonal road pricing and parking space management.

With respect to freight transport the aim is to shift transportation to the railway by expanding the consolidation centers.

### Scenario B

The strategically crucial point for Scenario B lies in the concentration of housing developments along the public transport axes. Parallel to this, road capacity will be reduced, that is, road space will be created for buses, taxis, and carpools (Figure 2). The urban railways and the regional railway systems will be improved and augmented. Fine-mesh coverage will be provided by a high-density system of bus routes. Further, additional consolidation centers will be expanded. In addition, a so-called conditional network for commercial road traffic will be introduced.

## EFFECTS

### General

Both Scenarios A and B were examined with and without a road pricing concept. A traffic and effect model was developed to illustrate the effects of the measures. The model was complex and iterative and addressed the aim and choice of transportation means simultaneously. To portray road pricing, the costs were interpreted as additional time resistances.

### Trend Scenario

The Trend Scenario serves as a comparison with the current situation. With respect to the majority of aims, a serious deterioration in some cases is expected. The cause of such deterioration primarily lies in the unrestricted advance of suburbanization, in growing motorization (+300 percent), as well as in a global increase in population (+128,000) and the number of people employed (approximately 84,000) by 2010.

These changes lead to a 31 percent increase in the number of journeys in passenger traffic and a 14 percent increase in truck traffic. The mileage covered in MIT on the road network increases over the entire planning area.

Fuel consumption—a key indicator of climate-relevant $CO_2$ emission—will increase by 10 percent in conjunction with the continuing trend toward more powerful vehicles. With regard to other pollutant emissions, it is expected that technical efforts (changeover to LEVs in vehicle fleets) will considerably improve the current situation. The nitrogen oxide ($NO_x$) emissions from private traffic will be reduced by 61 percent. The $NO_x$ emissions stemming from truck traffic have been increasing because no advances in technology have been identified. In addition, accessibility in the road network is being severely impaired, with the result that the attractiveness of the region as a commercial base appears to be in jeopardy.

### Scenario A

The concept of "short" distances will lead to a justifiable result only if it is coupled with road pricing and a parking area management concept. In this case, a considerable proportion of traffic volume will be shifted to the local public transport system.

However, there is evidence of "escape" reactions in which the road pricing area will be avoided. In spite of the greater use made of the public transport services, MIT mileage in this scenario is 7 percent above the trend.

On inner urban routes sensitive to the residential environment, MIT mileage will drop disproportionately (by 23 percent) in con-

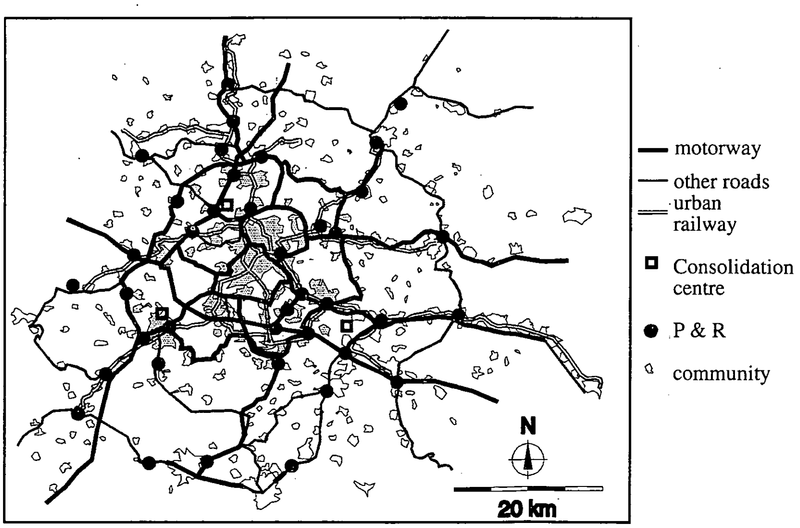


**FIGURE 1 Traffic infrastructure in Scenario A.**

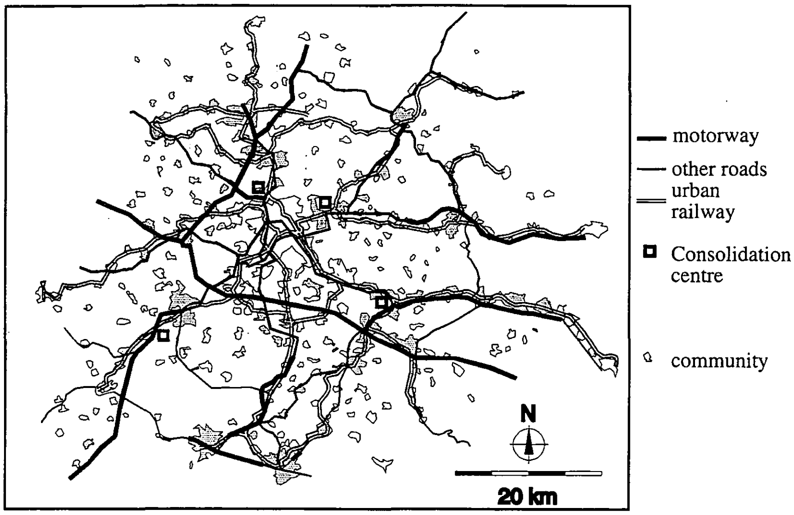


**FIGURE 2 Traffic infrastructure in Scenario B.**

junction with the new road-building measures. Reduction in MIT will be achieved within the network subject to road usage fees because road usage here will decrease by 24 percent.

However, critical questions must be posed concerning the zonal arrangement of the P + R concept examined here. The structural consequences for areas with high road usage fees are currently difficult to assess. For instance, trends toward migration to "cheaper" areas are just as conceivable as increases in the attractiveness of areas enjoying considerably less MIT.

### Scenario B

In Scenario B, the aims of reducing MIT mileage and increasing the share of public transport in overall traffic volume (+31 percent) are achieved without road pricing. The MIT mileage falls by 12 percent, although at the cost of greater traffic jam frequency and duration. Commercial traffic reliant on MIT will also be affected in particular. Under road pricing conditions, only marginal improvements can be seen in contrast to Scenario A because the potential for MIT transfer already has been largely exhausted through construction and operating measures.

Regarding MIT loads, Scenario B demonstrates clear relief in the conurbation core as well as additional relief on the axes served by public transport. However, these reductions contrast with increases in mileage in the areas between the axes.

Whereas in Scenario B positive effects are achieved with respect to the human and natural environment, one must assume that, distinctly, these will have negative effects on the commercial structure.

An important factor in both Scenarios A and B is costs. The investment costs compared with the trend amounted to 12.2 thousand million DM (36 percent road, 35 percent public transport, 29 percent P + R) in Scenario A and 11 thousand million DM (0 percent road, 100 percent public transport) in Scenario B. There are also the additional operating costs, which could be approximately 168 million DM in Scenario A and about 574 million DM in Scenario B. As already mentioned, the costs of investing in and implementing a road pricing concept still have to be considered.

## CONCLUSIONS

The following conclusions can be drawn from the investigation of the integrated traffic concept for Stuttgart:

1. A significant increase in the overall cost of traffic through "internalization" of external costs is necessary to sharpen awareness of the consumption of resources connected with traffic.
2. The previous investment as well as restrictive measures did not achieve their goal: the frequency and duration of traffic jams also increased, as did pollution of the environment.
3. The necessary quality of the road network can, however, be recovered through incisive road usage fees scaled according to time and area.
4. A road pricing concept must be coupled with a generous expansion concept for the local public transport system to facilitate migration away from MIT to the public system.
5. The transfer points for P + R in passenger traffic and consolidation centers in long-distance goods traffic are vital components of a future traffic concept.
6. Promotion of carpools takes on special importance in high-occupancy-vehicle concepts. Testing such concepts appears to be extremely interesting.
7. The intelligent utilization of such a complex traffic system is only conceivable on the basis of a comprehensive information system available in a fully updated form at any time and place.
8. Significantly, more must be invested in the transportation infrastructure. The road pricing concept can be fully integrated into financial planning.
9. Planning responsibilities in conurbations of this sort must be regulated anew.

## FINAL COMMENTS

Even if the best possible use is made of all strategies and instruments it will not be possible to reduce environmental pollution to the extent envisaged by the federal German government. The catalog of measures must be supplemented by a further requirement relating to the technical possibilities. The greatest potential for savings with respect to energy consumption and pollutant emissions can be achieved by making technical modifications to vehicles themselves. However, these measures also must be flanked by appropriate political regulatory and financial concepts.

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# Potential for Telecommuting in New England

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The potential impact of telecommuting on vehicle miles of travel (VMT) and the number of vehicle trips (cold starts) is estimated. Estimates are also made of the costs associated with the institution of home and satellite telecommuting per employee and per VMT saved. The factors that affect the amount of telecommuting are discussed and research into the values of these factors is cited. The factors are then assigned values on the basis of the research. Using these values, hypothetical examples are calculated of the potential ranges of VMT reductions and vehicle trip reductions for Massachusetts and Rhode Island and for the three southernmost counties of New Hampshire.

The purpose of this paper, based on research sponsored by the Conservation Law Foundation, is to estimate the effectiveness of telecommuting as a transportation control measure in Massachusetts and Rhode Island and for the three southernmost counties of New Hampshire. Because vehicle emissions are a function of both the amount of vehicle travel, measured by vehicle miles of travel (VMT), and the number of vehicle trips or "cold starts," the impact of telecommuting is estimated on the basis of both VMT and cold starts. Two distinct types of telecommuting are reviewed: home telecommuting and satellite telecommuting, where a worker travels to a site provided by the employer near home to perform daily work functions.

## FACTORS INFLUENCING THE EFFECTS OF TELECOMMUTING

The factors discussed in this section are likely to influence the effects of telecommuting on VMT and cold starts. Most obvious is the number or share of the work force that represents the telecommuting market, either as home or satellite telecommuters. The potential market may vary by type of industry and job classification most susceptible to telecommuting. Because home and satellite telecommunication are fundamentally different phenomena, the proportion of each is a key factor too.

The average number of days in the work week that the telecommuter participates in telecommuting will have an effect. The average trip length of telecommuters for their trip to their work sites on nontelecommuting work days will affect VMT. If telecommuters travel to a satellite center, the travel distance saved is the difference in the trip length to the satellite center and the usual work site. If they work at home, the difference is merely the distance to the usual work site. Trip length saved may also be based on "self-selection," that is, those who choose or volunteer to telecommute may have longer or more arduous work trips than the average worker. This will tend to skew the impact of telecommuting upward.

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There may be a change on telecommuting days in the amount of driving that occurs either for nonwork purposes by the telecommuter or by other members of the household when there is an additional automobile available. The amount of VMT saved is also determined by the mode of travel by telecommuters on days that they travel to their usual work sites. If they are transit riders or passengers in a carpool, the home telecommute will not save the full amount of the trip distance from home to the usual work site. The mode to the satellite center must also be considered.

In the long run, workers may consider changes in where they live if they can telecommute. This will tend to result in long commutes because they are traveling less frequently to the usual office site, negating some of the VMT savings associated with telecommuting.

## REVIEW OF LITERATURE

The literature has been reviewed with an eye toward providing quantitative estimates of the factors described earlier. Data are now becoming available as studies of telecommuting are being reported. Because the phenomenon of telecommuting is relatively new, more data can be expected to become available to provide more refined estimates of these factors.

### Participation Rates

Nilles (*1*) estimates that 40 percent of all workers could telecommute. He bases this estimate on the assumption that telecommuters will come from those with "information" jobs, that 50 percent of all jobholders hold information jobs, and that 80 percent of those workers can telecommute. The *Urban Transportation Monitor* survey (*2*) estimated (using a very crude arithmetic method) that 32 percent of employees working for the employers in telecommuting demonstration projects could eventually telecommute.

The question of who participates in telecommuting and whether their travel characteristics differ from the population at large remains an important one. The *Urban Transportation Monitor* survey asked about the distribution of telecommuters among managers, professionals, and clerical and data entry workers in telecommuting demonstration programs. Although not scientific, it suggests that the telecommuters tend to be skewed toward professional workers, which will suggest a higher-than-average trip length, as will be discussed in the section on length of trip saved.

### Frequency of Telecommuting

The *Urban Transportation Monitor* survey asked how many days a week the participants telecommuted. The results for the 15 usable employer responses are shown in Table 1. It indicates a wide variation among respondents, with an average of 1.72 days per week. Note that one respondent (Los Angeles County), with over 2,600 telecommuters, registered more than half of all the telecommuters in the survey, skewing the results. Fifty-three percent of their participants telecommuted 2 days per week, raising the overall average. The other respondents averaged well below 1.5 telecommuting days per week.

In a report of the Los Angeles experiment 2 years earlier, in 1990, JALA Associates (*3*) found that the average days per week was 1.5, when only 1,100 workers participated. On the basis of the *Urban Transportation Monitor* survey, the frequency of telecommuters had climbed considerably.

## Length and Number of Trips Saved

Nilles (*4*) reports that 108 telecommuters traveling to two satellite centers had an average commute of 3.8 mi, compared with the company average (2,700 employees) of 10.7 mi, or a savings of 65 percent. He points out that among home-based telecommuters the average commute varied by job type, with professionals and managers commuting farther than the average of all employees. If telecommuting is proportionally more prevalent among these groups, the VMT savings could be greater, if it were based on the average work trip lengths of all workers.

A telecommuting demonstration with 73 telecommuters in southern California reports that the average miles driven per day by telecommuters on telecommuting days dropped by 76 percent, from 49.7 mi before telecommuting to only 12.0 mi afterward. The number of trips per day per person dropped to half from 4.0 to 1.94 (*5*).

In the Puget Sound area, data from 119 telecommuters indicated that they averaged 52 mi/day before telecommuting began, and once they telecommuted they traveled only 13 mi/day, a 75 percent savings (*6*). The number of trips dropped from 4.3 per day before telecommuting to 2.6 per day on telecommuting days afterward.

**TABLE 1 Telecommuting Participation: Percent Distribution by Number of Days per Week**

| | | Days Per Week, Percent | | | | |
|---|---|---|---|---|---|---|
| Number of Telecommuters | less than 1 | 1 | 2 | 3 | 4 | 5 |
| 441 | - | - | 100 | - | - | - |
| 10 | - | - | - | - | - | -100 |
| 150 | - | -85 | 15 | - | - | - |
| 200 | - | 99 | 1 | - | - | - |
| 120 | - | 90 | 6 | 1 | 3 | - |
| 300 | 57 | 11 | 13 | 5 | 14 | - |
| 2600 | 18 | 8 | 53 | 14 | 61 | - |
| 40 | - | 100 | - | - | - | - |
| 59 | - | 38 | 33 | 13 | 16 | - |
| 64 | - | 10 | 80 | 8 | 2 | - |
| 24 | - | - | - | - | 20 | 80 |
| 100 | - | 40 | 30 | 20 | 5 | 5 |
| 20 | - | 100 | - | - | - | - |
| 8 | - | 95 | 5 | - | - | - |
| 7 | - | 57 | 29 | 14 | - | - |
| Weighted % | 15.4 | 30.3 | 37.5 | 10.0 | 5.4 | 1.4 |

Weighted Average per Week = 1.72 days*

* Assumes less than once per week equivalent to once every two weeks.

Source: Urban Transportation Monitor

In San Diego the average trip length saved per telecommute day was 24 mi round-trip (*7*). In Phoenix 134 telecommuters avoided an average of a 31-mi round-trip when they telecommuted an average of 1 day per week (*8*). This was confirmed by a telephone conversation with Susan Sears of AT&T (personal communication). In both demonstrations the average miles traveled before telecommuting or on nontelecommuting days was either not asked for or reported so percentage changes cannot be estimated. An average was not provided for any control group.

Both the southern California and the Puget Sound data indicate that telecommuters travel even less on days that they traveled to their normal employer work site. In the former case they traveled only 44.4 mi on nontelecommuting days, compared with their travel habits before they became telecommuters of 49.7 mi/day. In the latter case, the drop-off was less, 52 to 49 mi/day. JALA Associates reported a drop of 22 percent in VMT in telecommuter households. This surprising result may be the "anchoring" phenomenon of nonwork activities cited by Mokhtarian (*9*), whereby telecommuters begin to do their nonwork trips closer to home once they become accustomed to services nearer their home, rather than along their commutes.

## Self-Selection Factor

Self-selection is borne out by data reported by Nilles (*1*) of a study of 44 telecommuters and a control group of 35 workers with the same job profiles. The telecommuters had an average trip length of 30.2 mi, whereas the others had an average trip length of only 14.8 mi to work. The Puget Sound demonstration shows a similar relationship, with telecommuters having an 18-mi trip to work compared with an average of 8 mi for the control group. Moreover, in the Puget Sound area those who dropped out of the program had shorter trip lengths, suggesting that the motivation to remain telecommuters was greater among those with longer trips. A contrary result from San Diego reported that distance did not appear to be a factor when workers chose to enter the telecommuting program (*7*). However, the findings of this demonstration project can be discounted because only 14 telecommuters participated. The San Diego experience seems to be the exception. The *Urban Transportation Monitor* survey reported that in many cases the motivations were higher for longer-distance commuters and that participation was greater among managers and professionals, two factors that go hand in hand.

## Relocation of Residences

In California, the question of whether telecommuting prompts a change of residence was explored (*3*). Of the 16.8 percent of the telecommuters who moved since telecommuting started, and the 11.2 percent of telecommuters considering it, 19.4 percent said that their telecommuting experience was a significant influence and another 9.7 percent said it was decisive. Among those who moved, the average added distance was 1 mi farther from the home office.

## Other VMT on Telecommuting Day

The JALA Associates report on the California experiment (*3*) indicated that only a very modest number of additional trips are made because the automobile is available on telecommuting days. The

Puget Sound study could not determine whether there was an increase in nonwork trips on telecommuting days. However, Bowman and Davis (*7*) reported that about 20 percent of the VMT savings was offset by travel for nonwork purposes on telecommuting days.

### Mode Splits on Nontelecommuting Days

In San Diego, 17 percent of the telecommuters were carpoolers when they did not telecommute. In Puget Sound, 61 percent commuted in single-occupant vehicles (SOVs). The Puget Sound teleworking center experiment started with only 56 percent as SOVs to the main office, but that increased to 83 percent for travel to the satellite center, partially offsetting the reduction of VMT. This result suggests that if the home office is in a city center with transit available and the satellite center is in the suburbs, much of the VMT savings hoped for with telecommuting can be lost.

### Trips Avoided During Congested Periods

Another consideration is whether the congestion relief created by telecommuting will be evenly spread over the work week. There is evidence that Tuesdays and Thursdays are preferred, followed by Wednesdays and Fridays. This might suggest uneven relief from peak period congestion by day of week.

### Travel Avoided by Highway Type

Nilles (*1*) suggests that traffic patterns could be changed by telecommuting. Home-based telecommuters will clearly not use their home office commute routes on the days they work from home but likely will add to local road use to run midday errands, for example. Telecommuters bound for satellite centers may also switch from arterials or expressways used to reach the home office to local streets to reach the center.

## SCENARIOS TESTED AND ASSUMPTIONS MADE

Four scenarios are constructed to examine the VMT and trip-making reductions attributable to telecommuting for the entire states of Massachusetts and Rhode Island and for the three southernmost counties in New Hampshire. A step-by-step methodology is also presented. The values of the various factors used for this exercise are based on the evidence presented in the literature review.

The scenarios are as follows: minimal (a maximum of 5 percent of employees telecommute), modest (10 percent), major (20 percent), and maximum (40 percent). Whether the maximum is reached for any of the scenarios is likely to be a function of the difficulty of commuting in an area. The surrogate for the difficulty of the trip is trip length. For short trips, the incentive for telecommuting diminishes. It is assumed here that in municipalities in New England with average work trip lengths above 10 mi, the "nominal" participation within each scenario (5, 10, 20, and 40 percent) could be reached, but where the trip lengths are shorter, the participation rate will likely drop as a function of the average trip length for workers in the municipality. The drop-off in participation is assumed to be 10 percent for each mile less than 10 mi.

Existing average work trip lengths were based on the estimates made for each municipality in the study area in 1990 as part of the analysis in an earlier phase of this work (*10*).

Because the proportion of telecommuters who work at home or in a satellite center will have an effect on travel impacts, that proportion too must be assumed. Intuitively, it would appear that as the overall participation in telecommuting rises, so would the share of telecommuters who travel to satellite centers. The reasoning behind this is that involvement with higher and higher percentages of workers would require the management and structure found in a satellite center. The assumption is made that for the 5 percent scenario, one in five would be a satellite telecommuter, for the 10 percent scenario, one in four, for the 20 percent scenario, one in three, and for 40 percent, one in two would be a satellite telecommuter.

The VMT saved is next calculated by making the assumption that telecommuters average longer travel distances to the home office than the average worker and that the satellite telecommuters also average longer distances to the home office, but not as far as the home telecommuters. Moreover, it is assumed that as participation increases from scenario to scenario, the average trip length of participants to the home office decreases. An adjustment is made to increase the round-trip distance by 5 percent for 15 percent of the home telecommuters to account for housing relocation. The factors that address distance and home versus satellite telecommuters for the four scenarios are given in Table 2.

The assumption is made that telecommuting occurs an average of 1.75 times per week, or 35 percent of the work days. On telecommuting days the home telecommuters travel 75 percent less than they would have otherwise and the satellite telecommuters travel 67 percent less than they would have. The lower reduction in travel accounts for the fact that they will be inclined to carry out personal business and errands once they leave their home in an automobile. On nontelecommuting days home telecommuters are assumed to travel 10 percent less than on days when they travel to the office. No difference is assumed for satellite telecommuters.

Finally, all reductions in commuting distances account for the estimated share of workers who did not commute in SOVs in 1990. Although there is evidence that those telecommuting to satellite centers may shift to SOVs, diminishing the VMT savings, much will depend on the location of satellite centers relative to the location of the home office. This phenomenon is too speculative to permit any adjustments at this time to account for an increase in SOV share for satellite center-bound trips. However, this is a concern that could threaten the effectiveness of telecommuting to reduce VMT and should be watched closely.

The number of workers in each municipality to allow these calculations was determined using the data files assembled from the earlier effort (*10*).

**TABLE 2 Participation and Trip Length Factors for Four Telecommuting Scenarios**

| Scenario | Home/Satellite | % Home TC | Trip Length Factor |
|---|---|---|---|
| 5 percent | Home | 80 | 2.00 |
| | Satellite | 20 | 1.50 |
| 10 percent | Home | 75 | 1.80 |
| | Satellite | 25 | 1.40 |
| 20 percent | Home | 67 | 1.70 |
| | Satellite | 33 | 1.35 |
| 40 percent | Home | 50 | 1.50 |
| | Satellite | 50 | 1.25 |

## RESULTS OF SCENARIO TESTING

Table 3 gives annual VMT estimates for the base condition. The impacts on VMT of applying these assumptions to the four scenarios are given in Table 4. The data are presented on an annual basis by using a factor of 250 weekdays in the year. Table 4 gives the VMT saved in three ways. First, it indicates VMT reductions as a percent of all VMT for each state. Second, it shows the VMT saved as a percent of all work VMT. Finally, the table presents percent VMT savings as a portion of VMT generated by SOVs as part of the daily work trip itinerary, including VMT not strictly to and from the work site.

The VMT reductions increase with rising participation rates, from 0.5 percent of total regional VMT savings in the 5 percent participation scenario to 3.0 percent in the maximum participation scenario. As a percent of work VMT the savings is much higher, ranging from 1.8 to 9.9 percent. The third column of savings, the savings as a percent of work-related SOV VMT, is still higher, ranging from 2.3 to 12.7 percent. But each successive scenario, with double the nominal rate of participation, does not yield a doubling of VMT savings. Two assumptions are largely responsible for this, both dealing with a changing character of telecommuters and telecommuting with the higher nominal participation rates—that "normal" trip lengths of participants will diminish and that more workers will use satellite centers.

Also significant is the variation in percent savings between eastern Massachusetts and the rest of the study area. The longer work trip lengths in that area led to much higher assumptions of the participation rates in telecommuting. Eastern Massachusetts is estimated to have about double the percent VMT savings of the other parts of the study area.

Suburban locations in particular tend to have greater absolute and relative savings because trip lengths are long and few potential telecommuters use transit. Rural areas, typified by western Massachusetts, have low gains because of the short trip lengths, which encourage fewer telecommuters.

