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Innovations in Ridesharing

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Ridesharing Requirements in Downtown Los Angeles: Achieving Private-Sector Commitments

PATRICK ROCHE and RICHARD WILLSON

ABSTRACT

Developers of major projects in downtown Los Angeles now enter into commitments to achieve specified ridesharing participation levels over the life of their projects. The Community Redevelopment Agency (CRA) of the city of Los Angeles has completed agreements for more than 6 million square feet of office space that commit the project owners to achieve a 60 percent employee ridesharing participation level, that provide for regular monitoring of performance, and that define specified compliance measures if ridesharing levels are not achieved. The private-sector ridesharing commitments are part of a multiagency effort to address the transportation requirements of the 16 million to 20 million square feet of growth expected to occur in downtown Los Angeles by 1995. This paper is a report on the circumstances and processes leading to the endorsement of ridesharing commitments by the downtown development and business community and the adoption of the transportation system management (TSM) rideshare program by CRA. The concerns raised by developers during project negotiation are addressed. Suggestions are offered about the use of ridesharing requirements as a transportation strategy and about establishing a program.

A private- and public-sector consensus on a wide range of transportation strategies for downtown Los Angeles has been emerging during the past year. That consensus includes a recognition of the role of management-oriented approaches in providing transportation services and of the value of ridesharing as a permanent, long-term element of urban transportation policy. This paper is a report on the process by which private and public sectors have developed programs that will increase ridesharing in downtown Los Angeles.

Many cities are using ridesharing techniques more extensively to address commuter transportation needs. The downtown Los Angeles experience has focused on the facilitation of continued growth and associated transportation improvement issues. This is consistent with an overall trend toward promotion of area-specific ridesharing programs that have transportation access problems as the rationale for their implementation instead of regionwide concerns such as air pollution or energy conservation.

A variety of implementation techniques has been used in ridesharing programs throughout the country. For example, in Seattle the "Director's Rule" is a measure to implement ridesharing provisions and restrictions on the use of parking through ordinance-imposed conditions on the issuance of permits. The program includes entering into a memorandum of agreement regarding ridesharing program implementation and includes follow-up evaluation by the city. Alternatively, in Hartford, Connecticut, an extensive private-public consensus-building effort has resulted in the formation of a private nonprofit corporation to promote reliance on high-occupancy vehicles. The nonprofit corporation has been successful in gaining voluntary commitments to ridesharing from major employers. These examples and others demonstrate the variety of implementation techniques available to meet local needs.

The distinguishing characteristics of the downtown Los Angeles ridesharing program are that requirements are negotiated with developers before final design of the projects and that the ultimate agreements incorporate specified performance requirements as well as monitoring and compliance procedures. The ridesharing program requirements are registered on the title of the property and burden the land and subsequent owners. Thus the program is designed from the outset to achieve a long-standing commitment to ridesharing that will affect downtown commuter travel trends.

The Community Redevelopment Agency (CRA) of the city of Los Angeles, in conjunction with other Los Angeles City departments and the private sector, has begun to implement ridesharing requirements for development occurring in downtown Los Angeles. CRA has entered into agreements with developers for ridesharing programs for approximately 6 million square feet of development, and it will implement similar agreements for the additional 16 million to 20 million square feet of development expected by 1995. Under the current ridesharing performance requirement, 60 percent of a project's employee population would use a ridesharing mode, including transit, carpools, and vanpools.

In this paper the transportation and development context of downtown Los Angeles is outlined and the origins of the program and CRA's redevelopment role are described. The major program elements are analyzed, developer response to the program is described, and conclusions that may have applicability for other cities are drawn.

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EXISTING CONDITIONS

Downtown Los Angeles is encircled by freeways that extend radially outward to link downtown with many activity centers and residential communities. These freeways, along with the well-developed network of surface streets and an extensive bus system, provide regional access to downtown. Figure 1 shows the local street system and surrounding freeway system.

As the largest and strongest commercial market in the region, downtown Los Angeles currently contains nearly 51 million square feet of private and public-sector office space. Class A office space represents slightly less than one-half of this total. There are approximately 215,000 persons employed in downtown (1).

