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CARPOOLING: STATUS AND POTENTIAL

Donald C. Kendall

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FINAL REPORT

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16. Abstract

This report contains the findings of studies conducted to analyze the status and potential of work-trip carpooling as a means of achieving more efficient use of the automobile. Current and estimated maximum potential levels of carpooling are presented together with analyses revealing characteristics of carpool trips, incentives, impacts of increased carpooling and issues related to carpool matching services. National survey results indicate the average auto occupancy for urban work-trip is 1.2 passengers per auto. This value, and average carpool occupancy of 2.5, have been relatively stable over the last five years. An increase in work-trip occupancy from 1.2 to 1.8 would require a 100% increase in the number of carpoolers. A model was developed to predict the maximum potential level of carpooling in an urban area. Results from applying the model to the Boston region were extrapolated to estimate a maximum nationwide potential between 47 and 71% of peak period auto commuters. Maximum benefits of increased carpooling include up to 10% savings in auto fuel consumption. A technique was developed for estimating the number of participants required in a carpool matching service to achieve a chosen level of matching among respondents, providing insight into tradeoffs between employer and regional or centralized matching services. Issues recommended for future study include incentive policies and their impacts on other modes, and the evaluation of new and ongoing carpool matching services.

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PREFACE

During the height of the energy crisis, the Department of Transportation, through the joint efforts of the Urban Mass Transportation Administration and the Federal Highway Administration announced the inauguration of a nationwide effort to promote the use of carpools for the daily work trip. As part of this program, a series of studies on carpooling were conducted at the Transportation Systems Center throughout 1974.

The report presented herein was prepared by the Office of Systems Research and Analysis of the Transportation Systems Center in conjunction with the efforts of UMTA and FHWA. It is one of the work items on the project entitled "Urban Analysis" sponsored by the Office of R&D Policy, and is an amalgamation and extension of various working papers on carpooling prepared by TSC personnel throughout the year. Specifically, it delineates current and potential levels of carpooling, factors affecting participation in carpools, impacts of carpooling, and various techniques for estimating expected matching levels within areas potentially suitable to carpooling programs.

The work reported here was completed under the direction of the TSC Program Managers Peter Benjamin and Donald E. Ward. The research for this report and its final preparation were the responsibility of Donald C. Kendall. Research contributing to portions of the report was performed by Carla Heaton and David Anderson.

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EXECUTIVE SUMMARY

This report is a compendium of the results of a number of carpooling studies conducted at the Transportation Systems Center during fiscal year 1974. The findings presented here are intended to promote better understanding of the current status of carpooling and its potential contribution toward relieving problems stemming from inefficient use of the private automobile.

National survey results as recent as early 1974 indicate that the average auto occupancy for the urban work-trip is 1.2 passenger/auto. While this value, and the average carpooling occupancy of 2.5, have been relatively stable over the last four years, there was an increase in the rate of carpool formation during the energy crisis of late 1973 and early 1974. Work-trip occupancies tend to be highest in the Mid-western and South Atlantic states and lowest in the New England and Pacific Coast states.

Almost two-thirds of all carpools currently consist of one passenger. Larger carpools are more common for longer commute trips and to rural work-designations. 35% of all carpools are to rural work-destinations comprised of household members only.

A profile of the carpooler, constructed from the survey results, shows that he/she, in comparison with solo drivers, is likely to own fewer cars per household, to be somewhat younger, and more likely to be female.

The majority of carpools are formed at the place of work. About one-fourth of all carpools travel to more than one destination. About 44% of all carpools have members living less than one mile apart.

Carpoolers are more concerned with cost than solo drivers. Slightly over half of all carpool drivers are motivated by a desire to share expenses or reduce their fuel consumption. Cost sharing is more important to recently formed carpools. While there is no difference between solo drivers and carpoolers in the portion of those who must pay for parking, only 6% of all auto commuters currently pay to park. Even for destinations within the Central Business District, only 19% of auto commuters are without free parking.

Increases in auto occupancy can be expressed as an increase in percent participation. Currently, 27% of auto commuters are carpooling. This participation rate would have to double in order for occupancy to increase from 1.2 to 1.5. At an auto occupancy of 2.0, about 75-84% of all auto commuters would be carpooling. The possibility of achieving these levels depends upon the extent of limiting factors such as the number of commuters who are unable to carpool or for whom carpool matches cannot be found.

A model has been developed to predict the maximum level of carpooling in an urban area. Results from applying the model to the Boston region have been used to estimate a maximum level of participation, nationwide. This value is estimated to be within 47-71% of peak-period auto person work-trips. The corresponding auto occupancy range is 1.4 to 1.7. These estimates are based upon matching considerations only, and do not consider behavioral preferences. Higher levels of participation would entail significantly longer detours for pickup and delivery of passengers, as well as flexibility in adjusting work schedules, since multiple destinations would be much more common.

The primary benefits of increased carpooling are fuel savings, reduced congestion, less pollution, and a reduction in parking requirements. At the estimated maximum level of carpooling, the extent of these impacts are as follows:

1. Up to 10% savings in the amount of gasoline consumed in auto passenger travel (all purposes).
2. Up to 50-70% increases in speed on arterials and expressways that are currently heavily congested.
3. Over 30% reduction in auto emissions.
4. Up to 18% fewer parking spaces required in downtown areas.

As these figures show, reducing the vehicle densities during the peak travel periods has a striking effect on pollution and congestion. At high levels of participation, gas savings are substantial. However, below a 50% increase in the current number of carpoolers, gas savings would not exceed 3%.

An analysis of 77 carpool programs underway in various parts of the country has revealed:

1. Carpool programs are widespread throughout the major urban areas.
2. There is a trend towards multi-company carpool programs with merged data bases and centralized matching operations.
3. The majority of the programs surveyed have been formed within the last 2 years.
4. Based on a preliminary evaluation of 29 of these programs, 14 are considered to have been successful in achieving increases in the level of carpooling, or in stimulating interest in carpooling.
5. It is apparent that effective incentives to carpool (or disincentives for solo driving) are an important ingredient of program success.

The success of carpool programs also depends on the level of matching achieved from among the responses on questionnaires submitted. To achieve a given desired level of matching, the number of participants required is a function of the number of origins, destinations, and departure time intervals served by the program. A technique (described in Section 8) has been developed for estimating these parameters and thus structuring the matching service so as to maximize its productivity. It provides insights into the tradeoffs between single employer matching, merging employee responses from a selected group of employers, and attempting to serve a region by soliciting responses to a centralized matching service.

Much is still unknown about issues related to establishing national policies intended to encourage carpooling. Techniques are needed to predict commuter response to carpooling incentives, and to analyze the costs and impacts of alternative strategies.

Carpooling activities currently being coordinated by the public sector need to be evaluated to insure the effectiveness of future programs.

1. INTRODUCTION

By now it is a well-established fact that the automobile is and probably will remain the dominant mode of travel for most private purposes. However, the inefficient use of cars, especially in the journey to work, has contributed heavily to serious problems of fuel consumption, congestion, pollution, safety and parking.

In his report to Congress March 5, 1974, Secretary Brinegar stated: "We should move to do all we can to make sure that the automobile is energy-efficient and non-polluting and that its role in the city is effectively managed."

At the beginning of 1974, at the height of the energy crisis, Secretary Brinegar announced the inauguration of a nation-wide effort to promote the use of carpools for the daily work-trip; "The Department of Transportation through the joint efforts of the Urban Mass Transportation Administration and the Federal Highway Administration is preparing to promote, encourage and facilitate the use of carpools in every urbanized area in the country. As a matter of national energy conservation policy, Americans must be persuaded to give up single-passenger commuter travel wherever possible and use mass transit or carpools." To provide financial and technical assistance to metropolitan regions, a nation-wide carpool action plan was instituted. Financial aid under the Unified Transportation Assistance Program was made available on a 90-10 basis to regions submitting an approved program for organizing carpool formation services. The FHWA conducted a series of regional training seminars for personnel of federal and state highway offices and regional planning councils to familiarize them with the available techniques and materials for promotion and organization of carpools.

As part of this program, a series of reports was prepared summarizing the major issues and considerations relative to organization of carpools, and containing specifics of various carpool implementation tools. A compendium of these reports, entitled "Transportation Pooling", has been published by UMTA (10).

In conjunction with these efforts, the Office of Systems Research and Analysis of the Transportation Systems Center initiated a series of studies to determine the status of carpooling and its potential for alleviating the problems caused by widespread travel to work in single-occupant autos. This report contains the findings and conclusions drawn from these studies.

Prior to publication of this report, preliminary findings have had limited distribution as working papers. Although most of the results of the carpool study program are included here, two related reports will be published separately. A discussion of the effects of staggering work hours upon the potential for carpooling has been combined with a similar analysis of staggered work hours on transit fleet size requirements (11). Another TSC report, which is forthcoming, contains a case study of a campaign to foster carpooling in the Boston Metropolitan Area. This program, the first to attempt carpool organization on an area-wide scale, has been monitored by TSC staff. A follow-up survey is being conducted to determine the extent of new carpools formed as a result of the campaign.

The material assembled here is aimed at promoting an understanding of the current level and status of carpooling, factors affecting participation, and potential benefits of increased levels of participation. The analysis is focused on auto travel to work in urban areas, since the main thrust of programs to increase auto occupancy has been concerned with work trips, to take advantage of the regularity and commonality of work schedules. In spite of this commonality, the average auto occupancy for work trips has been lower than any other purpose.

The rest of this report is divided into seven parts. Section 2, an historical perspective, contains an account of carpooling activities during WWII in response to the fuel rationing measures and shortages of rubber. Section 3 contains statistical information regarding the current status and level of carpooling. Section 4 discusses characteristics of carpools and carpoolers obtained from recent surveys. Section 5 contains a partial survey of current carpool organization programs in the public and private sector, together with capsule descriptions of the status of each program. Section 6 describes a model developed for estimating the maximum potential level of carpooling together with results of preliminary runs and an estimate of the maximum potential nation-wide. Estimates of the impact of increased levels of carpooling are presented and discussed in Section 7. Section 8 deals with some of the problems associated with planning an effective carpool matching service, and contains a technique for estimating the probable level of matching based on regional parameters such as the number of origins and destinations to be served.

Conclusions and Recommendations for further study are presented in Section 9.

2. CARPOOLING EXPERIENCE DURING THE WORLD WAR II ERA

The energy crisis of 1973-74, a traumatic experience for millions of American motorists, had its precedent in the era during World War II when the entire nation found itself involved in an effort to conserve gasoline and tires. The availability of materials need to produce gasoline and tires was severely restricted due to enemy action.

The ominous signs of dwindling supplies, which were noticeable starting with the beginning of the European war in 1939, had little effect on the American motorist. The fact that in 1939 fuel oil and gasoline shortages were actually being experienced in the Northeastern United Stated did not deter him from his normal driving habits.

Throughout the summer of 1941, the Petroleum Administration for War (PAW) tried to convince the gasoline-using public along the east coast of the necessity for voluntary curtailment of their driving. PAW indicated a 33% cutback would do the job, at least for the time being. Eastern oil companies helped by issuing stickers which said "I'm using one-third less gasoline!"

In 1943 a speed reduction was called for although not yet legally implemented. People were warned that there were no new tires forthcoming. However, all these warnings made little impression on the motoring public. Habits are not easily broken and the desired cutbacks did not materialize.

Seeing they were making little progress, the PAW issued a series of recommendations to eastern oil companies for limitations in deliveries to gasoline service stations. The PAW staff were overwhelmed by the number of requests for adjustments received from suppliers and service stations. Although more tankers became available along the east coast in 1941 and some restrictions were lifted, it was quite apparent that there was little voluntary compliance. So consumer rationing with gasoline coupons was put into effect in the last days of 1942.

The impact that such an order had on the American motorist caused about the same reaction as was evident in 1974 when the energy crisis hit. The newspapers were filled with suggestions on how to circumvent the gasoline and tire shortages. But it was still the government's wartime policy to encourage voluntary conservation as far as possible and to involve state and local state and local defense organizations in the promotion and supervision of these efforts. In fact, government rationing, a speed limit of 35 mph, and the unenforcable ban on pleasure driving (later rescinded) were the only mandatory measures that affected private auto users. Requisitioning of cars by the government had been considered but never implemented. Other measures such as group riding, staggering of work and school hours, use of school and sightseeing buses for war worker transportation, foregoing holiday, pleasure and convention travel, were also voluntary, promoted, but not enforced by government agencies. To a considerable degree, public cooperation was the keynote of the policy.

2.1 RESPONSE TO GAS RATIONING

Carpooling policies were instituted after it became apparent that the rationing program could not overcome the shortage of essential gas and rubber. The problems of instituting an effective gas rationing program lasted throughout the war due to abuses such as black markets and counterfiting of coupons. But on the whole, it was essentially effective. The structure of the gasoline rationing program itself, with a very small basic ration and supplementary coupons for essential driving purposes, checked much of the nonessential driving. It was the gas rationing with carpooling that made it possible to keep war workers moving during the entire conflict. The combined programs reduced mileage and produced a plateau around 1943 that was sustained throughout the war.

The carpooling program itself caught on the minute the gas rationing regulations went into effect. An example was to be found in the Report of Car Occupancy Surveys, Ohio War Transportation Committee, May 1943 which concludes: "apparently the governmental regulations requiring group riding for supplemental gasoline allowances has produced favorable results."

The highly effective means for preserving passenger cars for continued use in the vital transportation of war workers were most enthusiastically endorsed by at least four federal government agencies: the Office of Price Administration, the Office of Defense Transportation, the Office of Civilian Defense and the War Department. Plant managements, with control over internal parking space, were in the best position to encourage carpooling. They made a variety of parking privileges available to workers who shared rides from areas where public transportation was not good or sometimes not even available. A Public Roads Administration report of 1942 revealed how the government promoted carpooling. In its report a major transportation crisis was predicted for war workers if the conservation measures for cars was not stringently followed. In fact, the report concluded that it was "absolutely necessary that universal group riding be instituted."

From 1941 through 1942, carpooling publicity reached its peak for any period during the war years. Hundreds of articles appeared especially in the most prestigious journals and newspapers. But response to carpooling was not uniform across the country. A December 1942 issue of Business Week reported that ride sharing was successful only on the east and west coasts. Because actual fuel shortages had occurred only in the east coast areas, some of the failure to comply with the edict elsewhere was due to lack of credibility. It was practically the same situation that developed during the energy crisis of 1974. Fuel shortages had indeed been regional. Furthermore, along with the complications of the gasoline rationing procedure, the fact that several overlapping government agencies were involved in its administration, the over-issue of coupons that facilitated the black market and the unpopular, unenforceable pleasure driving ban, all contributed to the credibility gap. And it was quite apparent that the public did not like the idea, anyway.

Indecisiveness with the Federal Bureaucracy contributed to the lack of public acceptance. In December, 1942, the head of the OPA (Office of Price Administration) resigned due to a policy difference between his department and the Congress, reflecting the irritation and mistrust of the public in relation to OPA policies. Congress urged the OPA to be more human in its dealings with the public, especially when it came to allocating fuel. The result was a new public relations compaign, a public education program and better understanding among government branches.

2.2 EMPLOYER CARPOOL PLANS

In order to enforce carpooling among war workers, the War Department in 1942 offered what was called "Share Ride Contracts" for those firms engaged in war production. The main stipulations were as follows:

1. The company should make a transportation survey of employees.
2. The company should submit a plan to include ride pooling, a record maintenance system, assistance to employees for tire recaps and gas ration cards.
3. The company should encourage the use of public transportation.

The plan was readily accepted by industry. Two major objections were:

1. Additional equipment and expanded clerical forces were needed to cross index riders in terms of location, shift, sex, race; and gas rationing could be an expensive proposition. Emphasis was placed on the time involved in updating records, especially where the rapid turnover due to men constantly leaving for the army was concerned.
2. The plan offered hidden possibilities for coercion since employees who resisted the "benefits" of the program could be pressured by local tire and gas rationing advisory committees which had the power to limit rations. Then there was fear of labor getting too deeply involved. Management feared thare would be a demand for the formation of joint management-labor committees and they did appear on

the horizon toward the end of the war. In general, it was felt that workers should be informed before applying pressure.

The government for the most part did not become involved in the carpooling programs. Instead, the plants handled the details themselves but the War Department did have an advisory group who were on call if needed. In January 1943, the New York Times announced that the War Department would assign trained transportation personnel to organize carpooling programs in plants that did not already have a program. This maneuver stimulated carpool activity throughout war plants. However, all action was coordinated at a local level with suggested alternatives from Washington.

Two firms can be delineated as examples of having working plans. One of them-The Briggs Manufacturing Company did not share the government's enthusiasm for the "share a ride" contract. They decided their own plan, which was designed to eliminate all paper work and bookkeeping and put the program on a voluntary basis was more efficient. Briggs used a map grid system based on a large map of Detroit and its suburbs. The map was divided into squares with coordinates. It was set up in a central point in the plant. Employees would meet at a place designated by their map square number and arrange their own carpooling. The system was tried out in one of their plants having 500 workers and in two weeks 80 percent of all drivers had formed their own ride-sharing groups. The employees liked it because there was no coercion. The company liked it because all costly paper work was eliminated.

The White Motor Company introduced a clever system involving driver remuneration in the form of tokens. The focus of the plan was to equalize the sharing in terms of driving and riding. The planners believed that although most people are willing to trade evenly, there are always those who prefer to take less of the driving load. Each of the 1,700 workers received 10 ride tokens. When he entered another worker's car, a token was given to the driver for a one-way trip. After all his tokens were used up (five round trips or one week's travel) the rider became the driver and he in turn gained tokens from riders in his car. If the driver filled his car daily with four people, he could drive his car for one week and leave it in the garage for four weeks.

A grid map in the plant helped drivers and riders match up geographically. In addition, company parking spaces were assigned so that employees living within a map square area parked in one section, thus easing the ride sharing arrangements. Windshield stickers identified the car's district number and lapel buttons identified ride sharing members of the White Motor Good Fellowship Club. A very subtle part of a pledge signed by each worker encouraged the use of public transportation whenever possible.

2.3 PRIVATE PLANS

Many groups, in a patriotic fervor, joined the drive for conservation of gas and tires. Organizations such as the American Legion and the Automobile Club of New York provided carpool matching services. A conference of 53 women's clubs in Westchester County, New York adopted a carpooling plan for shopping trips. In June 1942, over 1,000 women in the county had signed pledges to share a car while shopping, with each club handling sharing arrangements.

Windshield stickers for cars that could be hailed on the highways for "lifts" were distributed to all signers. This was extended to neighborhoods where clubs were formed for ride sharing. The New York Times, in a 1942 article, reported that War Production plants and the spontaneous neighborhood groups seemed to be the most successful in sponsoring carpooling activities.

Carpooling for small businesses did not enjoy the success that was so easily obtained by large plants and organizations. They lacked the means for centralized organizing and many people who lived in remote areas had no means of becoming part of a group.

2.4 INCENTIVES FOR CARPOOLING

A variety of incentives were offered to those who would share their cars with others. Among them:

1. Supplemental "B" and "C" gasoline coupons for Commuters who shared their cars.

2. Tire allocations or permits for tire recaps granted to carpool drivers.

3. Parking incentives such as:

   - Assigned most convenient parking lot spaces to carpools;
   - Refusing parking spaces to cars that were not full;
   - Charging or assigning a penalty parking fee for every empty seat;
   - Assigning of parking spaces according to home zones to encourage non-fixed car sharing.

4. Issuing of lapel buttons and windshield stickers to indicate patriotic carpool participation.

5. Issuing windshield sticker indicating driver could be hailed for a ride, with or without a fare.

6. Giving Army award to plant that organized successful plan.

7. Providing Police-protected lots at transit stations.

8. Offering special insurance coverage for carpools and employers who provided vehicles for ride sharing.

Some states amended their motor laws so that carpool drivers charging fares did not have to register their cars as commercial transport. Most states were liberal in waiving licensing and insurance laws that might normally apply to group riding plans. These applied to both carpool drivers and employers who provided for ride sharing.

2.5 RESULTS ACHIEVED

It is difficult to look back 30 years for an accurate assessment of carpooling activities, especially in the absence of national data relating to vehicle occupancy. Spot-check data available is both marginal and vague. There were few estimates of occupancy rates other than for commuter travel. Indications are that there was little increase in car occupancy outside of the commuter trip. In March 1943, the Highway Traffic Advisory

Committee, from a group-riding survey based on spot checks in different areas, reported that car occupancy has increased from 2.00 per car in July 1942 to 2.44 in December 1942 and to 2.66 in March 1943.

A study of 48 war plants throughout the United States revealed that an average occupancy of 2.86 persons per car was achieved for war worker transportation. There was considerable variation between the 48 plants, from a low of 1.27 at an old urban plant in the Midwest to a high of 4.17 at two rural plants, one in the South and one in the East. Sixty-four percent of the plants had occupancy rates of less than 3.0 and only 6% had rates as high as 4.0. Plants in the Midwest had the lowest average occupancy of 2.68 per car. The southern states' plants had the highest average occupancy rate of 3.24 per car. In between were the Far West, with a ratio of 2.72 and the Northeast with a ratio of 2.83, for plants included in the study. Average occupancies were considerably higher in rural plants than in urban plants - 3.53 compared to 2.45.

Social structuring had a pronounced effect on carpooling efforts. While the average citizen seemed to follow governmental guidelines within reason, his affluent neighbor in the high income areas did not always subscribe to the idea of relinquishing his advantage of one car, one man. The record of Nassau County, NY written by the Office of Defense Transportation reveals that towards the end of 1942, 60 percent of the war workers who received supplemental gas rations because of their work status and a promise to carpool, had failed to comply. ODT said that 2.9 occupants per car was the national average, but most disturbing in Nassau County was the fact that 60% of the cars were occupied by drivers only.

Some plants in the area had cooperated but others had done little to promote carpools. Public transportation in that area was used sparingly as is evident in the statement that 80% of the war workers in Nassau County were traveling in private cars. While only speculation can be made as to the reasons for this act of omission, it was apparent that highly ingrained personal habits plus the anomalies of a divergent social strata were more to blame than any blatant attempts to circumvent the carpooling regulations.

A survey made in July 1973 at three checkpoints of entry into New York City revealed that during peak hours the average load was 4.8 persons per vehicle. At other hours, it indicated less than 2.0 vehicle. California checks reported an average of less than two people riding in a five-passenger car.