The change in the number of cold starts is determined by estimating the vehicle trip reductions, assuming that each day a home telecommuter telecommutes, two trips (and two cold starts) are saved if they would otherwise have been SOVs. Telecommuters to satellites are assumed not to save vehicle trips. Telecommuters in carpools also are assumed not to save any vehicle trip making. In Table 5 the regionwide reduction in cold starts is shown to range from 50,000 for the minimal (5 percent) scenario to 260,000 per day for the maximum (40 percent) scenario. Here again, the savings increases more slowly with each scenario because the higher scenarios are assumed to have proportionally more satellite commuters, and traveling to satellite telecommuting centers does not reduce the total number of trips. The volume of cold starts associated with the trip to and from work from which these reductions are taken includes two cold starts for each SOV.

**TABLE 3 Annual VMT Estimates, Base Condition**

| | Total VMT (mil.) | Work VMT (mil.) | Work-Related VMT by SOVs (mil.) |
|---|---|---|---|
| E. Mass. | | 8,480 | 8,319 |
| W. Mass. | 38,145* | 3,091 | 1,516 |
| R.I. | 4,444 | 1,397 | 732 |
| N.H.(3 cos.) | 5,588 | 1,830 | 931 |
| Total | 48,177 | 14,799 | 11,499 |

* - eastern and western Massachusetts combined

**TABLE 4 Impact of Telecommuting on VMT**

| | VMT Saved (mil.) | Percent Saved: Total VMT | Percent Saved: Work VMT | Percent Saved: Work-Related VMT by SOVs |
|---|---|---|---|---|
| **5 % Telecommuting** | | | | |
| E. Mass. | 220 | -- | 2.6 | 2.6 |
| W. Mass. | 20 | 0.6* | 0.7 | 1.3 |
| R.I. | 11 | 0.2 | 0.9 | 1.5 |
| N.H.(3 cos.) | 13 | 0.2 | 0.7 | 1.4 |
| Total | 264 | 0.5 | 1.8 | 2.3 |
| **10 % Telecommuting** | | | | |
| E. Mass. | 387 | -- | 4.6 | 4.7 |
| W. Mass. | 36 | 1.1* | 1.2 | 2.4 |
| R.I. | 19 | 0.4 | 1.4 | 2.6 |
| N.H.(3 cos.) | 23 | 0.4 | 1.3 | 2.5 |
| Total | 465 | 1.0 | 3.1 | 4.0 |
| **20 % Telecommuting** | | | | |
| E. Mass. | 714 | -- | 8.4 | 8.6 |
| W. Mass. | 66 | 2.0* | 2.1 | 4.4 |
| R.I. | 36 | 0.8 | 2.6 | 4.9 |
| N.H.(3 cos.) | 42 | 0.8 | 2.3 | 4.5 |
| Total | 858 | 1.8 | 5.8 | 7.5 |
| **40 % Telecommuting** | | | | |
| E. Mass. | 1,214 | -- | 14.3 | 14.6 |
| W. Mass. | 113 | 3.5* | 3.7 | 7.5 |
| R.I. | 61 | 1.4 | 4.4 | 8.3 |
| N.H.(3 cos.) | 72 | 1.3 | 3.9 | 7.7 |
| Total | 1,460 | 3.0 | 9.9 | 12.7 |

* - eastern and western Massachusetts combined

**TABLE 5 Cold Start Reductions by Telecommuting**

| Scenario/Region | Cold Starts Saved Per Day |
|---|---|
| **5 Percent Telecommuting** | |
| Eastern Massachusetts | 37,233 |
| Western Massachusetts | 8,492 |
| New Hampshire | 5,212 |
| Rhode Island | 4,101 |
| *Region Total* | *55,039* |
| **10 Percent Telecommuting** | |
| Eastern Massachusetts | 69,812 |
| Western Massachusetts | 15,923 |
| New Hampshire | 9,773 |
| Rhode Island | 7,688 |
| *Region Total* | *103,198* |
| **20 Percent Telecommuting** | |
| Eastern Massachusetts | 124,731 |
| Western Massachusetts | 28,450 |
| New Hampshire | 17,462 |
| Rhode Island | 13,737 |
| *Region Total* | *184,380* |
| **40 Percent Telecommuting** | |
| Eastern Massachusetts | 186,166 |
| Western Massachusetts | 42,462 |
| New Hampshire | 26,062 |
| Rhode Island | 20,503 |
| *Region Total* | *275,193* |

## ADDITIONAL EMPLOYER COSTS OF TELECOMMUTING

In this section an attempt is made to estimate the added costs for employers to establish telecommuting for their employees. Among the studies cited earlier in this paper, only one addresses the issue of costs for telecommuting quantitatively. JALA Associates (*3*), in its report on the California Telecommuting Pilot Project, tried to estimate the cost of added equipment in the home. The firm found that 83 percent of telecommuters already own their own personal commuters, and some own other such relevant equipment as answering machines (79 percent), facsimile machines (5 percent), and even copying machines (2 percent). The percent of nontelecommuters who owned their own equipment was not provided in a usable form. JALA also found that most of those who have computers have a personal preference to own them rather than have their employer provide them. The report also found that the added cost of computers is offset, in large part, by the reduced costs of providing computers at the workplace. Researchers were unable to do a complete cost accounting that would incorporate these factors and proceeded to make an assumption that computer costs were small per telecommuter but did not provide the estimate they used in their cost modeling.

JALA was able to be more definitive for some costs. The researchers found that the cost of training for a telecommuter/supervisor pair is $300, added telephone charges are $30/month, and computer maintenance is $250/year. Other costs were either negligible or too difficult to estimate.

The difficulty of making these estimates is largely tied to the rapid advances in the capabilities of equipment related to telecommuting. Nevertheless, in an attempt to dimension the costs, personal experiences were relied on to a greater degree than is usual in this type of technical paper. Assumptions are as follows.

### Home Telecommuting

It is assumed that a personal computer costs $3,000 and is replaced every 5 years for an annual cost of $600. However, not every telecommuter will require a computer because some will own them already. Also, there may be an offset because fewer computers may be needed at the home office, because workers are telecommuting. Still, to be conservative it is assumed that five of six acquire a new personal computer for an average annual cost of $500.

Training comes to $300, a cost repeated every 5 years at a cost of $60/year. Telephone charges are $30/month or $360/year. Computer maintenance costs $250/year. The assumption that two in three home telecommuters need a printer at a cost of $800 each, with replacement in kind after 5 years, brings the cost per telecommuter to $107/year. Printer maintenance is assumed to be $80/year—the cost of one cartridge replacement on a laser printer. The total annual cost for each home telecommuter comes to $1,357, or $5.43/day.

### Satellite Telecommuting

The cost of a personal computer of $600/year can be shared by more than one telecommuter using the facility. With the average telecommuter telecommuting 1.75 days/week, the share of the computer cost per computer is lowered by a factor of 0.35 to $210 per person.

Training is assumed to be the same as it was for home telecommuters, $60/year. Annual computer maintenance charges of $250/year are factored by 0.35 to bring that cost to $88. The printer costs are divided among more people at the satellite centers. The combined annual cost of $240 for purchase and maintenance is factored with the assumption that there will be 1 printer for every 10 persons, resulting in $24 per telecommuter. Added telephone charges are assumed to be $180/year, discounting the full $360 cost to reflect some cost sharing of this item among telecommuters. The rental of space at the satellite center is assumed to be $17.50/ft$^2$/year inclusive of all utilities and other services, factored by 0.35 because the space can be shared, yielding $1,531 per telecommuter. The total annual cost for a satellite telecommuter equals $2,039, or $8.16/day.

The cost per day for home and satellite telecommuting is applied to the number of telecommuters assumed for each scenario, and the results are given in Table 6. The cost per VMT saved is considerably lower for eastern Massachusetts, a result of the long trip lengths there. Also, home telecommuting is less costly per VMT saved by about half, the result of lower costs per telecommuter combined with the lower VMT savings associated with satellite centers. Satellite center telecommuting may turn out to be even less cost-effective in reducing VMT if many trips now made to central cities by transit are replaced with travel by automobile to satellite centers in suburban automobile-oriented locations. Furthermore, the absence of reductions in cold starts for satellite telecommuting renders it highly questionable that satellite telecommuting will reduce vehicle emissions.

## STEP-BY-STEP METHODOLOGY

The methodologies described in this section were applied to each municipality in the study area to obtain the results discussed earlier in this paper.

### Calculation of VMT Reductions

1. Assume that the number of telecommuters equals the nominal participation rate (5, 10, 20, or 40 percent) multiplied by the number of workers in a municipality (from the earlier work) adjusted downward in municipalities where the work trip length is less than 10 mi, using a reduction factor for participation of 10 percent for every mile less than 10.0. Work trip lengths are those determined for each municipality in the study area in the earlier phase of this study.
2. Determine the number of participants on any given day by multiplying the number of telecommuters in Step 1 by 0.35 (the average days per week of telecommuting assumed as 1.75, divided by 5 work days per week).
3. Using the assumed splits for each scenario in Table 2, determine the number of telecommuters who work at home versus the number who work at satellite centers.
4. To account for the longer trip lengths for the subset of telecommuters compared with the average worker, use a trip length factor for each scenario and for both home and satellite telecommuters. These factors are also provided in Table 2. Note that the factors get smaller as the nominal telecommuting participation rates rise, reflecting the reduced effect of self-selection among longer-distance commuters. Note also that the factor is lower for satellite telecommuters because they are assumed to be less motivated to save commuting distance than are home commuters.

**TABLE 6 Cost of Telecommuting**

| Scenario/Region | Daily Number of Telecommuters | Daily Work VMT Saved | Total Cost | Cost Per Work VMT Saved |
|---|---|---|---|---|
| **5 Percent Telecommuting (Home)** | | | | |
| Eastern Massachusetts | 27,149 | 740,272 | $147,360 | $0.20 |
| Western Massachusetts | 5,497 | 68,693 | 29,837 | 0.43 |
| New Hampshire | 3,293 | 44,020 | 17,872 | 0.41 |
| Rhode Island | 2,664 | 37,111 | 14,461 | 0.39 |
| *Region Total* | *38,603* | *890,097* | *$209,530* | *0.24* |
| **5 Percent Telecommuting (Satellite)** | | | | |
| Eastern Massachusetts | 6,787 | 140,824 | 55,365 | 0.39 |
| Western Massachusetts | 1,374 | 13,066 | 11,210 | 0.86 |
| New Hampshire | 823 | 8,373 | 6,715 | 0.80 |
| Rhode Island | 666 | 7,059 | 5,433 | 0.77 |
| *Region Total* | *9,651* | *169,321* | *$78,723* | *0.46* |
| **10 Percent Telecommuting (Home)** | | | | |
| Eastern Massachusetts | 50,905 | 1,222,072 | 276,300 | 0.23 |
| Western Massachusetts | 10,307 | 113,388 | 55,944 | 0.49 |
| New Hampshire | 6,174 | 72,661 | 33,511 | 0.46 |
| Rhode Island | 4,995 | 61,256 | 27,114 | 0.44 |
| *Region Total* | *72,381* | *1,469,378* | *$392,868* | *0.27* |
| **10 Percent Telecommuting (Satellite)** | | | | |
| Eastern Massachusetts | 16,968 | 324,239 | 138,413 | $0.43 |
| Western Massachusetts | 3,436 | 30,084 | 28,025 | 0.93 |
| New Hampshire | 2,058 | 19,278 | 16,787 | 0.87 |
| Rhode Island | 1,665 | 16,253 | 13,583 | 0.84 |
| *Region Total* | *24,127* | *389,854* | *$196,808* | *0.50* |
| **20 Percent Telecommuting (Home)** | | | | |
| Eastern Massachusetts | 90,950 | 2,035,043 | 493,656 | 0.24 |
| Western Massachusetts | 18,415 | 188,818 | 99,953 | 0.53 |
| New Hampshire | 11,031 | 120,999 | 59,873 | 0.49 |
| Rhode Island | 8,925 | 102,007 | 48,443 | 0.47 |
| *Region Total* | *129,321* | *2,446,867* | *$701,924* | *0.29* |
| **20 Percent Telecommuting (Satellite)** | | | | |
| Eastern Massachusetts | 44,796 | 819,269 | 365,409 | 0.45 |
| Western Massachusetts | 9,070 | 76,014 | 73,986 | 0.97 |
| New Hampshire | 5,433 | 48,712 | 44,318 | 0.91 |
| Rhode Island | 4,396 | 41,066 | 35,858 | 0.87 |
| *Region Total* | *63,696* | *985,061* | *$519,572* | *0.53* |
| **40 Percent Telecommuting (Home)** | | | | |
| Eastern Massachusetts | 135,747 | 2,594,416 | 736,800 | 0.28 |
| Western Massachusetts | 27,485 | 240,718 | 149,183 | 0.62 |
| New Hampshire | 16,464 | 154,258 | 89,362 | 0.58 |
| Rhode Island | 13,321 | 130,045 | 72,303 | 0.56 |
| *Region Total* | *193,017* | *3,119,437* | *$1,047,648* | *0.34* |
| **40 Percent Telecommuting (Satellite)** | | | | |
| Eastern Massachusetts | 135,747 | 2,260,076 | 1,107,301 | 0.49 |
| Western Massachusetts | 27,485 | 209,697 | 224,201 | 1.07 |
| New Hampshire | 16,464 | 134,379 | 134,298 | 1.00 |
| Rhode Island | 13,321 | 113,287 | 108,660 | 0.96 |
| *Region Total* | *193,017* | *2,717,439* | *$1,574,461* | *0.58* |

5. To account for the effect of shifts in residential location among telecommuters, assume that 15 percent of telecommuters will move to locations an average of 5 percent further away.

6. Calculate the driving distances saved on telecommuting days by assuming that each home telecommuter drives 75 percent less on nontelecommuting days and that each satellite telecommuter drives 67 percent less.

7. Reduce the driving distances on telecommuting days by 10 percent for the home telecommuters to account for the lower amount of driving observed for the home telecommuters on non-telecommuting days (the "anchoring" effect).

8. In Steps 6 and 7, to account for telecommuters who did not drive alone, discount the distances for only those who were assumed to travel in SOVs on the basis of the SOV shares for each municipality derived in the earlier work. Assume no change in modal shares for telecommuters on nontelecommuting days.

9. Calculate the percentage reduction in VMT by determining the work VMT, multiplying the average work trip lengths by the number of workers.

## Trip Reductions

Calculate the vehicle trips to and from work saved as 2 × the number of workers × the SOV share × the nominal participation rate × the fraction of days home telecommuting occurs. This assumes that no trip savings occurs for satellite telecommuting or for home telecommuters on nontelecommuting days.

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# Assessing Users' Needs for Dynamic Ridesharing

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The findings of three user assessment methods that were used to gather information on commuter needs and preferences for the Bellevue Smart Traveler (BST) Traveler Information Center (TIC) are presented. The goal of the BST TIC is to reduce congestion in downtown Bellevue, Washington, by providing a new alternative to single-occupancy-vehicle commuting. The TIC's main function will be to help commuters form dynamic rideshare groups, in addition to providing traffic congestion and transit information. The current TIC design reflects the preferences and needs of its potential users as revealed by the assessment methods described. The strategy behind the development of the prototype BST TIC has been to (*a*) base its design on users' travel needs and (*b*) integrate existing technologies that enable an automated system to work efficiently and effectively. This prototype will be demonstrated and tested in a selected area of downtown Bellevue. Throughout the demonstration, researchers will solicit input from participants and, whenever possible, modify the BST prototype to meet their needs. The kind of user assessment presented is necessary for the design of efficient transportation information systems to appropriately meet the needs of commuters.

Much of the traffic congestion in urban centers can be attributed to large numbers of workers traveling in single-occupant vehicles (SOVs) to densely clustered downtown office buildings. A conventional method of dealing with this kind of congestion is to encourage high-occupancy-vehicle (HOV) commuting. However, this method has been unsuccessful at times, perhaps because of the flexibility, convenience, and other attractions of SOV travel, as well as commuters' lack of detailed knowledge of how to participate in HOV travel. For example, despite community and corporate efforts to encourage alternative travel in Bellevue, Washington, more than 80 percent of commuters travel in SOVs.

New approaches to HOV commuting may make it more attractive to current SOV commuters. One approach is to use innovative communication technology to provide commuters with the means to easily arrange for HOV commuting to and from their downtown office buildings. Bellevue Smart Traveler (BST) is a national intelligent vehicle highway system (IVHS) demonstration project developing such an approach. Under BST, a team of researchers at the University of Washington is working with the Bellevue Transportation Management Association (TMA) and with pager-service providers (PacTel, Tele-Page Northwest, and Seiko) to develop a prototype traveler information center (TIC), which is being implemented and tested in Bellevue Place, a downtown Bellevue office building. This center will integrate phone and paging technology to deliver three types of personal commuter information: (*a*) dynamic ridematching information, (*b*) up-to-the-minute traffic congestion information, and (*c*) transit information. A detailed description of the BST TIC design is given by Haselkorn et al. (*1*).

The research team began this project by conducting a survey of commuters traveling to and from the test site. They team also conducted telephone interviews and held focus group sessions. Results of the initial research are guiding the design and development of BST's information services.

## ASSESSMENT OF POTENTIAL USERS

To determine current commuting habits and needs, the team conducted a survey of employees at the test site, Bellevue Place. The survey gathered data on the employees' current knowledge and use of HOV modes, their information delivery preferences, and their general interest in the types of information that will be offered through the TIC. After results of the survey were analyzed, telephone interviews were conducted to elicit feedback regarding potential program features. Focus groups were then conducted with employees who did not participate in the survey to determine how well they would respond to a dynamic ridesharing program. This section presents the findings from each user assessment method and, on the basis of these findings, makes recommendations about user requirements for the planned traveler information center.

### Survey Results

The survey sought to determine how knowledgeable the employees at the test site were about alternative HOV modes. From the results, it was determined how detailed the information that was provided should be. If the employees were already highly knowledgeable about alternative modes but were not using them, the task would then be to motivate them to do so (in addition to simply providing information). To help design the BST ridesharing program, employees were asked how important various ridesharing features would be in making their decision to join a ridesharing program. Determination of the importance of safety issues to the participants was a specific aim. The survey also determined how participants would prefer to sign up for a ridesharing program and how they would like to receive ridematch information.

About 1,200 surveys were distributed to 54 companies at Bellevue Place; 420 people from 45 companies responded. The data were analyzed using Statview 4.0 for the Macintosh. Frequencies were calculated for all variables for the total sample. Because a large group of survey respondents worked for a major hotel at the site, tests of significance were run to determine whether there were any statistically significant differences between respondents who

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TABLE 1 Familiarity with HOV Modes

| Item | Percent | | |
|---|---|---|---|
| | Familiar with | Use | Unfamiliar with |
| Route number of most convenient bus to work | 31.66 | 11.31 | 57.03 |
| Departure time(s) of most convenient bus from work | 29.15 | —* | 70.85 |
| Departure time(s) of most convenient bus from home | 28.39 | — | 71.61 |
| Arrival time(s) of most convenient bus at work | 28.89 | — | 71.11 |
| Arrival time(s) of most convenient bus at home | 28.14 | — | 71.86 |
| Amount of fare needed to ride bus | 36.27 | — | 63.73 |
| Available carpooling/vanpooling programs | 25.88 | 4.77 | 69.35 |
| Park and Ride lot closest to your home | 66.58 | 6.53 | 26.89 |
| Location of nearest bus stop to work | 51.00 | 11.31 | 37.69 |
| Location of nearest bus stop to home | 49.50 | 10.80 | 39.70 |

* Data not applicable.

worked for the hotel and those who did not. Gender and income differences were assessed with *t*-tests for interval data, Mann-Whitney tests for ordinal data, and $\chi^2$ tests for nominal data. Results reported here are significant at an alpha level of 0.05. Because of the large number of variables analyzed, only variables that are relevant to user requirements and system features are reported.

*Employees' Current Commuting Schedules*

A total of 78 percent of the survey respondents reported arriving at Bellevue Place between 6 and 10 a.m., with nearly 60 percent arriving between 7 and 9 a.m. Approximately 77 percent reported usually leaving Bellevue Place between 3 and 7 p.m., with 53 percent leaving between 4 and 6 p.m. Respondents could vary the time they started work by an average of 21.21 min [standard deviation (SD) = 32.82, standard error (SE) = 1.7, median = 10.0] and the time they left work by an average of 27.39 min (SD = 35.85, SE = 1.9, median = 15.0).

*Prior Knowledge of HOV Modes*

Respondents indicated whether they were familiar with or used the items given in Table 1. More than half the respondents were unfamiliar with the route number of the most convenient bus to work, and more then two-thirds were unfamiliar with the departure and arrival times of the most convenient bus to or from work or home. Nearly two-thirds were also unfamiliar with the fare needed to ride the bus.

More than two-thirds of the respondents stated that they were unfamiliar with available carpooling/vanpooling programs. However, a later question cast some doubt on respondents' initial claim of unfamiliarity with ridesharing programs. Although only 26 percent of the respondents said that they were familiar with available carpooling programs, 47.33 percent indicated in a later question that they would know how to sign up for a carpooling/vanpooling program if they wanted to join one.

*Transit and Ridesharing Interest*

In response to the four types of transit information given in Table 2, more than one-quarter of the respondents said that they would be likely to commute by bus if various types of transit information were readily available to them at home and at work. For each of the information types given in Table 2, individuals who made less than $20,000 annually were significantly more likely to commute by bus if they had transit information than were those who made more than $40,000.

Respondents were asked to rate how likely they would be to use the ridesharing types given in Table 3 if these types of ridesharing were readily available in Bellevue Place. Nearly 24 percent said they would be moderately to very likely to carpool/vanpool on a regular, scheduled basis. Respondents who made less than $20,000 annually were significantly more interested in this type of carpooling than were respondents who made over $40,000 per year. About 21 percent of all respondents said that they would be moderately to very likely to carpool/vanpool for special trips on an on-demand basis. Of the three types of ridesharing described, carpooling/vanpooling to or from work on an on-demand basis was the most popular: nearly 35 percent of all respondents said that they would be moderately to very likely to use such a form of ridesharing if it were available in Bellevue Place.

*Importance of Ridesharing Features*

Respondents were asked to rate how important the ridesharing features in Table 4 would be in making their decision to join a carpool or vanpool. If respondents already carpooled or vanpooled, they were asked to rate how important these features were to them currently.

Having a guaranteed ride home was by far the most important ridesharing feature to respondents, with approximately 62 percent rating it very important. The second most important feature was saving time over their current transportation mode with 48 percent rating it as very important. Reducing pollution and having their preferences met were the third and fourth most important features, respectively.

Several ridesharing features related to safety issues: knowing other participants, meeting other participants before forming a carpool/vanpool, participants being co-workers, and participants being prescreened. Of these safety features, participants being prescreened appeared to be the most important to respondents, with 53.54 percent responding with moderately to very important. All of the safety features were significantly more important to lower-income respondents than to higher-income respondents.

**TABLE 2 Likelihood of Commuting by Bus**

| | Rating (in percent) | | | |
|---|---|---|---|---|
| Likelihood of commuting by bus if the following bus information were provided: | Very likely | Moderately likely | Slightly likely | Not at all likely |
| Scheduled bus departure time from your stop near home/work | | | | |
| All | 11.71 | 15.32 | 21.32 | 51.65 |
| Under $20,000 income | 22.58 | 17.74 | 29.03 | 30.65 |
| Over $40,000 income | 7.15 | 10.71 | 10.71 | 71.43 |
| Exact current location of your bus | | | | |
| All | 12.20 | 15.85 | 19.50 | 52.44 |
| Under $20,000 income | 21.67 | 21.67 | 25.00 | 31.67 |
| Over $40,000 income | 8.93 | 12.50 | 8.93 | 69.64 |
| Actual bus arrival time at your stop near home/work | | | | |
| All | 11.78 | 16.01 | 21.15 | 51.06 |
| Under $20,000 income | 22.58 | 17.74 | 30.65 | 29.03 |
| Over $40,000 income | 5.36 | 14.29 | 10.71 | 69.64 |
| Detailed route and transfer information between your origin and destination | | | | |
| All | 10.19 | 15.43 | 20.37 | 54.01 |
| Under $20,000 income | 17.24 | 20.69 | 29.31 | 32.76 |
| Over $40,000 income | 7.27 | 12.73 | 7.27 | 72.73 |

**TABLE 3 Likelihood of Carpooling**

| | Rating (in percent) | | | |
|---|---|---|---|---|
| Likelihood of carpooling if carpooling/vanpooling were available: | Very likely | Moderately likely | Slightly likely | Not at all likely |
| To or from work on a regular, scheduled basis | | | | |
| All | 10.65 | 13.12 | 17.21 | 59.02 |
| Under $20,000 income | 14.67 | 24.00 | 21.33 | 40.00 |
| Over $40,000 income | 3.28 | 4.92 | 19.67 | 72.13 |
| For special trips on an on-demand basis | 8.22 | 13.03 | 16.43 | 62.32 |
| To or from work on an on-demand, flexible basis | 12.50 | 22.01 | 17.66 | 47.83 |

### *Preferences for Sign-Up Methods*

Respondents were asked how they would prefer to sign up for a carpool/vanpool program and receive ridematch information. The three most preferred sign-up methods (in order) were: in person, interactive computer in Bellevue Place's lobby, and interactive phone system. The most preferred methods for receiving ridematch information were (in order): mail, in person, and interactive computer in the office complex.