During the past two decades, the Southern California region and downtown Los Angeles in particular have experienced major growth in office space development. The primary reasons for this growth are the region's emergence as a center for finance and Pacific-Rim basin trade and a strengthening of the region's traditional role in the aerospace and high-technology industries. This most recent wave of economic growth has established downtown Los Angeles as one of the world's leading concentrations of financial and corporate headquarters.

CURRENT DOWNTOWN TRAVEL PATTERNS

Downtown Los Angeles is the most accessible activity center in Southern California, with 7 freeways, 30 major surface streets, and 120 regional bus routes serving the area. An average of 690,000 people enter a defined downtown cordon area on an average weekday; almost two-thirds of these people arrive in automobiles, vans, and trucks; one-third arrives in buses, and a small percentage arrive by other means. A large percentage of the total persons entering the cordon area is either traveling to downtown for non-work purposes (tourism, shopping, business, etc.) or is making a through trip to destinations outside the cordon area.

Existing data sources have not been structured to provide primary data to answer certain questions concerning ridesharing behavior. The following table, based on a downtown Los Angeles cordon count (2), gives derived data on existing ridesharing participation in downtown Los Angeles based on transportation mode surveys and data from transportation agencies.

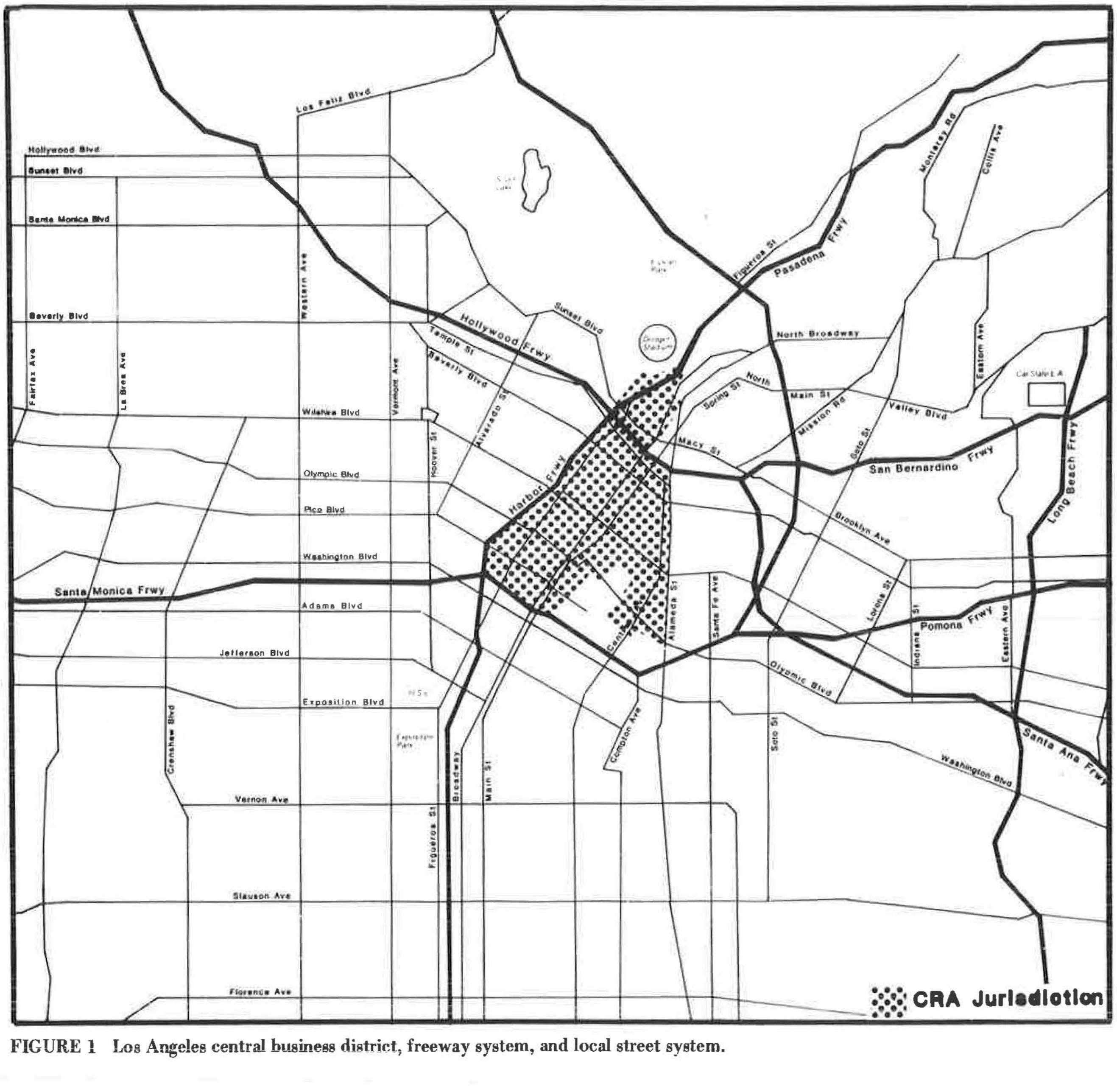

FIGURE 1 Los Angeles central business district, freeway system, and local street system.

Work Trips Made by	Percentage
Automobile (drive alone)	46
Ridesharing (carpool, vanpool)	19
Transit	35

The high volume of traffic into and through the downtown results in peak-hour congestion on the streets and freeways. Traffic speeds on the freeways that converge on downtown average less than 20 mph for more than 2 to 3 hr during peak morning and evening periods. On the Harbor Freeway and regional access streets located west of downtown, traffic congestion has intensified because of recently constructed high-rise office developments. Traffic volumes on the regional access streets average 3,000 vehicles per hour with speeds of 5 mph during the peak.

The level of employee participation in ridesharing programs depends on many factors, including the existence of employer-sponsored incentives. Some downtown employers promote well-established voluntary ridesharing programs. The Atlantic Richfield Company is a leader in this regard. Its program was established more than a decade ago and serves as a model for a large single-tenant program. Other factors that contribute to existing ridesharing levels are the escalation of parking prices (approaching $150 per month for new development) and increased public awareness of commute alternatives made possible by the highly visible success of TSM measures during the 1984 Summer Olympics.