Since overall data is sketchy for World War II years, only a rudimentary evaluation can be given as to the results obtained from the carpooling programs. A report published in 1943 concluded:

1. Only in a few cases were the potentials of group riding being fully used. Really effective measures had not been applied in most plants; incorrect occupancy figures had developed a false sense of accomplishment. (Carpool drivers tended to exaggerate the number of passengers carried in order to improve their chances for receiving supplemental gas rationing coupons. In addition, surveys taken were more than likely to be found self-serving.)

2. Overlapping controls and confusion came about due to the participation of too many local and national agencies that hardly ever worked in concert. Conflicting statements from both destroyed their creditability to a considerable degree so that motorists became cynical and snide.

3. The most pertinent fact that came out of the entire report was that the drivers were more interested in the economic aspects than conservation or patriotism. They had to consider the fact that the cost of living was steadily rising and a new car-whenever the war ended-would be costly. Then, of course, the inconvenience of participating in carpooling plus the anxiety and fatigue from war pressures, had an overall affect on their daily lives. Lethargy creeps into the best of programs and the programs enforced during the war years were constantly in need of stimulation in the form of awards and promotion.

2.6 COMPARING WWII EXPERIENCE WITH TODAY'S SITUATION

Any attempt to relate the carpooling activities of 1940-45 to energy conserving programs of the 1970's must be qualified. The conditions are entirely different because the cause and effect are not the same. The nation is not now engaged in a war or a critical fight for survival. The prospects of prolonged engagement with the enemy during World War II gave the motoring public valid reasons for attempting to conform to government edicts. Failure to comply could have led to a production crisis and the loss of a war.

In 1973-74, despite the gasoline shortage, there was no critical shortage of materials or public transportation although the latter suffered from the sudden increase in demand. Driving conditions are entirely different today and the urban profile is nothing like it was in the 1940's. In recent years, population diffusion into the suburbs and spreading employment centers has increased matching problems. In the 1940's, the less dispersed origins and fewer destinations made it easier to form ride groups of 3 to 4 members from among fellow employees.

Between the WWII period and the 1970's, car ownership has increased, transit patronage has dropped, and auto occupancies have been steadily declining. The combined effect is an ever increasing number of auto vehicle miles traveled. While energy resources are indeed limited, today's concerns also include problems of pollution, congestion, and parking; all of which stem from inefficient use of the private auto. Thus, in addition to the fuel supply, there are other equally substantial incentives for finding effective ways to reduce auto travel and increase average auto occupancy.

3. THE CURRENT LEVEL OF CARPOOLING IN THE UNITED STATES

This section discusses ways of measuring auto occupancy and provides national statistics regarding the current level of commuter carpooling. Average overall auto occupancy and average occupancy of carpool vehicles are presented together with data indicating recent trends in carpooling activity. Regional and seasonal variations are also included to provide a perspective regarding effects of geography, climate, and seasonal variations on the degree of carpooling.

3.1 AUTO OCCUPANCY MEASURES

There are four commonly used methods for computing auto occupancy:[1]

1. Auto Person Trips/Auto Trips
2. (Drivers and Passengers)/Drivers (1970 Census)
3. (Sum of Occupants/Auto)responses (1970 Census)
4. Passenger Miles/Vehicle Miles

Method 1 gives a true occupancy value from a count of all person-trips and vehicle-trips. Counting all trips is impractical on a national level, so the Census Bureau uses method 2 which is essentially the same as method 1, except that it deals with a random sample of 15% of the population. The reliability of this estimate is reduced by sampling error and inconsistencies such as the period of days over which a regional census is taken. The Census question asks how the respondent got to work on the last day he went to work in the preceding week. In order for the count of passengers and drivers to be as meaningful as intended, all responses should pertain to the same day.

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[1] It is important to distinguish between the overall auto occupancy and the average occupancy level for multiple occupancy cars. In this report, overall auto occupancy will be referred to as "average occupancy," while auto occupancy of multiple occupancy cars will be referred to as "average multiple occupancy."

Method 3 was employed by the National Personal Transportation Survey (NPTS), which asked respondents the number of people in the auto (including driver) on a specified day. However, the small sample size (6,000 nationally) relative to the Census reduces the reliability of the results.

Methods 2 and 3 were used by TSC in computing auto occupancy rates from the National Opinion Research Center's (NORC) continuous national survey,[1] covering the period from November 1973 to February 1974. In each four-week period of this survey, approximately 700 respondents are interviewed in households randomly selected from 101 primary sampling units based on the total U.S. population and balanced in respect of race and income. Responses were weighted by number of household members, yielding a total sample of 2084 auto commuters for the period in question.

Method 4 produces a slightly different measure, considering that the occupancy is weighted by trip length, and carpooling is more common among the longer work-trips. Its utility lies in the fact that it can be used to compute effects of carpooling on fuel consumption.

3.2 AUTO OCCUPANCY VALUES

a) Average Occupancy

For the journey to work, the 1970 Census data showed an auto occupancy rate of 1.2 persons per auto. This is in agreement with the occupancy computed from primary data obtained by the NPTS survey of 1969. A weighted occupancy of 1.3 passenger miles/vehicle mile was computed from the NPTS data.

In February 1974, the NORC data again indicated an average occupancy rate for auto commuters of 1.2 persons/auto, showing that there has been no change over the 5-year period, 1969-1974.

Work-trip occupancies are lower than any other trip purpose. The overall average for all purposes (from NPTS data) is 1.6.

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[1]See Appendix A for a description of the NORC survey design.

b) Average Multiple Occupancy

The auto occupancy in itself does not indicate the distribution of vehicles with 1, 2, 3, or more occupants. Results from the 1969 NPTS survey and the 1974 NORC survey, giving this breakdown, are shown in Figure 3-1. These results again show very little change in multiple occupancy over the 4-year period. However, Figure 3-1 does indicate that the percentage of solo drivers in 1974 has increased considerably over the 1969 figure.

The average multiple occupancy rate from the NPTS data (1969) was reported as 2.4 while the NORC data (1974) indicates an average multiple occupancy of 2.5 persons per carpool, again indicating very little change in the 5-year period.

It is noteworthy that the multiple auto occupancy results from these two surveys are so close, since the question about work-trip mode was asked in different ways. The Census and NPTS surveys asked how the respondent got to work on a specific day. On the other hand, the NORC survey asked how the respondent usually got to work. It seems that this latter question might be a better indicator of the level of routine carpooling. However, it spite of the two different questions, the overall average occupancy results are very similar.

3.3 TRENDS IN THE LEVEL OF CARPOOLING

The long range trend in urban area auto occupancies between 1945 and 1964 seemed to be decreasing, as indicated by Figure 3-2, although some SMSA's changed very little or increased slightly.

From the NORC data it was possible to compare average occupancy and multiple occupancy in the two periods November-December 1973 and February 1974. These rates are indicated below:

Occupancy rate:	Dec 1973	Feb 1974
All auto commuters	1.17	1.17
Carpool commuters (multiple occupancy)	2.41	2.49

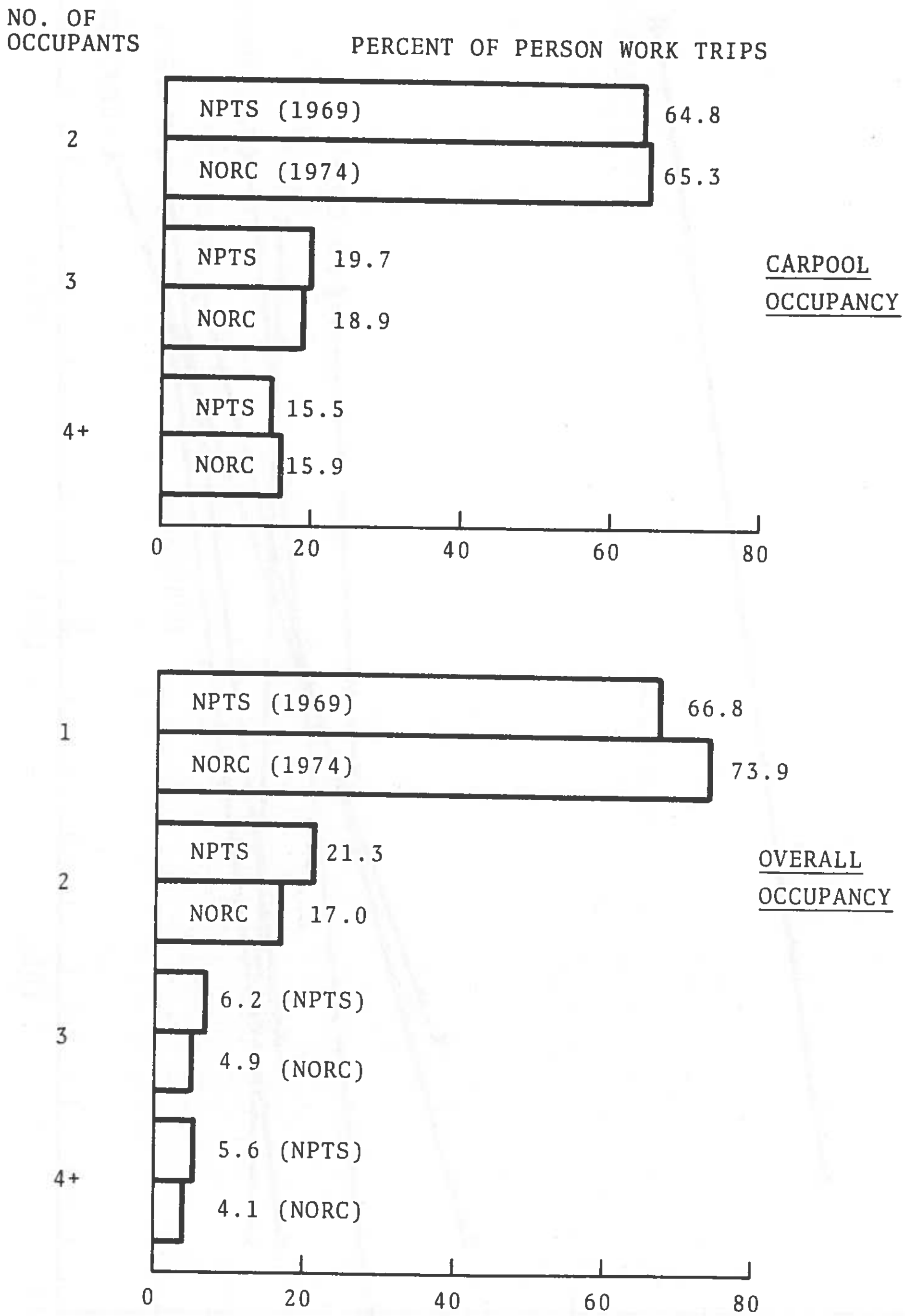

Figure 3-1. Distribution of Auto Occupancy NPTS and NORC Surveys - 1969 and 1974

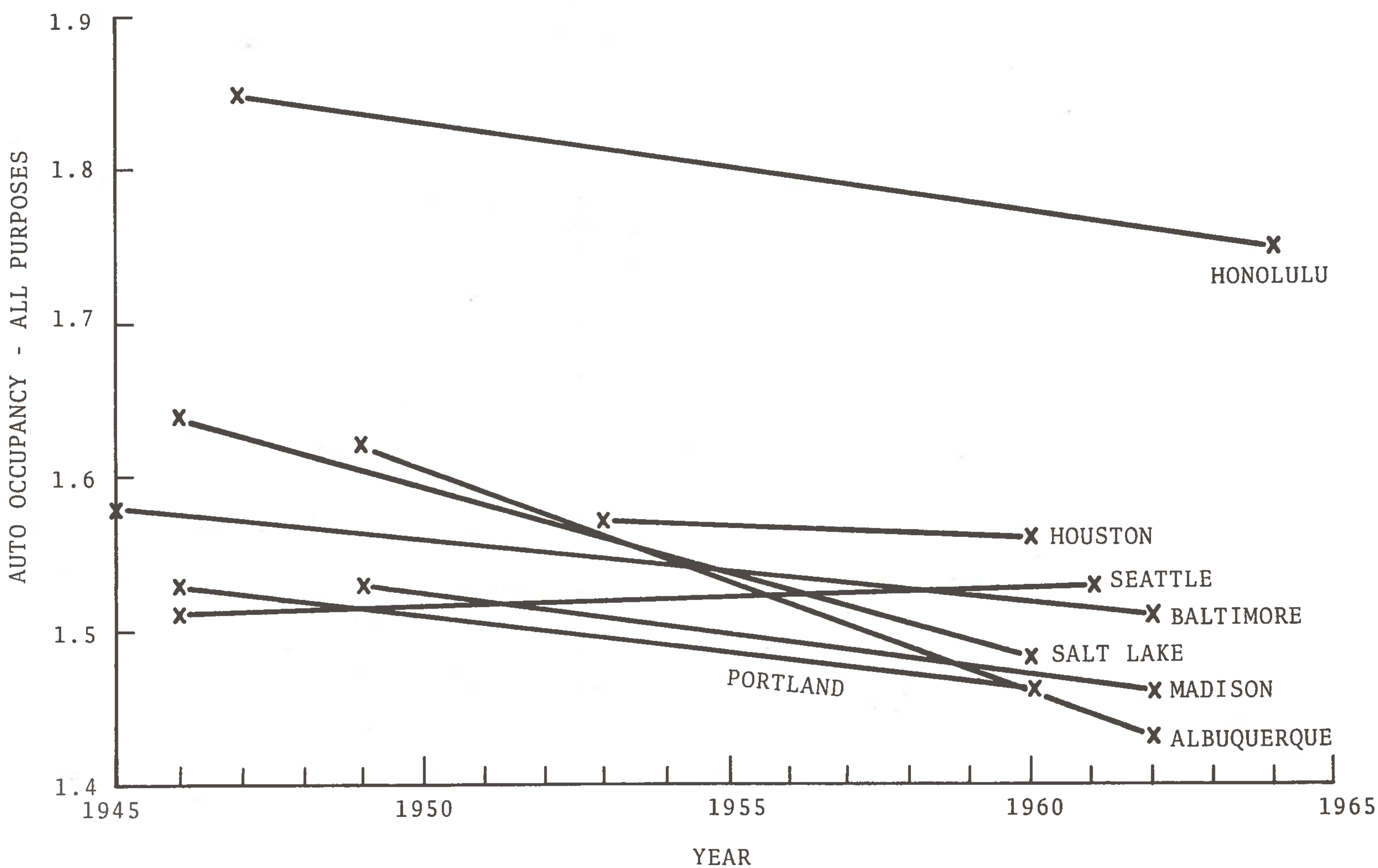

Figure 3-2. Auto Occupant Trends for Selected SMSA's

The slight increase indicated in the carpool occupancy during the three months December 1973 to February 1974 may be attributable to effects of the energy crisis. From the NORC data it is possible to calculate the percentage of new carpools started each month from May 1973 to February 1974.

The rate of new carpool formation indicates a peaking in November-December 1973, declining somewhat in January, February:

New carpools formed in:	% of carpoolers interviewed in Cycles 8, 9, 10
Jan-Feb 1974	15
Nov-Dec 1973	20
Sept-Oct 1973	9
Jul-Aug 1973	10
May-June 1973	8
Prior to May 1973	38

These figures indicate that the energy crisis had a relatively large effect in encouraging new carpool formation, especially in November-December 1973. The rate for January-February 1974 has dropped somewhat but is still higher than in the months before the energy crisis.

During this winter period there were sudden sharp increases in gasoline prices and long lines at the gas stations, especially between December 1973 and February 1974. Consequently, it is uncertain at this point in time whether the recent increases will remain in effect.

3.4 REGIONAL VARIATIONS IN AUTO WORK-TRIPS[1]

Differences in geography, climate, availability of public transit, per capita income, among other factors may affect work-trip characteristics in various areas of the U.S. Table 3-1

[1]From an internal TSC analysis of NPTS primary data records done by David Anderson

TABLE 3-1. REGIONAL VARIATIONS IN WORK-TRIP STATISTICS

CENSUS REGION	Pax Trips / Auto Trips	Pax Miles / Auto Miles	% Single Occupant Vehicles
New England	1.2	1.2	.87
Middle Atlantic	1.2	1.3	.81
E. North Central	1.2	1.2	.85
W. North Central	1.3	1.5	.82
South Atlantic	1.4	1.4	.77
E. South Central	1.3	1.4	.81
W. South Central	1.3	1.5	.77
Mountain	1.2	1.2	.89
Pacific	1.2	1.2	.88
U.S. Average	1.2	1.4	.84

contains work-trip statistics for each of the nine Census regions of the U.S.[1]

New England, Mountain and Pacific states have the highest percentage of single-occupant work-trips, averaging about 4% above the U.S. value. Factors such as dispersed living patterns, non-availability of public transit, and auto-oriented cities may explain the difference in behavior but are not entirely satisfactory. Regardless, these regions have fewer multiple-occupant auto work-trips and could be adversely impacted by further shortages.

Alternately, the South Atlantic and West South Central States have the highest occupancy rates and lowest number of single-occupant work-trips.

[1]All data used in the analysis is a seasonally adjusted Monday to Friday 24-hour average of work-trip information from the TSC analysis of NPTS person-trip records.

Overall, a significant amount of regional variation exists in the auto work-trip. Percent multiple-occupant trips range from a low of 11% of work-trips by auto in the Mountain states to 23% of auto work-trips in the South Atlantic and West South Central regions. However, the Census region may be too heterogeneous with respect to factors influencing travel behavior to be correct zones for analysis. Differences in geography, weather, urban/rural, etc. within Census regions are masked by aggregation. The resulting statistics may be substantially biased in a variety of ways. As a result, the above statistics and insights should be interpreted with caution.

3.5 SEASONAL VARIATIONS IN AUTO WORK-TRIPS[1]

The questions on whether shortages of gasoline would be more severe at certain times of the year relative to others has important planning implications. The FHWA/NPTS Report No. 8 examines seasonal variations in tripmaking by households but does not directly report any differences over time in work-trip characteristics.

Table 3-2 summarizes the TSC findings for all work-trips and multiple-occupant work-trips by season. For all work trips, occupancy rates are higher in the Spring and Summer with fewer single-occupant work-trips. During the Fall and Winter, single-occupant work-trips increase 3 to 4% out of total auto work-trips. The implication is a rise in total automobile use on the work-trip during Winter months, a not unexpected result.

For multiple-occupant trips, it appears that Summer and Winter have the smallest number of 'large' (greater than two person) carpools. The difficulty of coordinating larger carpools during vacation months or potentially less favorable weather conditions may explain some of this variation. Most carpooling appears to

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[1] From ATSC analysis of NPTS primary data records in an internal TSC research paper by David Anderson.

TABLE 3-2. SEASONAL VARIATION IN WORK-TRIP AUTO OCCUPANCIES

Statistics	Spring (April)	Summer (July)	Fall (October)	Winter (January)
A. All Work Trips				
Pax Trips / Auto Trips	1.3	1.3	1.2	1.2
Pax Miles / Auto Miles	1.3	1.4	1.3	1.2
% Single Occupant	.81	.81	.84	.85
B. Multi-Occupant Trips				
Pax Trips / Auto Trips	2.4	2.3	2.4	2.3
Pax Miles / Auto Miles	2.6	2.4	2.7	2.3
% Double Occupant	.74	.78	.75	.81

occur during the Spring and Fall when problems of coordinating auto usage among family members is reduced.

Overall, the Winter months have traditionally had higher auto usage on the work-trip. Carpooling is less frequently practiced and the number of single-occupant vehicle used on the work-trip increases by 4 to 6%. Fuel shortages during the Winter months are likely to be more severe in their impact on transportation.

3.6 SUMMARY

Currently the NORC data show an overall rate of carpooling among all auto commuters of 26.7%. The overall occupancy rate of 1.2 for all auto commuters and 2.5 for average multiple occupancy has changed very little in the four-year period since the Census and NPTS surveys. There was a slight increase in carpooling and carpool occupancy during the period of the energy crisis (September 1973 - February 1974). It is uncertain at this point whether these recent increases will remain in effect.

There is a significant regional variation in work-trip occupancies; New England, Mountain, and Pacific States have the lowest while Mid-western and South Atlantic States are slightly higher.

Occupancy rates are higher in Spring and Summer – single-occupant work-trips increase during Fall and Winter, possibly due to less favorable weather conditions. Summer and Winter have the smallest number of carpools with more than two occupants, apparently due to the difficulty of coordinating larger carpools during vacation months or unfavorable winter weather.

4. CHARACTERISTICS OF CARPOOLS AND CARPOOLERS

This section contains a wide range of information regarding existing carpools, and compares carpool travel characteristics with those of single drivers. Operating characteristics of carpools, socio-economic patterns, and the existence of motivating factors are discussed. The information presented in this section is intended to provide a better understanding of factors influencing the formation of carpools. This, in turn, is useful in planning effective carpool organization programs and identifying appropriate incentives.

4.1 DATA SOURCES

Most of the data reported in this section was obtained from the National Opinion Research Center (NORC) continuous national survey, covering the period from November 1973 to February 1974. During this period, respondents were asked questions concerning location of their workplace, distance traveled to work, mode of travel, parking arrangements, and if they were commuting in carpools, the number of occupants, when and where the carpool was formed, whether they shared driving, how far away the furthest passenger lived and whether costs were shared or not. In addition, there were some attitudinal questions about their mode of travel and demographic questions concerning age, education and income levels. Information about sampling, sample size, and statitical validity is contained in Appendix A.

4.2 CURRENT COMMUTER TRAVEL MODES

In order to assess the potential for commuter carpooling in the United States, it is useful first to estimate the extent of dependence on the automobile for commuter travel. Results from the NORC Continuous National Survey (using data weighted for number of household members from interviews collected during the period December 1973 through February 1974) indicate that nationwide 89% of all commuters use a car for the work trip. Broken down by work-trip destination the percentages are as follows:

			Of all commuters to:
Auto commuters to suburban work-destinations	-	94%	suburbs
Auto commuters to city (not CBD) destinations	-	90%	city areas (not CBD's)
Auto commuters to rural work-destinations	-	89%	rural areas
Auto commuters to CBD work-destinations	-	80%	CBD's

The majority of commuters (65%) travel to city work-destinations; 31% work in CBD's and 34% work in other parts of the city; 21% of commuters work in the suburbs and 14% work in rural areas. The preponderance of the city and CBD work destination highlights the need to find alternatives to the one-worker-one-car commuter mode headed for congested city streets. The evidence suggests that most current carpoolers were solo drivers, prior to carpooling. Excluding those who had not traveled to work before, 65% of the carpool passengers were previously commuting in their own cars and 35% were using public transportation. the NORC survey indicates that nationwide 89% of all commuters use a car for the work-trip and in most cases (70% of auto drivers) no other commuter mode was available. The term "available" was used in the questionnaire without any definition or interpretation supplied by the interviewer. Therefore, it can be inferred that availability is a subjective judgement as to the accessibility of another mode.