### *Incentives To Rideshare*

In most ridesharing programs, people needing rides can be expected to use the system more aggressively than people offering rides. Consequently, the research team wanted to determine how likely respondents would be to drive for a carpool/vanpool if offered various incentives, such as special parking privileges, expense sharing, and shopping discounts. As Table 5 indicates, all incentives received similar responses.

### *Delivery Preferences for Commuter Information*

Respondents were asked how likely they would be to change the following if up-to-the-minute traffic information were available to them at home and at work and that information indicated that their usual commute route was congested: (*a*) departure time from home to work, (*b*) departure time from work to home, (*c*) route, and (*d*) transportation mode. Respondents who made less than $20,000 annually were significantly more likely than those who made over $40,000 annually to change their transportation mode on the basis of up-to-the-minute traffic information. In addition, 34.33 percent of the lower-income respondents said that they would be moderately to very likely to change commute mode, whereas only 12.7 percent of the higher-income respondents were moderately to very likely to do so (see Table 6). These results replicated those of previous Seattle-area commuter surveys (*2,3*).

Respondents were then asked to rate how likely they would be to use commuter information if it were delivered in various ways (see Table 7). The most popular method for delivery of commuter information appeared to be by telephone (50.15 percent said they

**TABLE 4 Importance of Ridesharing Features***

| Ridesharing feature | Rating (in percent) Very important | Moderately important | Slightly important | Not at all important |
|---|---|---|---|---|
| Having a guaranteed ride home in an emergency | 62.08 | 23.70 | 9.48 | 4.74 |
| Saving time over current transportation mode | 48.33 | 27.75 | 15.31 | 8.61 |
| Reducing pollution | 43.26 | 35.10 | 17.79 | 3.85 |
| Having your preferences met (e.g., riding/ driving in a non-smoking environment) | 39.43 | 25.48 | 26.44 | 8.65 |
| Saving money over current transportation mode | | | | |
| All | 37.14 | 38.10 | 16.67 | 8.09 |
| Under $20,000 | 52.00 | 38.00 | 4.00 | 6.00 |
| Over $40,000 | 20.69 | 44.83 | 17.24 | 17.24 |
| Participants being pre-screened | | | | |
| All | 22.22 | 31.32 | 27.27 | 19.19 |
| Under $20,000 | 31.82 | 34.09 | 20.45 | 13.64 |
| Over $40,000 | 17.86 | 17.86 | 42.85 | 21.43 |
| Meeting other participants before forming a carpool/vanpool | | | | |
| All | 17.88 | 25.60 | 36.23 | 20.29 |
| Under $20,000 | 26.53 | 30.61 | 28.57 | 14.29 |
| Over $40,000 | 10.35 | 20.69 | 37.93 | 31.03 |
| Knowing other participants | | | | |
| All | 13.40 | 30.62 | 30.62 | 25.36 |
| Under $20,000 | 22.45 | 28.57 | 34.69 | 14.29 |
| Over $40,000 | 3.33 | 26.67 | 23.33 | 46.67 |
| Participants being co-workers | | | | |
| All | 12.08 | 24.64 | 25.60 | 37.68 |
| Under $20,000 | 18.75 | 39.58 | 18.75 | 22.92 |
| Over $40,000 | 10.00 | 20.00 | 20.00 | 50.00 |

*For variables that resulted in significant differences between lower income (<$20,000 individual annual income) and higher income (>$40,000 individual annual income) respondents, percentages for all respondents, lower income respondents, and higher income respondents are provided.

**TABLE 5 Likelihood of Riding/Driving in Carpool If Provided Incentives**

| Incentive | Rating (in percent) Very likely | Moderately likely | Slightly likely | Not at all likely |
|---|---|---|---|---|
| Carpool/vanpool (drive or ride) if given: | | | | |
| Special parking privileges | 22.66 | 29.06 | 33.01 | 15.27 |
| Drive for a carpool/vanpool if given: | | | | |
| Full compensation for expenses | 26.13 | 24.12 | 21.61 | 28.14 |
| Full compensation for expenses and special discounts at downtown businesses | 26.00 | 27.00 | 20.00 | 27.00 |

would be moderately to very likely to use it), followed by interactive computer in Bellevue Place's lobby (44.29 percent said they would be moderately to very likely to use it).

### *Level of Comfort Using Various Technologies*

Respondents were asked to rate how comfortable they are using various technologies (see Table 8). Overall, about 83 percent of survey respondents said that they were very comfortable using a touch-tone telephone to access information, 68 percent said that they were very comfortable using a voice mail system, and about 58 percent said that they were very comfortable using a computer.

For the last two technologies given in Table 8 (voice mail and computer), there were significant differences between the comfort levels of lower-income and higher-income respondents. Respondents who made over $40,000 annually were significantly more comfortable using voice mail systems (85 percent responded very

**TABLE 6 Likelihood of Changing Commute Features on the Basis of Traffic Information**

| Commute feature | Rating (in percent) Very likely | Moderately likely | Slightly likely | Not at all likely |
|---|---|---|---|---|
| Departure time from home to work | 41.39 | 24.16 | 16.45 | 18.00 |
| Departure time from work to home | 34.64 | 24.22 | 18.75 | 22.39 |
| Route | 48.66 | 22.69 | 14.92 | 13.73 |
| Transportation mode | | | | |
| All | 10.79 | 9.66 | 20.74 | 58.81 |
| Under $20,000 | 22.39 | 11.94 | 22.39 | 43.28 |
| Over $40,000 | 6.35 | 6.35 | 20.63 | 66.67 |

**TABLE 7 Likelihood of Using Commuter Information**

| Likelihood of using commuter information if delivered by: | Rating (in percent) Very likely | Moderately likely | Slightly likely | Not at all likely |
|---|---|---|---|---|
| Telephone (24 hours per day) | 22.93 | 27.21 | 26.93 | 22.93 |
| Interactive computer in Bellevue Place's lobby | 17.66 | 26.63 | 28.81 | 26.90 |
| Computer at home or work (via modem) | 13.32 | 19.57 | 25.27 | 41.85 |
| Hand-held message receiver (similar to a pager) | 10.47 | 14.60 | 23.69 | 51.24 |

comfortable) than were those who made less than $20,000 (41 percent responded very comfortable). As far as using a computer, 76.19 percent of the respondents who made over $40,000 said they were very comfortable compared with about 35 percent of respondents who made less than $20,000 annually, a significant difference.

### Telephone Interview Findings

After analyzing the results from the written commuter surveys, the research team conducted two sets of telephone interviews to gather user input on specific system features. For the first set of interviews, only survey respondents who said that they would be very likely to use an on-demand carpool system were contacted. In this group, nine randomly selected participants (seven women and two men) answered questions about how they would use the system as riders. For the second set of interviews, only survey respondents who said that they would be very likely to drive for a carpool if fully compensated for their expenses were contacted (seven people—six women and one man—were interviewed) about how they would use the system as drivers. For both groups, interviewees were asked how much in advance they would be likely to call the system if they were offering or checking for a ride, whether the free use of a pager was an incentive to offering or checking for rides, how much drivers/riders would be willing to wait beyond their desired departure time to make a ride match, how far they were willing to drive/walk to meet a ride match, and so on.

The results of the telephone interviews are as follows:

- In general, potential riders said that they would use the system to find rides much less frequently than potential drivers would use the system to offer rides.
- Pagers were an incentive to use the system for both riders and drivers.
- Drivers were more likely to offer a ride through the system 3 days in advance than were riders; drivers were also less likely to call the system close to their departure time than were riders. Only one potential driver said that he would call the system 1 hr before he planned to leave, yet some potential riders were willing to check the system for a ride offered up to 15 min before leaving.

**TABLE 8 Rating of Comfort Level with Various Technologies**

| Technology | Rating (in percent) Very comfortable | Moderately comfortable | Slightly comfortable | Not at all comfortable |
|---|---|---|---|---|
| Touch tone telephone to access information | 82.90 | 12.96 | 2.07 | 2.07 |
| Voice mail system | | | | |
| All | 68.17 | 18.83 | 8.75 | 4.24 |
| Under $20,000 | 40.85 | 38.03 | 12.67 | 8.45 |
| Over $40,000 | 85.48 | 3.23 | 9.68 | 1.61 |
| Computer | | | | |
| All | 58.16 | 22.10 | 13.16 | 6.58 |
| Under $20,000 | 34.72 | 31.95 | 20.83 | 12.50 |
| Over $40,000 | 76.19 | 6.35 | 15.87 | 1.59 |

- Although drivers were less likely to call the system and offer a ride close to their departure time, they were willing to accommodate a rider who contacted them up to 1 hr before they left.
- Drivers were less willing to delay their departure time to work to make a ride match than were riders (five out of seven drivers said that they would not delay their planned departure time to work). However, drivers were more willing to delay their departure time for the trip home; four out of seven said that they would delay their departure time for the trip home, of whom three would wait ½ hr to make a ride match.
- Riders were much more willing to wait past their desired departure time to make a ride match than were drivers (four out of nine said they would be willing to wait ½ hr and one said she would be willing to wait 15 min).
- Both drivers and riders were willing to go 10 to 15 min or 3 to 4 mi out of their way to make a ride match.
- Riders were willing to listen to five ride-offered messages. However, a few said they would be willing to read more than five messages on a pager but would not want to have to listen to more than five over the phone.

## Focus Group Findings

In addition to the written surveys and the telephone interviews, the research team held two focus groups to gather data from employees who did not participate in the survey. One focus group was held to determine the interest level and reactions to the proposed BST dynamic ridesharing program of employees of a major software developer at the test site. The employees who participated in the focus group were all SOV drivers (nine men and three women).

Because the research team was considering expanding its focus to an area greater than Bellevue Place, the second focus group was conducted with people who worked in downtown Bellevue and participated in the Bellevue TMA's ridesharing program. All of the participants in the second focus group (five men and nine women) were currently carpooling. This focus group was also held to determine their interest level and reactions to the proposed BST ridesharing program.

### *Software Developer Focus Group*

All software developer employees drove alone to and from work each day. Their reasons for not carpooling were consistent: all employees had flexible work hours and their departure times were always subject to change. Participants also reported having little motivation to carpool because they had daily access to free parking and usually commuted during nonpeak hours.

The employees were not particularly interested in the technology offered; e-mail, pagers, and an interactive phone system were viewed as archaic. Pagers were not viewed as an incentive for participating in the program.

Although there was little interest in riding in a carpool, the focus group participants were willing to drive for a carpool on the basis of a single ride offered in one direction. However, even as drivers, they were unlikely to use the system more than once if it was not trouble-free the first time they used it. For example, they did not want to wait more than 5 min for a rider. They also did not want to drive to an individual's house; they preferred to arrange pickup points.

Participants were most concerned about security issues. Participants were willing to rideshare with people who did not work at the same company provided that they were prescreened and that the system tracked who was riding together.

### *Bellevue TMA Focus Group*

Unlike the employees of the software developer, the participants in the TMA focus group reacted positively to the pager. However, those who already carried a pager said they would be unwilling to carry a second pager.

Participants in this group were concerned about the same security issues as those in the Microsoft group. Prescreening and tracking ride matches were important; however, this group was also interested in knowing the gender of other riders/drivers.

The most important issue to this group was having a guaranteed ride home. Participants were willing to go through a multistep process to search for an alternative before exercising a guaranteed ride home option, but they were concerned about the extra time involved in the process. They refused to use an alternative mode of transportation, such as a transit trip, if it took 25 min longer than their usual means of commuting.

## Summary of Survey, Interview, and Focus Group Findings

The results from the survey, telephone interviews, and focus groups inform the user requirements listed below. These requirements provided a basis for the development and design of the BST prototype traveler information center.

### *General Program Features*

A dichotomy exists between desire to use the TIC information and willingness to use the TIC's technology. Lower-income employees were significantly more likely to use the information offered by the TIC than were higher-income employees; however, the lower-income employees were also significantly less comfortable with various technologies. Therefore, system designers should not make assumptions about potential users' knowledge of technology and must make efforts to keep the system as simple to use as possible.

### *Ridesharing Component*

- To create a truly dynamic ridesharing system that accommodates all users' schedules, a system that allows people to rideshare at any time of day would be ideal. However, if system features prevent a 24-hr/day system, the system should minimally allow for ride matching between the hours of 6 and 10 a.m. and 3 and 7 p.m.; these hours would capture approximately 80 percent of the user audience.
- Given users' relative lack of knowledge regarding ridesharing programs, instructional information must be provided on such details as how to use a ridesharing system, how it works, and guidelines for contacting potential ride partners.
- A guaranteed ride home must be provided for ridesharing participants. Rides should be given on a point-to-point basis rather than on a door-to-door basis unless participants agree to do otherwise.

- Ride groups should be designed so that drivers/riders do not have to travel more than 4 mi to meet their ride match partners.
- The system should allow people to make a ride match 1 hr before their departure. The system should also minimize the number of messages a rider would have to listen to.
- For security purposes, the system should prescreen participants (minimally, they should be from selected employers), provide gender information, and record and monitor ride matches.
- Providing pagers and pager services would be a compelling incentive to use the system. In addition, other tangible incentives should be provided to encourage carpooling/vanpooling; the benefits of time savings and pollution reduction alone do not provide sufficient incentive.

### *Transit*

Given users' relative lack of knowledge of bus use, the TIC should provide customized bus information to users who are interested in commuting by bus.

## CONCLUSION

These findings have driven the development of the BST TIC, which is currently in the prototype stage. The goal of the BST TIC is to reduce congestion in downtown Bellevue, Washington, by providing a new alternative to SOV commuting. The TIC's main function will be to help commuters form dynamic rideshare groups, in addition to providing traffic congestion and transit information. The current TIC design reflects the preferences and needs of its potential users as revealed by the assessment methods described here. The strategy behind the development of the prototype BST TIC has been to (*a*) base its design on users' travel needs and (*b*) integrate existing technologies that enable an automated system to work efficiently and effectively. This prototype will be demonstrated and tested in a selected area of downtown Bellevue. During the demonstration, input from participants will be solicited and, whenever possible, the BST prototype will be modified to meet their needs. The kind of user assessment presented in this paper is necessary for the design of efficient transportation information systems to appropriately meet the needs of commuters.

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# Why Working Women Drive Alone: Implications for Travel Reduction Programs

SANDRA ROSENBLOOM AND ELIZABETH BURNS

A study was funded by the U.S. Department of Labor to analyze the differential impact of mandatory trip reduction programs on employed men and women in different family situations. Travel demand management (TDM) programs can be expected to have a direct impact on working women with young children, who compose the largest component of the growth in the use of the car in the last two decades. The study found that in Phoenix and Tucson, Arizona, men and women had different travel patterns, even when controlling for marital status and the presence of children of various ages, as well as income and occupation. Having children had far more impact on working mothers than on comparable working fathers. Women with children were more likely to drive to work at all income levels than were comparable men or other women. The younger their children and the more children they had, the more likely women were to drive to work alone. Conversely, the more and the younger their children, the less likely working women were to use alternate modes. The findings indicate how dependent working mothers are on the car to balance their domestic and child care obligations and the need to identify the equity consequences of specific TDM requirements, to develop sets of TDM measures that respond to the time and cost constraints of working women, and to develop ways to offset the negative impacts on working mothers.

In the last two decades society has seen a significant increase in the role of the car coupled with the declining use of transit and carpooling. In response to growing concerns about the use of nonrenewable natural resources, air pollution, and traffic congestion, the Intermodal Surface Transportation Efficiency Act and the Clean Air Act Amendments of 1990 mandate both employers and governmental entities to reduce worker dependence on the car. Travel demand management (TDM) programs and their individual measures include increasing the cost of using or parking the car, implementing mandatory changes in work schedules, and making alternative modes more attractive.

This paper describes the final results of a U.S. Department of Labor study designed to critically analyze the impact of travel reduction measures. These findings show that TDM programs differentially affect salaried men and women and working women in different household situations. The study also evaluated whether and how the negative impacts of TDM policies could be ameliorated. A growing body of research shows that women more often depend on the car than do comparable men because their multiple obligations require them to combine work trips with shopping, chauffeuring children, and responding to home emergencies. This research base supports questioning the impact of TDM policies and measures that penalize women who drive to work alone.

The study used two very large data sets from Tucson and Phoenix, Arizona—both the sites of mandatory TDM programs since 1988. All employees at firms with more than 100 workers are surveyed annually about their travel patterns, travel changes, and attitudes toward alternative modes. The overall study relied on these regional surveys for 1990 and 1991 with data sets of over 50,000 employees in each region for each year. Full details of the study, the methodology, the comparative Phoenix-Tucson analyses, and detailed findings from surveys of two large employers are available in work by Rosenbloom and Burns (*1*).

This paper reports on the final part of the study, determining whether travel differences between the sexes were related to key household variables of marital status and the presence and age of children. These issues were evaluated among workers at the two major universities in Arizona: the University of Arizona in Tucson (with a 1991 data base of 5,014) and Arizona State University (ASU) in Tempe (considered Phoenix, with a 1991 data base of 2,519). In fact, the university findings show that working mothers are more dependent on driving alone than are comparable male parents measured in terms of marital status, presence of children, and age of children as well as income.

Clearly, TDM programs and similar measures have the ability to seriously disrupt the working and family lives of women. In the short run many women will not be able to give up the car and will face severe financial burdens as a result. In the long run many women will not be able to move their jobs closer to their homes (or vice versa) and may actually have to travel farther to find appropriate jobs while continuing to shoulder TDM costs.

## WOMEN'S TRAVEL PATTERNS IN CONTEXT

### Converging Societal Trends

Women account for roughly two-thirds of the new entrants into the labor force in the last 20 years, and their new trips to work account for a substantial portion of the growth in travel and automobile use. A significant part of the societal dependency on the car has been among women, generally the mothers of young children, who became new workers and new drivers in the last 15 years. One expert has calculated, "For every 1 percent shift from nondriver to driver in the female population, total travel jumps almost 10 billion miles per year" (*2*, p. 48).

Since 1969 the number of female drivers has increased 84 percent compared with a 99 percent increase in the number of women in the work force. (*3*, p. 6). The number of miles driven by males increased 46 percent between 1969 and 1990, but those driven by all women increased 76 percent and went up more than 200 percent among women between the ages of 16 and 34—that is, those entering the labor force (*3*, p. 36). In spite of a substantial income gap in the aggregate between male and female workers, in 1990 women

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were as likely to come to work in a car (driving alone or in a carpool) as men; 90.8 percent of all trips made to work by women were made in a car compared with 91.2 percent of the work trips of men.

The growth of women drivers, and women driving, is fueled by the extraordinary increase in the number of women workers with young children. The largest increase in labor force participation in the last decade has been among mothers with very young children. In 1990 almost half of all mothers of infants under 6 months were in the paid labor force—1 in 12 employed women had an infant (*4*). O'Connell (*5*) found that over 44 percent of all women return to work before their babies are 6 months of age—over two-thirds of those on a full-time basis. Women's child care obligations obviously reinforce their need to drive to work if at all possible.

Thus the nature of the conflict that this paper addresses becomes clear: on the one hand, policies attempting to reduce automobile use have a major impact on working mothers both because they are the most visible part of the growth in automobile travel and because they may be the most responsive to financial sanctions and incentives, given their lower average incomes.

On the other hand, working women may use the car to make up for the other deficiencies of society. The car allows women to deal with discrimination in the housing and labor markets, the inability of their children to travel alone safely, and the dispersion of goods and services in the suburban areas in which most Americans live. Moreover, the car, although not without security problems, addresses the far larger security concerns that most women have with alternative modes.

### Recent Research and Overall Study Findings

Research over the last two decades shows that, in contrast to traditional thought, married mothers have travel patterns very different from those of roughly comparable men and that single working parents have travel patterns different from those of their married counterparts. Most of that research has concluded that working women, particularly those who are mothers, make transportation, job, and related decisions to successfully balance a number of employment, child care, and household responsibilities (*3,6–10*). These needs clearly constrain their travel options, work schedules, and even job choices (*11–13*).

Moreover, this body of work indicates that single mothers have travel patterns different from those of other women because they carry even a greater share of those domestic responsibilities lacking a resident partner (*14–17*). Finally, an emerging body of work suggests that men and women have different employment choices that play themselves out in very different spatial patterns—patterns that have profound implications for women's travel patterns (*18–25*).

The findings of the overall study strongly supported this body of international research. First, in both the Tucson and Phoenix metropolitan areas women were as likely as men or more likely than men to drive alone to work. Second, all but the poorest women were more likely to work substantially closer to home than comparable men, but to take relatively longer to do so. These findings reflect women's need to combine domestic and employment responsibilities with their trips to work, thus "artificially" lengthening the time needed to get to work. Third, men and women differed in their responses when questioned about the effectiveness of policies designed to increase the use of alternative modes—for example, free bus passes or covered carpool parking. In both regions, women were more responsive to strategies that addressed their domestic responsibilities—for example, dealing with their need to transport children or respond to family emergencies.

Fourth, the study concluded that most women would suffer seven major types of problems if they switched to alternative modes or mandated work schedules: (*a*) additional child or elder care expenses caused by time lost in traveling via alternative modes, (*b*) loss of the ability to conduct out-of-home domestic responsibilities (shopping, chauffeuring children) because of lack of time or flexibility, (*c*) loss of time to conduct in-home domestic responsibilities (preparing meals, spending time with children or aging parents), (*d*) inability to find appropriate child or elder care providers whose hours match new work schedules or longer commutes via alternative modes, (*e*) inability to respond to at-home emergencies or disruptions (a child becomes ill at school), (*f*) exposure to additional (perceived or real) danger walking to and from stops or riding transit, and (*g*) inability to find or use alternatives matched to work schedules or home location (buses that run infrequently or require several transfers or a long walk from employment site to stop).

Fifth, the study found that few of the strategies that are designed to overcome objections to the use of alternative modes or work schedules actually address these major problems. Giving transit passes, for example, does not compensate for the time lost to this slower mode, does not address women's security concerns, and does not create transit where none exists.

### Study Data Sets: University TDM Programs

In 1990 Arizona was 1 of 11 states with legislatively mandated TDM programs; the state had the largest number of employees in the country, after California, covered by mandatory programs. Arizona enacted these programs in 1988 because the two largest metropolitan areas, Tucson and Phoenix (with over 70 percent of the state's population), were not in compliance with federal clean air standards. The annual surveys that each region must administer to large employers constitute the data sets for the overall study. The overall study used the regional data sets for 1990 and 1991 to study general patterns and trends.

The data for this paper are the 1990 and 1991 surveys from the second- and fourth-largest public employers in Arizona: ASU and the University of Arizona. In 1991 both universities added questions about employee marital status and the presence and age of children to support this research.

The university data bases constitute 100 percent of all usable survey responses and represent over 60 percent of their respective work forces. The University of Arizona data bases include 5,014 and 4,693 respondents from 1990 and 1991, respectively; ASU data bases include 3,597 and 2,519 respondents from 1990 and 1991, respectively.

The data have limits. The University of Arizona survey information has only household income data, whereas the ASU survey contains no income information at all. Occupational data are provided in aggregate categories, and both income and age data are available only in group form (25 to 34 years old).

Compared with regional profiles, manufacturing/production and sales/service jobs are underrepresented at the two universities, whereas professional/managerial jobs are significantly overrepresented. Even these large data bases have sample size problems when they are disaggregated for analysis, for example, by sex and marital status and number and age of children. Moreover, men and women in the same household cannot be compared; only men and women within the same kind of household can be compared.

In addition, sociodemographic differences exist between men and women at the two universities, and between all university workers and their comparable regional work forces. Women workers were slightly younger than male workers, but all university workers were older on average than regional workers. Women were substantially more likely to be employed in clerical/secretarial jobs and substantially less likely to be employed in professional/managerial and technical/research jobs than men, but all university workers were underrepresented in production and sales jobs. Both university and regional women were slightly more likely than men to work fewer than 4 days/week, but over 80 percent worked 5 or more days in 1991. Both university and regional women were slightly more likely to work part time than men, but over 84 percent worked full time. Although women were much more likely to come from households making under $20,000 and substantially less likely to be in households making over $40,000 than men, all university workers averaged higher incomes than regional workers.