REDEVELOPMENT ROLE OF CRA

Under California law and the Los Angeles City Charter, the CRA is empowered to carry out a program of redevelopment and economic revitalization for portions of the city of Los Angeles. The CRA is answerable to the city council and the mayor. It is a separate governmental entity and has specific implementation powers and responsibilities for carrying out its city council-approved objectives. For example, the CRA can acquire property by eminent domain, assemble and dispose of property, borrow money from any public or private source, and use tax increment financing to issue bonds to support redevelopment activities.

The CRA, with policy directives from the city council and the mayor and state-mandated powers, is characterized by its implementation functions rather than any regulatory function. To implement redevelopment activities, the CRA frequently enters into legally binding agreements with developers. These agreements outline the scope of development and responsibilities of private and public parties. Often a developer is required to undertake certain actions either as a condition for development or as a condition for the agency's assistance in developing a project. This unique ability to negotiate public and private commitments enables CRA to pursue significant ridesharing requirements for new developments in downtown Los Angeles.

FACTORS LEADING TO PROGRAM ADOPTION

Concern about the ability of Los Angeles' transportation network to accommodate projected growth has been a driving force behind citywide efforts to link development programs with specific transportation commitments. This concern is based on a number of factors:

1. Strong market forces for the centralization of office growth in downtown Los Angeles. Downtown Los Angeles has grown because of its role as a financial and corporate center and its expanded links with the Pacific-Rim economy. Economic forecasts suggest that 16 million to 20 million square feet of commercial and government office space will be added by 1995 (3).
2. Reduced local funding available for transportation improvements. In California, Proposition 13 (a tax limitation initiative that was approved by the voters in 1978) has reduced the ability of local governments to fund transportation improvements. Fiscal problems of local governments have had an impact on state finances.
3. Potential federal policy changes regarding urban transit. For example, a reassessment by the Reagan administration of the federal role in and responsibility for funding new-start rapid-rail transit projects has introduced increased uncertainty about significant increases in rapid transit services.
4. Excessive use of existing roadway infrastructure. In many built-up areas, roadway capacity has been fully utilized and increasing roadway or freeway capacity is difficult or impossible.