4.3 TYPES OF CARPOOL AND WHERE CARPOOLS ARE FORMED

Even though the majority (61%) of carpools are formed at work, carpools travelling longer distances (more than 10 miles) are significantly more likely to be formed at the work place than are carpools travelling less than 10 miles (68% compared to 45%). People living farther away from the city center are more residentially dispersed and therefore encounter greater difficulty in finding other commuters travelling to the same work area. These longer distance commuters are more in need of a carpool matching service to help them find commuter matches from their lower density residence areas. The data suggest that these are the commuters making most use of carpool programs sponsored at the place of work.

4.4 CARPOOL DESTINATIONS

Slight variations occur in the percentages of carpoolers among all auto commuters according to the various work-trip destinations, as shown below:

WORK-TRIP:	RATE: CARPOOLERS/AUTO COMMUTERS
To CBD's	23.9%
To cities (including CBD's)	25.9%
To urban areas (cities and suburbs)	26.2%
To suburban areas only	26.7%
To rural areas	27.4%

These data yield an overall average rate of carpoolers/auto commuters of 26.7%. The slightly higher value for work-trips to rural areas probably reflects the higher average carpool occupancy for these work trips as indicated by the results shown in Table 4-1.

The number of solo drivers is somewhat higher for work-trips to suburban destinations, as shown in Table 4-2.

Eliminating commuters other than auto commuters, there is no statistical difference between solo drivers and carpool commuters with respect to work-trip destinations, shown as follows:

Work-Trip Destination:	Solo Drivers	Carpool Drivers	Carpool Passengers
	%	%	%
CBD	23	18	24
Other within city	41	44	40
Rural	14	18	11
Suburban	22	20	25
N =	(5535)	(322)	(227)

Table 4-1 shows percentages of commuter cars with two, three, four and five or more passengers and also gives the breakdown of car occupancy for carpool commuters to urban, rural and suburban work destinations.

TABLE 4-1. CAR OCCUPANCY RATES FOR CARPOOL WORK-TRIPS TO URBAN RURAL AND SUBURBAN WORK DESTINATIONS

	CBD	Other City	Rural	Suburban	Total N (%)
Occupants incl. Driver:	%	%	%	%	%
2 persons	65	66	48	76	(353) 65%
3	21	21	19	13	(102) 19%
4	12	11	17	8	(61) 11%
5+	2	2	16	3	(25) 5%
N* =	(111)	(233)	(81)	(116)	(541)100%

TABLE 4-2. MODE OF TRANSPORTATION BY WORK DESTINATION

	Work Destination				
	CBD	Other City	Suburb	Rural	Total
Mode:	%	%	%	%	%
Drive Alone	61	66	69	65	65
Drive Carpool	6	10	10	8	9
Alternate Driving in Carpool	4	5	3	8	5
Passenger in Carpool	9	9	12	8	10
Public Transportation	14	3	2	2	5
Other (walk, cycle, taxi)	6	7	4	9	6
N* =	(574) 24%	(959) 41%	(483) 21%	(339) 14%	(2355) 100%

*N = number of responses

Carpoolers commuting to rural work destinations are significantly more likely than other carpoolers to work at the same place and to travel longer distances to work. Workers in rural areas may also feel less inconvenienced than city workers by the carpooler's inflexible schedule, particularly in relation to the return trip from work. City areas with shopping and recreational facilities near the work place offer more distractions and reasons to delay the return trip home than rural areas.

Working at the same place, living further from work, and feeling less inconvienced by the carpool schedule may be the factors that encourage rural area commuters to join larger carpools.

The number of occupants in the carpool bears a direct relationship to the distance of the work-trip. The two-occupant carpool is most likely (43%) to travel less than five miles to work, while the four-occupant carpool is the most likely to be commuting 15 miles or more. Almost two-thirds of all the carpools in the NORC Survey are two-occupant carpools and almost half (46%) of these two-occupant carpools consist of carpool members living in the same household. The type of carpool also varies significantly in relation to the number of carpool occupants. The two- and three-person carpools are most likely to have only one driver and passenger, while the carpool with four or more occupants is more likely to have alternate drivers (see Table 4-3).

These findings have implications for programs concerned with increasing car occupancy rates for carpools. The alternate driving, longer distance type of carpool is more likely to have a larger number of occupants.

4.5 CHARACTERISTICS OF DIFFERENT TYPES OF CARPOOLS

Three types of carpool are considered:

1. Family carpools involving members of the same household
2. Carpools with only one driver and passenger
3. Carpools with alternating drivers.

Carpools formed within the household account for 35% of all the carpools in the NORC survey and most of these carpools (86%) had only two occupants. Respondents in this category were almost exclusively either drivers only of carpools (50%) or passengers only (46%). In only 4% of these family type carpools was the driving shared. The household member carpools are more likely to live closer to the work destination than non-household member carpoolers: of all carpoolers living within one mile of work, almost two-thirds (66%) are household member carpoolers; 45% live within five miles of their workplace compared to 29% of non-household member carpoolers. Apparently, the time required to pick up passengers outside the household is a deterrent to carpooling for shorter work trips.

4.6 TYPES OF CARPOOL AND LENGTH OF WORK-TRIP

Compared to solo drivers, carpoolers on the average travel longer distances to work. However, there are differences in typical trip length between the different types of carpool, as shown in Table 4-4. More than half of the alternate driver carpools are commuting more than 15 miles, more than half of the carpool drivers commute from 6-15 miles, while half of the passengers reported a work-trip of less than five miles.

In the NORC Survey, the question was asked of both carpool drivers and passengers: "How far away from you does the passenger who lives furthest away live?" The majority (56%) of carpools include passengers who live less than one mile away from each other, 43% live within a half-mile distance, as follows:

Furthest passenger lives less than 1 block away	16%
Furthest passenger lives 1 block to 1/2-mile away	27%
Furthest passenger lives 1/2 to 1 mile away	13%
Furthest passenger lives more than 1 mile away	44%

The NORC data also show that people who travel longer distances to work are willing to take more time and make longer

TABLE 4-3. NUMBER OF CARPOOL OCCUPANTS BY DISTANCE OR WORK-TRIP, SAME HOUSEHOLD MEMBERS AND TYPE OF CARPOOL

	No. of Carpool Occupants		
	2 %	3 %	4+ %
Distance from Work:			
0 - 5 miles	43	29	14
5 - 10 miles	19	43	14
10 - 15 miles	21	6	35
15 or more miles	18	22	37
C/P Members Live in Same Household	46	21	7
Type of Carpool			
One driver (reported by driver)	41	31	29
One driver (reported by pass.)	41	47	34
Alternative drivers	18	22	37
	N = (353) (65%)	(102) (19%)	(86) (16%)

TABLE 4-4. AUTO COMMUTERS MODE BY DISTANCE FROM WORK

	Drive Alone	Drive Carpool	Alternate Drive C/P	Passenger in C/P
Distance from Work:	%	%	%	%
0 - 5 miles	44	32	17	50
6 - 15 miles	38	52	32	37
More than 15 miles	18	16	51	13
N =	(1555)	(209)	(117)	(266)

detours to pickup carpool passengers. Table 4-5 indicates this result both in terms of distance and time.

According to the NORC data, destination of the work-trips is also associated with the distance travelled to pick up passengers, as shown in Table 4-6. Commuters to rural work destinations, who also commute the longest distance, are much more likely to make longer detours to pick up passengers. Apparently, commuters living in low density areas and making longer work-trips are willing to make these longer detours.

Among carpoolers commuting to urban and suburban areas, those travelling to CBD's are most likely to carry passengers living at greater distances from each other. This is not explained by the commuting distance traveled, since carpoolers to CBD's do not commute longer distances than other auto commuters. However, traveling towards a center of high density facilitates passenger pickup enroute to the work destination; the distance between passengers may be greater but little time is lost in pickup if these passengers live directly on the route to work. This is a more likely pattern of pickup for commuters to CBD's than for other auto commuters.

These findings imply that techniques for enroute matching to downtown centers should induce increases in carpooling. Higher carpool occupancies might result without significant increases in detour time associated with pickup of passengers.

4.7 PARKING COST AND AVAILABILITY

Many of the existing carpool programs which have been successful have operated in areas where traffic congestion and parking problems are critical, as for example in the CBD of Washington, D.C. The question occurs to what extent nationwide, parking difficulties may be an incentive to increased carpooling. The NORC survey asked all auto commuters to respond to a series of questions concerning their parking arrangements. Results are tabulated in Tables 4-7, 4-9. Responses to these questions indicate:

TABLE 4-5. DISTANCE BETWEEN RESIDENCES OF PASSENGERS BY CARPOOLER'S DISTANCE FROM WORK AND COMMUTING TIME

	Distance from Work (miles)			Commuting Time (minutes)		
	0-10	11-15	15+	0-15	15-30	30+
Furthest Passenger Lives:	%	%	%	%	%	%
0 - 1/2 mile	54	36	30	65	33	13
1/2 - 1 mile	15	9	16	6	26	31
1 mile or more	32	55	54	29	41	56
N =	(157)	(67)	(97)	(77)	(132)	(112)

TABLE 4-6. WORK-TRIP DESTINATION BY DISTANCE BETWEEN PASSENGERS' RESIDENCES

	Work-Trip Destination			
	CBD	Other City	Rural	Suburban
Distance to Furthest Passenger's Residence:	%	%	%	%
Less than 1 mile	53	62	40	63
More than 1 mile	47	38	60	37
N =	(55)	(154)	(62)	(52) (323)

1. Nationwide, only 6% of auto commuters are currently paying any parking fees.
2. There is no difference between solo drivers and carpoolers in the percentage who pay for parking.
3. 73% of all auto commuters walk less than two minutes from the parking lot to the work location.
4. 85% of all auto commuters use a parking lot, 12% park on the street and 3% use a garage.
5. Of all auto commuters who do not pay for parking, 87% use employer provided parking lots.

Only workers in urban core areas lack to any extent free, employer-provided parking lots, and even there less than 20% of workers are without free parking. Suburban, rural and "other within city" workers, nationwide, experience few problems with parking. Only 5% of city workers, other than those working in CBD's, have to pay for parking and little more than 10% do not have free employer-provided parking lots. These conditions may change significantly as a result of the new EPA regulations that require a reduction in parking spaces in urban areas to reduce work-trip vehicle-miles.

In terms of distance from the parking lot to the workplace there is no significant difference for commuters to the various work destinations and most people have less than two minutes walk.

Considering the 6% of auto commuters who do pay for parking, few are paying more than 50¢ per day, and those who do pay more all work in CBD's as shown in Table 4-8. Respondents who used on-street parking paid the most, although they were few in number.

In addition to the question on how much was currently being paid for parking, respondents were also asked how much they would be willing to pay for parking each day. The large majority of commuters report that they are (hypothetically) not willing to pay more than they pay now. About 15% of all those who pay are willing

TABLE 4-7. VARIATIONS IN PARKING CONDITIONS AT DIFFERENT WORK LOCATIONS

All Auto Commuters (N=1860):	Work In			
	CBD	Other City	Rural	Suburb
	%	%	%	%
A. Pay for parking	19	5	0.4	0
B. Where park:				
on street	18	14	10	3
parking lot	71	85	88	96
garage	11	1	2	1
C. Employer provides free parking	78	87	89	93
D. Time to walk from parking place to work:				
0-2 minutes	70	72	75	76
3-4 minutes	11	12	7	9
5+	19	16	18	15
N =	(1410)	(773)	(278)	(399)

TABLE 4-8. COST OF PARKING BY WORK DESTINATION AND WHERE PARK

Pay for parking (per day)	Work Destination				Where Park		
	CBD	Other City	Rural	Suburb	On Street	Parking Lot	Garage
	%	%	%	%	%	%	%
0-50¢	49	100	-	-	12	74	54
51¢ - $1.00	24	-	-	-	50	16	7
More than $1.00	27	-	-	-	38	10	39
N =	(76)	(33)			(8)	(73)	(28)

to pay more, up to $3.00 per day. These results are shown below:

	Currently Pay (per day)		
	0-.50	0.51-1.00	1.01-2.00
How much willing to pay (per day):	%	%	%
0 - 0.50	80	-	-
0.51 - 1.00	3	89	-
1.1 - 2.00	-	-	90
2.01 - 3.00	17	-	-
More than $3.00	-	11	10
	N = (70)	(18)	(21)

As yet, parking is perceived as an expense by a small minority of commuters, and at 50¢ per day it is a minimal expense for the majority of those who do pay for parking. While higher parking fees might be an incentive to carpool, unless the parking supply situation changes, only a small minority of auto commuters would be affected by parking costs and therefore responsive to parking cost incentives.

Even though there is no difference between solo drivers and carpoolers in the percentage who pay for parking, there is some evidence that carpoolers are currently faring slightly better than solo drivers in terms of parking convenience and expense. More carpoolers than solo drivers have employer-provided parking, carpoolers are more likely to use parking lots than park on the street or in a garage, and carpoolers pay less in parking fees than solo drivers, as shown in Table 4-9.

4.8 INCOME LEVEL OF CARPOOLERS

According to the NORC data, carpoolers tend to have slightly lower incomes than solo auto drivers. (see Table 4-10) 61% of carpoolers have incomes less than $15,000 compared to 54% of solo auto commuters, 38% of carpoolers and 29% of solo drivers have incomes below $10,000.

TABLE 4-9. SOLO DRIVERS AND CARPOOLERS BY WHERE PARK, EMPLOYER PROVIDED PARKING AND PARKING FEES

		Solo Drivers	Carpoolers
		%	%
Where Park:	on street	13	5
	parking lot	83	94
	garage	4	1
Employer provides free parking:		86	91
		N = (1512)	(320)
Parking fee:	0 - 0.50	59	86
(per day)	0.51 - 1.00	17	14
	1.00 - 2.00	24	-
		N = (88)	(21)

TABLE 4-10. INCOME LEVEL OF CARPOOLERS AND SOLO AUTO COMMUTERS

Income Level:	Solo Drivers %	Carpoolers %
Under $6,000	11	18
$6,000 - $ 9,999	18	20
$10,000 - $14,999	25	23
$15,000 - $19,999	23	16
$20,000 - $24,999	10	12
$25,000 and over	13	11
	N = (1474)	(536)

Comparing carpool drivers, alternate drivers and passengers, there are some significant income differences. Carpool drivers only are similar to solo drivers in the percentage with incomes above $15,000, and more carpool drivers only are in the higher income brackets than other carpoolers. Carpool passengers tend to have somewhat lower incomes than other carpoolers - 41% compared to 35% have incomes less than $10,000. Incomes of alternate drivers are in the middle of the scale between drivers only and passengers only with a larger percentage earning between $10,000-$15,000, as shown in Table 4-11.

With over one-third of carpool drivers and 41% of passengers below the $10,000 income level, commuting expenses may become more of an incentive to carpool, especially if gasoline and parking costs continue to increase above their present levels.

There are significant income level differences between commuters to urban, suburban and rural work destinations, as shown in Table 4-12. Commuters to rural work destinations have lower incomes and commuters to suburban work destinations are higher on the income scale than other auto commuters.

These results may be related to the findings that the rate of carpooling and the carpool occupancy rate is highest for commuters to rural areas and lowest for commuters to suburban areas. This again points to the cost-saving incentive of carpooling and its greater relevance for people at lower income levels. It should also be noted that the recent increase in carpooling resulting from the energy crisis was greater for commute trips to rural areas than to suburban areas.

4.9 NUMBER OF CARS PER HOUSEHOLD

Commuter carpoolers, on the average, are likely to own fewer cars per household than solo driver commuters, although in both cases (all auto commuters) the dominant category is the two-car household, as shown in Table 4-13.

TABLE 4-11. INCOME LEVEL BY TRANSPORTATION MODE

	Transportation Mode					
	Solo Drivers	Tot. C/P	Carpool Driver	Carpool Alt. Dr	Carpool Pass.	Publ. Transp.
Income:	%	%	%	%	%	%
Under $10,000	29	39	36	34	41	48
$10,000-$15,000	25	23	15	35	24	14
Over $15,000	46	39	49	31	35	38
N =	(1474)	(541)	(203)	(117)	(221)	(111)

TABLE 4-12. WORK TRIP DESTINATION BY INCOME LEVEL

	Work Trip Destination		
	Urban	Rural	Suburb
Income Level:	%	%	%
Less than $10,000	34	44	23
$10,000-$14,999	25	23	23
$15,000 or more	41	33	54

TABLE 4-13. NUMBER OF CARS IN THE HOUSEHOLD BY SOLO DRIVERS, CARPOOLS, ALTERNATE DRIVERS AND PASSENGERS

No of Cars per Household	Solo Dr.	Tot. C/P	Drivers	Carpool Alt. Dr.	Pass.
	%	%	%	%	%
0	0	6	0	0	13
1	26	31	27	20	39
2	53	44	45	66	33
3	15	11	12	6	13
4+	6	8	16	8	2
N =	(1582)	(541)	(203)	(117)	(221)

The difference between solo drivers and carpoolers is explained by lower car ownership of carpool passengers and alternate drivers. More than half of the carpool passengers are from households owning only one or no cars. 74% of solo drivers own more than one auto, compared with 63% of carpoolers.

4.10 SEX DIFFERENCES: CARPOOLERS/SOLO COMMUTERS

Of all male auto commuters, 26% are in carpools; of all female auto commuters, 30% are in carpools. Women are a considerably higher percentage of carpool passengers, whereas carpool drivers are predominantly male, shown in Table 4-14.

4.11 AGE DIFFERENCES

Age differences between solo commuter drivers and carpoolers are slight, though there is an indication that more of the youngest commuter age group (18-24 years) are carpoolers, as shown in Table 4-15.

Among the different types of carpoolers, passengers include more of the younger age groups. This probably reflects the fact

TABLE 4-14. SEX DIFFERENCES-CARPOOLERS AND SOLO DRIVERS

	Solo Dr.	Tot. C/P	Drivers	Carpool Alt. Dr.	Pass.
Sex:	%	%	%	%	%
Male	61	55	73	62	37
Female	39	45	27	38	63
N =	(1580)	(541)	(203)	(117)	(221)

TABLE 4-15. AGE OF SOLO DRIVERS AND CARPOOLERS

	Solo Dr.	Tot. C/P	Drivers	Carpool Alt. Dr.	Pass.
Age:	%	%	%	%	%
18-24 years	19	25	26	17	30
25-34 years	23	23	25	25	20
35-44 years	21	18	17	24	17
45-54 years	24	21	22	28	16
55+ years	13	13	10	6	17
N =	(1580)	(541)	(230)	(117)	(221)

that most carpool passengers are women and women in the youngest age groups are less likely to own cars than males in this age group. Also, many of these younger passengers may be related to the carpool drivers.

Alternate drivers (52%) are considerably more likely to be in the middle years (35-54) than are carpool drivers (39%) and carpool passengers (33%).

From the above data, a profile of the carpooler, as compared to the solo driver, shows that he/she is more likely to own fewer cars per household, to be somewhat younger and, as a proportion of auto commuters, more likely to be female. In addition, there are differences between the three types of carpoolers. The carpool driver is most like the solo driver in respect of income and number of cars owned, but he is more likely to be male and is typically younger. Carpool passengers are much more likely to be female, to own no cars or only one car, to have lower income, and to be in the youngest (18-24) or the oldest (55+) commuter age group. The alternate driver is most likely to be in the middle years (35-54), and to be male.

There are implications from these data for carpool program organizers and matching programs. The distinct differences and needs of the three types of carpooler have to be met in such programs.

4.12 ATTITUDES TOWARD CARPOOLING

The NORC survey respondents were asked to check off from a given list the aspect they considered most important about the work trip. All commuters emphasized time (shortest time or directness of route) and dependability. Solo drivers were most likely to mention time, and only 7% considered cost to be most important. Proportionately more carpoolers than other commuters mentioned cost as an important consideration. These results are shown in Table 4-16.

Carpool drivers were also asked why they decided to take passengers along in a commuter carpool. The predominant response to this question was concerned with cost sharing, as shown in Table 4-17.

Table 4-18 contains carpool motivation factors broken down by recency of joining a carpool. Although the base numbers in Table 4-18 are small and the differences are not statistically significant, the direction of the differences is in accord with prior interpretations of the data, suggesting that cost sharing was of more importance to recent that to longer term carpoolers. With continued high costs of fuel, these findings have implications for carpool incentive programs, in which cost saving aspects might be emphasized.

However, despite the more recent concern with cost sharing, the NORC data indicate that cost sharing as an incentive to carpooling is currently not a <u>major</u> issue for the majority of carpoolers. Both drivers of carpools and passengers were asked if the passengers paid for the ride or rode free, and if they did pay, was such payment on a regular basis. Approximately only one-third (35%) of all carpoolers are sharing the costs of the commuter ride. Of those who do share costs, 64% pay regularly, the remaining 36% helping out occasionally with the expense of gas and parking.

The NORC data indicate that cost sharing in commuter carpools occurs not for the longest distance commuter trips, but is more prevalent for intermediate work trip distances of 5-10 miles, where the kind of carpool is predominantly the one-driver carpool.

The extent of cost sharing reported by carpool drivers, alternate drivers and passengers varies. Only 38% of carpool drivers report that their passengers share the costs and there is very little reported cost sharing in alternate driver carpools, the majority of which commute more than 15 miles. However, since most alternating drivers pay the costs when they drive, cost sharing becomes inherent in the arrangement. Of the relatively small number of carpool passengers who responded to the question on cost sharing, in the NORC survey, and who are not in family carpools (N=75), 64% do pay for the ride and most of these (81%) pay a

TABLE 4-16. MOST IMPORTANT CONSIDERATION FOR WORK-TRIP BY COMMUTER MODE

	Solo Drivers	Carpools	Public Transp.
	%	%	%
Time/Directness of Route	43	37	23
Dependability	24	19	34
Cost	7	12	6
Other	16	17	26

TABLE 4-17. CARPOOL DRIVERS - REASONS FOR JOINING CARPOOL

Someone to share expenses	28%
Wanted to save gasoline	25%
Someone needed a ride	24%
Wanted company in the car	4%
Other	19%

TABLE 4-18. MOTIVATION TO CARPOOL

	What Matters Most For the Work-Trip		
	Time	Cost	Dependability
	%	%	%
Joined carpool 0-3 mos ago	31	52	56
Joined carpool 4-12 mos ago	23	22	22
Joined carpool 12 mos ago	46	26	22

regular rate. On the whole, however, it can be concluded that the number of carpoolers who share costs regularly is relatively small.