## UNIVERSITY ANALYSES

### Aggregate Travel Patterns

Workers at both universities were highly dependent on the private automobile for commuting, although less so than regional workers. In both 1990 and 1991 over 60 percent of all workers drove alone to work compared with over 78 percent in the Phoenix region and 71 percent in the Tucson region. Although driving alone dropped in both regions between 1990 and 1991, driving alone increased at both universities. Over 65 percent of University of Arizona workers and over 75 percent of ASU workers drove alone to work in 1991 compared with 60 and 74 percent, respectively, in 1990.

Conversely, the use of most alternative modes went down at both universities while increasing regionally. Carpool use dropped from 11.5 to 8.5 percent at ASU; bus use dropped from 12.5 to 10.4 percent at the University of Arizona. In contrast, walking as a commute mode went up slightly at ASU from 3.3 to 3.5 percent.

Employees at both campuses had substantially shorter commutes than aggregate regional commutes. Well over three-fourths of University workers lived within 10 mi of their homes. Over 65 percent of both sets of workers traveled less than 20 min to work.

Disaggregating travel patterns shows marked differences by sex. At both universities women were much more likely to drive alone to work than men. This gap intensified between 1990 and 1991 because fewer women switched to alternative modes and more women switched away from alternative modes. Thus women were more likely to depend on the car even though they were more concentrated in lower-paying jobs and in households with lower incomes.

Women at both universities worked further from home than men—in marked contrast to regional findings—and work trip distances went up from 1990 to 1991. In 1991 the mean travel distance for University of Arizona women workers was 8.3 mi compared with 7.5 mi for men and 8.7 mi compared with 7.8 mi at ASU. These findings are not what would be expected by traditional theories of travel behavior, since the women involved are, on average, earning less than the men. Women at both universities also spent more time in commuting—not surprising given the fact that their trip lengths were greater. When travel times are compared with travel distances, however, women take longer than men to cover comparable distances.

In summary, the aggregate university data show that, in spite of being concentrated in lower-paying occupations and having lower household incomes at the University of Arizona, women workers at the two universities are (*a*) more dependent on the private car than are men, (*b*) more likely to choose different modes when they switch to alternative modes, and (*c*) likely to take longer to cover a comparable distance to work regardless of the mode used.

### Impact of Socioeconomic Variables

The aggregate figures presented may be hiding differences in income or occupation that have more impact on travel behavior. However, the overall study did not find that either variable contributed much to the understanding of differences in the travel patterns of men and women at the two universities.

Figure 1 shows mode choice to work in 1991 at the University of Arizona by sex and income. Women were far more likely to drive to work at all but the highest income levels— over $80,000. The gap between men and women was often large. For example, at household incomes between $20,000 and $30,000 over 68 percent of women but only 56 percent of men drove alone to work. It is improbable that women make more than men in every household at the university and therefore unlikely that personal income explains travel choices. It is more likely that women in these households, on average, make significantly less than comparable men but must drive anyway.

Men were far less likely to carpool in 1991 than comparable women in all but one income category. For example, at household incomes between $30,000 and $40,000, women were twice as likely to carpool as comparable men: 7.2 percent compared with 14.7 percent. Overall, women's use of carpooling went up as income went up with the exception of the lowest income categories, but the pattern was less clear among comparable men.

Although bus usage in 1991 tended to be highest for women with incomes below $20,000, at incomes above $20,000 men were far more likely than women to take the bus. In other words, in house-

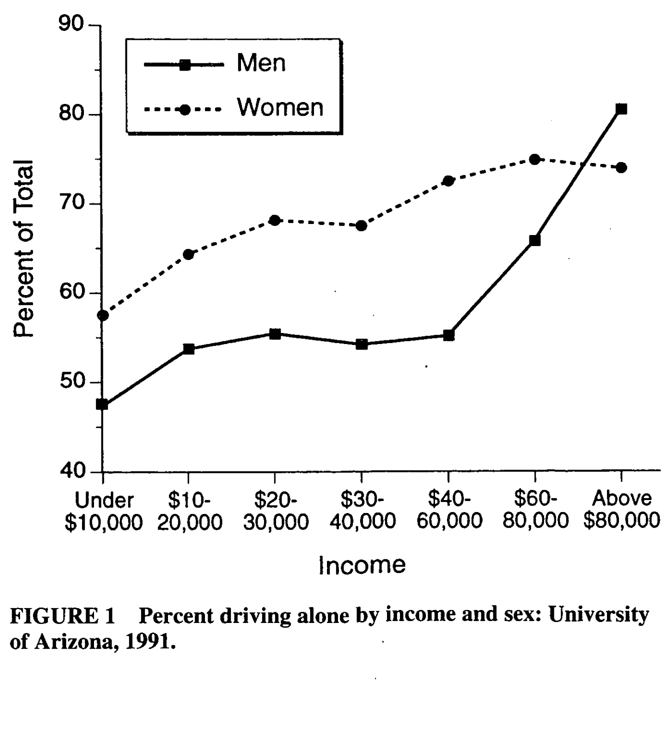


**FIGURE 1 Percent driving alone by income and sex: University of Arizona, 1991.**

holds in which higher incomes made it possibly easier for both sexes to give up the bus, women were more likely to do so. In fact, between 1990 and 1991 women were much more likely to give up coming to work by bus than comparable men—although bus use dropped for both sexes.

For ASU, travel differences between the sexes were compared using aggregate occupational categories that approximated personal income. Four categories with enough respondents were ranked in order of declining wages: professional/managerial, technical/research, crafts/trades, and clerical/secretarial. In each category, women were substantially more likely than comparable men to drive alone to work. This gap widened as the wage level of the occupational category decreased, confirming that women's personal income levels do not explain travel choices. For professional/managerial employees, 83.1 percent of all women and 76.5 percent of all men drove alone to work. For clerical/secretarial employment, however, 74.9 percent of all women and 51.9 percent of all men drove alone.

Other travel differences between the sexes were not explained by income or occupation; women generally lived closer to work than comparable men but took relatively longer to get there. As in the regional analyses, women's work trips appeared to be combined with other domestic or child care responsibilities, which lengthened the time required to get to work. Clearly, controlling for either household income or occupation does not provide much explanation of the differences between men's and women's travel patterns in terms of mode chosen, distance traveled, or time spent in commuting.

## Impact of Family Structure and Children

Even if traditional economic variables of income and occupation have limited explanatory power, these aggregate analyses by sex may obscure the impact of individual household variables on women's and men's travel. So far, the analyses may be recording differences between those who are or are not married or those who are or are not a parent, rather than differences between men and women. This section examines these differences.

### *Marital Status and Number and Age of Children*

Table 1 indicates the impact of marital status on travel choices for ASU and for the University of Arizona. Although unmarried people generally are more likely to drive alone than those who are married, women are always more likely to drive alone to work, regardless of marital status. Over 82 percent of unmarried women at ASU drove to work alone compared with 67 percent of unmarried male workers; over 66 percent of married women workers but only 60 percent of married male workers drove alone at the University of Arizona.

Conversely, married people of both sexes are substantially more likely to carpool than unmarried people; almost 19 percent of married women but only 6 percent of unmarried women workers carpooled at the University of Arizona, whereas over 8 percent of married men but only 3 percent of unmarried men at ASU carpooled. It is likely that married people are carpooling with one another.

Tables 2 and 3 indicate the joint impact of marital status and the presence of children on travel choices; the differences between the sexes hold even when being a parent is added. Whether or not they have children, married and unmarried women are more likely to

**TABLE 1 Most Frequent Mode to Work by Marital Status and Sex, 1991**

| | University of Arizona | | | | Arizona State University | | | |
|---|---|---|---|---|---|---|---|---|
| | *Married* | | *Not Married* | | *Married* | | *Not Married* | |
| *Mode* | M | F | M | F | M | F | M | F |
| ***Drive Alone*** | 60.2% | 66.2% | 61.4% | 71.2% | 71.3% | 76.2% | 66.9% | 82.1% |
| ***Carpool*** | 12.5 | 18.5 | 3.5 | 6.1 | 8.1 | 13.5 | 3.3 | 4.6 |
| ***Bus*** | 10.4 | 10.1 | 9.1 | 11.5 | 2.3 | 2.1 | 1.1 | 2.0 |
| ***Walk*** | 2.2 | 1.6 | 7.8 | 4.5 | 1.8 | 1.8 | 5.1 | 4.4 |
| ***Bike*** | 13.2 | 3.4 | 16.1 | 6.3 | 14.9 | 3.7 | 19.9 | 6.4 |
| ***Other*** | 1.5 | .2 | 2.1 | .4 | 1.5 | 2.7 | 3.7 | .4 |
| ***Total Responses*** | 1,267 | 1,222 | 515 | 999 | 652 | 709 | 272 | 497 |

Note: Most Frequent Mode equals 4 or more days per week.

**TABLE 2 Most Frequent Mode to Work by Presence of Children, Marital Status, and Sex, ASU, 1991**

| | No Children Under 18 | | | | Children Under 18 | | | |
|---|---|---|---|---|---|---|---|---|
| | *Married* | | *Not Married* | | *Married* | | *Not Married* | |
| *Mode* | M | F | M | F | M | F | M | F |
| ***Drive Alone*** | 70.6% | 72.1% | 65.9% | 84.1% | 72.4% | 82.5% | 82.4% | 75.8% |
| ***Carpool*** | 9.3 | 16.6 | 3.1 | .5 | 6.5 | 8.7 | 5.9 | 17.5 |
| ***Bus*** | 2.1 | 2.1 | 1.2 | 2.4 | 2.5 | 2.2 | 0.0 | .8 |
| ***Walk*** | 2.4 | 2.3 | 5.5 | 4.5 | 1.1 | 1.1 | 0.0 | 4.2 |
| ***Bike*** | 14.1 | 4.6 | 20.8 | 8.0 | 16.0 | 2.2 | 5.9 | 1.7 |
| ***Other*** | 1.6 | 2.3 | 3.5 | .5 | 1.5 | 3.3 | 5.9 | 0.0 |
| ***Total Responses*** | 377 | 434 | 255 | 377 | 275 | 275 | 17 | 120 |

Note: Most Frequent Mode equals 4 or more days per week and Presence of Children means children living in respondent's household.

**TABLE 3 Most Frequent Mode to Work by Presence of Children, Marital Status, and Sex, University of Arizona, 1991**

| | No Children Under 18 | | | | Children Under 18 | | | |
|---|---|---|---|---|---|---|---|---|
| | *Married* | | *Not Married* | | *Married* | | *Not Married* | |
| *Mode* | M | F | M | F | M | F | M | F |
| ***Drive Alone*** | 59.4% | 63.7% | 60.2% | 69.9% | 61.2% | 69.7% | 72.0% | 76.3% |
| ***Carpool*** | 14.3 | 19.8 | 3.2 | 5.7 | 10.3 | 16.7 | 6.0 | 7.7 |
| ***Bus*** | 9.6 | 11.1 | 9.2 | 11.7 | 11.4 | 8.8 | 8.0 | 10.8 |
| ***Walk*** | 1.9 | 1.7 | 8.2 | 5.2 | 2.6 | 1.6 | 4.0 | 1.5 |
| ***Bike*** | 13.1 | 3.5 | 17.2 | 7.1 | 13.3 | 3.1 | 6.0 | 3.1 |
| ***Other*** | 1.7 | .3 | 1.9 | .4 | 1.2 | 0.0 | 4.0 | .5 |
| ***Total Responses*** | 687 | 713 | 465 | 805 | 580 | 509 | 50 | 194 |

Note: Most Frequent Mode equals 4 or more days per week and Presence of Children means children living in respondent's household.

drive alone to work than comparable men; the only exception is among the small number (17) of unmarried ASU fathers. For example, over 82 percent of married women with children but only 72 percent of married men with children drove alone to work at ASU. Over 76 percent of unmarried women with children drove alone to work at the University of Arizona, compared with 72 percent of comparable men.

Although the impact is more pronounced for women, having children tends to increase the likelihood that both men and women will drive alone. For example, over 72 percent of married male ASU workers with children drove alone to work compared with just under 71 percent of married men without children. But over 82 percent of married women with children drove to work at ASU compared with 72 percent of married women without children.

Conversely, married workers—who were more likely to carpool than single people—were much less likely to do so when they had children. Almost 17 percent of childless married men, but only 8.7 percent of comparable men with children, carpooled to work at ASU, whereas roughly 20 percent of childless married men but only 17 percent of married men with children carpooled at the University of Arizona. In general, women with children are less likely to use the bus than comparable women who have no children.

Table 4 indicates the impact of the age of the children on men's and women's travel choices and clarifies the importance of young children to women's travel patterns. First, all women with children are more likely than comparable men to drive to work alone. Among mothers, those who have children aged 0 to 12 are the most likely to drive alone; the highest percentage is for mothers of children between 6 and 12. Over 84 percent of women with very young children (compared with 71 percent of comparable men) and over 92 percent of women with children 6 to 12 (compared with 77 percent of comparable men) drove alone to work in 1991 at ASU. Over 75 percent of comparable women in both groups did so at the University of Arizona compared with under 65 percent of most comparable men.

Second, both men and women are affected by the presence of children (women much more so than men). Table 2 indicated, for example, that slightly over 72 percent of all married men with children at ASU drove alone. However, over 75 percent of ASU male workers (not controlling for marital status) drove to work when they had children 6 years old or older. The same patterns are seen among women, although the differences are more striking; almost 70 percent of all married women with children drove alone to work, whereas 76 percent of mothers of children 6 to 12 did (not controlling for marital status) at the University of Arizona.

**TABLE 4 Percentage of People Driving Alone by Age of Children, 1991**

| Employees With | University of Arizona | | Arizona State University | |
|---|---|---|---|---|
| | *Male* | *Female* | *Male* | *Female* |
| Children 0-5 | 62.8% | 75.3% | 70.6% | 84.6% |
| Children 6-12 | 67.7 | 75.9 | 77.7 | 91.1 |
| Children 13-17 | 62.7 | 67.2 | 73.6 | 79.9 |
| Children Over 17 | 66.7 | 63.9 | 76.9 | 71.9 |
| No Children | 59.2 | 67.8 | 67.9 | 77.5 |
| *Total Responses* | 2,036 | 2,514 | 1,053 | 1,505 |

Third, women seem more affected than comparable men by the presence of very young children (under 6 years of age). Although both men and women are the most likely to drive alone when they have one or more children aged 6 to 12, a higher percentage of women drive in each category. Moreover, almost 85 percent of the mothers of very young children drive alone at ASU compared with just under 71 percent of comparable men; the gap is almost as large at the University of Arizona, where over 75 percent of the mothers of very young children drive alone compared with almost 63 percent of comparable men.

Related study data indicate that having more than one child under 6 years old increases even more the likelihood that women will drive alone; 74.3 percent of women with one very young child but 79.3 percent of women with two or more very young children drove alone to work at the University of Arizona; the comparable ASU figures were 84.5 and 85.7 percent. In fact, at the University of Arizona the highest car use is among women with more than one very young child; at Arizona State University the highest drive-alone rate is among women having more than one child aged 6 to 12.

Related study data also show that having young children affects the use of alternative modes—the complement of the data just presented; the use of alternative modes tends to increase among women with older children. Married women with young children are less likely to carpool and use the bus than are comparable women with older children; at ASU 6.5 percent of women with young children but 19.8 percent of women with children over 17 (living at home) carpooled to work. However, carpool use tended to drop steadily among married men as the age of their children increased; somewhat similar patterns were seen for men's bus usage. Indeed, the only child age category in which more men drive alone than comparable women is for employees with children over 17 who live at home. In conclusion, women have more choice in their travel patterns once their children reach driving age and no longer require chauffeuring.

### *Joint Impact of Household Responsibilities and Income*

Figures 2 and 3 show the joint impact of children and family income on women's and men's travel choices at the University of Arizona, the only data set with income information. The patterns seen in these figures replicate all of the patterns seen earlier in simpler cross-tabulations—that is, household income differences do not explain the differences seen in men's and women's travel patterns.

Figure 2 shows the impact of household income combined with being married but having no children, a complement to Table 3. As expected, there are differences between married workers with no children. At all but one household income level ($40,000 to $60,000), women are significantly more likely to drive alone to work; the difference is the greatest at the lowest income levels, where 76 percent of married women but only 50 percent of comparable men drive.

The impact of household income combined with being married and having one young child replicates earlier patterns seen in more aggregated cross-tabulations. Women with children are generally more likely to drive alone than women with comparable incomes but without children. For example, 75 percent of women with one

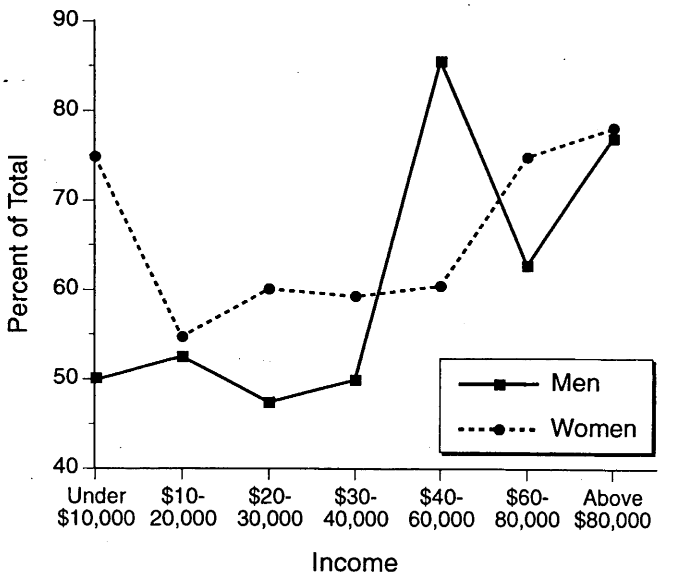


**FIGURE 2 Percent driving alone by income, sex, and marital status: University of Arizona, 1991, married with no children.**

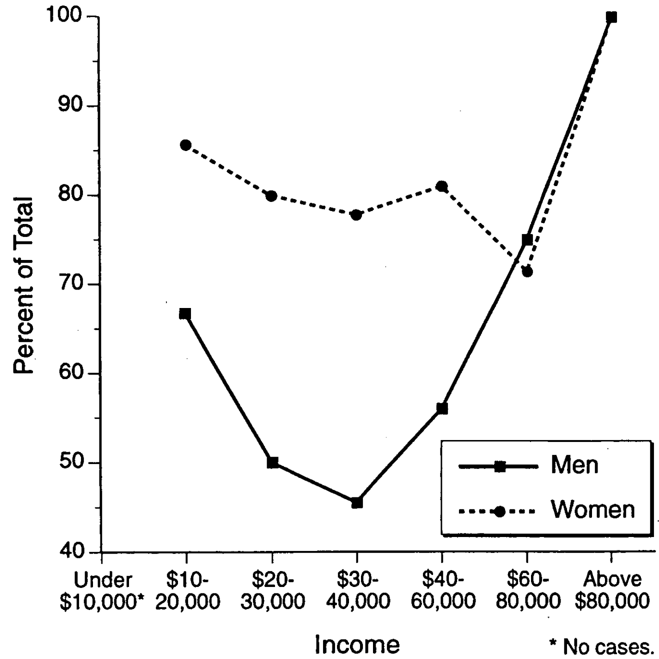


**FIGURE 3 Percent driving alone by income, sex, and marital status: University of Arizona, 1991, married with two or more children ages 0 to 5.**

child and an income between $30,000 and $40,000 drove alone to work, compared with 60 percent of comparable women without children. Moreover, women are more likely to drive alone than comparable men with young children. In fact, the women with the lowest household income are the most likely to drive alone to work when they have very young children: 100 percent of women but only 68 percent of men with incomes under $10,000 drove to work if they had one young child.

Figure 3 shows the joint impact of household income, marital status, and having more than one young child. This figure shows the same patterns seen in earlier data not controlled for income. At most income levels married women with more than one young child are more likely to drive alone to work than are women without children or with only one child, and substantially more likely than any men. For example, over 80 percent of women with two or more young children with incomes between $30,000 and $40,000 drove to work, compared with 46 percent of comparable men and 74 percent of women with only one young child.

In short, the more children she has, and the younger these children are, the more likely a mother is to drive to work, regardless of her household income. Clearly, mothers are disproportionately driving alone to work—and disproportionately shunning alternative modes—because of the domestic and child care duties they retain when they enter or remain in the paid labor force. Moreover, the very strong dependence on the car even among women who are not married or have no children suggests that women still have more domestic duties and perhaps a greater concern with personal security and convenience than comparable men.

## CONCLUSIONS AND IMPLICATIONS

Every analysis in this study shows that the car is a necessity and not a luxury for most working women and their families, given current land use, housing, employment, and service patterns. This study validates a growing body of international travel behavior research that indicates that working women, particularly those who are parents, drive alone to accommodate their daily household and child care responsibilities.

Travel reduction programs and similar measures have the ability to disrupt the working and family lives of women. Many women workers will continue to drive, accepting the new expenses and constraints imposed by travel reduction programs, because driving still meets their overall responsibilities better than any alternatives. It is clear that almost no single employer-sponsored incentive would have any meaningful impact on working women's time and money costs associated with switching to alternative modes. For example, transit passes do not compensate for time lost to travel on longer commutes, added hours of child care or elder care expenses, the lack of current transit service, and associated security issues.

Moreover, working women will have added time and monetary commute costs without offsetting advantages if employers enact sanctions—removing parking, raising parking prices, and mandating work schedule changes. Proposed market-based strategies for travel reduction—increased gas taxes, parking prices, road tolls, and restrictive parking policies—would have similar negative impacts on working women.

This study concludes that working women, particularly those with young children, require a package of incentives and services to be able to switch modes or work hours. Multiple employer-sponsored measures have potential for offsetting alternate mode disadvantages through vanpools, group bus service, and shared-ride taxis, flextime set by the employee, guaranteed ride home, and working at home. Equitable and efficient travel reduction programs can make participation by working women possible by maximizing employee choices, reducing the constraints under which working women operate, providing low-cost transportation alternatives, and compensating workers for alternate mode time and monetary costs.

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# Feasibility of Employee Trip Reduction as a Regional Transportation Control Measure

MARY R. LUPA

The passage of the Clean Air Act Amendments of 1990 resulted in the introduction of a number of transportation control measures (TCMs) that are designed to reduce the number of vehicle kilometers traveled in ozone nonattainment regions. Employee trip reduction (ETR) is one of those strategies. A policy analysis of ETR and a preliminary cost comparison of ETR among TCMs are presented. ETR is an evolving TCM and, as such, provides an arena for strategic planning using many tools, including direct political action, classical economics, technological implementation, pricing, and regional consensus building. Thus far ETR has not affected regional vehicle miles traveled, and yet it is premature to say that it has no effect on regional clean air goals. ETR strategies cannot successfully be separated from related mode split component strategies such as transit expansion, transit user subsidy, and parking fees; this synergistic quality complicates freestanding analysis of ETR. Finally, the positive and negative results of ETR indicate that pricing of some sort is the most direct means of securing behavioral change.

The passage of the Clean Air Act Amendments of 1990 (CAAA) resulted in the introduction of a number of transportation control measures (TCMs) that are designed to reduce the number of vehicle kilometers (miles) traveled in ozone nonattainment regions. Employee trip reduction (ETR) is one of those strategies. A policy analysis of ETR and a preliminary cost comparison of ETR among TCMs are presented. ETR is an evolving TCM and, as such, provides an arena for strategic planning using many tools, including direct political action, classical economics, technological implementation, pricing, and regional consensus building. Thus far ETR has not affected regional vehicle kilometers traveled (VKT) or vehicle miles traveled (VMT), and yet it is premature to say that it has no effect on regional clean air goals. ETR strategies cannot successfully be separated from related mode split component strategies such as transit expansion, transit user subsidy, and parking fees; this synergistic quality complicates freestanding analysis of ETR. Finally, the positive and negative results of ETR indicate that pricing of some sort is the most direct means of securing behavioral change.

## REGULATORY OR MARKET-BASED APPROACH?

One of the most challenging problems surrounding the issue of the growing number of peak-hour regional VKT is the definition of the problem. Is the problem solo drivers, the growing incidence of suburb-to-suburb work trips, the number of nonwork peak-hour trips, or the number of automobiles making a "cold start" each peak period? Is it possible to associate urban sprawl with regional travel costs? How closely can geographical and meteorological attributes be associated with air quality? Each of these concerns plays a part in the ongoing debate on VKT reduction that is taking place in those regions required by the CAAA to reduce VKT. Can ETR reduce VKT? If it can, what are the costs associated with the reduction?