These factors were reflected in a number of studies conducted by public transportation planning agencies (4). Some of these issues were raised by community groups. Early in 1985 city council members voiced concern over these issues and subsequently several city council motions were introduced to impose a construction moratorium on new developments in certain areas because of strained transportation conditions or to impose transportation impact fees on new development. The CRA ridesharing program described in the next section was part of a multiprogram response to these issues.

DESCRIPTION OF PROGRAM

The central elements of the TSM ridesharing program, approved by CRA, are the establishment of a specific ridesharing participation requirement, the establishment of monitoring and compliance measures, and the registration of the program on the project's title. The program is implemented through developers, rather than tenants, because CRA has enforceable development agreements with developers and because up-front assurances concerning ridesharing performance are needed in order for CRA to approve projects with yet-to-be-identified tenants. This approach ensures that a buildingwide program will be developed in projects with numerous tenants and that tenants begin to plan for their employees' participation in the program at an early stage (i.e., during lease negotiations).

Summarized hereafter are the key elements of ridesharing programs that are included as part of CRA Owner Participation Agreements (OPAs) and Disposition and Development Agreements (DDAs) with developers of projects with 50,000 or more square feet of office space.

1. Developer commitment that at least 60 percent of the building employee population will participate in ridesharing programs (i.e., carpools, vanpools, private or public bus, rail transit, walking, etc.). The intent of the requirement is to achieve a level of ridesharing participation that is 10 percent greater than current levels in the central business district (CBD).
2. Establishment of an employee ridesharing program by the developer as part of the overall development program. The program would detail policies and actions to promote and reinforce ridesharing

among building employees, including transit pass subsidies, subsidized or preferential parking, or both, for carpools and vanpools, provision of staging areas, and so forth.

3. Establishment and staffing of a commuter transportation coordinator (CTC) office to operate the ridesharing program and assist tenant companies in developing a comprehensive ridesharing program for their employees.

4. Implementation of a monitoring program so that the CTC office can report progress to CRA on (a) level of ridesharing participation; (b) percentage of employees using transit, carpool, vanpool, or other ridesharing modes; and (c) use of on-site parking to achieve ridesharing objectives.

5. A provision that the developer will augment transit and carpool modes by creating a vanpool program, should ridesharing participation requirements not be met. In that instance, the developer will be required to provide free vanpool seats equivalent to the shortfall between the ridesharing performance requirements and actual performance, under the provisions of the development agreement. The developer has the right to propose alternatives to a vanpool program provided that such measures are likely to be of equivalent effectiveness.

6. A commitment to participate in areawide private-sector efforts to coordinate management of site-specific ridesharing programs.

7. Recording of the program on the project's title and application to subsequent owners. Agency development agreements cover a wide range of project construction and implementation specifications and programs. Ridesharing programs are included in development agreements. After completion of a project and termination of the development agreement, ridesharing agreements and other programmatic obligations are recorded as covenants that run with the land in an Agreement Affecting Real Property and burden the land and apply to all subsequent project owners.

Monitoring ridesharing agreements requires a substantial time commitment on the part of the developer or project owner and CRA. Performance monitoring occurs every 6 months for the first 5 years and annually thereafter. The developer or owner reports on financial records of ridesharing incentive programs, surveys employees, and reports to CRA on compliance with performance requirements. CRA reviews the report, works with developers on program improvements if performance requirements are not being met, and administers compliance measures outlined in the foregoing Item 5 if performance is below requirements. This approach is feasible because of the limited geographic scope in which CRA conducts detailed planning and implementation activities. In addition, CRA will conduct an areawide survey of downtown employees on a periodic basis to monitor trends and refine subsequent TSM requirements.

RESPONSE OF DEVELOPERS

Developers have responded to the program collectively through a private-sector committee on CBD transportation established by Mayor Bradley and individually through development project review. Reactions at both levels are discussed.