4.13 SUMMARY

A profile of the carpooler, constructed from the survey results, shows that he/she, in comparison with solo drivers, is likely to own fewer cars per household, to be somewhat younger, and as a proportion of auto commuters, more likely to be female.

Almost two-thirds of all carpools currently have two members. The larger carpools are more common for longer commute distances and for rural work destinations. Members of these carpools are more likely to share the driving than in the smaller, shorter distance ride groups.

The majority of carpools are formed at the place of work. However, there was no measured increase in the portion of carpools formed at the place of work during the 1973-74 energy crisis.

Carpools containing household members only comprise 35% of all carpools and tend to travel shorter distances to work.

Carpoolers who travel further tend to make longer detours for pickup and delivery of passengers. About 44% of carpools have member(s) living more than one mile apart, and 26% travel to more than one destination.

While there is no difference between solo drivers and carpoolers in the portion who must pay for parking, only 6% of all auto commuters currently pay to park. Even for CBD destinations, only 19% of auto commuters are without free parking, and 50% of these pay 50 cents per day or less to park. Therefore, at the current time only a small minority of auto commuters would be affected by and responsive to parking cost incentives.

Motivation to carpool or drive alone is based on a tradeoff between travel time, cost, and dependability. Carpoolers are more concerned with cost than solo drivers or users of public transportation. Slightly over half of all carpool drivers became carpoolers to share expenses or reduce their fuel consumption.

Cost sharing seems to be more important to those who joined carpools recently, compared with those who have been carpooling for some time. However, 80% of carpoolers belong to carpools where the driving is not shared, and only 35% of all carpoolers are sharing costs. Even assuming that all of the household carpools do not share costs, this still leaves 30% who belong to carpools where expenses are not shared.

5. SOME EXAMPLES OF EXISTING CARPOOL PROGRAMS

This section summarizes the information which has been collected on 77 carpool programs currently planned or in operation in several major U.S. cities. The carpool programs are detailed in Table 5-1.

This information was gathered during the month of January, 1974. A number of new programs have been initiated since then, and it is possible that some of those reported here have changed in scope or operation, or have been superseded by new programs. However, the purpose of this summary is not so much to describe individual carpool programs in specific cities as to provide a generalized, aggregate picture of the geographic extent, sponsorship, duration, and operation of carpool programs. More detailed information on some of these programs and others is contained in another DOT (UMTA) report entitled <u>Transportation Pooling</u> (10). Although it is generally too early to evaluate the success of these programs in encouraging the formation of carpools, some statistics are reported which give rough preliminary indications of program effectiveness and public participation. A regional promotion and matching service conducted within the Boston area (see Table 5-1) is being evaluated by TSC, and the results will be available in a forthcoming DOT publication.

5.1 GEOGRAPHIC EXTENT OF CARPOOL PROGRAMS

Table 5-1 provides some indication of the geographic extent of carpooling. Although by no means an exhaustive list of programs, the 77 programs shown cover 40 cities in 30 states. Thirteen of the 40 cities have more than one ongoing carpooling program, the extreme case being Denver with nine separate programs. Since this study did not involve systematic area sampling, there is no accurate data on comparative levels of carpool activity in different areas. However, it is apparent that carpool programs are widespread in major cities and even in suburban towns throughout the country.

TABLE 5-1. SUMMARY OF SELECTED CARPOOL PROGRAMS

CITY	STATE	SPONSOR	PARTICIPANTS	MATCHING METHOD	INCENTIVES	STARTED	COMMENTS
Huntsville	Alabama	N.A.S.A	NASA, Army, Contractor Employees	Computer		Feb. '74	Car pools, use of cars, buses, church buses and parking lots
Tucson	Arizona	Kitt Peak National Observatory	Employees	Computer-grid map		Nov. '73	5 other car pool programs in Tucson mentioned
Little Rock	Arkansas	Governor's Office	State Employees	Manual-map-pins	Preferred parking	Fall '73	Increase of employees in carpools from 400 to 1100. Noticeable decr. in traffic congestion
Little Rock	Arkansas	State High-way Dept.	Employees	Manual	Preferred parking	Fall '73	All state-owned cars must have 3 passengers if taken home at night.
Los Angeles	California	Group W Radio Station	City Wide	Computer		Fall '73	
Los Angeles	California	7 Major Banks	Bank Employees (20,000)	Computer (Operation Oxygen)-grid map		Oct. '72	850 participants; 60 to 70 carpools
Los Angeles	California	Operation Oxygen, Inc.	Regional	Provides in-formation to employers		1971	500 co.'s requested information on setting up of carpool programs
Los Angeles	California	Federal Office Building	Federal Employees (5,000)	Grid map-card racks	Preferred parking (4+occ.)	1972	Poor response
Los Angeles	California	Dept. of Traffic	City Wide (eventually)	Computer (FHWA)	Preferred parking	Not yet	Public information program - may develop into city wide program

TABLE 5-1. (CONT'D) SUMMARY OF SELECTED CARPOOL PROGRAMS

CITY	STATE	SPONSOR	PARTICIPANTS	MATCHING METHOD	INCENTIVES	STARTED	COMMENTS
Los Angeles	California	County Government	County Employees (8,200)	Computer (CARPOL)-DIME File	Preferred parking	Fall '73	1500 employees expressed interest
Los Angeles	California	City Government	Employees (12,500)	Computer (FHWA)	Preferred parking	July '73	500 new car poolers. City wished to join with neighboring county car pool - but unable to merge data
Sacramento	California	Calif. D.O.T.-to oversee and give direction to state agencies	State Employees	Computer		Not yet	To be handled by each state agency separately
Sacramento	California	State Dept. of Highways	Employees in D.O.T. Building (2,000)	Manual-grid map-cards	Priority parking	Nov. '73	About 15% of 2,000 employees are car pooling
San Bernardino	California	State College at San Bernardino	Students and faculty	Computer matching - students; grid map/cards - faculty		1972 - students; just starting for faculty	Failure for students-little response; program terminated No parking problem-there
San Francisco	California	A group of public and private org's	Regional	D.O.T. Computer		Not yet	
San Francisco	California	Census, Dept. of Highways Assoc. of Govt's	Regional			Not yet	Making survey
San Francisco	California	Group W Radio	City Wide	Computer		Fall '73	

TABLE 5-1. (CONT'D) SUMMARY OF SELECTED CARPOOL PROGRAMS

CITY	STATE	SPONSOR	PARTICIPANTS	MATCHING METHOD	INCENTIVES	STARTED	COMMENTS
Santa Clara County	California	County Govt.	County Employees (8,500)	Manual - self-operating	Preferential parking may be offered	Jan. '74	Only 6% response to survey in Sept. '73
Pasadena	California	Burroughs Corp.	Employees	Computer-coffee hours-advertising by Operation Oxygen		1971	35% reduction in parking; 53% increase in auto occupancy
Raleigh	N. Carolina	State	State and City Employees (16,000)	Computer	Free/Preferential parking	Not yet	Instructions, data form, map sent out with pay checks
Charlotte	N. Carolina	Chamber of Commerce	Companies with 500+Employees	Chamb. of Commerce provides computer		Dec. '73	Co's match own employees
Columbia	S. Carolina	State Highway Department	Employees (1,100)	Manual	State cars for car pools	Nov. '73	Only 35 responded
Denver	Colorado	State Health Department	Employees (400)	Manual-map	Free/Preferred parking if 3+ occupants	July 1973	Increased car pools from 18% to 36%
Denver	Colorado	Mountain Bell	Employees at 11 installations (10,000)	Computer	Free parking+ $1.00 payment per day	Not yet	
Denver	Colorado	Gen. Services Administration	Federal Building Employees (7,000)	Self-service-location boards		1973	Publicized in Departmental Bulletin

TABLE 5-1. (CONT'D) SUMMARY OF SELECTED CARPOOL PROGRAMS

CITY	STATE	SPONSOR	PARTICIPANTS	MATCHING METHOD	INCENTIVES	STARTED	COMMENTS
Denver	Colorado	Martin Marietta	Employees (6,000)	Computer		July 1973	Full-time coordinator hired
Denver	Colorado	Ski Country (Promotional organization)	Skiers	Park at High School lot and form own pools	Discounts on lift tickets if 4+ occupants	1973	Plans to go into computer matching
Denver	Colorado	D.T.C. Pool - 50 Co's in Technol. Center incl. United Airlines and Diners Club	Employees	Computer and grid map		Nov. 73	Plan to merge with Greenwood Plaza Tech. Center
Denver	Colorado	Greenwood Plaza Tech. Center	Employees	Computer and grid map		Just starting	Plan to merge with D.T.C.
Denver	Colorado	COG (Council of Governments)	Regional Program for city (5 counties)	Computer		Not yet	In planning stage. May use DIME files.
Denver	Colorado	City Govt.	City Employees	Computer		Just starting	Had very poor response to original manual operation
Hartford	Connecticut	State D.O.T.	State Employees (4500)	Computer-Koffee Klatches	Preferred parking	July '72	1,000 Conn. DOT employees matched-175 carpools. Extended to other Gov't. agencies in Capitol Building. Offers computer service to private cos.
Hartford	Connecticut	Aetna Life Casualty	Employees	Computer personnel file	Preferred parking	Dec. '73	2,700 participants-600 carpools formed
New Haven	Connecticut	A Newspaper, Radio Station and Motor Club	Regional	Computer-Conn.D.O.T.		Not yet	Newspaper prints registration forms

TABLE 5-1. (CONT'D) SUMMARY OF SELECTED CARPOOL PROGRAMS

CITY	STATE	SPONSOR	PARTICIPANTS	MATCHING METHOD	INCENTIVES	STARTED	COMMENTS
Washington	D.C.	N.A.S.A.	Employees (1,700)	Manual-grid map	Parking allocated every 6 months, on point system	Since 1964	800 participants
Washington	D.C.	F.H.W.A.	Employees (1200)	Computer-grid map	Priority parking	July 1972	Auto occupancy increased from 2.34 to 2.45. Computer matching needed at regular (6-month) intervals
Washington	D.C.	Gov't. Employees Insurance Co. (GEICO)	Employees (4,200)	Grid map and cards - manual	Preferred parking	Nov'73	Auto occupancy increased to 3.27
Washington	D.C.	Walker & Dunlop	Employees (70)	Manual - (Personnel Office)	Green Stamp awards - free parking	Oct. 1972	60% of employees in carpools. 4+ occupancy for 51%
Washington	D.C.	Metro. Council of Gov'ts	Area Wide	Computer		Just starting	NVTC pilot program underway
Miami	Florida	County Government	County Employees	Computer-W2 Tax Forms as data source		Fall '73	Has considered use of DIME files
Atlanta	Georgia	State D.O.T.	Employees in D.O.T. Bldg.	Computer		Fall 1973	
Atlanta	Georgia	Atlanta Regional Commission	City Wide - major employers in region	FHWA grid maps placed in large employee centers	Some of the employers are working on incentives	Jan. '74	12 large companies involved so far. May use computer-DIME Files later.
Honolulu	Hawaii	City and County Govt.	City/County Employees (7,000)	Computer -zip code	Preferred parking	July '73	Not much response at beginning. Picking up since energy crisis
Honolulu	Hawaii	2 City Newspapers	City Wide	Computer - application forms published in newspaper		Not yet	

TABLE 5-1. (CONT'D) SUMMARY OF SELECTED CARPOOL PROGRAMS

CITY	STATE	SPONSOR	PARTICIPANTS	MATCHING METHOD	INCENTIVES	STARTED	COMMENTS
Chicago	Illinois	Chicago Transit Authority	Drivers of vehicles parked at rapid transit stations		Reserved parking	Not yet	In planning stage. Working with radio Station WIND.
Chicago	Illinois	Illinois D.O.T.	State Employees			Since Fall '73	State cars to take more than 1 passenger-combine trips and deliver goods
Chicago	Illinois	Group W Radio	City Wide	Computer		Fall '73	
Kansas City	Kansas	Hallmark Card Co.	Employees (4500)	Manual-grid map-plan to computerize	Preferred parking	Fall '73	Long time employee as coordinator. 2+-person car pools expanded to 280
Baltimore	Maryland	State DOT & Dept. of Education	Employees	FHWA grid map		Jan '74	Pilot program-800 employees initially- in suburban location.
Baltimore	Maryland	Group W Radio	City Wide	Computer		Fall '73	
Boston	Massachusetts	Dept. Public Works	Employees	Self-matching	Reserved parking for carpools (3+ occ)	1973	
Boston	Massachusetts	John Hancock, Liberty Mutual & New England Life	Employees (11,000)	Personal ads in co. newspapers		Not yet	Planning to computerize program using zip codes
Boston	Massachusetts	Prudential	Employees	Computer listings through personnel office	Free parking	Since 1960's	Car Pools = 3 or more (44% of employees carpool)

TABLE 5-1. (CONT'D) SUMMARY OF SELECTED CARPOOL PROGRAMS

CITY	STATE	SPONSOR	PARTICIPANTS	MATCHING METHOD	INCENTIVES	STARTED	COMMENTS
Boston	Massachusetts	WBZ/ALA	Regional	Computer		Sept. '73	8,800 responses; 2,100 (23%) matched (Jan. '74). Program may be merged with Mass. DOT program.
Boston	Massachusetts	Gillette Co.	Employees	Computer matching-zip code	Preferred parking	Nov. '73	Limited success-200 people in 70 carpools. Many workers live close to plant (10 min. drive)
Lansing	Michigan	Michigan D.O.T.	State Employees	Computer matching; 1-mile grid in city; 2 mile for rural	Preferred parking	Not yet	10,000 questionnaires sent out; 5,000 responses. 70% interested
Port Huron	Michigan	St. Clair Community College	Students	Computer		Not yet	In planning stage. Have offered computer services to others.
St. Paul	Minnesota	3M Company	Employees (8,500)	Map-pins	Incentives to van drivers	Early 1973	Co. supplies 40 vans-Very successful-1,000 employees in van pools
Jackson	Mississippi	City Govt. and Radio WRBC	City Wide	Voluntary manual		Jan. '74	Only 20 applications received (Jan. 1974)
St. Louis	Missouri	East-West Gateway Coordinating Council	Participating companies	Computer	Heavy traffic congestion	Not yet	1/3 of questionnaires returned

TABLE 5-1. (CONT'D) SUMMARY OF SELECTED CARPOOL PROGRAMS

CITY	STATE	SPONSOR	PARTICIPANTS	MATCHING METHOD	INCENTIVE	STARTED	COMMENTS
St. Louis	Missouri	LaClede Cab Co.	Town Wide	Taxi pools to and from work		Not yet	10-mile fare = $6.80. Share between 5 = $1.36
St. Louis	Missouri	University of Missouri	Students (5,000)	Computer-DIME Files	Share parking costs	Feb. '74	Original program began 1969-not successful. New program will use DIME Files for students, zip codes for faculty.
St. Louis	Missouri	McDonnell Douglas Corp.	Employees (30 000)	Manual-grid map	Preferred parking (3+ occ)	20 years ago	Carpooling declined as no. of employees declined from 47,000 to 30,000
Philadelphia	Pennsylvania	Group W Radio	City Wide	Computer		Fall '73	
Pittsburg	Pennsylvania	Group W Radio	City Wide	Computer		Fall '73	
Omaha	Nebraska	Jr. Chamber of Commerce	100+ Companies	Computer-grid system-donated by Gas Co.		Fall '73	Ch. of Commerce gives training program, publicity, posters, etc.
New York City	New York	Group W Radio	City Wide	Computer		Fall '73	
Montclair-Riverside	N.Y. and N.J.	Interchurch Center, N.Y.C.	Employees (34 participants)			1959	By carpooling in 3 vans save 500 gallons of gas per week
Tulsa	Oklahoma	KRMG Radio	City Wide	Computer	Bumper stickers	Not yet	150 responses after 2 weeks
Portland	Oregon	Port of Portland	Port Employees	Manual	Payment of parking fees and mileage (if 3+ occ)	Dec. '73	25% either carpooling or riding transit. Have been criticized for use of taxes to pay parking fees.

TABLE 5-1. (CONT'D) SUMMARY OF SELECTED CARPOOL PROGRAMS

CITY	STATE	SPONSOR	PARTICIPANTS	MATCHING METHOD	INCENTIVE	STARTED	COMMENTS
Knoxville	Tennessee	Knoxville Transit Authority (Helped by Univ. Tenn.)	Town residents			Fall '73	1 successful bus pool in suburbs with 40-60 riders. Conducting survey to help residents form bus and car pools
Dallas	Texas	City of Dallas	City Wide	Computer		Jan. '74 (Pilot program for City employees)	City to provide information, maps, questionnaires and computer services to employers
Dallas	Texas	KLIF Radio	Regional	Computer		Dec. '73	Competing with other carpool programs
Fort Worth	Texas	KFJZ Radio & Ft. Worth Ch. of Commerce	Regional	Computer		Dec. '73	
	N. Virginia	N.V. Transport Commission	Regional (3 sites; 4,000 employees)	Computer matching with Washington COG		July 1, '73	Pilot program; 60,000 questionnaires distributed by end of 1973
Vienna	Virginia	Town of Vienna (Washington suburb)	Town Residents 5,000	Grid map matching from returned questionnaires matches contacted by telephone		July 1973	Volunteers from Jr. Ch. of Commerce made the telephone calls
Salt Lake City	Utah	Utah Ski Areas	Weekend Skiers		Discount on lift tickets if 4+occupants	Dec. '73	

5.2 CARPOOL PROGRAM SPONSORSHIP

Carpool programs are being sponsored by a variety of public and private organizations, alone or in combination with one another. Table 5-2 gives some indication of the diverse sponsorship of the 77 programs examined in this report.

City, county, state, and federal government agencies in major cities are taking a lead in developing carpool programs for their own employees and, in some cases, for employees in other organizations. Some of these publicly sponsored programs (e.g., in Los Angeles and Honolulu) are merging their data bases and centralizing their matching operations. Moreover, in the planning stage are various schemes for metropolitan-wide operations involving both government and private agencies and typically sponsored by regional Councils of Governments; examples are in Denver, Atlanta, Washington, D.C., and San Francisco. The level of coordination of carpool operations even extends to statewide. The California D.O.T. is planning to coordinate carpooling throughout the state for both public and private agencies. The Connecticut D.O.T. has been providing free computer matching services for private firms throughout the state. Within the private sector, carpool programs are operated on an individual company or pooled (multi-company) basis, examples of the latter type being in Denver, Los Angeles, and Boston. It is interesting to note that the merged programs involve companies that are occupationally similar as well as geographically clustered; the homogeneity of employees--technological, bonding, and insurance fields, respectively--may well be an important ingredient in the success of these merged operations.

Still other sponsors or co-sponsors of carpool programs include Chambers of Commerce (e.g., Charlotte, Omaha), transit companies (e.g., Chicago), universities (Missouri, Minnesota), radio stations, newspapers (Honolulu, New Haven), churches, suburban towns, and ski areas.

5.3 DURATION OF CARPOOL PROGRAMS

A small number of the carpool programs listed in Table 5-1

TABLE 5-2. BREAKDOWN OF CARPOOL PROGRAMS BY SPONSOR

Type of Sponsor	No. of Programs
Public Agency	
Federal	6
State	12
County	3
City	4
Council of Governments	4
Transit Authority	3
Other	4
Subtotal	36
Private Organization	
Individual company	11
Group of companies	4
Subtotal	15
Miscellaneous Sponsors	
Radio station (alone or in combination with other sponsor)	13
University	3
Chamber of Commerce	2
Ski area	2
Other (newspaper, taxicab company, church, town)	6
Subtotal	26
Total	77

have been in operation for a long time, 10 to 20 years; these include the NASA program in Washington, the Prudential Insurance Company program (Boston), and the McDonnell Douglas Corporation program (St. Louis). About half of the carpool programs reported on here were established in late 1973 or early 1974 (apparently in response to the energy crisis), and another 20 (mainly the larger regional operations) are in the planning stage.

5.4 OPERATION OF CARPOOL PROGRAMS

a) Matching Method

Of the 77 programs detailed in Table 5-1, 44 are computer operations and 28 are manual operations (the remaining five programs either do not provide matching services or have not been designated as to type of operation). In general, manual matching techniques are confined to single-organization programs (ranging in size from 70 to 30,000 employees), whereas computer matching methods tend to be used in multi-organization, city-wide regional programs which have larger anticipated data bases.

The sources of matching data for the programs include questionnaire surveys or application forms, personnel records, W-2 forms, and student registration forms. Many of the earlier carpool programs relied on employees to request application forms on a voluntary basis. More recent programs are processing all names on employee or student listings and sending out lists showing prospective matches. It is then up to each individual to decide whether or not to contact the other people on the list and organize a carpool.

The computerized carpool programs surveyed employ a variety of matching domains, or geographic areas within which prospective candidates are grouped together. These include square grids (usually 1 mile or 1/2 mile), zip codes, traffic zones, and Census tracts. In most of the programs, the grid, zip code, or tract location must be specified by the individual applicant; however, a few of the programs (e.g., Los Angeles County, Northern Virginia Transportation Commission) involve automatic geocoding.