ETR is a regulatory means of reducing peak-hour travel. Vapor recovery at the commercial gasoline pump is an example of a technological approach to achieving clean air, although not through reducing regional miles of travel. The instigation of parking fees at work sites that previously had free parking is an example of a market-based approach. In the present stage of CAAA implementation, data are being gathered to estimate the success of each of these three types of strategies as well as the short- and long-range value of each.

### Regulatory Approaches

Regulatory policies can be directed at the source of a problem or funnelled through an intermediary organization or institution. In the case of air quality regulations on stationary sites, the source of a problem is a polluting smokestack. A state or federal agency enforces the law that sets a limit on the quality of the smokestack waste emitted. The regulatory policy, then, is accurately directed at the source of the pollution.

Assuming in the case of automobile emissions that the single-occupancy driver is the problem, efficiency would dictate some type of control on solo drivers. Historically, however, controls of this kind are considered politically infeasible and are consistently rejected by policy makers. If the problem is seen as one related to VKT, whether driven by one or more than one driver, the imposition of limits on the number of kilometers (miles) traveled by private citizens or the assessing of a fee for those kilometers (miles) traveled is again not politically acceptable. An indirect approach such as ETR is followed instead. Indirect policies have three major shortcomings:

1. The placing of an administrative burden on the regulatory agency and the targets of the regulation;
2. Inefficiency, since action and not performance targets are mandated; and
3. Inequity, that is, discrimination can be made between employers in different locations and of different size, and between work and nonwork trips (*1*).

Important in this discussion is an estimate of the costs that ETR imposes on each regulated work site. Studies from southern California, where trip reduction results have been tracked since 1990, offer the most reliable figures on employer costs of trip reduction programs. The mean estimated annual expenditure on implement-

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ing Regulation XV, the southern California clean air regulations, was $31 per employee and the median was $20 per year per employee (*2*). Preliminary reports from the northeastern Illinois ozone nonattainment region show that the local ETR pilot program costs per employee ranged from a low of $5.46/year to a high of $181.65 (*3*). FHWA national averages for trip reduction were $118 per employee per year.

Examining costs may also be done from the standpoint of the cost of reducing single-occupant vehicle trips. According to a recent South Coast Air Quality Management District (SCAQMD) study involving 1,094 employers, the cost of reducing one commute vehicle trip has been approximated as between $2,000 and $3,000, assuming that the entire change in employee commute behavior is attributed to clean air regulation. Thus the community has spent approximately $11.76/day to remove each vehicle from a work commute (*4*).

### Market-Based Approaches

One of the basic laws of economics is the relationship between the quantity demanded of any good and its price. When the price is lowered, the amount demanded will rise; when the price is raised, the demand will fall. An argument can be made that VKT (VMT) growth can be reduced by increasing the cost of driving. VKT (VMT) may be priced by using (*a*) gasoline prices, (*b*) parking fees, (*c*) toll collection, or (*d*) different tax treatment of automobile-related costs. Any of these strategies would shift the external costs of driving from society in general to the individual drivers.

Unlike the regulatory program sketched out above, which effectively keeps existing price structures in place but tells consumers to ignore them, a pricing-based strategy sends powerful signals to drivers without an expensive intervening bureaucracy. However, the CAAA allows the possibility of economic disincentives such as higher gasoline prices only after a nonattainment area has failed to meet a milestone.

Reliance on the private automobile is a rational decision in the framework of the existing set of incentives and disincentives to drive. Thus the potential success of any TCM, including ETR, can be assessed only on the basis of meaningful incentives for behavioral change. These meaningful incentives must change the relative cost or convenience of travel choice alternatives; they may be price based or time based. When commuters can save time, for instance, by carpooling and gaining access to a high-occupancy-vehicle (HOV) lane that may save 30 min, that savings is a meaningful incentive. Studies have shown that if new transit users are given a $15/month subsidy, as they were in a study in Los Angeles in 1989, there is no resulting increase in transit use. Apparently, $15 is not enough to offset the time and inconvenience of taking the bus. Meaningful incentives also must have public acceptance. Some strategies that could have a strong impact on traffic congestion, for instance, prohibition of private automobiles in the central business district or alternative driving days, face public resistance.

Flexibility and the offering of a wide range of choices to commuters best improve the acceptance and the viability of TCM programs, including ETR. Mandatory alternative work hours, for instance, are not popular or likely to be successful, but voluntary alternative work hours, based on the needs of both the employer and the employee, are more likely to meet with success.

Many of the positive and negative impacts of ETR are difficult to quantify. On the positive side are reduced congestion in the peak period, more efficient use of existing facilities, provision of an institutional structure for public- and private-sector cooperation in trip reduction, increased commuter pool from which to create rideshare matches, incremental conversion to vehicles that use cleaner fuels, positive community image for companies with active programs, and, perhaps most important, the provision of a valuable exercise in teaching employers and the public about the effects of their benefits packages (i.e., free parking) and location choices on regional congestion and pollution. The last-mentioned learning exercise, in part, led to substantial changes in the federal tax code regarding commute benefits and to California state legislation to equalize subsidies for parking and alternatives. Some negative impacts include inequity in transportation costs between high- and low-income workers, inequity in ETR-related expenses between large and small employers, and employee adjustment to alternative travel modes.

## COSTS AND BENEFITS OF ETR

The Clean Air mandate is interesting because it calls into question the costs of the various air pollution abatement strategies, whether regulatory, technological, or market based. The law is concerned with $NO_X$ (nitrogen oxides), $SO_X$ (sulfur oxides), and PM-10 (particulate matter), as well as ozone. The photochemistry of ozone formation is well documented and will not be replicated in this report.

Discussion of conformity with air quality standards differs depending on the pollutant chosen. A look at the levels of atmospheric lead in the South Coast Air Basin (SOCAB) of California, for example, demonstrates the success that may be achieved when the source of a pollutant is easily defined. Because atmospheric lead is a mixture of chemical compounds of lead, the combustion of leaded gasoline accounts for nearly all the lead emitted into the atmosphere. Thus the sharp decline in both the use of leaded gasoline and the average lead content of gasoline accounts for the dramatic decrease in atmospheric lead concentration in the SOCAB and other regions. In the mid-1970s almost all the lead-testing stations in the SOCAB exceeded the federal lead standard. By 1983, all SOCAB stations met and have continued to meet both the federal and the more stringent state lead standards.

SOCAB's success with lead is mirrored by other regions and states that have outlawed the sale of leaded gasoline. In 1989, the regions with atmospheric lead exceedances were in Montana, Alabama, and Missouri because of stationary sites involved in lead-related industry. Regions such as the Los Angeles and New York areas, where VMT was increasing, however, did not experience lead exceedances. Reducing the level of atmospheric lead from mobile sources, then, was a straightforward matter even when the number of automobile kilometers (miles) traveled in an affected region was growing (*5*).

A pollutant such as ozone, however, is a different matter. The difficulty in forming a clear and effective program for the reduction of ozone in affected regions is based on five points:

1. The complicated nature of the formation of ozone;
2. The fact that its precursor gases come from numerous sources, only one of which is the automobile;
3. The behavioral aspects of automobile trip making;
4. The divergent needs of solving traffic congestion versus solving automobile pollution problems; and
5. The controversy surrounding the point at which regulations on automobile emissions might be imposed. For instance, should they

be imposed on the manufacturers of automobiles or on the producers of gasoline? Should they be imposed on drivers at the gas pump, at the emissions testing station, or at the work site? Should drivers of grossly polluting vehicles be ticketed and fined on the streets themselves in the same way that speed limit violators are handled? Should employers be involved in any way in reducing trips to reduce automobile emissions in the ambient air?

The difficulty of arriving at an effective ozone reduction strategy results from the lack of cohesion among these five points. An additional difficulty is the need to address the issue of how to limit the production of ozone precursor emissions when all the hard strategies such as fuel-efficient automobiles, reformulated gasoline, vapor recovery systems ("Stage II controls"), and highway capacity are exhausted. When the point of diminishing returns with respect to these technical solutions occurs, the solution strategies may be limited to those that address the behavioral aspects of trip making.

This discussion will examine the costs of the various strategies involved on the basis of the amount of reactive organic gases (ROG) removed from the air per dollar spent; typically this costing is done in dollars per megagram (ton) of ROG per year removed. The choice of ROG as a measuring stick underlines the difficulty in analyzing the information. ROG is not a straightforward "smokestack" type pollutant on which legislators can set limits. It is formed by a complex set of chemical, photochemical, geographical, political, sociological, and behavioral actions. However, because lowering ROG is perceived as a direct step to lowering the probability of ozone noncompliance, ROG was chosen as the guide (*6*).

### Relative Costs of ETR

Table 1 gives (*a*) 13 air quality strategies, (*b*) the pollutant chosen to measure the effectiveness of each, (*c*) the megagrams per year that would be removed from the ambient air by using the strategy, (*d*) the cost of the strategy in thousands of dollars, and (*e*) the proportional cost of each strategy in dollars per megagram per year. The table is based on a report by SCAQMD. The cost-effectiveness evaluations are calculated by taking the ROG as the primary emission benefit. The procedures developed to evaluate cost-effectiveness discount all costs to a common base year of 1987.

ETR was placed in mode split strategies with its related subcategories, including cash transit incentives, automobile use restrictions, merchant transportation incentives, parking management, HOV facilities, and transit additions/improvements.

### Analysis of the Cost-Effectiveness of 13 TCMs

Measure 1 in Table 1, the most cost-effective, consists of paving unimproved roadways and parking lots to tamp down the fugitive dust. Quite predictably, this measure permanently eliminates a large amount of particulate matter (in this case, road dust). However, it has no effect on the level of ozone or any other pollutant in the region. Road paving may be compared with gasoline vapor recovery that has been implemented in southern California. Vapor recovery provides suction locks on consumer and commercial gasoline pumps so that gasoline vapors cannot leak into the air. This extremely cost-effective measure has a one-time effect. In this respect Measure 1 may be classed with Measures 3 (general aviation vapor recovery), 4 (replacement of high emitting aircraft), 8 (rail consolidation to reduce grades), 9 (railroad electrification), and 13 (centralized power system). A close look at the air quality improvements that these six strategies provide will not further this discussion; the more highly complex seven strategies remaining more clearly outline the difficulties and challenges of TCM planning.

Those emissions reductions that are reduced by changes in vehicle use instead of changes at the tail pipe or gas pump are measured through change in travel indicators such as VKT, vehicle trips (VT), and vehicle hours of travel (VHT). Control measures that reduce these three indicators through better transportation demand management and system management have a direct impact on emissions. Land use controls (such as jobs-housing balance) also affect travel indicators and, as such, are effective at reducing emissions. In this category of strategies in Table 1 are Measures 2 (growth management), 5 (goods movement), 6 (capacity enhancements), 7 (traffic flow improvements), 10 (alternate work schedules and locations), 11 (solutions for nonrecurrent emergencies, such as emergency road services), and 12 (mode shift strategies).

Before a closer look is taken at these seven, it must be noted that projected emissions reductions are calculated according to specific groupings of measures that work in concert. The measures are divided and emissions reductions are calculated according to subgroups that work together synergistically. The costs and benefits of ETR are embedded in the mode split strategies. Quantification of reductions by group prevents double credits from being taken. Often, strategies on growth managements, housing, mobility, and air quality are coordinated to ensure consistency of approach and methodology. Although the synergistic approach is necessary, it prevents freestanding analysis of the ETR strategy.

Of the following seven measures, three (Measures 6, 7, and 11) are related to traffic flow.

Measure 6, capacity enhancement, relies on construction of additional capacity such as (*a*) widening roads, (*b*) double decking of freeways, and (*c*) construction of new freeways and corridors. Certain new road construction, however, can worsen traffic congestion and contribute to urban sprawl and thus is subject to review under the CAAA.

Measure 7, traffic flow improvements, increases flow by means of technological advances such as computerized interconnected traffic signals and freeway ramp metering.

Measure 11, solutions for nonrecurrent emergencies (for example, emergency road service), provides for emergency freeway turnouts as well as emergency tow trucks and related personnel.

There is a clear difference between these measures and the four measures discussed next. Flow-related improvements, although they may cost more or less than other improvements, are not perceived as interventions by drivers. Instead, they are viewed as helpful solutions. When added safety is provided by a measure such as emergency road services, drivers acknowledge the benefit from that protection as well as from the amplification of traffic flow. In addition, the results of these measures are quickly perceived and utilized by drivers. These two positive aspects of flow-related TCMs are not readily applicable to the final four measures that will be considered.

Measure 2, growth management, has as a principal goal obtaining reductions in VKT by (*a*) accelerating housing growth in job-rich areas and (*b*) promoting more employment development in areas where abundant housing already exists. The result given in Table 1 projects a reduction in ROG as a result of a drop in long-distance commutes, VKT, and VHT, which would result if jobs and housing growth, by subregion, were managed by policy compared with projected 2010 results attained without policy intervention.

**TABLE 1 Ranking of Cost-Effectiveness for TCMs**

| STRATEGY | POLLUTANT | MG/YEAR in 2010 | COST $1000 | DOLLARS/MG/YEAR in 2010 |
|---|---|---|---|---|
| 1. Road paving | PM-10 | 41793 | 9142 | 219 |
| 2. Growth management | ROG | 10093 | 3568 | 354 |
| 3. Gen aviation vapor recovery | ROG | 84 | 78 | 930 |
| 4. Replacement of high emitting aircraft | ROG | 2290 | 4292 | 1,874 |
| 5. Goods movement (Trucks) | ROG | 639 | 5171 | 8,097 |
| 6. Capacity enhancements | ROG | 3980 | 37721 | 9,479 |
| 7. Traffic flow improvements | ROG | 1234 | 14248 | 11,548 |
| 8. Rail consolidation (to reduce grades) | ROG | 103 | 2479 | 24,115 |
| 9. Railroad electrification | ROG | 265 | 11748 | 44,282 |
| 10. Alternate work schedule/location | ROG | 4832 | 415942 | 86,081 |
| 11. Non-recurrent congestion (emerg. serv.) | ROG | 1 | 260 | 260,000 |
| 12. Mode shift strategies | ROG | 2063 | 1149865 | 557,267 |
| 13. Centralized power system | ROG | 5 | 7356 | 1,634,667 |

1 megagram = .907 ton

Measure 5, goods movement, specifies a range of actions to reduce truck-related emissions, including (*a*) shifting heavy-duty vehicles involved in goods movement to off-peak periods and (*b*) shifting port-related truck traffic to rail.

Measure 10, alternate work schedules and locations, works by reducing emissions from vehicles traveling to and from work. Examples are 4-day/40-hr week, 9-day/80-hr bimonth, flexible hours, and telecommuting.

Measure 12, mode shift strategies, includes employer rideshare and transit incentives, parking management, merchant transportation incentives, automobile use restrictions, HOV facilities, and transit improvement. This category is made up of six distinct strategies, none of which works alone and two of which (HOV facilities and transit improvement) involve large capital outlays. Getting realistic data on the costs of individual mode shift strategies may not be possible. Preliminary cost reports that include the relatively high capital expenses mentioned earlier in a grouping would make ETR appear more expensive than it actually is.

Cost-effectiveness may not be as important as which TCM selections are mandated by law, which serve more than one objective, which complement or conflict with one another, which may be more likely to serve long-term change, and which may be more likely to succeed.

## EVALUATING ETR AS AN EFFECTIVE TCM

Table 2 evaluates 19 TCMs according to four criteria:

1. Relieves traffic congestion,
2. Relieves ROG,
3. Maintains personal privacy and autonomy, and
4. Is market based from the perspective of the private consumer.

These four decision criteria were chosen to address four critical planning concerns that are strongly related to all TCMs. This table is presented mainly as a discussion guide; depending on the

**TABLE 2 Effectiveness of Air Quality Strategies**

| Measure | Relieves traffic congestion | Relieves ROG | Maintains privacy and autonomy | Market-based VKT (VMT) pricing possibilities |
|---|---|---|---|---|
| Road paving | no | no | yes | no |
| Growth management | yes | yes | no | yes |
| Aviation vapor | no | yes | yes | no |
| Aviation replacement | no | yes | yes | no |
| Goods movement | yes | yes | yes | yes |
| Traffic flow improvements | yes | yes | yes | yes |
| Capacity enhancements | yes | yes | yes | yes |
| Rail consolidation | yes | yes | yes | no |
| Railroad electrification | yes | yes | yes | no |
| Alternate work schedules/locations | yes | yes | no | yes |
| Emergency services | yes | yes | yes | no |
| Mode shift | | | | |
| employer rideshare | yes | yes | no | yes |
| parking management | yes | yes | no | yes |
| merchant transportation incentives | yes | yes | no | yes |
| auto use restrictions | yes | yes | no | yes |
| HOV | yes | yes | no | yes |
| transit improvements | yes | yes | yes | yes |
| Centralized power system | no | yes | yes | no |

approach that is taken toward a strategy, that strategy could tend toward being regulatory or market based.

**Relief from Traffic Congestion**

Traffic congestion is undesirable to drivers because it is wasteful and frustrating. From the viewpoint of society, congestion misallocates scarce resources and causes economic inefficiency. Costs are high. In 39 large urbanized areas of the United States the cost of congestion in 1988 alone exceeded $34 billion, or $290 per resident (*7*).

Traffic congestion may be relieved using "hard" measures (supply-side remedies), such as traffic flow improvements, or "soft" measures (demand-side remedies) such as employee rideshare programs. Hard measures typically have a one-time effect and do not change human behavior. Nevertheless, each of the supply-side remedies that assists in solving the congestion problem is important. The type of TCM most likely to be successful in relieving traffic congestion—pricing—does not appear in Table 2. Peak-hour road and parking pricing are powerful measures to address congestion. ETR has a very small impact on traffic congestion.

**Relief from ROG**

Elimination or reduction of ROG and the associated reduction in other air pollutants would provide both short- and long-term benefits in health, the environment, and energy conservation. ETR provides very little relief from ROG, and even that change is very costly. The "hard" measures such as gas pump vapor recovery are much more useful and cost-effective. Coming to terms with the basic inefficiency of ETR is important, though, in the scheme of things. Only then can feedback from employees and employers adjust the course of VKT reduction strategies away from ETR while beginning the process of identifying and utilizing the positive aspects of the program.

**Personal Privacy and Autonomy**

Many commuters are willing to travel long distances or tolerate time wasted in traffic so they can live and work where they choose. Most Americans also prefer to travel in private vehicles, usually alone, because such travel provides convenience, comfort, privacy, and speed far superior to public transit or carpool. TCMs must address these powerful desires or they will not succeed. ETR fails on this point since the independence of both employees and employers is threatened.

**Market Based**

Driving alone to work in the current-day United States is a rational act. What would make it irrational? What would make it irrational at the margin? The most effective course of action to decrease drive-alone trips is to decrease the net benefits of driving alone, mainly by raising the costs. The powerful force of the market in shaping policy is not at the moment used in shaping policy on traffic congestion or mobile pollution mitigation.

## IS ETR A SOLUTION?

Even though California's Regulation XV is an extremely ambitious effort to change the travel behavior of Los Angeles region commuters and the first-year results are positive with respect to changes in carpooling employees per job site, the results do not suggest that the VKT reduction targets will be reached or that indirect control strategies such as ETR are efficient or popular. More research is required on the indirect effects of Regulation XV on commuters and employers to assess its overall effectiveness.

There is a growing school of thought that trip reduction is an insignificant part of air quality planning. More transit use, ridesharing, and telecommuting may not be needed to achieve clean air objectives in the southern California region. The increase in the average vehicle ridership (AVR) during the first year under Regulation XV was small, the trend is uncertain, and there is a strong possibility that most of the ridesharing opportunities will be mopped up in the first year or two, with little change thereafter (*8*). A high regional target for AVR discourages compliance among employers, especially if it imposes a standard beyond that met by any U.S. region but New York.

Difficulties abound in the quantification of TCMs, including ETR. One example is provided by examining the TCM strategy of growth management or the balance of jobs and housing. The points argued here may be applied equally to the ETR strategy. Comparison of data on the basis of the travel patterns before and after a land use change is not feasible for the following reasons:

1. The lack of calibration in getting beginning figures with which to evaluate the land use strategy renders any result inaccurate.
2. Exogenous factors, such as the growth of unemployed persons in proportion to the total population in a region, can effectively "solve" problems like VKT reduction requirements without changing anything.
3. Land use concerns are extremely sensitive to (*a*) initial conditions, such as types of infrastructure already existing, land use restrictions, zoning regulations, and building permit process time; (*b*) intermediate interferences; and (*c*) the number of years of commitment to an idea or strategy. Thus, they are not readily quantifiable.
4. Cost-effectiveness ratings on TCMs may not be feasible processes.
5. The desire to run costing per unit of ROG per year in a short time frame is a severe case of front-loading costs while discounting benefits. After all, when subway systems, for instance, are built in a city such as Washington, D.C., a transportation network, not just an anti-ROG machine, is built.
6. Air quality is a technical issue, whereas mobility is a decidedly social issue. After technical solutions have been found to replace the internal combustion engine, cities will still be looking at the questions of access, the human desire for hands-on experience, the need for social relationships, and the desire for livable cities.

Transportation planners, policy analysts, and local government officials are involved in the current debate over the usefulness of ETR as well as other TCMs that CAAA has brought into the foreground as VKT reduction strategies. ETR suggests the need for compromise and continued analysis to recognize what ETR can change and what it will never change.

## RECOMMENDATIONS AND CONCLUSIONS

1. Provide for research on TCMs. The result of some of the California TCM efforts suggests that ROG cost-benefit analysis is not the route to take in assessing ETR.
2. Work with the "critical mass" theory. All TCMs are in some sense marginal. Those strategies with great power like tail pipe and gasoline regulations have a one-time effect, whereas many strategies with the possibility of long-term usefulness, such as mode shift alternatives or land use planning, have small but continuing impacts on air quality. Many strategies, including technological fixes, behavioral shifts, and pricing, working in concert, may provide the beginning of feasible air quality management programs.
3. Investigate the efficiency of the ETR strategy. Admit that ETR has an extremely marginal effect on both traffic congestion and air pollution abatement. As CAAA matures, "reality check" may force marginally successful and counter-market-intuitive strategies such as ETR out of the TCM mix. Perhaps the "soft" benefits of ETR, such as positive community image for companies with active programs and stronger regional profiles, will be the primary good that will result from ETR.
4. Investigate the equity of the ETR strategy. Equity concerns cover workers, employers, and political entities in the nonattainment area. Trip reduction strategy may target certain groups for unfair treatment. Which TCMs, including the pricing-based ones that will begin to appear in the future, are equitable? How can they be made equitable if they are not? As an example, Southern California's affluent Orange County has begun negotiations to allow solo drivers to purchase the right to drive on an underused HOV lane into downtown Los Angeles. Are such strategies located at the intersection of efficiency and equity?
5. Investigate the economics of ETR zones. The Los Angeles region has a three-zone target average passenger occupancy (APO) map for employee trip arrivals. The closer to the central business district a work site is, the higher the APO of the automobiles arriving at that site must be. Employers seeking prospective sites may choose a zone with the lowest APO. Would it be feasible to design industrial parks with extremely low APOs in southern California and thus attract dense industrial settlement and lower regional travel costs? If ETR is not eliminated as inefficient, is it possible that APO zonal strategy could become a land use tool? How many businesses are locating or relocating out of regions with air quality concerns because they do not want to pay the price of complying with trip reduction programs?
6. Use pricing tools. How can pricing and taxing be combined with ETR goals to effect change? Emphasizing straightforward, market-based measures such as market rate parking fees, VKT fees, and pollution fees is important here. A lesson from California may very well be to avoid the strong emphasis on cost-effectiveness and concentrate instead on designing for other regions a customized regional program for traffic congestion and air pollution mitigation that is based on the political, social, geographic, meteorological, and economic realities of the region.
7. Continue technological improvement on automobiles and enforce its adoption. High-emissions vehicles cause more than their share of mobile source pollution. Clean-running automobiles such as the "California car" must be available in all states with a timetable

for the year in which only they are sold. Cash programs that buy back high-polluting, usually older vehicles have been very successful. Traffic patrol programs that locate, stop, and ticket high-polluting vehicles on arterial streets in the same way speeders are treated is a possible strategy. Improved vehicle inspection is another. The link between these four strategies is that they go directly to one source of ROG and other emissions violations, the high-polluting vehicle.