The Mayor's Blue Ribbon Committee, comprised of 27 major development interests and community leaders, reviewed CRA's ridesharing program. This committee endorsed the concept of mandatory ridesharing programs for new development. They recommended that new development achieve 10 percent improvement over current levels of ridesharing for comparable buildings in the relevant area. This requirement is comparable to the 60 percent requirement in the CRA program.

During the course of committee deliberations, the following concerns and recommendations were expressed to the mayor and presented to city council members:

- Recognition of the need for private and public sectors to jointly address transportation access to the CBD through transportation system management and transit improvement programs,
- The need to treat projects equitably,
- A challenge to government agencies to match the private sector's performance and commitment to ridesharing,
- Encouragement of existing employers to participate in ridesharing programs, and
- Maintenance of flexibility in the methods of complying with ridesharing requirements.

The Blue Ribbon Committee's final position in support of the program was preceded by considerable discussion concerning issues such as the appropriateness of imposing the program on developers instead of on employers, the extent of ridesharing improvement to which developers thought they could commit, and the general issue of developing programs that attempt to induce shifts in commuter transportation modes instead of supplying additional roadway capacity. Concerns in these areas were addressed through numerous discussions at subcommittee meetings.

The staff of many public transportation agencies played an educational role, informing the Blue Ribbon Committee members about the extent of the problem facing downtown Los Angeles and stressing the potential of ridesharing as a key component of the solution. Providing examples of successful programs was helpful in illustrating the different ways in which programs could be implemented, stressing the potential cost savings of replacing drive-alone parking subsidies with extensive incentives to rideshare. In this regard, illustrating the extent of current subsidies became important because parking prices in new developments in downtown Los Angeles are commonly $150 per month. Finally, the near-term advantages of the ridesharing program for employers, such as improved access to the labor pool and reduced absenteeism and employee turnover, were presented.

The citywide political climate also influenced the committee's perceptions because the downtown community wished to play a leading role in addressing transportation and land use issues and in expressing their concerns to the city council.

Individual developers have responded to the program through the project review and approval process. Responses at the project level have varied. Some developers retained ridesharing consultants during project negotiations and offered counter proposals, whereas others relied primarily on their legal counsel to review legal implications. Often these discussions focused on CRA's assumptions and definitions as well as factors relating to registering the agreement on the title. In some cases, developers based their agreement to the ridesharing program on assurances that no subsequent comparable project would have less stringent ridesharing requirements. Because the concept of incorporating ridesharing provisions in urban development projects is so new, some developers believed that any problematic aspects would be resolved before the development projects were completed. Typical development projects require between 1 and 5 or more years lead time before the commencement of construction, so there is a time during which experience would be gained in developing and implementing development-related ridesharing programs.

Summarized next are overall responses to the program that emerged during meetings with individual developers:

1. Project location will affect the ability to meet requirements. Some parts of downtown Los Angeles are better served by transit than others. Accordingly, some projects must rely more heavily on carpool and vanpool ridesharing.

2. Project tenant mix will affect the ability to meet requirements. Developers of projects who expect to have higher numbers of small professional firms raised concerns about meeting the same targets as projects with large employers.

3. Flexibility among ridesharing modes is essential. Developers resisted attempts to prescribe the ridesharing mode or modes to be implemented in the program.

4. Alternatives to free vanpool compliance measures are necessary. Alternative compliance measures, which recognized the unique tenant and locational characteristics of the project, were proposed.

5. All projects should have similar requirements so that no project would be subject to perceived market risks.

CRA's staff response to the first two concerns has been to assist in the identification of ridesharing techniques that can be used in areas off major transit routes or in multitenant buildings. In addition, CRA will undertake a survey of the CBD work force in 1986 to examine variations in ridesharing behavior that can be attributed to locational and tenant mix variables. Few data are currently available on those variations and the effect they have on achieving a successful program.

Concerns about flexibility among ridesharing modes and the need for alternative compliance measures have been addressed through modifications of the original program. The core of the program is the ridesharing performance requirement, which can be achieved by a number of means. It is expected that a wide range of ridesharing incentive programs will be developed as project owners explore least-cost solutions to the transportation requirements of projects.