The carpool programs which use manual matching generally involve a centrally located large-scale grid map with card racks or stick pins. In the first case, a prospective carpooler fills out an application form and places it in a pigeon hole corresponding to his grid location (pigeon holes are sometimes further subdivided into drive-only, ride-only, and share-driving sections). In the second case, color-coded stick pins can be placed on the map to indicate residence and used with matching card files showing names, addresses, etc. of prospective carpoolers from the same area. Manual-matching methods such as these are useful for smaller one-company carpool programs and have the advantage of low cost and small administrative burden. The initiative to find matched ride-sharers and to organize carpools is placed on the employee. However, to maintain employee awareness of and participation in the program, frequent promotional campaigns (e.g., coffee hour get-togethers) may be necessary.

b) Incentives

Still another aspect of carpool program operation to consider is the use of incentives for carpooling and disincentives for solo driving. Twenty-four of the programs examined involve free or priority parking for multi-occupant vehicles, five involve positive monetary incentives (in the form of cash payments, premium stamps, or discounts) for carpool members, and two encourage carpool participation by permitting the use of company-owned cars for commuting purposes. More than half of the programs have no special incentives for carpooling; however, in many cases heavy traffic congestion and/or parking shortages (factors exogenous to the carpool program per se) are serving as indirect program stimuli. In addition, some programs are undoubtedly benefiting in an indirect fashion from the existence of exclusive lanes for buses and carpool vehicles (generally established by the state highway department).

c) Promotion

The final item to be considered is the promotional techniques used in carpool programs. As can be seen from Table 5-2, 13 of the programs are area-wide programs sponsored wholly or partly by radio stations, where promotion generally consists of periodic spot announcements. The publicity campaign for the Boston area carpooling program (sponsored by WBZ/ALA) included TV spots and shows, ads in periodicals and newspapers, and billboard ads as well as radio announcements. The promotional efforts for area-wide programs not tied to a local radio station usally consist of printed ads, public information borchures, and extensive appeals to individual employers to promote carpooling within their own company. Employer-sponsored programs have used the following types of promotional techniques: articles and advertisements in company newspapers, pep talks by company officials, and get-together coffee hours where employees can initiate their carpooling arrangements.

5.5 SOME REPORTED EFFECTS OF CARPOOL PROGRAMS

Of the 77 carpool programs examined, 48 cannot be evaluated as to effectiveness, either because they are too new or because of lack of statistical information. For the remaining 29 programs, results have been reported by program administration in different ways, which makes comparison difficult. The disparity in reporting measures is illustrated by the following compilation, based on information from Table 5-1.

Reporting Measure	No. of Programs
Increase in number of employees in carpools	5
Increase in auto occupancy	2
Reduction in company parking requirements	1
Number of participants (i.e., carpoolers)	10
Number of responses to survey probing people's interest in carpooling	7
Qualitative statement	4
Total	29

In the absence of well-defined criteria for program effectiveness--e.g., a threshold value for percentage increase in employees carpooling--it is difficult to identify successful and unsuccessful programs. However, based on a preliminary, somewhat subjective evaluation of the reported results, which uses the national average level of carpooling and auto occupancy as benchmarks where before-data is lacking, the following programs are considered "successful:"

Little Rock, Arkansas (Governor's Office) - number of employees in carpools increased from 400 to 1,100.

Pasadena, California (Burroughs Corp.) - 35% reduction in parking; 53% increase in auto occupancy (multi-occupant vehicles) to about 2.5.

Denver, Colorado (State Health Dept.) - percent of employees in carpools increased from 18 to 36%.

Washington, D.C. (NASA) - 47% of 1,700 employees carpool; auto occupancy (multi-occupant vehicles) or 3.95.

Washington, D.C. (FHWA) - over 65% of 1,200 employees carpool.

Washington, D.C. (GEICO) - about 25% of 4,200 employees carpool; auto occupancy (multi-occupant vehicles) increased to 3.27.

Washington, D.C. (Walker and Dunlop) - 60% of 70 employees carpool.

Boston, Massachusetts (Prudential) - 44% of employees carpool (3 or more occupants).

St. Paul, Minnesota (3M Co.) - 12% of 8,000 employees in carpools; waiting list for carpool service.

Portland, Oregon (Port) - 25% of employees carpool or ride transit.

The above ten programs have resulted in what are considered significant levels of participation substantially above the national average. In addition four programs (Los Angeles County Govt., Michigan DOT, St. Louis East-West Gateway Coordinating Council, and KRMG Radio, Tulsa) have experienced responses to preliminary surveys which indicate a high degree of interest in carpooling.

The following three programs are considered to be relatively unsuccessful, in that they have failed thus far to elicit much interest from or participation by employees:

Los Angeles California (Federal Office Building) - "poor response" according to program representative.

San Bernadino, California (State College) - "failure for students-little response" according to program representative.

Santa Clara County, California (County Govt.) - only 35 out of 1100 employees "responded".

A detailed analysis of why certain programs have been successful and others have met with little response is not possible without more information on individual program structure, the environment in which each program is being conducted (i.e., degree of traffic congestion, parking conditions), and before-after carpooling or auto occupancy levels. However, an examination of the use of incentives does provice a plausible partial explanation of program results: "Of the 14 programs judged successful, 11 involve special incentives such as free or priority parking, premium stamps, and cash bonuses for drivers; in contrast, only 20 of the remaining 63 programs examined involve special incentives.

It would appear that effective incentives for carpooling are an important ingredient of program success. Further monitoring of a variety of ongoing programs is necessary to determine what set of factors (either within the program or exogenous to it) encourages a successful program. Among the specific questions to be answered are: (1) which types of incentives are most effective, (2) which forms of promotion are most effective, and (3) which methods of program organization (viz., regionwide vs. employer-based) are most efficient, effective, and long-lasting. The results of such an evaluation would no doubt be invaluable to program planners and sponsors in structuring new carpool programs or modifying existing ones.

5.6 CONCLUSIONS

The 77 carpool programs described in this report can be considered to constitute a fairly representative spread of programs in terms of geographic location, sponsorship, duration, operation, and reported effectiveness. Based on the preceding discussion of these programs, the following conclusions can be drawn:

1) Although no systematic area sampling was undertaken and accurate estimates of carpool program intensity around the country cannot be given, the indications are that carpool programs are widespread throughout the major cities.

2) Carpool programs are being sponsored by a variety of public and private organizations, alone or in combination with one another.

3) There is a noticeable trend, in both the public and private sectors, toward multi-agency or multi-company carpool programs with merged data bases and centralized matching operations.

4) The majority of carpool programs surveyed here are of very recent origin (late 1973 or early 1974) or are still in the planning stage. Judging by the surge of new carpool programs in late 1973, the energy crisis has been an important stimulus to carpool operations.

5) More than half of the carpool programs investigated involve computer matching, reflecting the relatively large size of the anticipated data base.

6) Based on a preliminary evaluation and comparison of the reported effects of 29 of the 77 carpool programs, 14 programs are considered to have been successful in achieving increases in the level of carpooling or in stimulating interest in carpooling, and four programs are judged to be relatively unsuccessful.

7) From the description of "successful" and "unsuccessful" carpool programs, it appears that effective incentives for carpooling or disincentives for solo driving are an

important ingredient of program success.

8) Further monitoring and evaluation of carpool programs is necessary in order to determine what factors constitute a successful program.

6. THE MAXIMUM POTENTIAL OF CARPOOLING

In order to assess the potential of carpooling as a strategy to reduce the number of single-occupant work-trips, some means is required for estimating the practical limits of participation in carpools. Policy makers can then evaluate the potential contribution of carpooling to overall transportation goals. Moreover, realistic goals for increased participation can be established once these limits are known.

This section presents a technique for estimating the practical maximum level of carpooling in an urban area. Preliminary results of an application to the Boston area are included. A probable range of the maximum, nationwide, is extrapolated from these results.

6.1 CONVERTING OCCUPANCY TO CARPOOL PARTICIPATION RATES

Average auto occupancies can be expressed as percent participation in carpools. This participation rate is useful in computing impacts of increased carpooling, and obtaining an understanding of the extent of carpooling required to achieve the goals of carpool promotion campaigns, most often expressed in terms of increased auto occupancy.

The following expression[1] shows the mathematical relationship between auto occupancy and carpool participation:

$$C = \frac{1 - \frac{1}{A}}{1 - \frac{1}{M}} \qquad (1)$$

where C = participate rate, or fraction of auto commuters in multiple occupancy autos

A = average auto occupancy, persons per auto

M = average multiple auto occupancy, persons per carpool vehicle

[1] Developed by C.H. Perrine of the Transportation Systems Center.

The preceding equation is plotted in Figure 6-1 for multiple (carpool) occupancy values of 2.0, 2.5, and 3.0. At current overall and multiple occupancies of 1.2 and 2.5, the curve indicates 27% of auto commuters traveling with others to work. This is in agreement with the results of the NORC survey (Section 3).

In general, a change in average occupancy indicates either a change in the size of carpools or fraction of commuters carpooling, but not necessarily both. In fact, both multiple occupancy and proportion of commuters in multiple occupancy vehicles may vary without any change in average auto occupancy. However, changes in multiple occupancy will not produce large shifts in the portion of commuters in carpools, except at high participation levels.

To increase auto occupancy from 1.2 to 1.3, holding multiple occupancy constant, would require a 40% increase in the proportion of commuters riding together, from 27 to 38 percent. More significant increases in auto occupancy require very substantial increases in participation rate, particularly at the current multiple occupancy of 2.5--almost 70% of carpools contain only one passenger. For instance, to achieve an occupancy of 2.0, about 84% of all auto commuters would be carpooling at a multiple occupancy of 2.5, or 75% at an average multiple occupancy of 3.0. This is almost three times the number of persons currently riding to work together.

6.2 MAXIMUM LEVEL OF CARPOOLING

While there is an abundance of data concerning existing carpools and carpoolers, very little has been done to develop methods for assessing the maximum potential of carpooling, short of a costly and time-consuming data-collection process. To avoid such an effort, and yet provide a practical means of estimating this potential, a model has been developed at TSC which employs standard format origin-destination data of the type available for most urban areas. The following sections describe the rationale and analytical techniques used, followed by a presentation of results from an application of the model to the Boston area.

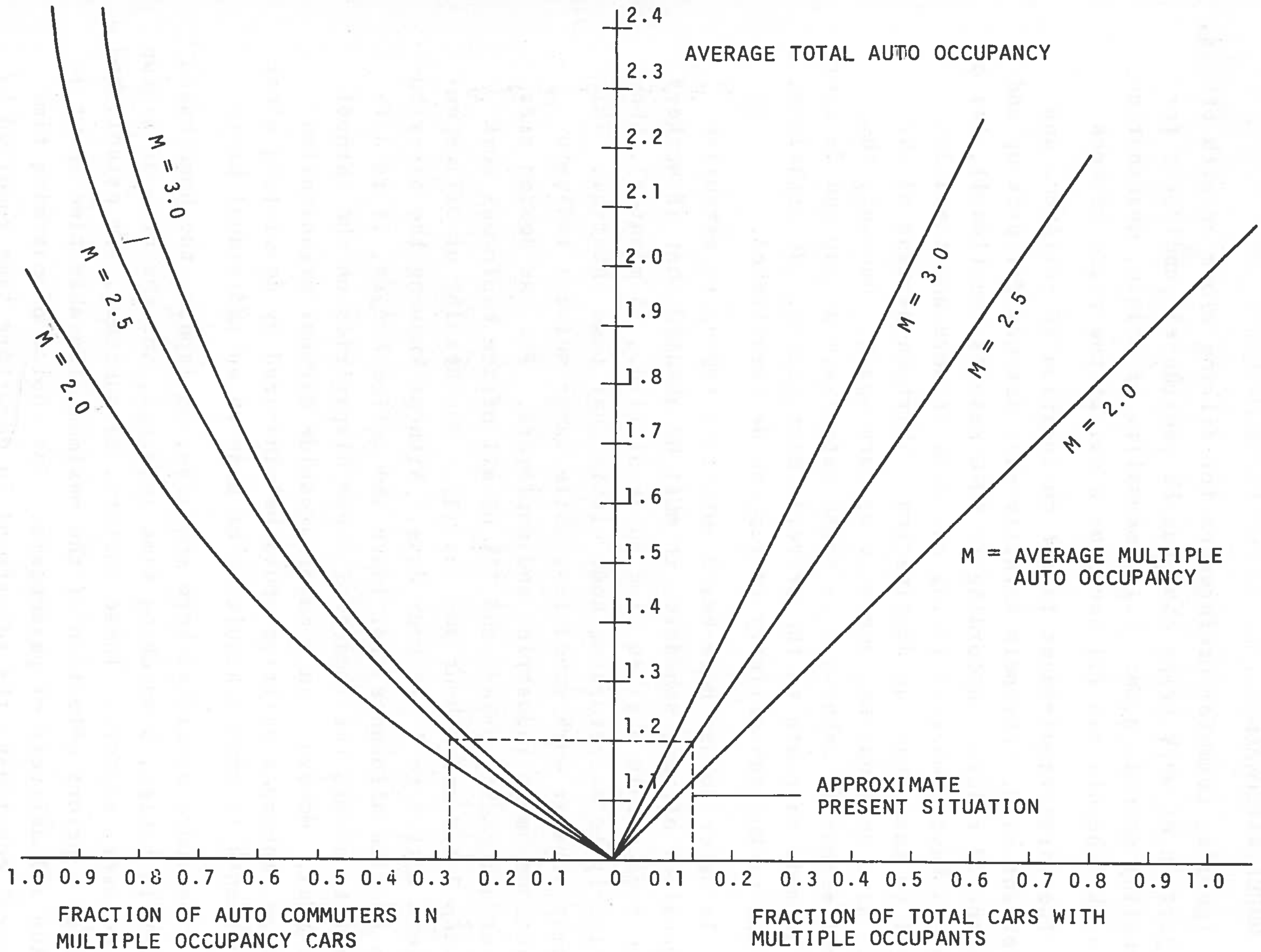

Figure 6-1. Carpooling/Auto Occupancy Relationship

6.3 MODEL RATIONALE

Ignoring commuter preferences for driving alone or with others, the portion of work trips that can be considered candidates for carpooling depends upon: (1) commonality of origin, destination, and work schedule and (2) need for a car at the place of work.

The first requirement is the co-location of residence and employment site. Carpools normally make detours for pick up and delivery of riders. According to NORC results (Section 4), 44% of carpools have member(s) living one mile or more apart and 26% travel to more than one destination. Thirteen percent of carpools have destinations one mile or more apart. However, the actual detour is unknown from these data since pickup and delivery may be made en-route to the driver's destination. Nevertheless, a maximum pickup and delivery sector can be established.

In order to use home-based work-trip tables to establish commonality of work schedule, it must be assumed that if workers leave home within a given time interval (i.e., 15 minutes), they are likely to be returning home within that time interval. This assumes similar work schedules, while labor surveys indicate variations among industries and employers. For the Boston area, 94% of all plant workers and 72% of all office employees work between 7 1/2 and 8 hour per day (1). Another 15% of office employees work 7 to 7 1/2 hour days. Without knowing the distribution of time allowances for lunch and coffee breaks, it is difficult to assess the impact of these disparities on the carpool potential. However, in a major areawide carpool organization program, incompatibilities could be minimized by permitting minor adjustments in work schedule to be made on an individual basis.

The model described here requires, as inputs, the home-based work-trip tables, a matching time interval, and the area of pickup and delivery sectors. These sectors, or subzones, are established from an a priori selection of the maximum allowable time spent in pickup and delivery of passengers. The choice of matching time interval constrains the adjustment in departure time required by members of a carpool. Within the limits established by these constraints, the model will estimate the maximum potential of carpooling.

Origin and destination sectors for trips from home to work are shown in Figure 6-2. The average tour length is computed from the sector area and the highway topography of the region. Tour length, as a function of the dimensions of these square sectors, can be estimated using Haggett and Chorley's empirically determined coefficients (2). Total detour time is then computed as a function of tour length, average speed, and number of passengers as follows:

$$T_E = N \left[\frac{.9 \sqrt{a}}{S_a} + \frac{.8 \sqrt{b}}{S_b} \right] \tag{2}$$

T_E = total excess time for all detours

N = number of passengers (1.5)

a = origin sector area

b = destination sector area

S_a = average speed in origin

S_b = average speed in destination sector = 15 mph

Various combinations of origin and destination sector areas can be chosen which satisfy the constraint, T_E. Sector areas need not be constant over the entire region, and may be set according to zone type, i.e., urban, suburbs, and outer suburbs. This takes into account variations in network density and speed within different locales.

The second constraint, matching time interval, is set at the chosen maximum range of departure times among carpool members. Assuming a uniform distribution of departures within an interval, the average difference among departure times is about one half the matching interval. A maximum matching interval, in terms of inconvenience to the commuter, should probably not exceed one half hour.

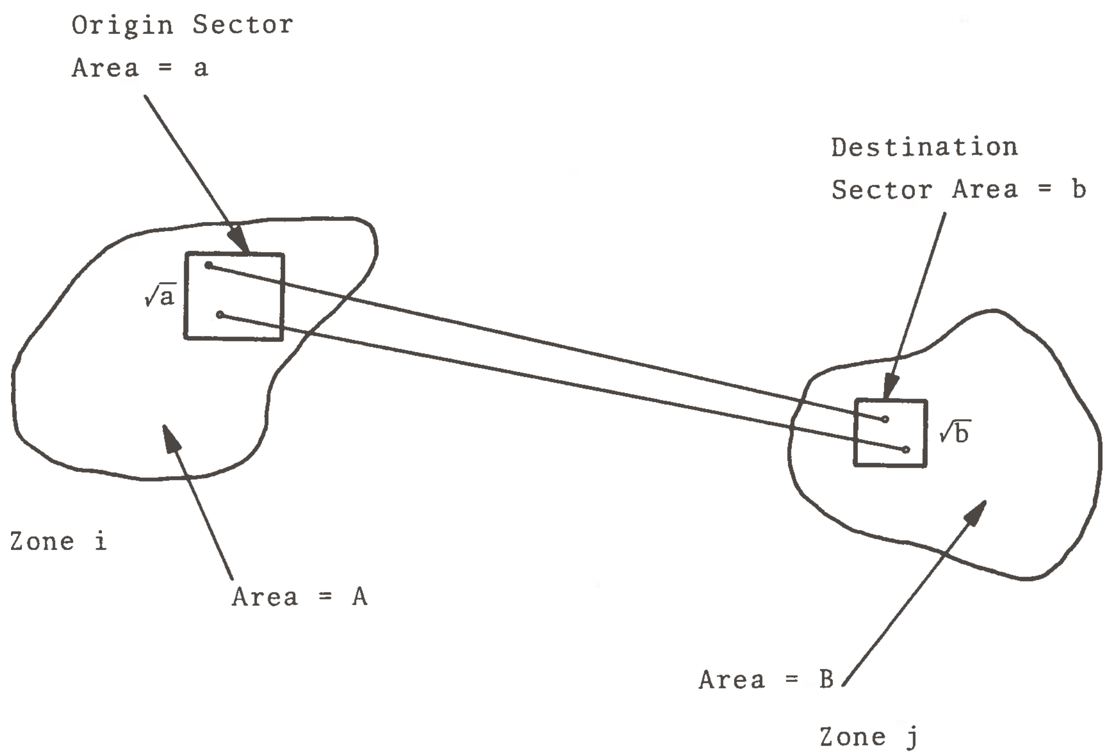

Figure 6-2. Origin and Destination Sectors

In order to use the work trip tables to determine carpooling potential, the following assumptions are made:

1. Work trip productions are evenly distributed over the origin zone.

2. Attractors, or employment sites, are evenly distributed over the commercial portion[1] of a destination zone or district.

3. Workers with common origin and destination who depart from a sector of a zone within the same time interval are candidates for a carpool.

From these assumptions, the number of potential carpool trips n_{ijk} from any origin sector to any destination sector can be expressed as:

$$n_{ijk} = T_{ijk} \frac{a}{A} \frac{b}{B} \tag{3}$$

where a = origin sector area

b = destination sector area

A = origin zone area

B = destination zone area

T_{ijk} = person auto work trips from zone i to zone j originating within time interval k

If the number of sector trips that can be carpooled, n_{ijk}, is equal to or greater than two, then all trips from zone i to zone j occurring during time interval k are declared to be potential carpool trips. Likewise, if n_{ijk} is less than two, then none of the trips T_{ijk} can be carpooled, since the uniformity assumptions preclude any other sectors from having a higher commonality of trips.

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[1]If a destination zone is not primarily commercial, its area is corrected by subtracting the area of the non-commercial portion, i.e., the residential or open space.

Thus if $n_{ijk} < 2$, $N_{ijk} = 0$, and if $n_{ijk} \geq 2$, $N_{ijk} = T_{ijk}$. The maximum level of participation, expressed as a percent of the total person work trips (by auto), becomes:

$$P_{MAX} = 100x \left[\sum_i \sum_j \sum_k N_{ijk} / \sum_i \sum_j \sum_k T_{ijk} \right] \tag{4}$$

While this rationale makes no attempt to pinpoint carpool trips, it provides a technique for making gross estimates of the maximum potential for carpooling by summing all trips over all time intervals for those zone pairs having two or more common sector trips. Parameterization of inputs will provide an understanding of the sensitivity of the maximum potential to the length of pickup and delivery detours and matching time intervals.

6.4 MODEL RESULTS

The model has been applied to the Boston area for all person work-trips by auto originating over a 3-hour morning period from 6 to 9 a.m. Trip tables used were developed from a 1963 home interview survey of the 626-zone Eastern Massachusetts metropolitan region, an area comprising approximately 1300 square miles surrounding and including the city of Boston.

Origin and destination sector areas were selected for each of three subregions; urban, inner suburbs, and outer suburbs. This categorization of zones was done to enable selection of sector areas according to population density and traffic on local streets. For example, in one case origin sector areas were 1/4, 1, and 4 square miles for the three subregions; destination sectors were all set at 1/4 square miles.

Table 6-1 contains conditions and results for the combinations of parameters investigated. The computed maximum carpool potential is expressed as a percent of all auto person trips originating within the 3-hour period.

At a matching interval of 30 minutes, and average origin destination sector areas of one mile each, the maximum carpool

TABLE 6-1. MAXIMUM CARPOOL POTENTIAL-MODEL RESULTS USING BOSTON 1963 MORNING WORK-TRIPS

PICKUP SECTOR AREA SQ. MILES REGION[a] I	II	III	AVE.	DELIVERY SECTOR AREA, SQ. MILES I	II	III	AVE	MATCHING TIME INTERVAL MIN.	MAXIMUM CARPOOL POTENTIAL, PERCENT
1/4	1	1	.94	1/4	1/4	1/4	.25	15	28
1/4	1	4	2.9	1/4	1/4	1/4	.25	15	39
1/4	1	1	.94	1/4	1	1	.94	15	50
1/4	1	4	2.9	1/4	1	4	2.9	15	78
1/4	1	1	.94	1/4	1/4	1/4	.25	30	43
1/4	1/4	1/4	.25	1/4	1	1	.94	30	38
1/4	1	1	.94	1/4	1	1	.94	30	65
1/4	1	4	2.9	1/4	1	2	1.6	30	88
1/4	1	4	2.9	1/4	1	4	2.9	30	90

[a]Region I - All Urban Zones
Region II - Inner Suburban Zones
Region III - Outer Suburban Zones

potential is 68% of all commute trips by auto. At these conditions, the average increase in travel time necessitated by pickup and delivery is less than 10 minutes.