8. Foster local and regional political feedback. In regions where regional planning occurred around the question of ETR, there is an enhanced commitment to the decisions eventually made. In Northeastern Illinois, for instance, 1992 and 1993 were the years for organizations, employers, and employees to contribute to the discussion on regional air quality management. The Chicago Lung Association and the Sierra Club, among others, were and are active in the ETR process by standing firm for clean air concerns, no matter how marginal and costly they might be. The coalition building that occurred around the content of the ETR section of the state implementation plan in Illinois demonstrated the desire that retail employers had to take part in an important political decision whose outcome would directly affect them (Illinois Retail Merchant's Association, Unpublished data, 1992; *9*).

9. Build regional profiles. Regions that have experience in operating collectively (for example, Minneapolis–St. Paul), call on a history of cooperation, including regional tax strategies that affect land use, housing and industrial growth, and retention. Thus when traffic congestion or air pollution concerns became important in these regions, the framework was in place to address these new concerns. How can other regions profit from this knowledge?

10. Emphasize education. Start with education programs as early as high school driver's education. Is this trip really necessary?

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# Parking Management in Downtown Norfolk

GUZIN AKAN

A study was conducted in Norfolk, Virginia, in response to a significant loss of downtown retailing to suburban areas caused in part by congested downtown traffic and inadequate short-term parking. The study focused on parking and consisted of an assessment of the existing parking conditions in downtown Norfolk, establishment of new parking strategies, and monitoring of the results of the implementation of these strategies. The assessment of the existing parking system indicated that short-term parking was inadequate to satisfy the existing and future demands. Therefore, the overall parking strategy along the major routes of downtown was changed, and a restricted parking program was established. The program implemented 1-hr free parking in the retail area and metered parking in the financial district. Moreover, transit bus operations went through a dramatic change, and the bus company restructured its downtown routes. The implementation of the new program began in January 1992 and was completed in 1 month. The usage of the parking spaces has been continuously monitored since then. A gradual increase in parking turnover and a decrease in parking duration have been observed. Strict enforcement was established to reduce the negative impacts of illegally parked vehicles. A downtown advisory committee composed of city and business representatives was established to regularly discuss the parking issues. The impact of the new program on parking usage is discussed in detail.

Downtown Norfolk, Virginia, has gone through a tremendous improvement process during the last two decades. Modern traffic arterials were constructed, entertainment and cultural centers were built, hotels were added, and a new financial and business district of high-rise office buildings was formed. While these activities were taking place, loss of downtown retailing to the suburbs continued during the last decade. One of the city's planning goals for downtown Norfolk for 2000 is to expand the depth and variety of downtown retail activities. The city therefore has intensified its efforts to reactivate retailing. The availability of short-term, on-street parking is one of the key issues to achieve this goal. The objective of this study was to assess the existing on-street parking conditions in the downtown area and to evaluate strategies for increasing its capacity.

## STUDY AREA

Downtown Norfolk covers an area of about 1.5 million $m^2$ of land use as shown in Figure 1. This study is focused on the core area highlighted in the figure. Office and retail space total 330 000 $m^2$ and 81 400 $m^2$, respectively.

The area houses approximately 26,700 employees. The area to the south of City Hall Avenue, which runs east-west and divides downtown into approximately equal portions, is generally referred to as the financial district. It primarily houses the major office buildings. The rest of downtown is referred to as the northern district and is composed primarily of retailers and restaurants.

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## ASSESSMENT OF EXISTING CONDITIONS

This part of the study includes an extensive survey of the existing conditions in terms of land use, on-street and off-street parking inventories, and traffic circulation, with particular emphasis on transit bus operation.

### Land Use Survey

On the basis of surveys conducted in 1991, the total retail space in downtown is 81 400 $m^2$. Total office space covers an area of 330 000 $m^2$. The distribution of office space by streets is given in Table 1. In downtown Norfolk, approximately 40 percent of the retail space is vacant. According to the same survey, 88 percent of this vacant space is along one of the major north-south corridors, Granby Street. Along the corridor, 60 percent of the retail space is vacant.

### Parking Survey

There were a total of 116 available on-street parking spaces. These spaces were composed of 1-hr free parking, metered parking, and handicapped parking. Most of the 1-hr parking spaces were on Granby Street. In addition, 184 loading spaces were available, and 47 percent of them were located along Granby Street. The demand for on-street parking to support the occupied retail space exceeds the supply. Table 2 demonstrates the on-street parking demand/supply ratio for some of the major streets. This finding is based on an industry standard of 4 spaces per 1,000 $ft^2$ of retail space, which is confirmed by observation in the area.

Off-street parking accounts for about 99 percent of the total parking in downtown. The available off-street parking is shown in Table 3. The supply of off-street parking (lots and garages) exceeds the demand. The finding is based on an industry standard of 3 spaces per 1,000 $ft^2$ of office space.

### Traffic Circulation/Transit Survey

The survey analyzed the existing street pattern in the downtown area and the operation of the transit service. Because of the limited right-of-way, some of the side streets in the downtown area have been designated as one-way streets. This configuration sometimes confuses motorists unfamiliar with the area and is viewed as having

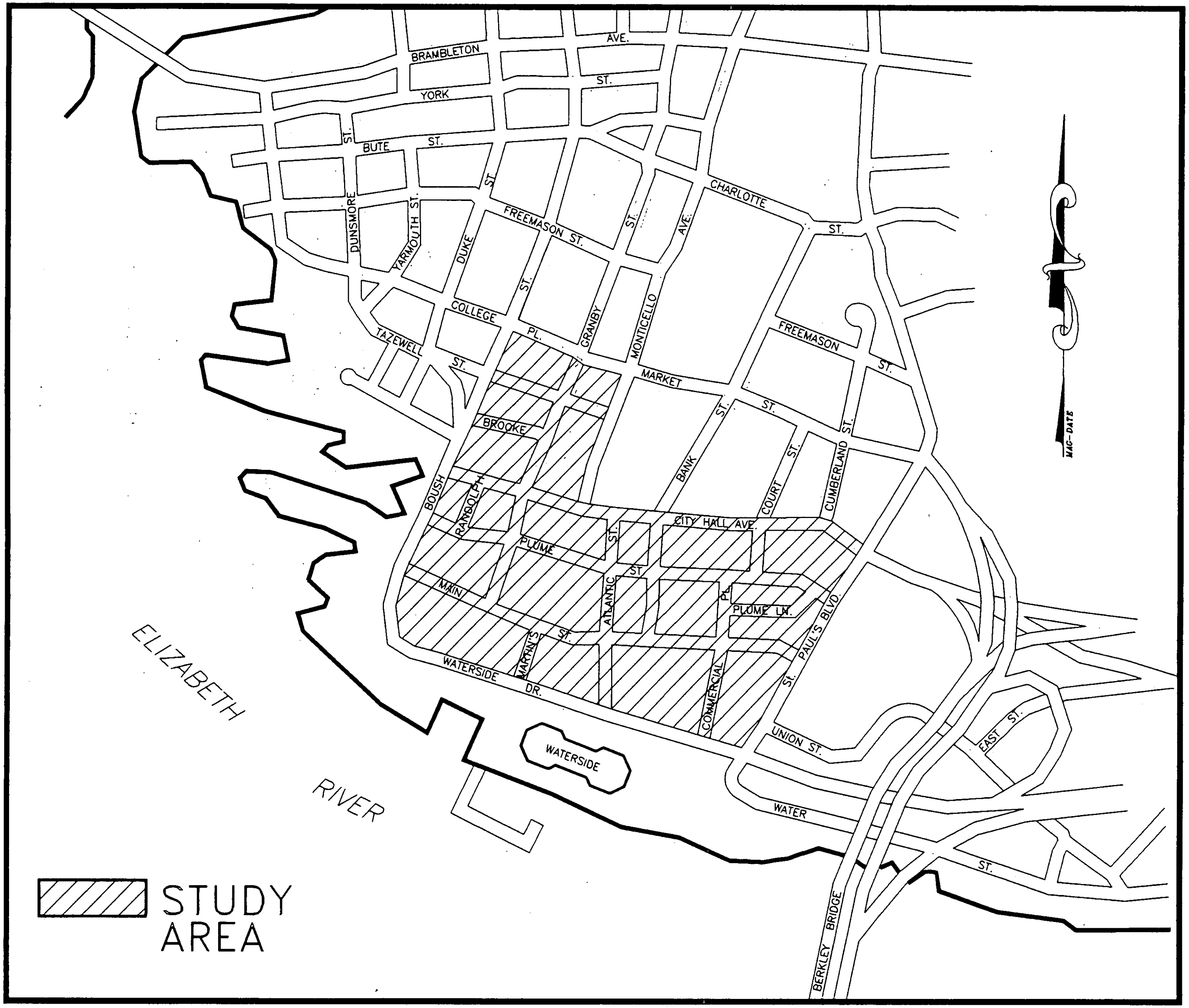


**FIGURE 1 Downtown Norfolk.**

**TABLE 1 Downtown Norfolk: Land Use (Before) (m²)**

| Street | Retail Floor Area | Retail Percent | Office Floor Area | Office Percent |
|---|---|---|---|---|
| Granby St | 51708 | 63.53 | 75528 | 22.90 |
| Main St | 8510 | 10.46 | 26198 | 7.94 |
| Waterside Dr | 6187 | 7.60 | 39947 | 12.11 |
| Monticello Av | 4311 | 5.30 | 23411 | 7.10 |
| Freemason St | 2406 | 2.96 | 279 | 0.08 |
| Brooke Av | 1858 | 2.28 | 344 | 0.10 |
| Atlantic St | 1839 | 2.26 | 418 | 0.13 |
| Boush St | 1301 | 1.60 | 17001 | 5.15 |
| College St | 948 | 1.16 | 864 | 0.26 |
| Plume St | 743 | 0.91 | 20122 | 6.10 |
| York St | 715 | 0.88 | 6410 | 1.94 |
| Duke St | 530 | 0.65 | | |
| Charlotte St | 334 | 0.41 | | |
| City Hall Av | | | 2833 | 0.86 |
| Commercial Pl | | | 69183 | 20.98 |
| Plume La | | | 11046 | 3.35 |
| St Paul Blvd | | | 34206 | 10.37 |
| Tazewell St | | | 2025 | 0.61 |
| Total | 81390 | | 329814 | |

Total Vacant Retail Space: 35047 sq meters (43%)
Granby Street Vacant Retail Space: 30858 sq meters (88%)
Percentage of Vacant Retail Space on Granby Street: 60%

a negative impact on the area's overall development. Careful study of the operation of these streets indicated that converting these streets from a one-way pattern to two-way pattern would help improve the traffic circulation. The change would have no negative impact on the parking pattern.

The survey of the transit service indicated that Monticello Avenue, which parallels Granby Street, was the most heavily used public transportation corridor (Table 4). About 40 percent of the downtown transit passengers used this corridor, whereas the corresponding percentage for Granby Street was only 7.4 percent.

### License Plate Survey

To evaluate the usage of the existing parking spaces, a license plate survey was conducted. The survey indicated that the majority of loading zones were used by all-day parkers. The parking spaces in the financial district showed a higher turnover rate than those in the northern district. The overall results of the survey are summarized in Figure 2. Although Granby Street has the highest available retail space, it also had the highest demand for parking. The corridor was not as heavily used by transit as the other major corridors. The existing on-street parking was not efficiently used. Granby Street had a 36-ft curb-to-curb width, and parking was permitted along its west side. The east side of the street was used for overnight merchandise loading and unloading, and parking on this side was restricted during the daytime. Granby Street, which once was one of the city's most attractive shopping districts, lost its importance to suburban retailers during the 1980s and has been going through difficult times since.

## DECISIONS AND IMPLEMENTATIONS

In light of these survey results, the following decisions were made to improve on-street parking conditions in the downtown area:

1. After consultation with the transit operators, it was decided to remove bus service from Granby Street corridor and to make Monticello Avenue the major north-south transit corridor. This arrangement provided more space on Granby Street for additional parking. As a result, transit operators reevaluated the downtown transit operation and created a circular pattern within the downtown area.
2. On-street parking on both sides of the Granby Street corridor, with loading zones of one- or two-car capacity at each block, was established. Transit buses were the only large vehicles using the corridor. The removal of the transit service provided more areas where parking would be provided on both sides of the street. Currently, about 95 percent of the traffic is composed of passenger cars.
3. Loading zones were converted into regular parking zones as much as possible. Because the survey results revealed that most of the loading zones were being used by long-time parkers, it was decided to establish loading zones of one- or two-car capacity at each block and convert the rest of the loading zones into regular parking zones. Loading zones were established according to the location and type of businesses and their needs.

**TABLE 2 Downtown Norfolk On-Street Parking: Demand/Supply 1991**

| Street | Supply 1-hr | Supply MP | Supply HC | Supply Total | Demand | Percent |
|---|---|---|---|---|---|---|
| Granby St | 27 | 14 | 0 | 41 | 50 | 1.21 |
| Freemason St | 4 | 0 | 0 | 4 | 9 | 2.25 |
| College Pl | 0 | 0 | 0 | 0 | 8 | |
| Tazewell St | 0 | 0 | 0 | 0 | 6 | |
| City Hall Av | 0 | 6 | 0 | 6 | 9 | 1.50 |
| Plume St | 0 | 22 | 2 | 24 | 31 | 1.29 |
| Main St | 0 | 19 | 2 | 21 | 15 | 0.71 |
| Plume La | 0 | 5 | 0 | 5 | 13 | 2.60 |
| Commercial Pl | 0 | 5 | 1 | 6 | 10 | 1.66 |
| Atlantic St | 0 | 5 | 0 | 5 | | |
| Total | 31 | 76 | 5 | 112 | 151 | 1.35 |

Total Number of Loading Spaces: 184
Loading Spaces on Granby Street: 86 (47%)

1-hr = 1-Hour Parking
MP = Meter Parking
HC = Handicapped Parking

*Does not Include All Downtown Streets

**TABLE 3 Downtown Norfolk Off-Street Parking: 1991**

| | Public | | Private | |
|---|---|---|---|---|
| | Spaces | Percent | Spaces | Percent |
| Lots | 2847 | 35 | 337 | 11 |
| Garages | 5236 | 65 | 2692 | 89 |
| Total | 8083 | | 3029 | |

Total Off-Street Supply: 11,112 spaces

**TABLE 4 Downtown Norfolk Transit Bus Passenger Loading**

| | Passenger | | | |
|---|---|---|---|---|
| Corridor | ON | OFF | Total | Percentage |
| BOUSH | | | | |
| City Hall-York | 91 | 2 | 93 | 1.10 |
| GRANBY | | | | |
| City Hall-Bute | 91 | 538 | 629 | 7.43 |
| Bute-Plume | 32 | 35 | 97 | 0.79 |
| MONTICELLO | 2319 | 1495 | 3814 | 45.00 |
| ST PAUL'S | | | | |
| City Hall-Bramb | 335 | 717 | 1052 | 12.42 |
| Bramb-Waterside | 288 | 313 | 601 | 7.10 |
| Downtown Plaza | 280 | 132 | 412 | 4.87 |
| CITY HALL | | | | |
| Boush-Montc | 57 | 59 | 116 | 1.37 |
| Montc-St Paul's | 105 | 50 | 155 | 3.63 |
| PLUME | | | | |
| Waterside-Atlantic | 25 | 71 | 96 | 1.13 |
| Atlantic-St Paul's | 100 | 207 | 307 | 3.63 |
| MAIN | | | | |
| Waterside-Atlantic | 123 | 291 | 414 | 4.89 |
| Atlantic-St. Paul's | 94 | 83 | 177 | 2.09 |
| ATLANTIC | 20 | 18 | 38 | 0.45 |
| WATERSIDE | 76 | 74 | 150 | 1.77 |
| UNION | 225 | 122 | 347 | 4.10 |

4. Parking spaces were rearranged to increase their number. Most of the parking spaces originally were not painted. With the implementation of the program, each parking space was painted by using the "paired parking" layout. In this layout, parking stalls are marked so that two vehicles park bumper to bumper and pairs of stalls are separated by maneuver areas. This arrangement provided more parking spaces than the regular parking layout.

5. A metered parking zone was established in the financial district, and the rest of the area was posted for 1-hr free parking. This measure was taken to improve the turnover in the financial district and to provide free and convenient customer parking for the retailers.

6. Handicapped zones were kept as they were. Handicapped zones are established through a petition process. A check of the status of the existing handicapped zones indicated that no changes were necessary.

## STUDY RESULTS

The parking situations on major corridors were monitored monthly for the first 4 months after implementation of the parking strategies. The surveys are now periodically repeated during the noon peak hours for a 3½-hr period. The survey results, in terms of parked cars, average parking duration, and daily turnover, are presented in Table 5 and Figures 3 through 5.

The results of these surveys indicate a gradual improvement in overall parking conditions:

1. The total on-street parking spaces increased from 116 to 287 (see Table 6). This number was not only sufficient to satisfy the de-

**TABLE 5 Parking Surveys: Before and After**

| Street | Spaces Available | No. of Different Cars Parked | Daily Turnover Veh/Day/Space | Average Duration Min/Veh/Space |
|---|---|---|---|---|
| Granby Street(1-hr Free Parking Zone) | | | | |
| Before | 104 | 253 | 2.43 | 48.6 |
| February, 92 | 98 | 317 | 3.23 | 35.2 |
| March, 92 | 98 | 314 | 3.20 | 39.9 |
| April, 92 | 98 | 316 | 3.22 | 35.1 |
| May, 92 | 98 | 347 | 3.54 | 37.3 |
| April, 93 | 118 | 357 | 3.03 | 44.0 |
| Main Street(Meter Zone) | | | | |
| Before | 32 | 126 | 3.94 | 46.7 |
| February, 92 | 42 | 206 | 4.90 | 46.6 |
| March, 92 | 42 | 168 | 4.00 | 48.9 |
| April, 92 | 42 | 200 | 4.76 | 52.5 |
| May, 92 | 42 | 204 | 4.86 | 48.8 |
| April, 93 | 45 | 216 | 4.80 | 46.0 |

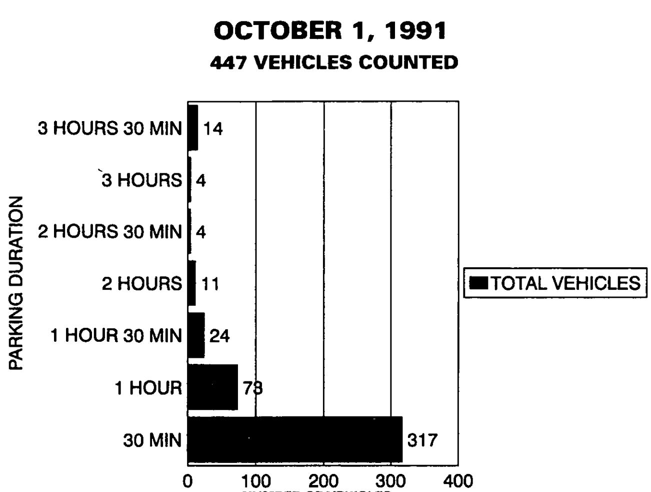


FIGURE 2 Downtown parking usage (before).

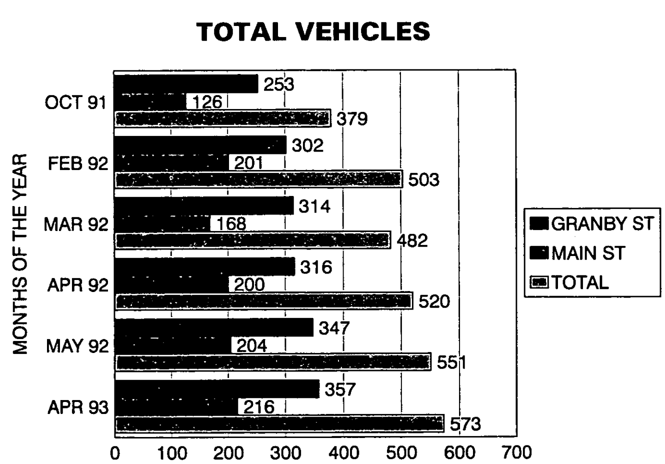


FIGURE 3 Downtown parking study (before and after).

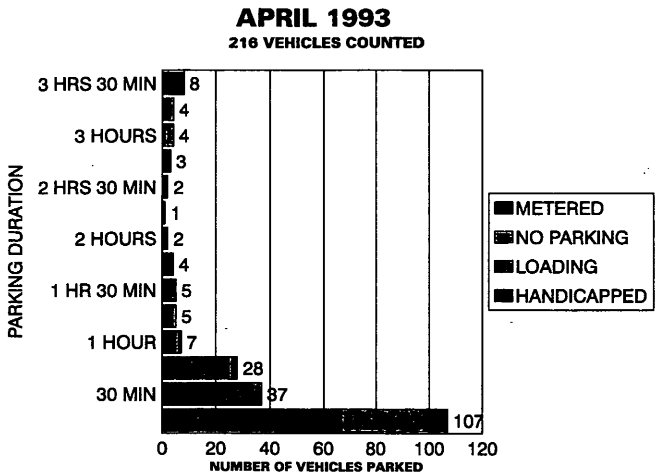


**FIGURE 4 Main Street parking usage (before).**

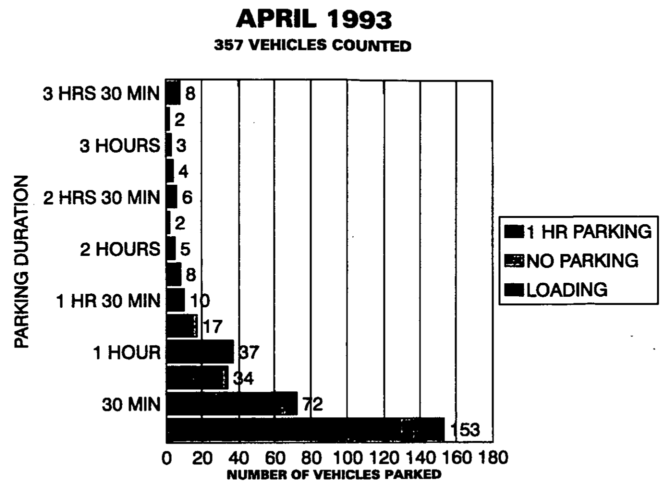


**FIGURE 5 Granby Street parking usage (after).**

mand for the core area, but it also provided additional spaces for the rest of the downtown area.

2. The number of parked cars has been gradually increasing. This is partially because of the ongoing modification of the parking pattern. More efficient usage of the parking spaces is also a contributing factor.

3. In general, parking turnover is higher than it was before. An increase of 25 percent in parking turnover has been observed in the northern district. Turnover increased 22 percent in the financial district. In particular, financial district (metered parking) surveys show a higher turnover than the free parking zone surveys.

4. Since the implementation of the program, a substantial decrease in parking duration has been observed. As much as 10 min of decrease in the parking duration has been observed along Granby Street.

5. Reports from the parking administration office show a gradual increase in parking meter revenues. Year-to-date revenues through April 1992 increased by $12,453 over the previous year.

## PROJECT MONITORING

Effective enforcement is essential to the success of the program. The police department uses its parking enforcement squad to continuously monitor parking conditions. The department also works in close coordination with the city's Transportation Division and Parking Administration.

A downtown parking advisory committee has been established since the implementation of the new parking program. The committee is composed of downtown merchants and appropriate city staff. The primary goal of the committee is to ensure that lines of communication are maintained between the area businesses and the city relative to downtown parking. It is advisory in nature and monitors the status, use of, and policies for on- and off-street parking facilities. The committee is also charged with providing regular status reports to the city council. Overall, the new parking program has been operating successfully and getting very favorable reviews from area businesses.

There is significant new development under way along the Granby Street corridor. As a result, surveys along the corridor were halted until the new construction is complete. An annex to City Hall will be in full operation in 1995. One of the area community colleges will open its downtown campus by the end of 1994. With these new developments and the new parking plan, it is expected that the retail business in the area will grow stronger. Once these new developments are in place, follow-up surveys will be conducted to evaluate any new strategies warranted by the new land use characteristics.