The last concern, equal treatment, has been addressed through "favored nations" clauses that give project owners assurance that subsequent comparable programs will not have substantially less stringent requirements. By addressing the concern over equitable treatment, these clauses have made possible the institutionalization of the program for new development.

CONCLUSIONS

Although the ridesharing requirement has been institutionalized in general terms, refinements are sometimes needed for developments that may involve some unique characteristics. Accordingly, all the agreements with developers have comparable requirements; however, in some cases they contain variations that reflect particular concerns that have been raised by the developer during project negotiations. The review of the details of each program with the developer provides a valuable dialogue about the nature of the ridesharing requirements and, in some instances, opportunities to incorporate provisions reflecting any unique characteristics of particular development projects.

The ridesharing agreements discussed in this paper will be implemented in projects that are currently under construction or are scheduled for construction in the next 5 years. Accordingly, the conclusions summarized here pertain to experience gained through the process of establishing requirements and achieving consensus on the extent of private-sector commitments rather than implementation experience. The processes outlined in this paper are applicable in urban centers that are now adopting ridesharing programs, or in those that are moving from voluntary approaches to commitments to ongoing monitoring and achievement of performance requirements.

Summarized next are some overall conclusions about the role of ridesharing as an urban transportation strategy.

1. Management-oriented transportation solutions are being recognized by the development community as a major part of long-term transportation solutions in dense urban areas. Decreases in funding available for capital improvements to transit and roadway systems have increased private-sector awareness of the need for other feasible cost-effective approaches to addressing future transportation needs.

2. Market trends favor increased ridesharing. Key among these factors are increases in parking prices, decreasing parking supply ratios, increasing time costs of congestion, and continued growth of development in activity centers.

3. The strongest attribute of ridesharing programs is that they can contribute to the continued growth of urban activity centers. The CRA program was tied to the issue of the continued growth of downtown Los Angeles as an economic and cultural center in the Pacific Rim. One of the first ridesharing agreements was part of a creative development project that had strong public benefits. These linkages place ridesharing programs in the context of a long-term vision of the future. Justifications for programs should be broader than concern about traffic congestion, air pollution, or energy conservation.

On the basis of recent experience in Los Angeles, it is likely that ridesharing programs implemented through similar development agreements will be more commonly used in urban centers. However, the process of establishing the type of program described in this paper rests on a number of factors. The experience in downtown Los Angeles suggests that the following considerations are important in establishing a program:

1. A perceived crisis helps to focus political and private-sector attention on the problem. A short program design and public review period enabled CRA to respond while the issue was in the forefront.

2. The ability to propose that ridesharing programs be an established component of development agreements is enhanced by the existence of a working relationship with the development community. The CRA program added an element to an existing development-planning process that was familiar to the development community.

3. A forum for private-sector involvement, separate from individual project review activities, is critical. In Los Angeles, the Blue Ribbon Committee provided an opportunity for CRA to directly communicate the rationale for the program and to illustrate how it could be implemented. This committee also afforded downtown leaders the opportunity to prepare an independent assessment of downtown's transportation problems and solutions.

4. Monitoring and compliance measures represent major time commitments for the public agency and the developer. Because of the long-term performance requirement and monitory effort, the development agreement approach outlined in this paper may be most appropriate for limited geographic areas.

Ridesharing represents a major component of the transportation future of downtown Los Angeles. The change in attitude toward management-oriented transportation strategies has been dramatic. Further improvements in ridesharing participation are expected as regional transit projects are implemented, as parking prices rise, and as the positive interactive effects of ridesharing programs currently being established manifest themselves.