The results of the parameterization runs were plotted to create the curves shown in Figures 6-3 to 6-5. In Figure 6-3, maximum carpool potential is plotted for varying average origin sector area. Origin and destination sector areas are weighted averages; the sector area chosen for each subregion (urban, inner suburbs, outer suburbs) was multiplied by the number of zones in the subregion. The average origin and destination sector areas ranged between .25 and 3 square miles. Figure 6-4 shows effects of varying destination sector area on carpool potential.

Results plotted in Figures 6-3 and 6-4 were computed for a matching interval of 30 minutes. As shown in Figure 6-5, reducing the matching interval to 15 minutes diminishes the maximum carpool potential by about 12-15 percent. By holding destination sector area at .9 square miles (any further increases in destination sector area beyond one square mile may be unreasonable, especially in downtown areas of congestion) and increasing origin sector size to 3 square miles, the potential can be increased to 82%. However, this case requires a detour time of approximately 12 minutes--over one-half of the average commute time for single drivers.

It can be argued that the disparity among departure times of carpoolers matched within 30-minute intervals is less burdensome than the increase in travel time caused by the pickup and delivery detours. Nevertheless, to achieve 68% carpooling potential, the overall impact of both on the necessary departure time may average about 20 minutes. This means that the driver may have to leave 20 minutes earlier than he would if he drove alone.

Considering the inconvenience caused by the excess time and disparities in the departure time, a realistic maximum level of participation for the Boston area is probably close to 65-70% of morning auto commute trips. At this level, carpool travel times would be 40-50% higher, on the average, than the time required for commuters who drive alone.

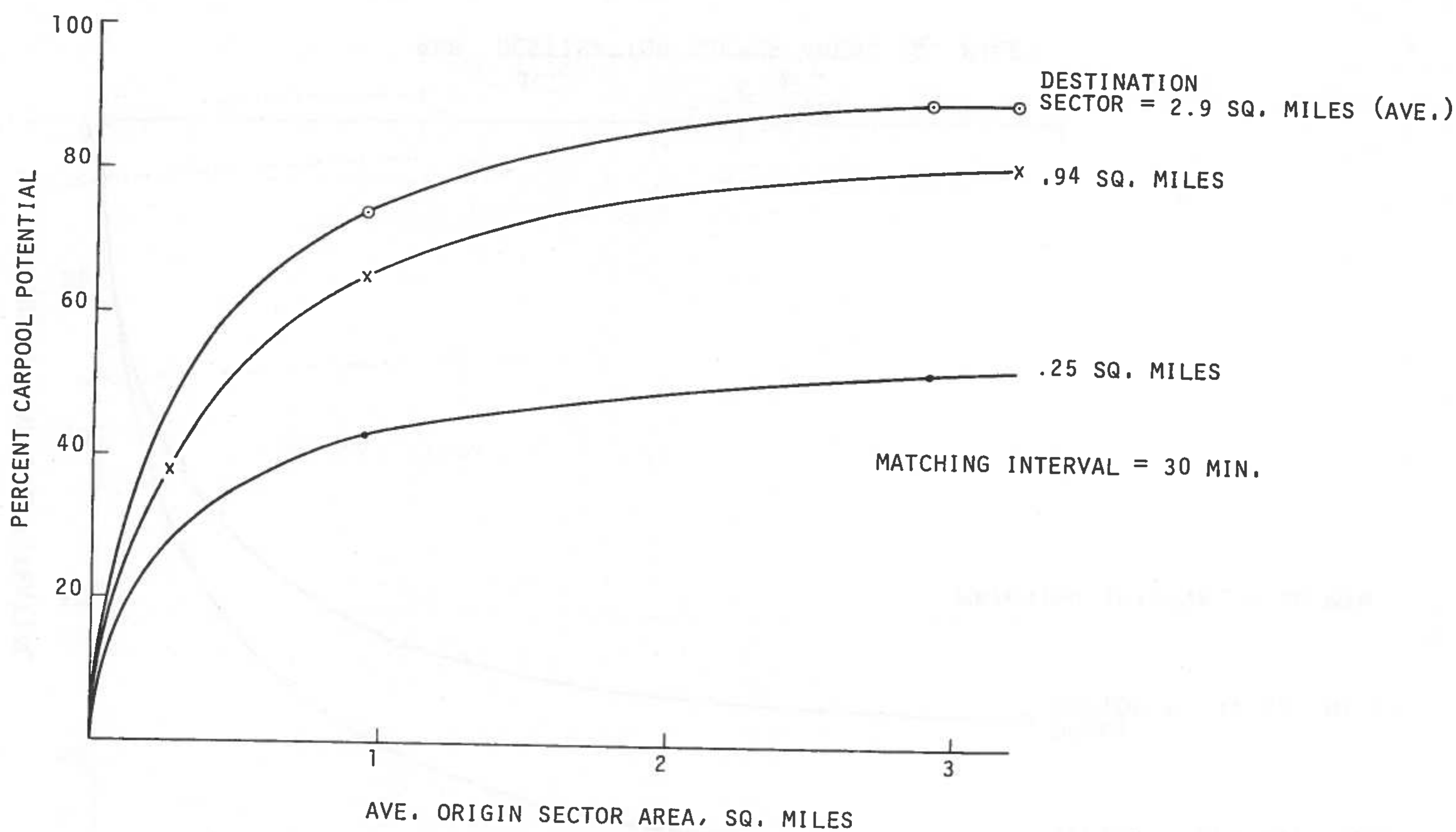

Figure 6-3. Effects of Matching Sector Areas on Maximum Carpool Potential (Basis: Boston 1963 AM Work-Trips)

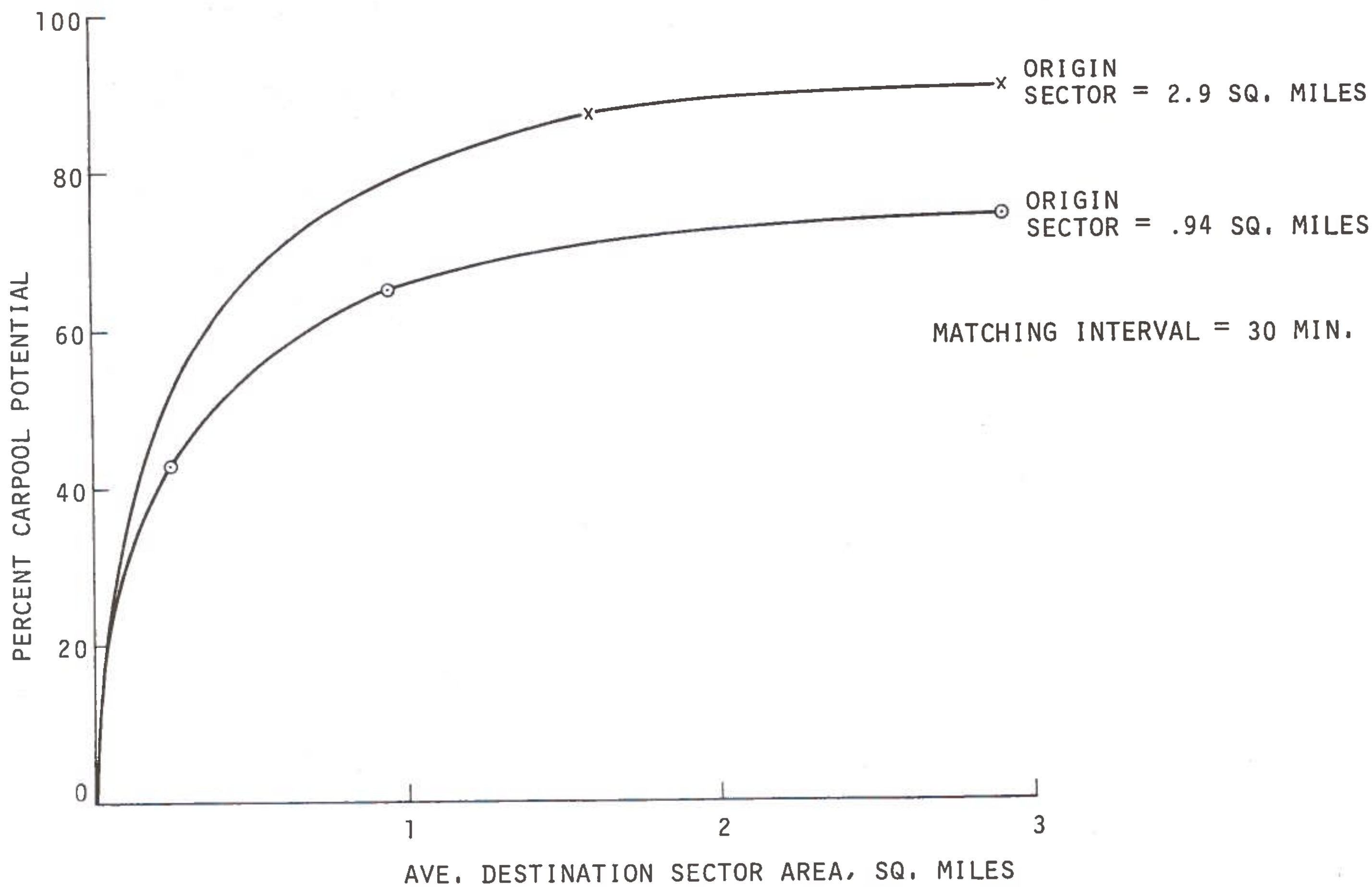

Figure 6-4. Effect of Matching Sector Areas on Maximum Carpool Potential (Basis: Boston 1963 AM Work-Trips)

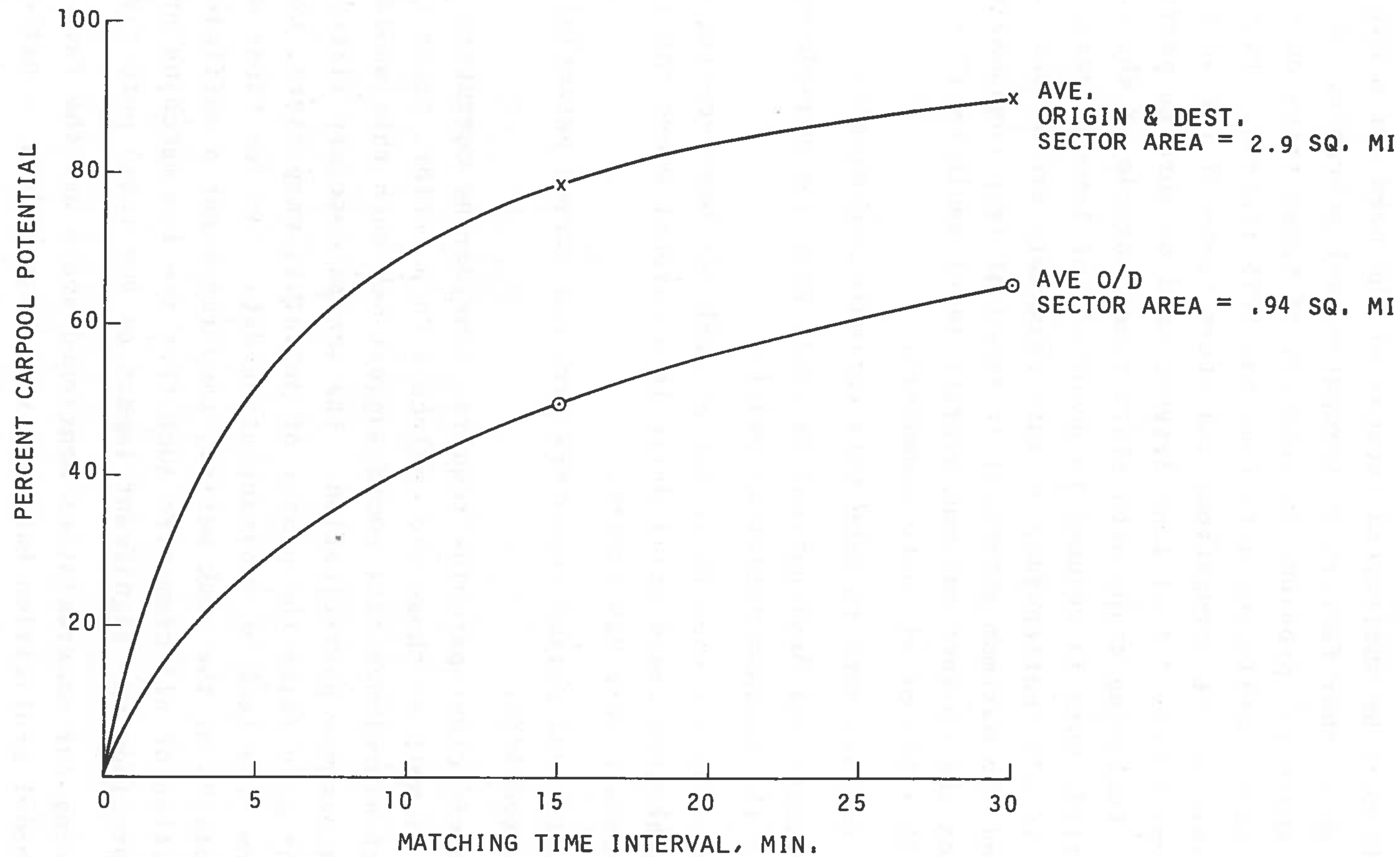

Figure 6-5. Effect of Matching Time Interval on Maximum Carpool Potential (Basis: Boston 1963 AM Work-Trips)

A portion of the trips identified by the model as candidates for carpools must be subtracted because of the need for a car at work or such other factors as irregular work schedule. A recent TSC analysis[1] provides an estimate of those trips on a nationwide basis, utilizing data from the NPTS reports. This was done by examining the occupations and start times of the work trip. Approximately 27% of lone drivers need an auto to perform their job. Excluding trips with start times outside of the morning commute period, this is reduced to about 25% of lone drivers. Therefore, if 27% (nationwide) of auto commuters are already carpooling, and the maximum potential in terms of trip commonality is 70%, then the correct maximum overall level would be 27 + (70 - 27).75 = 59% of all auto commuters.

Three factors tend to make this estimate conservative:

1. Origins and destinations en route were not considered by the maximum potential model.
2. Drivers who need their car at work but have regular work schedules could still drive in a carpool where the other members were passengers.
3. Only peak period commuters were considered potential carpoolers.

While efficient matching requires considering commuters along the route as well as those who co-locate in a sector, there is no basis of expreience that would suggest how much this would affect the maximum participation. The second category listed above might also raise the number of potential carpoolers, however, again there is a lack of substantiating data. As for those who commute outside of the peak period, they represent a sufficiently small fraction of all commuters such that the low matching probabilities preclude any signifcant impact on the total potential.

Allowing for uncertainties mentioned above and the fact that the only model application has been with Boston data, a national maximum will be assumed to be within 20% of the estimated potential

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[1] Research done by David Anderson.

for Boston, or somewhere between 47 and 71% of all auto commuters. The corresponding maximum auto occupancy is between 1.4 and 1.7. Having established these brackets, the range of possible impacts of a large-scale nationwide carpool mobilization program can now be evaluated.

Obviously, aggregate empirical estimates cannot predict with accuracy where so many individual considerations must be made to determine the actual number of potential carpoolers. Still, the method and results described above are useful in determining the level of impacts that are most likely achievable. Moreover, they provide insights into the nature of the requirements for carpooling, and factors other than personal attitudes that are currently limiting the expansion of carpools.

6.5 SUMMARY

Increases in auto occupancy can be expressed as an increase in percent of auto commuters carpooling, or participation rate. Participation rate is a function of average auto occupancy (all autos) and average multiple or carpool vehicle occupancy. This participation rate would have to double, from 27 to 54%, in order to increase auto occupancy from 1.2 to 1.5. To achieve an auto occupancy of 2.0, about 84% of all auto commuters would be carpooling at a multiple (carpool occupancy of 2.5, or 75% at a multiple occupancy of 3.0. The average multiple occupancy has remained stable, at about 2.5, for at least the last 5 years.

Preliminary estimates of the maximum level of carpooling have been made, based on results of applications of the Maximum Carpool Potential Model to the Boston region. The maximum national participation rate appears to be between 47 and 71% of peak-period auto work-trips. At 71%, the corresponding auto occupancy is 1.7 at the current multiple occupancy of 2.5, or 1.9 for a multiple occupancy of 3.0. Therefore, a realistic maximum average work-trip auto occupancy will probably not exceed 2.0 considering work-trip commonality constaints and occupations requiring autos.

Concomitant with these higher participation rates is an overall increase in travel time necessitated by pickup and delivery detours.

At the estimated maximum level of carpooling, travel time will increase by about 10 minutes on the average. Also, some adjustment in departure time among carpool members is likely to accommodate minor differences in work schedules, since at these higher levels of participation, more carpools will consist of employees of more than one company.

While the accuracy of these projections is admittedly limited by the assumptions within the rationale, the results are useful in gaining an understanding of the practical limits to participation in carpools based on commonality of work-travel requirements.

7. IMPACTS OF INCREASED CARPOOLING

This section deals with potential benefits accruing from increased ride sharing. Such benefits include fuel savings, congestion relief, reduced pollution, and a reduction in the demand for parking spaces. The extent of these impacts are related to increases in carpool participation above the current level.

Inherent in these projections is the assumption that new carpoolers are drawn primarily from the ranks of lone drivers. If large numbers of commuters switch from transit to carpools, vehicle-miles of travel (VMT) would not decrease, and transit revenues would drop as well. Therefore, it is important to insure that policies designed to promote ride sharing do not result in an overall increase in the percent of auto commuters.

7.1 FUEL SAVINGS

Savings in gasoline consumption corresponding to increases in participation rates are shown in Figure 7-1. These savings are based on the following calculation:

$$GS = VM_o \left[1 - \frac{B_o}{B_x} \right] \times FC \times FP \qquad (5)$$

where GS = national gasoline savings, billion gallons/year

VM_o = annual commuter VMT for 1973

B_o = current weighted auto occupancy, passenger miles/vehicle miles

B_x = projected auto occupancy, passenger miles/vehicle miles

FC = average auto fuel consumption for urban commuting, gallons/mile

FP = fuel penalty associated with average pick-up and delivery detours and weight increase from additional occupants.

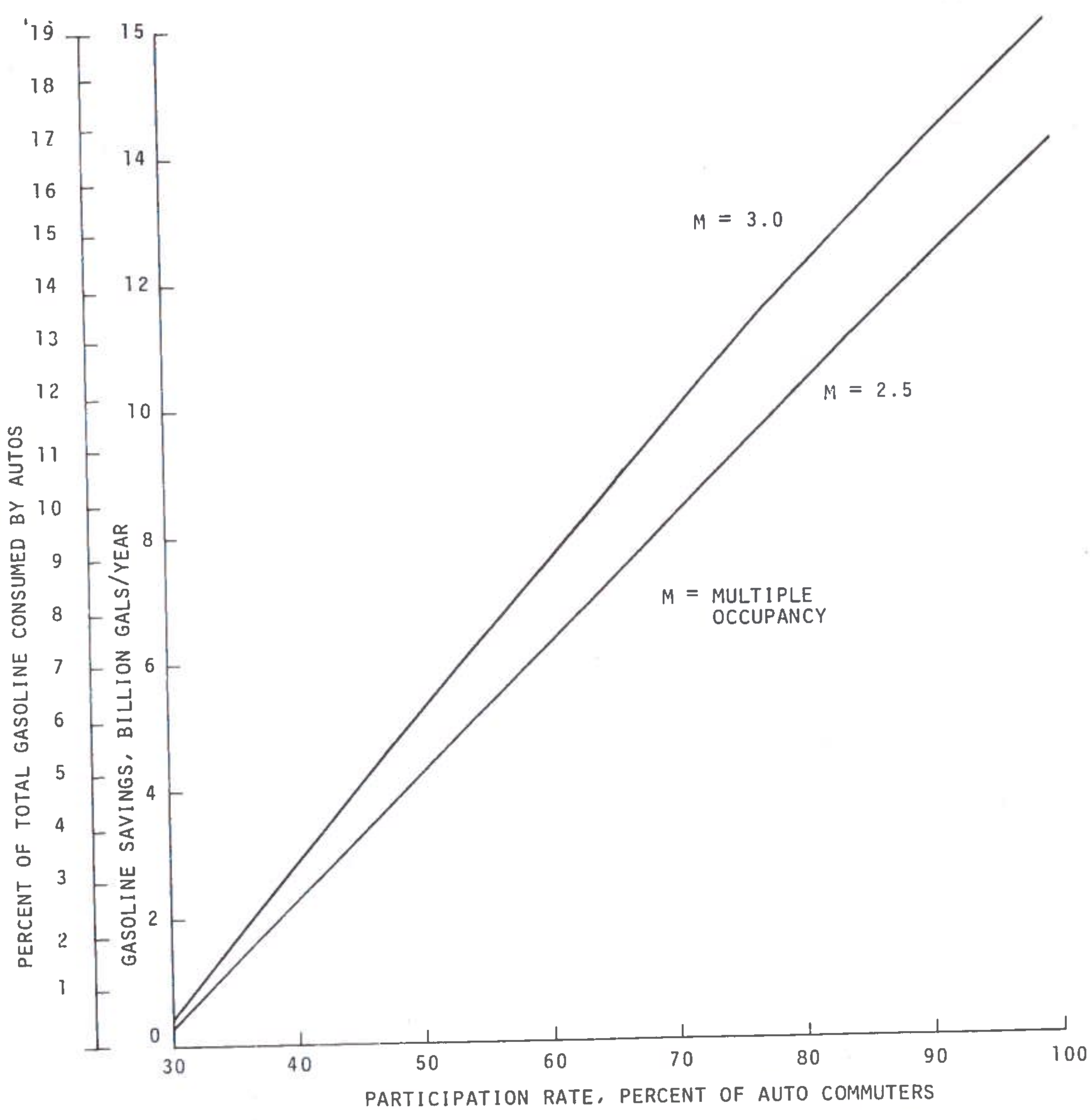

Figure 7-1. Gasoline Savings from Increased Carpooling

The total VMT of 335 billion miles/year was calculated from 1970 NPTS data[1] adjusted to 1973 by applying a growth rate of 6% estimated from FHWA statistics. The rate of auto fuel consumption (for cold start driving on urban trips averaging 10 miles) reported by Hirst (4) is .0874 gallons/mile (11.45 mpg). A fuel penalty of 13% was included to account for the weight of additional passengers and the increased trip length necessitated by pick up and delivery of riders.[2]

A weighted auto occupancy, to account for the longer trip lengths typical of multiple-occupant travel, was used to compute fuel savings. This weighted occupancy can be converted to unweighted auto occupancy by ratioing with measured values for each survey results.