**TABLE 6 Parking Implementation Results**

| | Before | | | | After | | | |
|---|---|---|---|---|---|---|---|---|
| Street | 1-hr | MP | LZ | HC | 1-hr | MP | LZ | HC |
| Northern District | | | | | | | | |
| Granby St | 27 | - | 77 | - | 80 | - | 18 | - |
| City Hall Av | - | 6 | 3 | - | - | 6 | 3 | - |
| Brooke Av | - | - | 14 | - | 19 | - | 2 | 4 |
| Tazewell St | - | - | 10 | - | 21 | - | 2 | - |
| College Pl | - | - | 5 | - | 6 | - | 5 | - |
| Freemason St | 4 | - | 9 | - | 15 | - | 1 | - |
| Market St | - | - | 5 | - | 8 | - | - | - |
| Subtotal | 31 | 6 | 123 | - | 149 | 6 | 31 | 4 |
| Financial District | | | | | | | | |
| Main St | - | 19 | 11 | 2 | - | 40 | - | 2 |
| Plume St | - | 22 | 10 | 2 | - | 26 | 6 | 2 |
| Plume La | - | 5 | 7 | - | - | 19 | 7 | - |
| Granby St | - | 14 | 9 | - | - | 20 | 3 | - |
| Randolph St | - | 3 | 3 | - | - | 7 | - | - |
| Commercial St | - | 5 | 9 | 1 | - | 5 | 9 | 1 |
| Bank St | - | - | 8 | - | - | - | 8 | - |
| Court St | - | - | 1 | - | - | - | 1 | - |
| Atlantic St | - | 6 | 3 | - | - | 6 | 3 | - |
| Subtotal | - | 74 | 61 | 5 | - | 123 | 37 | 5 |
| Total | 31 | 80 | 184 | 5 | 149 | 129 | 68 | 9 |

1-hr = 1-Hour Parking
MP = Meter Parking
LZ = Loading Zone
HC = Handicapped Parking
- = None Existed

*Publication of this paper sponsored by Committee on Transportation System Management.*

# Parking Utilization at Work Sites in King and South Snohomish Counties, Washington

EILEEN KADESH AND JAY PETERSON

To help local jurisdictions review their parking policies as mandated by Washington State's new commute trip reduction legislation, the Municipality of Metropolitan Seattle conducted a parking utilization study in 1991 to assess the demand for parking, compared with supply, at employment sites throughout King and south Snohomish counties. A total of 36 employment sites in suburban, noncentral business district areas were included in the study. The sites represented two land uses: (*a*) professional office and (*b*) industrial sites (both light industrial and manufacturing). Results showed that the average parking supply was 30 percent greater than the average parking demand. The average number of parking spaces per 1,000 gross ft$^2$ (GSF) was 3.15, compared with a demand of 2.54 (a 24 percent excess). If projected employment and demand figures are used, a 13.5 percent excess parking supply still exists, in relation to spaces per 1,000 GSF. On the basis of the results of this study, it is recommended that local jurisdictions consider reducing their parking requirements, at least for professional office uses. The reduction of parking requirements in local codes will apply only to new or expanding developments; therefore local jurisdictions are encouraged to establish an administrative review process so that property owners of existing work sites, on behalf of employers, may request reductions in parking supply.

The oversupply of parking at suburban office sites has been well documented in previous research (*1–3*). The purpose of this study was to determine how well the results of these earlier studies compared with those of suburban work sites in King and south Snohomish counties.

Washington's commute trip reduction law mandates that each affected jurisdiction's commute trip reduction plan "shall include . . . a review of local parking policies and ordinances as they relate to employers and major worksites" [RCW 70.94.527(4.e)]. The Municipality of Metropolitan Seattle (Metro) conducted the parking utilization study to assess the demand for parking, compared with that of supply, at employment sites throughout King and south Snohomish counties. A total of 36 employment sites were included in the study. The sites, which were all in noncentral business districts, represented two land use types: (*a*) professional office sites and (*b*) industrial sites (combination of light industrial/manufacturing).

The parking utilization study had the following objectives:

- To assess the demand for parking, compared with supply, focusing on sites with 100 or more full-time employees arriving between 6 and 9 a.m.;
- To expand the geographic distribution of sites from previous parking studies;
- To collect data relating to long-term versus short-term parking behavior;
- To identify the level of spillover parking;
- To provide data and recommendations relating to parking standards for new development in local jurisdictions;
- To conduct the study within ITE standards so as to provide reliable and consistent findings; and
- To provide a procedural model for parking demand studies.

A parking utilization study advisory committee (including local jurisdiction staff, developers, academic researchers, and a representative from the local chapter of ITE) was formed to assist with the methodology, scope of work, site selection criteria, and data analysis.

## METHODOLOGY

This was a pilot study. However, the methodology may be viewed as a model for future parking demand studies. The following criteria were used for selecting sites:

- All sites were located outside central business districts.
- Each site needed to have 100 or more full-time employees arriving between 6 and 9 a.m.
- The parking lot for each site was distinct (that is, parking was not shared with neighboring sites).
- All sites had surface-level parking areas.
- Pay (commercial) parking was not available within three blocks.
- Cooperation of the building manager or site contact person was necessary.

Single-tenant sites were preferred to multitenant sites. An even mixture of "ample" and "tight" parking situations was sought. Telephone contact was made with each site's contact person to determine each site's parking situation (i.e., ample or tight). This provided for the ability to choose an even mixture of both parking situations. An attempt was also made to include only sites that were as free as possible from unique characteristics that would make parking counts and analysis more difficult than necessary, as well as less accurate. Snohomish County sites were suggested by Community Transit staff. Local jurisdiction planners suggested particular work sites of interest to them.

The parking lots in this study were counted in the morning and afternoon of two different days, not of the same week, during hours

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having the greatest occupancy (generally from 9 to 11 a.m., and again from 1 to 3 p.m.) as determined by Metro or each site's building managers. Data from the four visits were compared, and any sites for which counts varied between visits by more than 10 percent were revisited and recounted. The counts were conducted during October and November 1991 (excluding the week of Thanksgiving and all Mondays). Two sites were counted during the first 2 weeks of December.

Phone contact was made with each site's building manager or contact person to explain the scope of the study. If approval was granted to perform the supply and demand counts, questions relating to each site's parking characteristics were asked. These questions related to the following: the peak parking times, the peak parking days, whether spillover parking occurred, and whether the site shared parking with other sites. These questions were asked to ensure that each site was "pure" in that parking would not be shared with other sites. This also assisted in collecting data relating to the best times of day and days of the week to perform the counts at each site.

Data collection was performed using two methods. The first method consisted of mailing a site profile to the contact person for each site. The site profile was used to collect data relating to the age of the building, square footage, number of employees (both current and projected) and other site characteristics. The other method of data collection was the actual supply and demand counts performed at each site. Hand-held computers were selected to collect the data. Paperwork, time, and margin for error were greatly reduced since the hand-held computers eliminated data transfer from paper to personal computer. The hand-held computers were programmed with fields for entering parking space supply and demand data for each type of parking space.

Six types of parking spaces were examined for the purposes of this study.

1. Visitor,
2. Disabled,
3. Carpool/vanpool,
4. Reserved,
5. Other (general), and
6. Spillover (a definition of this parking type is given later in the paper).

Each site's counts were entered into a data base broken down by visit number, parking space type, and time of day the count was conducted. Information from each site that returned a site profile was used to perform calculations regarding spaces per 1,000 gross $ft^2$ (GSF) and spaces per employee. The same calculations were also performed using projected number of employees and projected parking demand. An attempt was made to arrange the sites into groups. Three groups were created:

1. Professional office sites (not including medical sites),
2. Light industrial and manufacturing sites, and
3. Combination professional office/light industrial and manufacturing sites.

Because the groupings reduced the number of light industrial and combination professional office/light industrial sites into such small segments, no attempt was made to analyze them in detail. Table 1 provides supply and demand figures relating to spaces per 1,000 GSF and spaces per employee for the 33 sites that returned site profiles. The demand figures used in Table 1 were the highest demand figures at each site, not the average demand.

In addition to the supply and demand data, the hand-held computers were programmed with fields for entering license plate numbers of all vehicles at each site. This was intended to provide information relating to long-term versus short-term parking behavior. Unfortunately, because of employees' security concerns, license plate data were collected at only six sites.

## RESULTS

The results summarized next are based on the long-term commuter parking supply and demand data collected at the 36 employment sites. For calculations of supply and demand for spaces per 1,000 GSF and spaces per employee, a base of 33 is used. This was because 33 of the 36 sites (91.6 percent) returned their site profile containing the data necessary for the calculations. For purposes of this study, supply is defined as the sum of all types of parking with the exception of spillover. Demand is equal to the sum of all types of parking, including spillover.

Analysis was also performed with regard to spaces per 1,000 GSF and spaces per employee using projected numbers for employees and parking demand. Of the 33 sites that returned site profiles, 24 answered the section about the projected number of employees at full occupancy (72.7 percent). Of the 24 responses, 14 sites projected numbers higher than the current number of employees, whereas the other 10 sites indicated that they were at peak occupancy. The projected parking demand was recalculated using current employee to demand ratios. These are projected numbers using the assumption that parking demand will remain at the same proportion as that at current levels. In addition, no attempt was made to adjust parking supply figures, among other variables.

Each site was contacted for permission to use company names in the report. Five sites requested to remain anonymous. These sites are referred to as Sites A through E.

### Overall Averages

The average supply of parking spaces exceeded the average demand for spaces by 29.9 percent. Of the 36 sites in the study, the average parking supply was 374 total spaces with an average parking demand of 208 spaces (see Figure 1). For office sites the average parking supply was 370 spaces with an average parking demand of 272 spaces. This represents an average excess supply of 36 percent (see Figure 2).

### Occupancy Rates

The average parking lot occupancy rate (all parking space types except spillover) was 74.6 percent. For office sites the average parking lot occupancy rate was 71.9 percent.

### Supply Versus Demand: Profiled Sites

Parking supply and demand figures were also calculated in relation to spaces per 1,000 GSF and spaces per employee. These figures were calculated using data obtained from each site's profile and the

**TABLE 1 Parking Supply and Demand, All Sites: Spaces per 1,000 gsf and Spaces per Employee**

| | | | | | | Parking Supply | | Parking Demand | | Parking Excess | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| All Sites | Gross Sq Ft Leased | Full-Time Employees | Parking Spaces | Parking Demand | Employee Density emp./1000 gsf | Sp/1000gsf | Sp/Emp | Sp/1000 gsf | Sp/Emp | Sp/1000 gsf | Sp/Emp |
| Advanced Tech Labs | 285,024 | 1,266 | 1,027 | 1,053 | 4.44 | 3.60 | 0.81 | 3.69 | 0.83 | - 2.44% | - 2.41% |
| Site A | 175,947 | 685 | 769 | 556 | 3.89 | 4.37 | 1.12 | 3.16 | 0.81 | 38.29% | 38.27% |
| AMI Building | 62,500 | 350 | 290 | 252 | 5.60 | 4.64 | 0.83 | 4.03 | 0.72 | 15.14% | 15.28% |
| Attachmate | 32,697 | 161 | 111 | 117 | 4.92 | 3.39 | 0.69 | 3.58 | 0.73 | - 5.31% | - 5.48% |
| Blue Cross Hdqrtrs | 93,991 | 300 | 378 | 295 | 3.19 | 4.02 | 1.26 | 3.14 | 0.98 | 28.03% | 28.57% |
| Boeing Material Div | 300,000 | 1,500 | 1,349 | 1,078 | 5.00 | 4.50 | 0.90 | 3.59 | 0.72 | 25.35% | 25.00% |
| Coca-Cola | 190,286 | 195 | 223 | 157 | 1.02 | 1.17 | 1.14 | 0.83 | 0.81 | 40.96% | 40.74% |
| Container Corp | 120,000 | 100 | 130 | 93 | 0.83 | 1.08 | 1.30 | 0.78 | 0.93 | 38.46% | 39.78% |
| Site B | 82,027 | 104 | 112 | 95 | 1.27 | 1.37 | 1.08 | 1.16 | 0.91 | 18.10% | 18.68% |
| Eddie Bauer - OLE | 28,649 | 150 | 159 | 178 | 5.24 | 5.55 | 1.06 | 6.21 | 1.19 | -10.63% | -10.92% |
| Eddie Bauer - OLW | 41,176 | 187 | 116 | 137 | 4.54 | 2.82 | 0.62 | 3.33 | 0.73 | -15.32% | -15.07% |
| Eldec | 194,000 | 636 | 818 | 555 | 3.28 | 4.22 | 1.29 | 2.86 | 0.87 | 47.55% | 48.28% |
| First Interstate Bank | 60,000 | 217 | 236 | 178 | 3.62 | 3.93 | 1.09 | 2.97 | 0.82 | 32.32% | 32.93% |
| Site D | 28,800 | 60 | 118 | 68 | 2.08 | 4.10 | 1.97 | 2.36 | 1.13 | 73.73% | 74.34% |
| Harbor Marina Corp Center | 106,477 | 290 | 290 | 190 | 2.72 | 2.72 | 1.00 | 1.78 | 0.66 | 52.81% | 51.52% |
| John H. Harland Co | 41,451 | 100 | 180 | 127 | 2.41 | 4.34 | 1.80 | 3.06 | 1.27 | 41.83% | 41.73% |
| Kirkland City Hall | 39,000 | 160 | 136 | 105 | 4.10 | 3.49 | 0.85 | 2.69 | 0.66 | 29.74% | 28.79% |
| Modern Manufacturing | 100,000 | 142 | 151 | 92 | 1.42 | 1.51 | 1.06 | 0.92 | 0.65 | 64.13% | 63.08% |
| Northgate Meridian Building | 37,000 | 96 | 116 | 70 | 2.59 | 3.14 | 1.21 | 1.89 | 0.73 | 66.14% | 65.75% |
| Opportunity Building | 82,258 | 330 | 380 | 222 | 4.01 | 4.62 | 1.15 | 2.70 | 0.67 | 71.11% | 71.64% |
| Site E | 75,000 | 256 | 265 | 210 | 3.41 | 3.53 | 1.04 | 2.80 | 0.82 | 26.07% | 26.83% |
| Physio Control | 254,131 | 678 | 742 | 678 | 2.67 | 2.92 | 1.09 | 2.67 | 1.00 | 9.36% | 9.00% |
| Puget Power | 73,087 | 190 | 161 | 135 | 2.60 | 2.20 | 0.85 | 1.85 | 0.71 | 18.92% | 19.72% |
| Safeway Dist Center | 1,221,990 | 630 | 750 | 672 | 0.52 | 0.61 | 1.19 | 0.55 | 1.07 | 10.91% | 11.21% |
| Sierra Building | 50,000 | 220 | 173 | 161 | 4.40 | 3.46 | 0.79 | 3.22 | 0.73 | 7.45% | 8.22% |
| Sun Sportswear | 226,242 | 180 | 325 | 229 | 0.80 | 1.44 | 1.81 | 1.01 | 1.27 | 42.57% | 42.52% |
| Two/Three Renton Place | 275,876 | 1,250 | 1,238 | 938 | 4.53 | 4.49 | 0.99 | 3.40 | 0.75 | 32.06% | 32.00% |
| Unigard Insurance | 120,000 | 500 | 427 | 392 | 4.17 | 3.56 | 0.85 | 3.27 | 0.78 | 8.87% | 8.97% |
| USAA Insurance | 39,835 | 160 | 175 | 127 | 4.02 | 4.39 | 1.09 | 3.19 | 0.79 | 37.62% | 37.97% |
| U.S. Food & Drug Adm | 54,000 | 127 | 121 | 136 | 2.35 | 2.24 | 0.95 | 2.52 | 1.07 | -11.11% | -11.21% |
| West Coast Paper | 198,000 | 117 | 67 | 81 | 0.59 | 0.34 | 0.57 | 0.41 | 0.69 | -17.07% | -17.39% |
| Weyerhaeuser-Corp HQ | 356,000 | 775 | 1,123 | 572 | 2.18 | 3.15 | 1.45 | 1.61 | 0.74 | 95.65% | 95.95% |
| Weyerhaeuser-W. Campus | 117,500 | 350 | 376 | 295 | 2.98 | 3.20 | 1.07 | 2.51 | 0.84 | 27.49% | 27.38% |
| Mean | 156,453 | 378 | 395 | 310 | 3.07 | 3.15 | 1.09 | 2.54 | 0.85 | 24.02% | 28.24% |

parking supply and demand counts. Only sites that returned their site profile were included in this analysis (33 of 36 sites using current numbers, 24 of 36 sites using projected numbers). Calculations were performed using averages for all sites, as well as breaking them down into groups of professional office sites, light industrial sites, and those sites that were a mix of professional office and industrial. The parking demand figures used in the spaces per 1,000 GSF and spaces per employee were the highest demand figures of the two visits, not the average demand.

### Spaces Per 1,000 GSF

There was an average 24 percent parking supply excess over parking demand, in relation to parking spaces per 1,000 GSF. The average number of parking spaces per 1,000 GSF was 3.15. These figures ranged from a low of 0.34 spaces per 1,000 GSF to a high of 5.55 spaces. The average parking demand was 2.54 spaces per 1,000 GSF, ranging from a low of 0.41 to a high of 6.21.

For office sites the average number of parking spaces per 1,000 GSF was 3.78. The average parking demand was 3.05 spaces per 1,000 GSF. This represents an average excess supply of 23.9 percent in relation to parking spaces per 1,000 GSF.

Using the projected number of employees and projected parking demand numbers still produced a 13.5 percent excess of parking supply over demand, in relation to parking spaces per 1,000 GSF. The average number of parking spaces per 1,000 GSF was 3.19, and the average demand was 2.81.

### Zoning Requirements Versus Parking Supply and Demand

Local jurisdiction zoning requirements for spaces per 1,000 GSF at each site were compared with each site's parking supply and demand per 1,000 GSF. Of the 33 sites that returned site profiles, zoning requirements for off-street parking were obtained for 31. The average zoning requirement for spaces per 1,000 GSF was close to the average supply. The average requirement was 3.0 spaces per 1,000 GSF, whereas the average supply was 3.3 spaces per 1,000 GSF. The average demand was 2.6 spaces per 1,000 GSF, representing an excess supply of 15.4 percent over the average supply requirement.

### Spaces per Employee

There was an average 28.2 percent excess of parking supply over parking demand, in relation to parking spaces per employee. The average number of parking spaces per employee was 1.09. These figures ranged from a low of 0.57 to a high of 1.97. The average parking demand was 0.85 spaces per employee, ranging from a low of 0.65 to a high of 1.27.

For office sites the average number of spaces per employee was 1.03. The average parking demand was 0.84 spaces per employee. This represents an average 22.6 percent excess of parking supply over parking demand.

Using projected number of employees at full occupancy and projected parking demand at full occupancy still produced a 16.5 percent excess of parking supply over demand, in relation to parking spaces per employee.

### Employee Density: Employees per 1,000 GSF

The average number of employees per 1,000 GSF was 3.1. This ranged from a low of 0.5 to a high of 5.6. Using projected number of employees at full building occupancy resulted in an average of 3.6 employees per 1,000 GSF. This ranged from a low of 0.63 to a high of 6.0.

### Long-Term Versus Short-Term Parking (License Plate Matching)

In addition to parking space supply and demand counts, the researchers had intended to examine long-term versus short-term parking behavior. The approach was to record the license plate numbers of all vehicles at each site. Because of concerns about security by employees at several sites, this portion of the study was conducted at only six sites.

Although only six sites were observed, the high percentage of license plates matching indicates that the counts measured peak occupancy reasonably well. That is, there was little variation between a.m. and p.m. counts, and the average total percentage of license plates matching was fairly high.

## LESSONS LEARNED

The parking utilization study endured many challenges and changes during inception, data collection, and analysis. Parking behaviors varied from site to site. Because this was a pilot study, the lessons learned during the course of this project may prove useful for future studies.

### Site Selection Criteria

Although costly and time consuming, the ability to personally inspect a site's parking characteristics, perhaps with the assistance of the site's contact person, would assist in maximizing the number of "pure" sites. More in-depth phone contacts to ensure distinct parking between sites would help minimize this problem.

Although the actual site selection criteria assisted in selecting sites with "pure" parking situations, additional measures need to be implemented to ensure that this happens. During and after site data collection, some sites were found to share parking with or lease parking from other sites. This was not a major concern, however, because the instances of shared parking were small.

To assist those performing the supply and demand counts, a site map was drawn for each site before it was counted. Although this map helped find problems with a few sites that were thought to be "pure," other methods could also be of assistance.

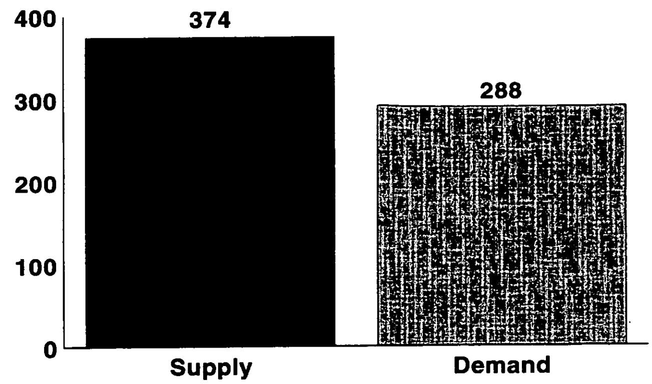


**FIGURE 1 Average supply versus demand (all sites). Excess is 29.9 percent.**

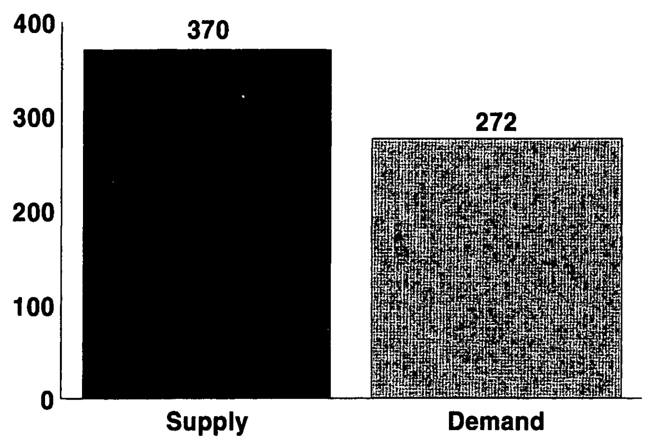


**FIGURE 2 Average supply versus demand (office sites). Excess is 36 percent.**

### Spillover Parking

Spillover parking is a complex parking type. Both on-site and off-site spillover parking need to be documented.

For purposes of this study spillover was categorized in one of two ways: (*a*) on-site spillover or (*b*) off-site spillover. On-site spillover occurs in the confines of a site's parking lot. This may happen for many reasons, but the two most common reasons seem to be either parking along curbs or "no parking" areas because all other spaces were occupied, or parking for convenience. That is, it was found that some people park in areas not designated for parking because these areas may be closer than is a designated parking space to a person's destination. Off-site spillover parking, on the other hand, occurs outside the confines of a site's parking lot. The two reasons for spillover mentioned above also apply to off-site spillover. In addition, a site may lease parking from another site. For the purposes of this study this was also considered spillover.

Although it is difficult to count supply for spillover (unless a site has a designated number of spaces capable of "counting"), in many instances it was done. Two main reasons stand out. The first reason is that a supply and demand figure had to be entered because of the hand-held computers' programming. Therefore, although a site may have had no specific or discernable parking spaces relating to spillover parking, a supply number had to be entered to, in turn, enter a demand number. Second, in some instances an actual number could be deciphered. Spillover parking is an area deserving further research and review.

### Site Profile

Two separate site profile forms, one for those who owned their building and a second for those who leased space, might have worked better.

In some instances site contacts got confused and did not answer questions because they thought the questions did not apply to them. Revisions to the site profile to include both situations or the use of two distinct profile forms would help to ensure better response rates.

### Precount Confirmation

Ensure that all affected parties at each site are aware of when the counts are to be conducted.

Initially, there were problems at a few sites when employees protested the recording of their license plate numbers. In addition, because of past instances of theft and car break-ins, a few employees did not care for people "wandering" through their parking lot.

### Accuracy of Counts

Take steps to strive for greater consistency between counts.

It was difficult to accomplish completely consistent counts of the parking lot sites. These counts were logged at the site into preprogrammed minicomputers. The difficulty with the use of computer entry is that there is no way to check one's work at the site. It is all too easy to lose track of whether a spot has just been counted or was just about to be. The firm contracted to perform the counts offered the following suggestions:

- Supply field workers with chalk on a long string, and mark each parking space (not the vehicle) after counting.
- Reprogram the computers to allow subtotals to be called up while still in the field. Alternatively, if there is space on the computer, the last entry could be displayed. The feasibility of these two steps would have to be checked with the computer supplier; these steps are also not likely to be helpful in very large lots.
- Program computers to beep at the end of each entry. (Again, feasibility would have to be confirmed with the computer suppliers.)
- Conduct counts on paper, or have a paper count as a backup to the computer count. The advantage of a paper copy is that the field worker has a readable record of work at the time of the entry. The disadvantage is that paper counts are fraught with their own difficulties.
- Expand the amount of time put into mapping the location so that the number of slots available, labeled per type, is provided on each map.