Participation rates shown in Figure 7-1 were developed from unweighted occupancies using equation (1) above (Section 6.1). Gasoline savings in Figure 7-1 are shown as a percent of total gasoline consumption, calculated from FHWA data (9), of 83.8 billion gallons/year. Only the fuel consumed by autos and trucks while transporting passengers is included in this total.

At the current multiple occupancy of 2.5, approximately 70% participation in carpools would be required to reduce gas consumption by 10%. Thus, if the maximum potential level of carpooling for all urban areas is between 60-70%, a maximum of 7-10% savings in auto fuel consumption could be achieved from the reduction in auto miles traveled.

Additional fuel savings would result from decreased congestion, since uniform speeds are the most economical and fuel economy drops sharply in heavily congested traffic. Optimum economy is achieved at uniform speeds of 30 mph and above. For example, a 50% increase

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[1]Calculated from daily average total work trip VMT based on the TSC research done by D. Anderson and J. Cliff.

[2]A 10% increase in trip length was assumed, combined with 3% drop in fuel economy; 1.5% per additional hundredweight multiplied times average increase in weight of (2.5 - 1.2) x 150 = 195 lbs.

in travel time due to congestion can result in a 100% increase in fuel consumption.

Indirect energy savings will accrue from decreased auto travel. These savings include energy consumed in repair and maintenance, manufacture of tires and replacement parts, petroleum refining, and consumption of motor oil. Ignoring other items such as manufacture of new autos, insurance, and highway construction and maintenance, that might be less significantly affected by carpooling, the indirect energy savings, according to Hirst (4), would amount to 6% of the energy consumed while driving.

7.2 ADDITIONAL BENEFITS

Relatively small reductions in VMT during the peak period can have a substantial effect upon congestion. Average speed is most sensitive to vehicle density when traffic is highly congested. A 20% reduction in vehicle density on severely congested highways can increase speeds by two-thirds on freeways and 50 to 80% on urban arterials (2). In both cases traffic conditions are restored to stable flow. Since 75% of commuter autos are bound for urban destinations, substnatial congestion relief on the major urban arteries can be expected.

Reduced congestion creates many side benefits: increased gas mileage, decreased emission production, fewer minor accidents, reduced travel time for autos and buses, and relief from the nervous stresses of stop-and-go driving on jammed highways.

These additive effects of reduced VMT also apply to the rate of emission of pollutants and atmospheric concentrations. Hydrocarbon production during the morning peak period has the most critical effect on daily concentrations of oxidants. The rate of production of CO and hydrocarbons increases as congestion decreases average speed, as shown in Figure 7-2. An increase in speed from 20 to 30 mph reduces the rate of CO emission by 46%.

Another benefit of decreasing commuter vehicle trips lies in the reduction of demand for parking spaces. In addition to the current limits to parking supply in downtown urban areas, EPA

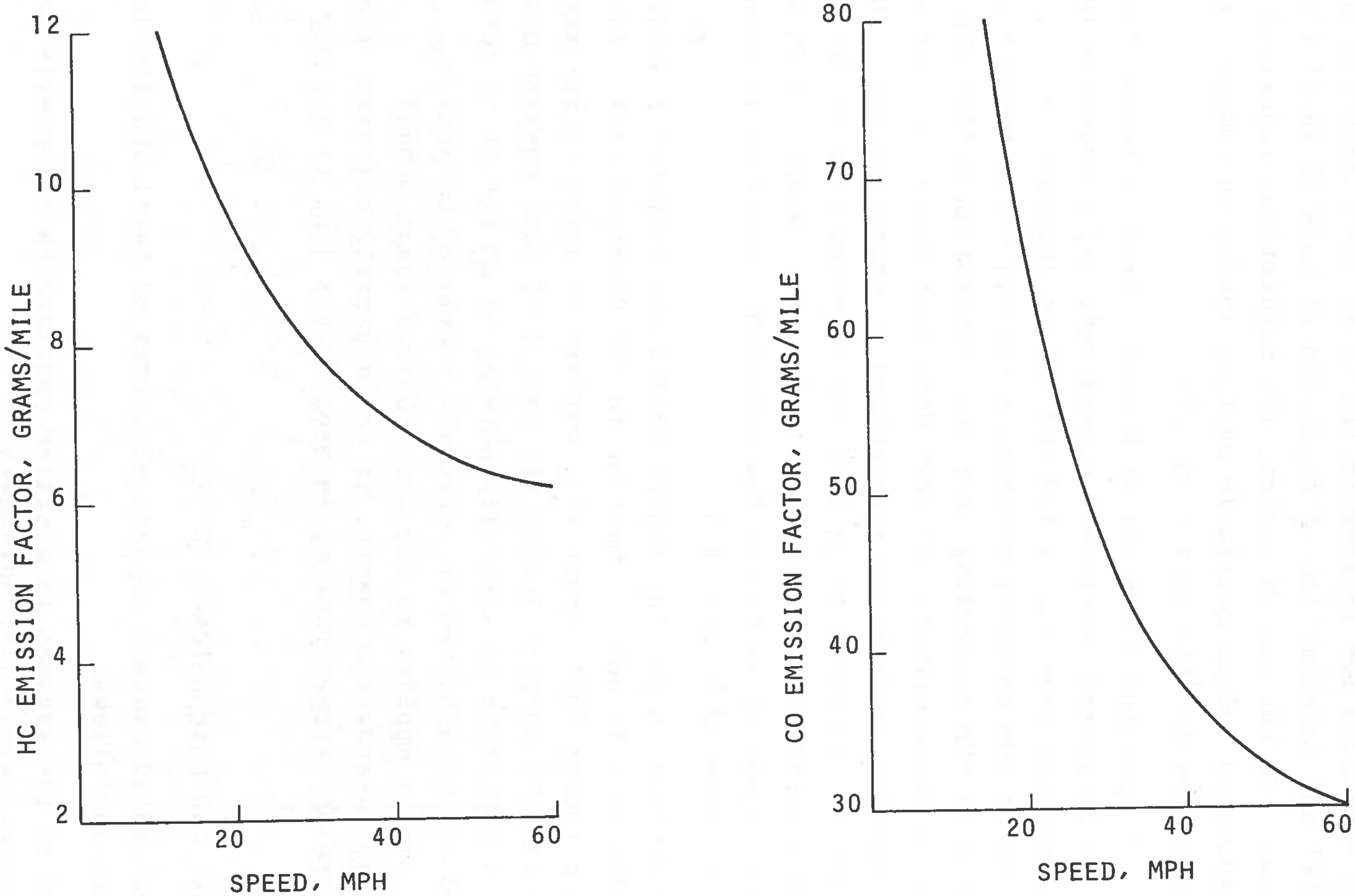

Figure 7-2. Hydrocarbon and Carbon Monoxide Emission Rates as a Function of Automobile Speed for 1972 Model Autos.
Source: L. Pratsch (8)

regulations scheduled for implementation in at least 28 urban areas will prohibit new construction or expansion of parking facilities in core areas. In the Boston region, EPA regulations requiring that all employers reduce available parking spaces on company lots by 25% or more may go into effect in 1975.

Table 7-1 contains a summary of benefits from increased carpooling. Two increased levels are considered; (1) a moderate increase in occupancy from 1.2 to 1.4 and (2) an increase to 1.7, corresponding to the probable maximum, estimated using the rationale described in the preceeding section. Congestion relief estimates apply to those streets and corridors that currently have a volume to capacity (V/C) ratio approaching or exceeding one. The greater reduction in emissions within the downtown area is due also to improvements in traffic flow as described above. Even for the moderate occupancy increase, the emission production in downtown areas is reduced by over 25%.

The reduction in parking spaces needed was computed from the resulting decrease in autos commuting to the downtown area. According to a recent FHWA report (7), workers in large cities account for 63% of all CBD parkers during the period of peak parking demand. Therefore, a reduction in work-trip parking of up to 18% of total peak demand can be achieved at increased levels of carpooling. Since this saving applies to the CBD, where parking demand approaches or exceeds the supply, it could greatly alleviate the need for more off-street parking in areas where land is already at a premium.

7.3 SUMMARY AND CONCLUSIONS

The estimated maximum impacts of increased participation in carpools are as follows:

1. Up to 10% savings in gasoline consumed in automobile passenger travel (all purposes).
2. As much as 50-70% increases in speed on arterials and freeways that are currently heavily congested.

TABLE 7-1. BENEFITS OF INCREASED AUTO OCCUPANCY VIA WORK-TRIP CARPOOLING

	Moderate Increase 1.2 To 1.4	Estimated Maximum Increase 1.2 To 1.7
Participation Rate, % of Auto Commuters	47	70
% Reduction in Auto Work Trips	14	28
Fuel Savings, %	4	10
Congestion Relief, % Speed Increase[a]		
Arterials	25	50
Freeways	56	70
% Reduction in Emissions (CO)		
Downtown[a]	25	45
Elsewhere In Region	14	30
% Reduction in Downtown Parking	9	18

[a]Estimated for badly congested freeways and arterials with $V/C \geq 1$.

3. Over 30% reduction in auto emissions resulting from fewer vehicle trips and congestion relief.

4. Up to 18% fewer parking spaces required in downtown areas.

From the findings reported here, the following conclusions can be drawn:

1. Benefits from increased carpooling are greatest in areas of pollution, congestion, and parking relief. This is primarily due to the effect of reducing vehicle densities during the peak travel periods.

2. At high levels of participation, gas savings are substantial. However, below a 50% increase in the current number of carpoolers, gas savings would not exceed 3%.

3. Considering the rather slight effect of the recent energy crisis on the behavior of auto commuters, future policies aimed at major increases in carpool participation will require extreme disincentives or very favorable economic incentives. Such a policy will also require an infrastructure capable of providing more sophisticated matching services to all auto commuters in urban areas.

8. A PLANNING MODEL FOR CARPOOL MATCHING SERVICES

The success of carpool formation programs depends to a high degree on the level of matching achieved from among the responses or questionnaires submitted. A match occurs every time a respondent receives names of one or more other potential carpoolers with common origin, destination, and time. If the level of matching is too low, the participants become discouraged, lose interest, and the program loses impetus and may fail. These participants may be sufficiently disgruntled to abandon their interest in carpooling. Hence, if the scope of a carpool organization program is too far reaching and ambitious, the ultimate effectiveness, in terms of participants and carpools formed, will fall short of expectations.

For example, when a local radio station in Boston launched a campaign to match people into carpools, they attempted to serve a 1300 square mile region with a population of over 3,000,000. After a five-month intensive multi-media promotional campaign, less than one in four respondents could expect to receive matching letters with names of other commuters that fit their requirements. One of the factors attributing to the low level of matching was the fact that out of the 391 origin zones containing respondents, only 74 had a number respondents greater than 1/2 of 1 percent of the total responses. In other words, the response density was too low in many of the origin zones to permit a reasonable level of matching to the destinations served by the program. Although they allowed for over 74 destinations, 75% of the requests were bound for 22 destinations in the downtown area. Therefore, matching to other destinations was well below the 24% overall level.

This is not intended to suggest that only selected origin-destination groups should be served by carpool matching centers--instead, local or employer-based facilities should be available to serve those sectors which cannot be handled effectively by an area-wide system. Then the regional facility can structure its territory so as to concentrate on the most productive markets such as high density residential districts and downtown districts, or the regional facility can serve as a coordinating agency or higher level repository for a network of local and employer-level matching services.

This section contains a technique for planning the size of the territory served and its zonal components to permit an acceptable level of respondent matching. It allows the planning agency to design and revise origin and destination groupings until the desired level of matching, as predicted by a probabilistic model, is achieved. The model, to be described later in the report, should provide a feeling for how matching is affected by the size of the response pool, and the degree of matching for many-to-one trips compared to the many-to-many case.

8.1 PREDICTING THE LEVEL OF MATCHING

For the purpose of understanding how matching probability is affected by the origins and destinations served, consider the following basic scenarios in Table 8-1. The table provides typical ranges of values for origins, destinations, departure time groups, and number of respondents. A respondent is a person who has requested names of people with similar origin, destination, and work schedule who are also interested in carpooling. Usually, these respondents submit a filled-out questionnaire indicating their requirements.

Origins and destinations refer to zones, grid squares, census tracts, or other geographical sectors which generate or receive work trips. In order to estimate the expected level of matching, the number of departures are assumed to be equal for all origin zones. Therefore, some adjustment to the number of origin zones or zonal size must be made to account for the greater incidence of work-trip in high density residential zones. This can be accomplished by choosing zonal size in an inverse proportion to population density. That is, higher density zones or grid squares would be smaller in area than those with low residential density.

Departure times are aggregated into time bands of equal length which comprise the morning period when most trips occur. These

TABLE 8-1. CARPOOL MATCHING SCENARIOS

	No. of Destinations	No. of Origins	No. of Time Bands	No. of Markets*	Estimated No. of Responses**
1. Employer (medium-to-large corporation)	1	50-200	2	100-400	50-500
2. Industrial Park	1	50-200	4	200-800	100-1000
3. Small Urban Area pop. 100,000	10-30	30-100	6	1800-1800	1000-10000
4. Medium Urban Area pop. 300,000	20-50	60-300	6	7200-90000	3000-30000
5. Large Urban Area pop. 2,000,000	30-100	100-500	6	18000-300000	10000-200000

*No. of Markets = (# origins) x (# destinations) x (# time bands)

**These estimates were based on a survey of existing programs, and are sensitive to such factors as promotion, incentives, and gasoline supply.

time bands can refer to the usual time of departure from home or time of arrival at work, as long as the basis remains consistent over the area served by the matching program. Although time bands used for estimating matches are set at 1/2 hour, the matching program can use 1/2 hour, 15 minutes, or other periods.

The matching rationale used here seeks commonality in home departure schedules and ignores work departure times, assuming most people work an 8-hour day.

The range of responses for each case in Table 8-1 was estimated based on the population or number of employees, and previous experiences of employer and community carpool matching services. The number of time bands for urban areas (3) was selected because it spans the period when most work-trips occur. Obviously, matching can be done for any time or shift. Since the degree of matching is much lower for other periods, they can be omitted for the purpose of developing initial estimates to plan the size of a matching service. The probability of matching is a function of the number of responses and the number of possible combinations of origin, destination, and time groupings. The product of the number of origins, destinations, and time bands is called the number of markets. Each unique combination of origin, destination, and time band is considered a market for the purpose of establishing the relationship between matches and responses. The estimated number of markets is also shown for each of the scenarios in Table 8-1.

As the number of markets increases, the number of responses must also increase in order to maintain a constant level of matching. Since the level of matching is considered a measure of effectiveness of any carpool organizing facility, the relationships between markets, responses, and matches will provide important insights into the potential success of a carpool organization plan.

8.2 MATCHING PROBABILITY MODEL

The Matching Probability (MP) Model[1] is an aggregate technique for computing the number of matches as a function of the number of markets and total number of respondents. Markets are defined as the product of the number of origins times the number of destinations times the number of time intervals within the peak period (time intervals were set at 1/2 hour for this study).

For n markets the probability of a given market containing any respondent is equal to 1/n. Applying binomial probability theory, the probability of j respondents showing any given market is:

$$P = \left(C_j^r\right) \left(\frac{1}{n}\right)^j \left(\frac{n-1}{n}\right)^{r-j} = \left(C_j^r\right) \frac{(n-1)^{r-j}}{n^r} \qquad (6)$$

where C_j^r is the number of ways r respondents can be arranged with j members in each group.

The expected number of markets containing j respondents becomes

$$n \left(C_j^r\right) \frac{(n-1)^{r-j}}{n^r} = C_j^r \frac{(n-1)^{r-j}}{n^{(r-1)}} \qquad (7)$$

For any market, the expected number of respondents that will be matched with j-1 respondents in the same market is expressed as

$$m = j \left(C_j^r\right) \frac{(n-1)^{r-j}}{n^{(r-1)}} \qquad (8)$$

Summing over all possible values of j up to r produces the total expected number of matches for the region served:

$$M = \sum_{j=2}^{r} j \left(C_j^r\right) \frac{(n-1)^{r-j}}{n^{(r-1)}} \qquad (9)$$

[1]Developed by E.J. Roberts.

Thus, given the number of respondents, or participants in a matching program (or an assumed value), and the total estimated number of markets (computed), the above equation will predict the number of matches to be expected. The only assumption here is that for any given respondent the probability of his being in a given market equals the probability of his being in any other market. That is, each market has an equal probability of containing a respondent, which does not imply that all markets should have an equal number of respondents. This suggests that only markets having a high probability of containing respondents should be chosen.

The primary difference between this model and the maximum potential model described in Section 6 is its generalized aggregate formulation. It is intended to provide quick probabilistic estimates of the matching potential with a minimum of input data (no disaggregate origin destination data is required). Only an estimate of the likely number of markets to be served is required to use the model for estimating the number of responses required for a given level of matching, or the level of matching likely for an assumed number of respondents.

Some results obtained by applying this model to the scenarios in Table 8-1 are shown in Table 8-2. The matching level, or percent matches, is shown as a range corresponding to the range of responses and markets assumed in Table 8-1. It is apparent from these results that the one destination (employer/industrial park/high rise office building, etc.) case has a distinct advantage over the others in terms of the higher level of matching for a given number of responses. The many-to-many case exemplified by the urban area scenarios have more markets, and consequently require more responses to achieve the same degree of matching.

A set of curves generated by the MP model are plotted in Figure 8-1. The shape of the curves reveals the nature of the probability functions; the percent matches remains low until the response pool exceeds some value, then the slope of the surve increases. As the percent matches approach 100%, the curve again

TABLE 8-2. MATCHING LEVELS FOR CARPOOL SCENARIOS DESCRIBED IN TABLE 8-1

	No. of Markets	No. of Responses	% Matches*
1. Employer	100-400	50-500	40-75
2. Industrial Park	200-800	100-1000	40-74
3. Small Urban Area	1800-18000	1000-10000	44-49
4. Medium Urban Area	7200-90000	3000-30000	37-28
5. Large Urban Area	18000-30000	5000-10000	27-32

*The range (% matches) corresponds to the ranges of markets and responses.

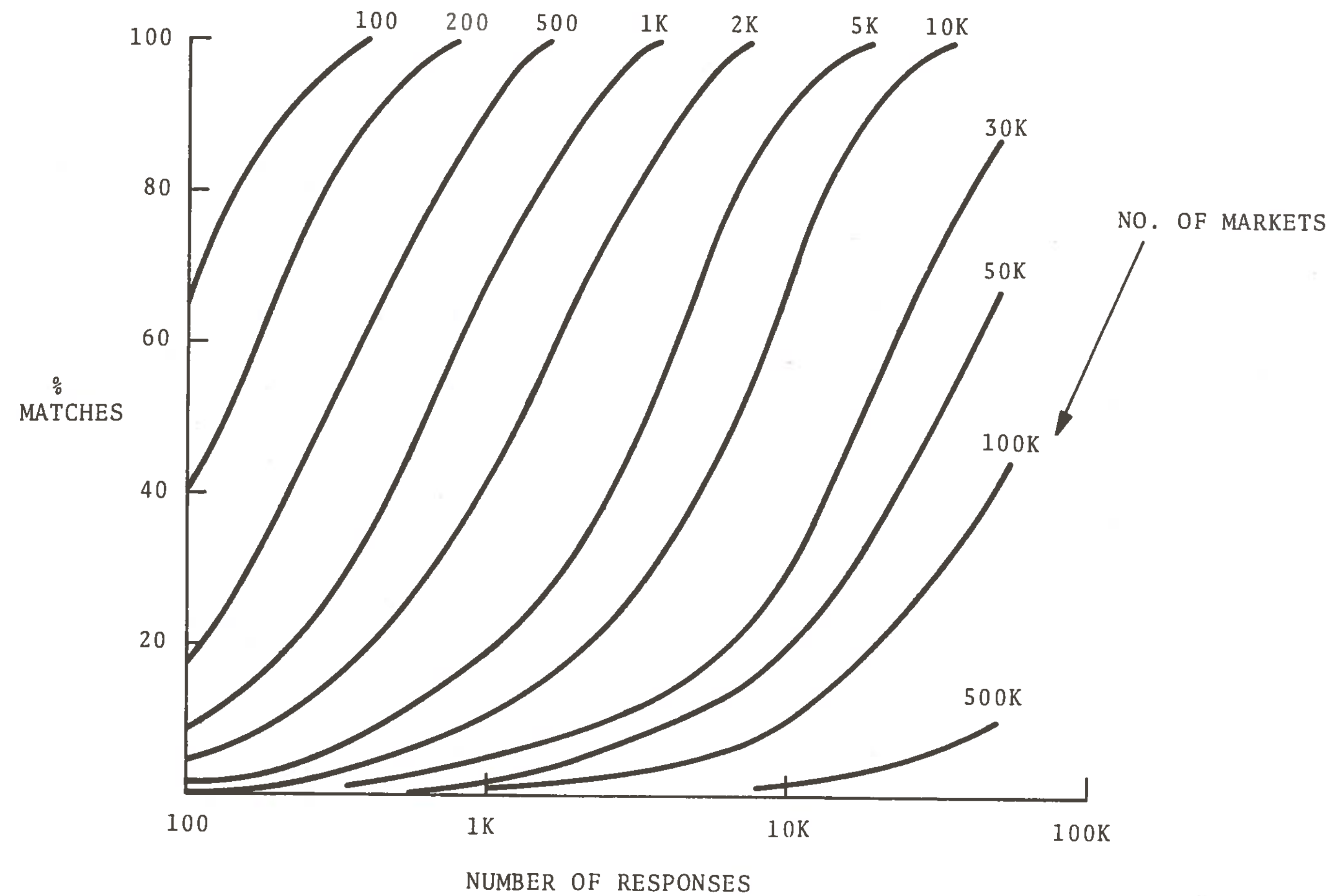

Figure 8-1. Matching Probability Vs Number of Responses

levels off, indicating a point of diminishing returns beyond which the matching can no longer be improved by more responses.

These curves provide a means of determining the expected percent matches for any given number of markets and responses. (A description of how to use the curves to plan and size a carpool matching service is given later in this report.) Once an expected value for the number of markets has been estimated, either the required number of responses for a desired matching level, or the degree of matching for an expected number of responses, can be established. Because of the "S" shaped property of these curves, there exists a point where the percent matches becomes more sensitive to and increases more rapidly with the number of responses. The number of responses corresponding to this point is a base value, and should be easily attainable within a short period of time in order for the program to rapidly gain momentum. The Boston area program referred to above contains over 30,000 markets. The point where the curve begins a steep ascent occurs at about 7000 responses and a matching level of about 22%. This point was not reached until about 4-1/2 months into the campaign, accounting for the low yield of matches (and consequently carpools) that was achieved.

8.3 ILLUSTRATIVE EXAMPLE

A theoretical urban region is described by the 24 mile square shown in Figure 8-2. The downtown area is a 4 mile by 4 mile sector in the middle of the region. A grid of one square mile sectors has been superimposed on the area as shown partially by the horizontal and vertical lines in the lower and rightmost portion.

For the initial estimate of the number of markets, origin and destination grid squares are all one mile in area. Origin A is an outer suburban locale and origin B is near the downtown area. A destination grid square, D, is shown in the downtown region. Since most of the work-trips in the region are assumed to be destined for this 4 square mile area, the estimated number of destinations

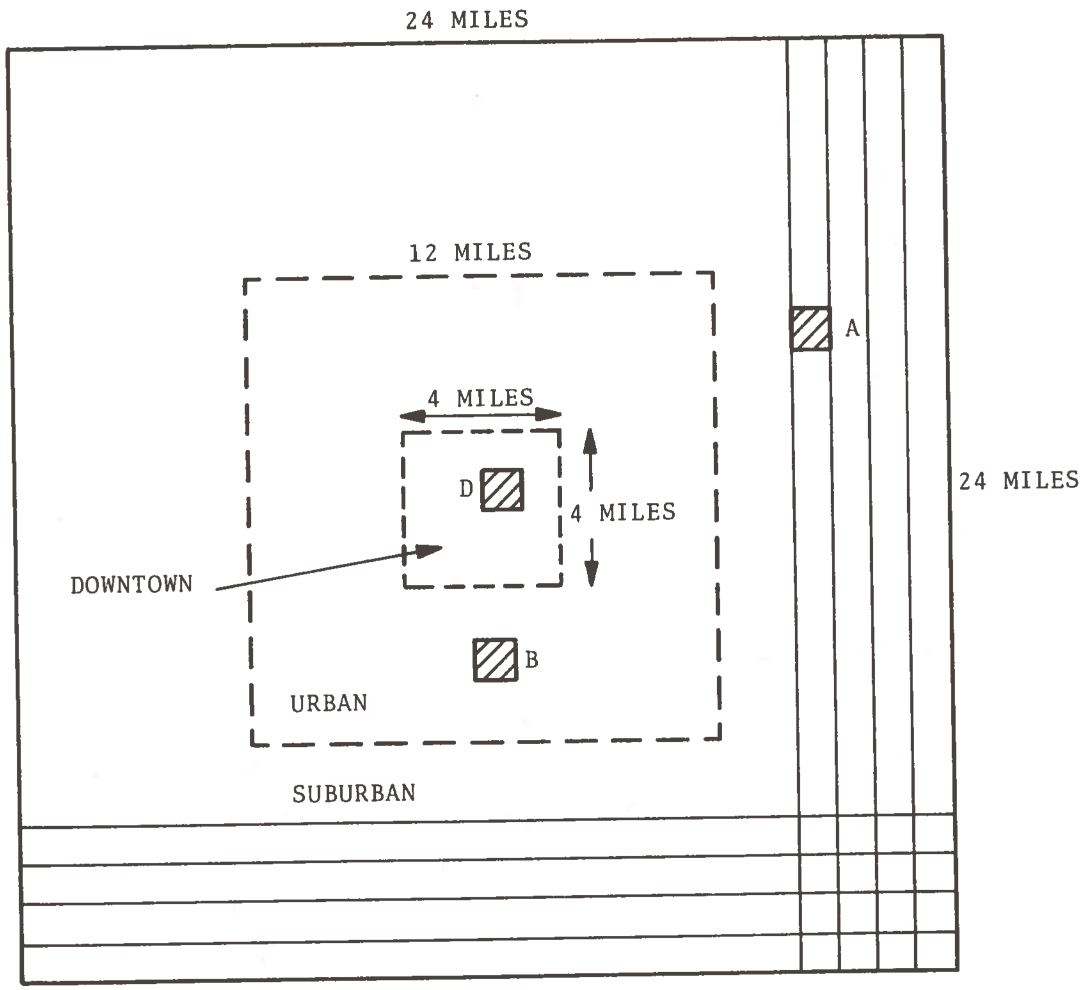

Figure 8-2. Urban Region-Uniform Grid Size

is 16. If the downtown area is primarily business and commerical property, the total number of origins as 24 x 24 minus 16, or 560.

In order to calculate the number of markets for this example, the number of time bands are set to 6, for 1/2 hour periods from 6:30 to 9:30 a.m. The number of markets becomes 6 x 560 x 16 or 53,700. Now the curves in Figure 8-1 can be used to estimate the responses required for a given level of matching. If 50% matching is established as a goal, the number of responses required, as obtained from the curve for 50,000 markets, is 30,000.

Since it may take a fairly long time to obtain 30,000 responses, it becomes evident that something should be done to decrease the number of markets. The suburban region can be aggregated into larger grid cells, which is reasonable due to the lower population density and congestion on local streets, making it possible for carpoolers to travel farther to pick up riders than they could in denser sectors.

In Figure 8-3, the same region has been broken up into one square-mile grid cells in the urban sector, and 4 square-mile grid cells in the outer suburban region. Now origin A has been expanded to include more residences, hence increasing the number of commuters to match from. The number of markets now becomes 6 x 16 x [(12 x 12 - 16) + (12 x 12 - 36)] = 22,700. This is less than half of the number of markets for the first case. Although there is no curve for 23,000 markets in Figure 8-1, the number of responses can still be estimated by interpolating the location of a curve between 10K and 30K. This increase in gird size for part of the region has reduced the number of responses required to match 50% of participants from 30,000 to approximately 12,000.

Computer matching programs, such as the FHWA Program for Carpool Matching, will permit the user to enlarge the grid cells in outer areas. The potential for carpooling may be exploited further by the capability of the computer logic to perform searches in adjacent cells or along the route to the destination. These techniques will increase the probability of matching beyond that predicted by the curves in Figure 8-1. However, the exercise carried

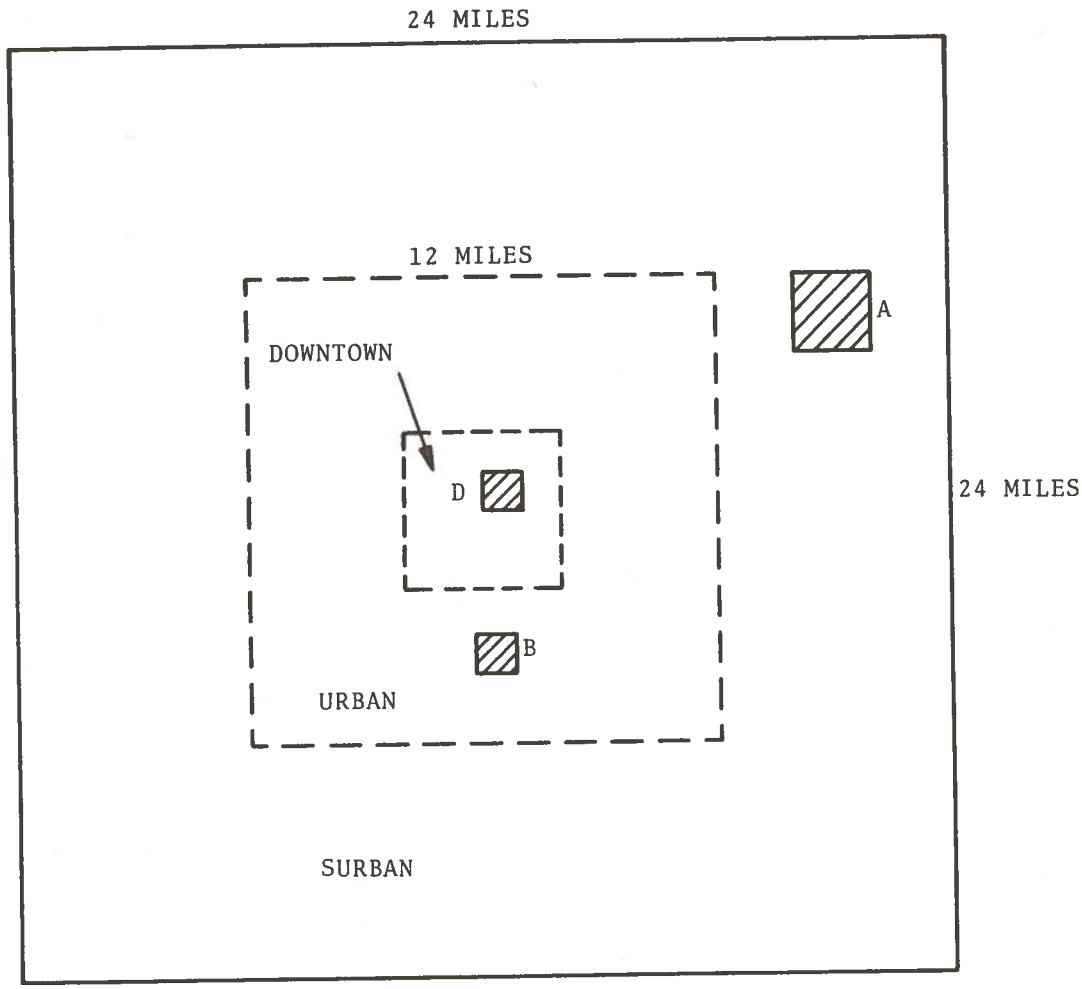

Figure 8-3. Urban Region with Enlarged Grid Cells in Suburbs

out above is still worthwhile as an aid in establishing the size of the region to be served and arriving at a sensible level of aggregation of origins and destinations.

8.4 HOW TO SIZE A CARPOOL MATCHING REGION

As demonstrated above, the MP model can be used to structure the territory served by the carpool matching center in order to maximize the yield of matches for an expected or estimated number of responses. It can also be used to establish the number and size of origin and destination sectors (grid squares, zones, etc.) The following is a procedure for choosing these matching parameters using the results of the MP model plotted in Figure 8-4.

1. Establish the set of departure time bands; the number of 1/2 hour periods that comprise the a.m. peak period, or period wherein most trips to work occur. This value is usually between one and six.

2. Establish the number of <u>destinations</u> or destination zones, tracts, or grids. This value will contain a selected set of downtown industrial/business centers. The set of destinations can include major commerical centers in other parts of the region as well.

3. Count the number of <u>origin</u> zones, tracts, or grids. Only those zones which are primarily residential and likely to produce work trips to the set of destination zones should be included in this estimate.

4. Multiply (departure time bands) x (destinations) x (origins). This product is the estimated number of markets. Obtain the required response pool size from the graph in Figure 8-4 as follows:

   a) Decide on a matching objective--usually between 25 to 50%.

   b) Locate the point on the selected matching curve corresponding to the calculated value for the number of markets.

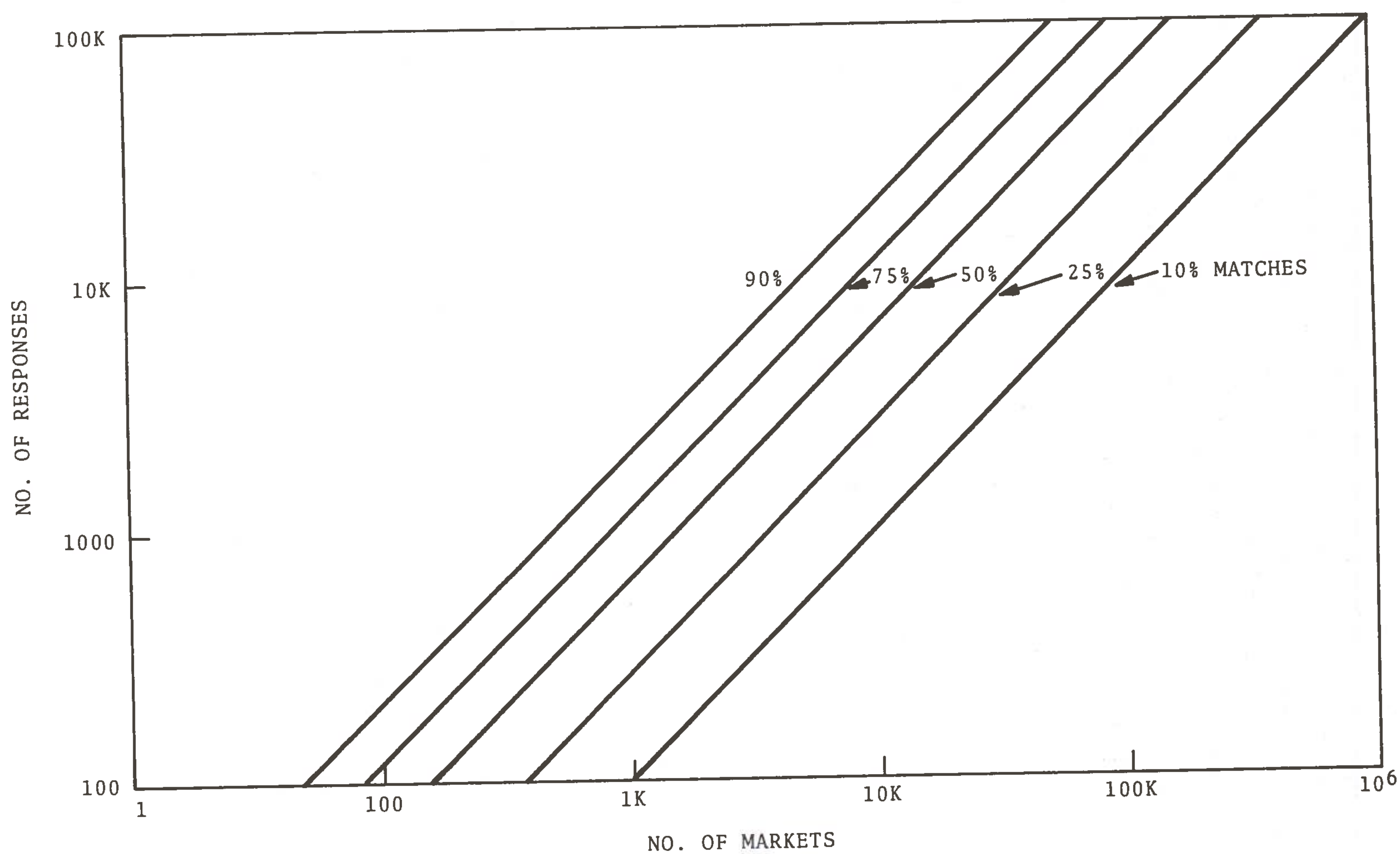

Figure 8-4. Responses Vs Markets

c) Draw a horizontal line over to the vertical axis and read off the number of responses required for 50% matching.

5. Evaluate the required number of responses. If it seems higher than would be expected within a fairly short time, say one to three months, then consider decreasing the number of markets to permit more matches. This can be achieved by either; (a) reducing the size of the region to be served by the carpool matching system, (b) choosing fewer destinations, or (c) enlarging the size of the origin or destination cells. The implications of aggregating origins or destinations are mainly the possibility of impractical or undesirable matches, since the participants may not want to incur the additional pickup or drop off time. However, aggregation will increase the matching probability as shown in the previous example. Choosing fewer destinations could mean reducing the area coverage of the matching service or simply not including destinations which have a small number of work attractors relative to the average. This is done to avoid overly pessimistic predictions from the MP model. Some rules of thumb can be applied here:

- The region served for promotional and matching purposes should not extend beyond the immediate suburbs of a methopolitan center.
- The size of origin zones or grids should be based on the population density and average speed on the local streets. Drivers will usually be willing to travel up to 5-10 minutes to pick up passengers.

9. RECOMMENDATIONS FOR FUTURE STUDY

Most of the literature and research on carpooling has been related to organizational techniques, case studies, and statistics relative to existing characteristics of carpools. The studies discussed in this report deal with those areas as well as the future potential of carpooling. Beneficial impacts of carpooling have been identified here, together with results of analyses performed to estimate the levels of participation required to achieve substantial benefits. However, much work is still needed in order to assist the government in establishing policies aimed at furthering interest and participation in carpools.

From this and other studies, it has become clear that the level of carpooling is not likely to increase substantially unless new policies are instituted which create additional incentives to carpool. While many incentives have been tried in various programs to date, and others have been proposed, the following questions still need to be answered:

1. What incentives have the greatest potential and where do they apply?
2. How many auto commuters are likely to be affected by incentive policies related to preferential parking, exclusive lanes, reduced tolls, etc?
3. What are the likely effects of carpooling incentives on transit ridership, auto ownership, and induced travel?
4. What are the administrative requirements and enforcement problems related to the various incentives?
5. Among those incentives related to cost of auto travel (gasoline tax, gasoline rationing, parking surcharge, etc.) which are most cost effective and least inflationary? What are the inequities and how can they be dealt with?

New analytical tools are needed to determine the potential impact of government strategies to increase carpooling. Such tools include policy sensitive models that can accept the attributes of incentives (cost, travel time, convenience) and predict mode choice behavior. Techniques for translating the changes into auto occupancy and vehicle travel into decreased fuel consumption, pollution, congestion, etc. can then be applied to evaluate the impacts of each strategy. Finally, the most cost effective strategies can be compared and studied further to determine the mechanisms required for implementation and enforcement.

Attitudinal considerations are very important in predicting the behavior of commuters in response to new policies. Little is known regarding the current attitude of single drivers toward carpooling and the degree to which they are willing to incur additional expense rather than join a carpool. It is likely that attitudes are changing and drivers may be more receptive to carpooling today than they were a few years ago when gas and automobile prices were much lower. Market analysis techniques can be employed to assess current attitudes and predict public acceptance of those policies that appear to be promising.

In conjunction with policy planning, there is a need to closely monitor the experience of operational carpool programs. A comparative evaluation of those programs coordinated by the public sector would be particularly useful. Such programs are underway in L.A., S.F., and other major cities. In some cases the regional coordinating agency is attempting to encourage organization at the employer level, while others (Boston) have attempted to provide a central matching service for all workers. There are currently at least six pilot programs underway at the regional level receiving financial support under the Unified Transportation Assistance Program (UTAP). When these and selected other programs are evaluated, the lessons can be applied toward structuring and maximizing the effectiveness of future programs. A comparison and evaluation of current efforts in the public and private sector should consider all aspects of the program including incentives, promotion, organization, matching techniques, community support and the role of various agencies involved.

APPENDIX A DATA

NORC Survey Design

The Continuous National Survey (CNS) was conducted by the National Opinion Research Center and funded by the Department of Transportation. The purpose of the survey was to develop nation-wide data relative to energy consumption and transportation.

The survey used a sampling design which devides the United States into 101 primary sampling units. A full probability sampling procedure is used, whereby a dwelling unit is randomly selected, the members of the household are enumerated by the interviewer and a particular member, 18 years of age or older, is then randomly chosen for interviewing. Each week about 175 interviews were obtained from households distributed across all the primary sampling units and balanced with respect to race and income. In each four-week interviewing cycle about 700 interviews were obtaine

The data analyzed in this report is taken from Cycle 8 (November 20 - December 23), Cycle 9 (January 1974) and Cycle 10 (February 1974). Responses from these 3 cycles are weighted by number of household members and aggregated for the main part of the analysis. For the section of trends in car occupancy, Cycle 8 and Cycle 10 are compared for differences over the three-month period.

The total number of auto commuters in the weighted sample from the three cycles was 2084, of which 549 were in carpools. Of the 549, 190 (or 35%) were in family type carpools composed of the same household members. This group of family member carpoolers were not asked to respond to most of the carpool questions, and are therefore excluded from most of the analysis. The base number of carpoolers in the sample therefore is 359. The no-response category is eliminated from the tables and therefore there are varying base numbers for carpoolers in each of the tables presented. All tables were subjected to the chi-square test of significant differences and only statistically significant results ($p < .05$) are reported.

APPENDIX B BIBLIOGRAPHY

1. Bureau of Labor Statistics, "Area Wage Survey: Boston, Massachusetts Metropolitan Area," Bulletin 1775-13, US Dept. of Labor, Boston, MA, December 1972.
2. Haggett, P. and Chorley, R., "Network Analysis in Geography," St. Martin's, New York, 1969, pp. 118-119.
3. Highway Research Board, "Highway Capacity Manual," Report No. 87, National Academy of Sciences, Washington, DC, March, 1966.
4. Hirst, E., "Direct and Indirect Energy Requirements for Automobiles," ORNL-NSF-EP64, Oak Ridge National Laboratories, Oak Ridge, TN, February 1974.
5. Kendall, D., "Work Trip Carpooling and Its Potential," ASC/EIC/RTAC Joint Transportation Engineering Meeting, Montreal, Canada, July 17, 1974.
6. Pratsch, L., "Carpools: The Underutilized Resource," Civil Engineering, January 1974.
7. Stout, R.W., "A Report on CBD Parking," No. 83, US DOT (FHWA), Washington, DC, December 1973, pp. 14-22.
8. Svercl, P. and Asin, R., "Nationwide Personal Transportation Study: Home-to-Work Trips and Travel," Report No. 8, US DOT (FHWA), Washington, DC, August 1973.
9. US DOT (FHWA), "Facts Bearing on the Problem," FHWA Statistics Division Report, Washington DC, November, 1973.
10. Voorhees, A.M., "Transportation Pooling," prepared for US DOT (UMTA), Washington, DC, January 1974.
11. Ward, D. E. and Kendall, D. C., "Providing Increased Transit capacity During Peak Periods: Examination of Two Techniques," DOT-TSC-OST-75-7, Cambridge MA, February 1975.