## CONCLUSIONS

The parking utilization study has indicated that there is an excess supply of employee parking provided at the majority of sites counted. An average excess parking supply of nearly 30 percent exists for the 36 sites studied. An average excess supply of 24 percent in relation to spaces per 1,000 GSF and 28.2 percent in relation to parking spaces per employee was found. Even using a conservative approach (using projected employee numbers at full occupancy and projected parking demand at full occupancy), parking supply excesses of 13.5 and 16.5 percent were estimated for spaces per 1,000 GSF and spaces per employee, respectively.

This excess parking supply makes a case for local jurisdictions to consider reducing their parking requirements, at least for professional office uses. Local jurisdiction parking requirements closely matched the actual parking supply. This may be because, to request a variance below the minimum, the developers must pursue a lengthy administrative process, which causes most of them to provide parking at minimum levels or above.

Reduction of local parking requirements will apply only to new or expanding developments. The commute trip reduction law, on the other hand, applies to existing employment sites; therefore it is recommended that local jurisdictions establish an administrative review process so that property owners of existing work sites, on behalf of employers, may request reductions in parking supply.

## FUTURE RESEARCH

This project focused on finding trends and developing a methodology that could be used by local jurisdictions in conducting their own parking demand studies. During this study, additional research needs on several aspects of parking demand emerged, including the following:

- Parking supply/demand at office sites of 100 or more, with a larger sample size;
- Parking supply/demand focusing on industrial sites;
- Parking supply/demand at business parks;
- Parking supply/demand focusing on suburban central business districts;
- Parking requirements based on access to transit;
- The impact of work site transportation demand management programs on parking demand (based on implementation of the commute trip reduction law); and
- Spillover parking.

Parking utilization study data are being used to help develop guidelines for commuter parking policies in King County, including recommendations for constraining the supply of commuter/employee parking.

## ACKNOWLEDGMENT

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# Downtown Parking Management System

R. G. THOMPSON AND E. C. COLLINS

The planning and management of parking facilities within downtown areas are among the most challenging tasks facing transport planners. Information relating to a wide range of components in a city's transport and land use systems must be processed, analyzed, and effectively communicated to policy makers and concerned groups. These tasks are not easily performed by traditional methods because of the spatial nature of the data, the large amount of data required, and the large number of interactions involved. A microcomputer-based parking management system was developed to assist the planning of public car parks within a downtown area. The two major components of the system are a parking survey analysis package (PARKSTAT) and a graphical data base (PARKINFO). PARKSTAT allows data collected from parking surveys to be processed and analyzed. Numerous plots and tables specifically designed to highlight important operational features of car parks can be produced. PARKINFO allows data relating to the parking stock to be managed within a graphical environment. It also allows information of related systems, including traffic and land use, to be integrated. The main features of these packages are illustrated using a system that is based on the Wollongong downtown area. These tools have been used in evaluating development proposals as well as for developing parking contribution plans for commercial centers in the region. Both packages have provided information for parking operators, transport analysts, and policy makers and have assisted in the development and review of parking strategies.

The planning and management of downtown car parks are major responsibilities of transport planners. These roles present substantial challenges for analysts, particularly in processing, analyzing, and communicating information to policy makers and interested groups. Information relating to the operation and utilization of car parking facilities in downtown areas is critical for policy formulation and evaluation. Knowledge of the usage characteristics of car parks is also crucial for their efficient management.

Car parks are an important component of the transport system and can be considered valuable assets. Therefore, monitoring their usage is essential to ensure that existing parking, land use, and traffic policies meet their objectives.

The need to efficiently manage the parking stock is even more important if downtown areas are to be effectively revitalized. However, many parking management tasks are not easily performed by traditional manual methods because of the spatial nature of the data and the large number of interactions involved. Because the attributes of the parking and related systems are constantly changing, past surveys and studies quickly become out of date. Many existing procedures for processing, analyzing, and presenting these data are slow, costly, and inaccurate. They also are not generally integrated and the quality of presentation is poor.

Traffic engineers and planners require a large amount of information to adequately plan, manage, and operate parking systems in downtown areas. Recent developments in microprocessor technology have substantially increased both the quantity and quality of the data that can be collected (*1*). However, without the accompanying development of information delivery systems, transport planners can easily become swamped with data.

There is currently a gap between the technology available to collect parking data and the associated information processing software required to process, analyze, and present it. Traffic engineering, including parking, is currently experiencing a data explosion (*2,3*), in which enormous amounts of data are being collected using electronic equipment. New advanced parking technology (e.g., automatic ticketing machines and traffic detectors) allows an enormous amount of parking-related data to be easily collected. However, many of these data are not being adequately processed or transformed into useful information; therefore a large proportion of existing data are left unprocessed or poorly presented, resulting in the extraction of little, if any, knowledge.

New technology can significantly speed up analysis time and translate data into information by making the data more understandable, accessible, and presentable to decision makers (*4*). The role of computer graphics in delivering information to decision makers is becoming vitally important. Several microcomputer parking information systems have been developed recently (*5,6*).

## PARKSTAT

PARKSTAT is an interactive parking survey analysis package developed using the Think Pascal programming language (*7*) for the Apple Macintosh series of microcomputers (*8*). It makes extensive use of business graphics as well as exploratory data analysis techniques to highlight important usage patterns at car parks. Several features of this package are presented here using data collected from a moderate (580 stalls) car park in the Wollongong downtown area.

### Parking Utilization Analysis

A range of numerical indicators are produced by PARKSTAT to provide a description of the overall operations of individual parking facilities. These statistics include the average utilization, peak accumulation, space hours of use, and turnover.

Utilization profiles displaying the temporal variation of accumulation levels (demand) throughout the day (Figure 1) can also be produced. The vertical axes are used to express the utilization and entry and exit flows in terms of the number of vehicles as well as a percentage of capacity.

### Parking Duration Analysis

PARKSTAT calculates parking durations by matching arrival and departure observations of individual vehicles. Numerous analysis

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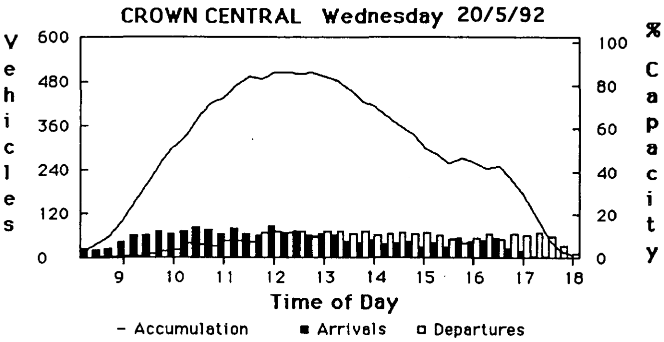


**FIGURE 1 PARKSTAT utilization profile.**

techniques are available for investigating the characteristics of these distributions, including summary statistics, cumulative frequency plots, and histograms.

PARKSTAT also allows the production of multiple box plots of parking durations (*9*). Parking durations are grouped according to their hour of arrival to highlight the temporal variation throughout the survey period (*10*). The width of the boxes indicates the number of vehicles arriving within the arrival hour, with a wide box indicating a large number of arrivals. Figure 2 shows that there were only a small number of arrivals before 9:00 a.m. and a large number of arrivals between 10:00 a.m. and noon. The decaying ranges and medians after 10:00 a.m. are also evident. The long-term parking durations are most prevalent in the hours beginning 8:00 and 9:00 a.m. This graph also highlights the skewed nature of the distributions as well as several outliers.

## PARKINFO

PARKINFO is a graphical data base designed to manage car parks in downtown areas. It has been expanded to incorporate data from a number of related areas including the traffic, land use, and public transport systems.

The development of the system involved a process that incorporated numerous components and linkages (Figure 3). Initially, the data items to be included in the system were identified. These data were then collected and collated. Before they were recorded into the system the data had to be coded and edited. A large number of components had to be designed before any data could be transferred into

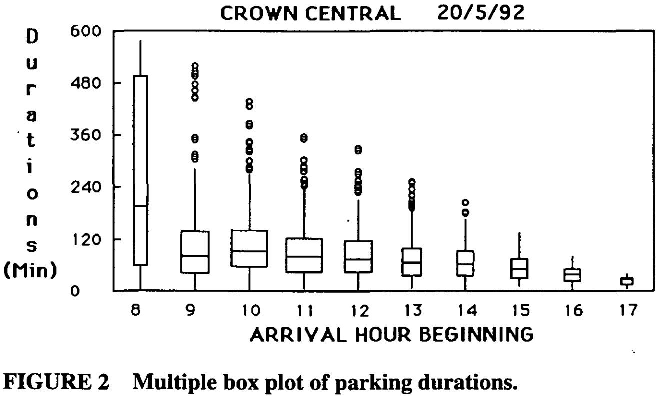


**FIGURE 2 Multiple box plot of parking durations.**

the system. After the data had been input, an evaluation of the performance of the system revealed the need to collect more data and redesign several elements.

The aims of this information system were determined by identifying the requirements of the city council. The council's primary need was for a system to manage a large number of parking-related data (e.g., inventory and utilization survey results). There was also a need to produce a system that could present these data and allow them to be updated on an ongoing basis.

Two types of data are incorporated into this system: data necessary for implementing traffic and parking models (*11*) and additional items to enhance its usefulness as a general transport planning tool.

Designing PARKINFO involved specifying the types (data bases) as well as their associated attributes (fields). Each visual item belongs to a type that has an individual file structure with specified fields. Numerous types or data bases must be defined to create an integrated visual environment. These include site (land use parcels), garage (off-street parking stations), lot (off-street car parks), onstreet (on-street car parks), link (traffic), intersection (nodes), bus stop, bus terminal, railway station, and movement (traffic turning movements).

Graphical images, reports, and screen layouts were designed, including specific symbols for intersections and parking facilities as well as turning movements. Clear and attractive screen layouts were also created. This involved defining icons, line styles, buttons, and network drawings. Standard colors, shades, and orientations of shapes consistent with data types were determined. Textual reports which included parking inventories and land use summaries, were also developed.

## WOLLONGONG CENTRAL BUSINESS DISTRICT SYSTEM

PARKINFO was used in the Wollongong central business district (CBD) traffic and parking study conducted by the local council to allow the generation of numerous maps and reports. It provided information to assist in the planning and reviewing of parking and traffic operations together with their relationship with land use. It also provides an ongoing tool that can be used to monitor the downtown transport system and undertake parking policy analysis. The Wollongong CBD parking information system was developed using the FILEVISION software package (*12*) on an Apple Macintosh IIci, microcomputer.

Numerous data items relating to the characteristics of car parks are stored for each car park (Figure 4). These include the physical characteristics (e.g., capacity), management policies (e.g., duration limits, restricted times, direct fee rates), and performance measures (e.g., average utilization and turnover). Several graphical images associated with each car park were also constructed, including a lot's geometric layout, daily profile utilization (Figure 5), and a duration histogram. These are used to store the results of analysis undertaken using PARKSTAT. Data relating to a specific car park can be accessed by double clicking the mouse on its image. This feature provides a convenient medium for managing a variety of relevant textual and graphical data for each facility. Data were similarly stored for road links, intersections, and land use sites.

Text and numeric data fields associated with objects can be used to search and highlight the graphical map-based images (records) meeting specified criteria. This allows reporting of complex queries

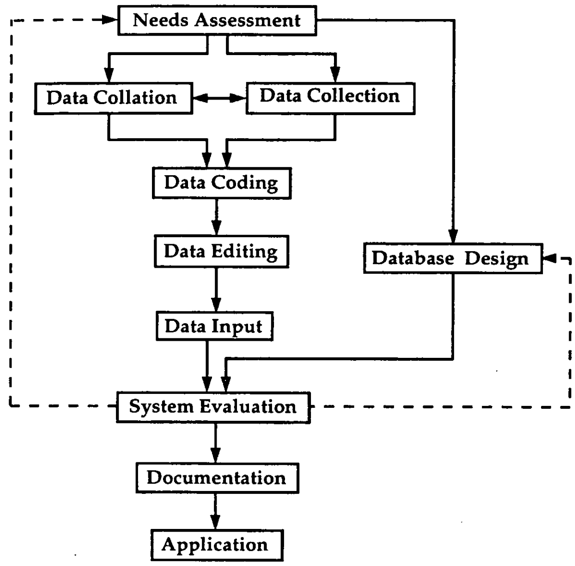


**FIGURE 3 PARKINFO development process.**

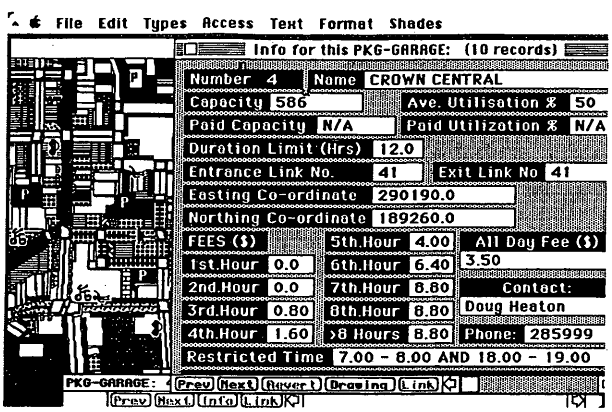


**FIGURE 4 Numerical attributes of garages.**

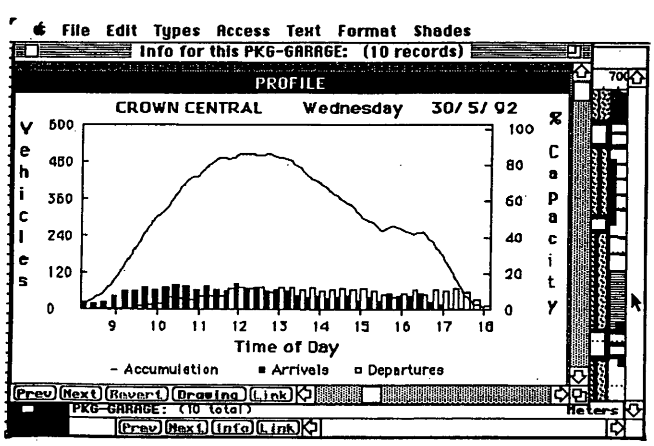


**FIGURE 5 Utilization profile of a lot.**

in graphical form. This particular example involves identifying parking lots within the CBD that have a capacity of more than 50 stalls and an average utilization level of less than 50 percent. Car parks satisfying these criteria are highlighted as a result of such a query (Figure 6).

Additional searches can be undertaken to highlight related objects that in turn can be shaded to create thematic maps with legends that indicate the characteristics of objects. Figure 7 shows a map of the location of public on-street car parks; the shading indicates their duration limits. Predefined textual reports can also be produced in a manner similar to that for traditional data base management systems.

Numerous data also have been stored for traffic links and turning movements, allowing the management of a wide range of traffic data. Important data relating to the traffic generation characteristics of land use sites have also been incorporated, including the number of employees and area of floor space. Details relating to the public transport services, including terminals, timetables, and routes also have been included.

This system has been expanded to incorporate other major business centers within the region. These centers are linked, providing an integrated system for managing and presenting parking-related information throughout the region.

## APPLICATIONS BY WOLLONGONG CITY COUNCIL

PARKINFO and PARKSTAT have been used extensively by Wollongong City Council's traffic section and have been found to be essential parking management and planning tools.

The traffic section of Wollongong City Council has recently been required to undertake detailed parking studies as a direct consequence of amendment to Section 94 of the New South Wales Environmental Planning and Assessment Act, 1979. This section of the act gives local governments the power to impose conditions on a development so that surrounding public infrastructure is provided and existing infrastructure capacity and performance are not adversely affected.

Most government authorities have numerous policies with which various types of development must comply. Under certain circumstances where a development is considered desirable or appropriate and some or all of the required infrastructure cannot be provided, the local authority has the power under Section 94 to charge a levy on the development for a monetary contribution toward the future provision, by the authority, of those facilities. These facilities may include open space, public roads, or parking garages or lots.

The recent amendments to Section 94 of the act now require a local government authority to have a publicly adopted plan or strategy in place for each type of public infrastructure for which a Section 94 levy is sought.

Wollongong City Council was fortunate because some 12 months beforehand extensive inventory surveys of downtown parking were done as part of the development of the PARKINFO data base. Time constraints and the incorporation of a downtown computer traffic and parking model necessitated the following approach for the development of the Section 94 parking plan. The study included downtown Wollongong (referred to as the CBD) as well as some eight suburban commercial centers of significance. Numerous actions were identified and applied to various parts of the city, depending on the locality, existing public availability, and levels of utilization (Figure 8).

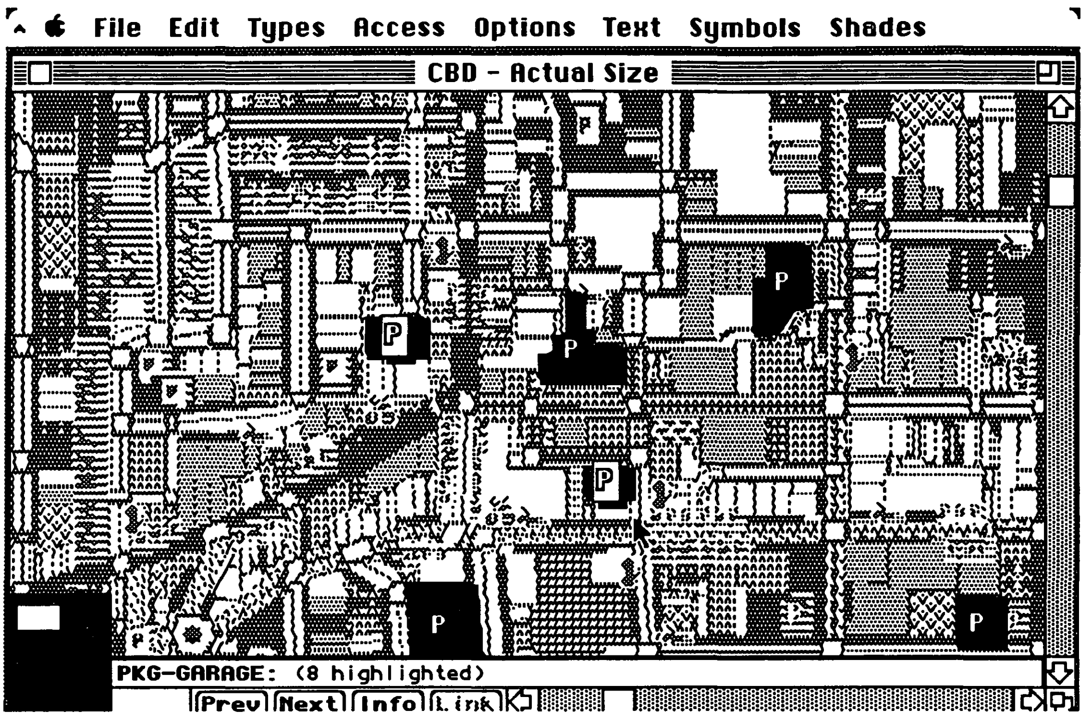


FIGURE 6 Large and underutilized lots highlighted.

The Section 94 parking study was therefore planned to be undertaken in two stages:

- Stage 1, which involved (*a*) inventory of all parking (on street and off street), (*b*) establishment of precincts and selection of locations, (*c*) development of policies and actions, (*d*) parking surveys and analysis, (*e*) data base design and modifications, and (*f*) documentation and adoption of Section 94 plans; and
- Stage 2, which involved strategic planning of infrastructure using advanced land use, parking, and traffic modeling techniques to evaluate various future planning scenarios.

Both the PARKSTAT and PARKINFO software packages were used extensively during Stage 1 of the study. Significant amounts

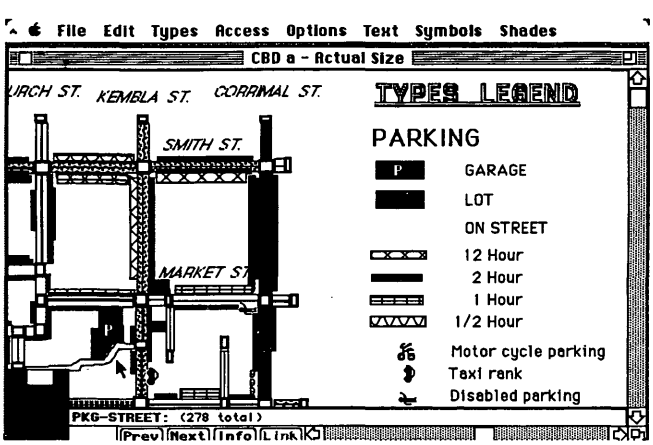


FIGURE 7 Car park duration limits.

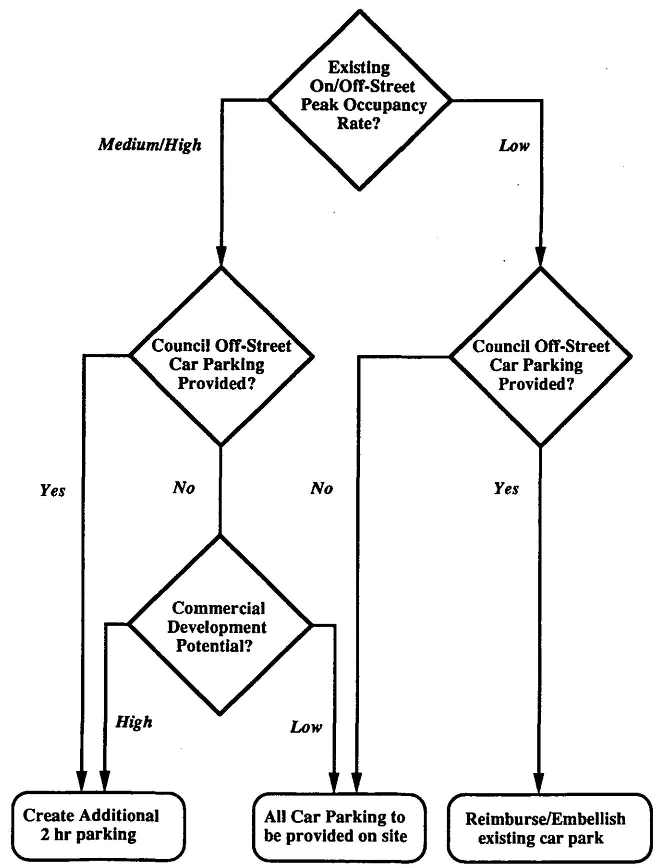


FIGURE 8 Section 94 parking contributions plan action flowchart for commercial centers.

of data were collected, processed, and input into the relevant data bases within the PARKINFO system.

On-street parking was surveyed hourly and data were input into the PARKSTAT software to provide estimates of utilization and peak occupancy. PARKINFO map presentation facilities were then utilized to present output showing those areas where, for example, peak occupancy was less than 50 percent. On-street parking lots with peak occupancies of 50 percent or greater were also highlighted and presented in map form.

Visual examination of the map output revealed general areas of either low or medium-to-high parking usage, allowing the predetermined policy actions to be applied.

The plan for car parking contributions in Wollongong is anticipated to be a dynamic document. As new developments occur, further parking will be undertaken with these statistics also stored in PARKINFO and compared with those previously surveyed. The contribution plan can then be amended as necessary.

As computer modeling is about to commence, the parking data held within PARKINFO will be called on in the model validation process. Furthermore, output from computer modeling can also be stored in PARKINFO and retrieved and presented in color graphical form as an aid in interpretation and communication of results.

## CONCLUSIONS

Both the PARKSTAT software and PARKINFO data base have greatly assisted the Wollongong City Section 94 parking study. The efficient management of quantities of data has allowed the timely completion of Part 1 of the study by the due date set by legislation. The PARKINFO data base will continue to be used during Stage 2 of the study and will be modified and updated as required according to future planning needs.

PARKINFO has also been used to assess the impacts of development applications. Numerous maps have been produced that show the location of major car parks and developments, combined with traffic and public transport networks. Another major application of this system has been to manage a wide range of transport-related data required for modeling exercises. It has also allowed for easy identification of planning issues within precinct. The system is extremely easy to use, requiring minimal training and technical support.

Both PARKINFO and PARKSTAT utilize relatively inexpensive microcomputer hardware and software to provide tools for aiding the planning and management of parking facilities within downtown areas.

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