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Part-Time Carpooling: A New Marketing Concept for Ridesharing

JESSE GLAZER, ANN KOVAL, and CAROL GERARD

ABSTRACT

The most common objection of solo drivers to carpooling is lack of flexibility. Part-time carpooling (two persons 2 days per week) appears to answer much of this objection. A demonstration project was undertaken to test the effectiveness of part-time carpooling, identify the nature of the market for this concept, and determine what elements contribute most to the success of this type of undertaking. Participants were asked to commit to a two-person carpool 2 days a week for 3 months. A total of 212 people registered, which indicated that the market size for part-time carpooling is approximately 5 percent of the drive-alone commuters at the demonstration site. Half of the registrants had had no previous carpooling experience, and there was a higher-than-normal spread in work schedules. Of the 212 registrants, 100 were matched in potential carpool groups, and 44 people formed new, part-time carpools. There was no ongoing matching support, which may explain in part the high attrition rate (75 percent in 8 months). This demonstration project indicates that part-time carpooling is a promising technique for reaching beyond the commuter market segments traditionally served by conventional ridesharing programs.

The most common and strongest objection voiced by solo drivers to ridesharing is lack of flexibility. Every ridesharing professional who has contact with commuters hears this objection more often than any other. Studies in Los Angeles (1) and elsewhere have found that the perception of the inflexibility of ridesharing is the single largest barrier to acceptance of the idea among solo-driver commuters.

This appears to be a major reason why fewer than one-third of all commuters who are offered free ridesharing information will even bother to apply for this service. It may also explain in large part why such a small percentage, typically 5 to 15 percent, of those who do apply for ridesharing matching services actually use that information to join or form a carpool (2).

If significant improvements are to be realized in the carpool placement rates that result from ridesharing efforts, something must be done to overcome this common objection of solo drivers. The potential for improved placement rates is enormous. If half of all commuters who voice this objection were to be won over by the part-time carpooling concept, the typical ridesharing placement rate would almost double.

This demonstration project was an attempt to directly and strongly respond to this objection by offering commuters a highly flexible ridesharing program--part-time carpooling. The organizers of this demonstration believed that promotion of this concept

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would correct the common misperception of the inflexibility of carpooling and thereby increase the percentages of solo drivers who adopt this ridesharing mode. The clearest way to test this belief was to conduct a demonstration of this new concept for marketing ridesharing and then evaluate the results.

The demonstration project was conducted at the El Segundo site of the Hughes Aircraft Company, Space and Communications Group (SCG). El Segundo, which is a high-density, suburban employment site, is located on the west side of the greater Los Angeles area immediately south of the Los Angeles International Airport. El Segundo contains both residential and high-density office development. Total employment in the El Segundo area is about 60,000 at present, and employment density is 20,690 employees per square mile. There are approximately 14 million square feet of occupied office space.

Office development is continuing, and concern about traffic impacts is relatively high among both residents and developers. The El Segundo Employer's Association (ESEA) was created, in large part, to address those concerns and to explore traffic-mitigation measures.

Approximately 6,500 employees of SCG are located in the main plant facility in El Segundo. Because SCG is an aerospace engineering and research facility, more than 82 percent of the employees have management/administration and professional/technical job descriptions. The remaining 18 percent of SCG employees may be classified in secretarial/clerical, service, and production job categories. This is a higher-than-average percentage of executive and professional employees, who are traditionally those with the greatest perceived needs for flexibility in commuting.

Before the demonstration project, roughly two-thirds of SCG employees drove to work alone. About 70 percent of SCG employees commuted less than 15 mi one way to work. Public transportation service is limited, as is the case in most suburban employment centers; 14 bus routes carry about 1.2 percent of the home-to-work trips of El Segundo employees. It should be noted that there are only two publicly funded express commuter bus trips into the city each day; all other service is local and generally not oriented toward providing commuter service to El Segundo.

When the demonstration project began, SCG had an active ridesharing program. The Commuter Services Office administered a fleet of 20 company-owned vans that were used for pools and provided route and schedule information and ticket sales for the Hughes-sponsored bus system that serves Hughes employees living within a 15-mi radius of the El Segundo plant. The Commuter Services Office also offers a carpool-matching service, bicycle information, public transportation (bus) route and schedule information and monthly pass sales, and information about private commuter bus operations serving the area.

The demonstration environment offered both the facilities needed to conduct such an experiment and circumstances that are not unlike those of many suburban employment centers. Thus the results should be reasonably reliable and transferrable to other locations.

DESCRIPTION OF THE PROJECT

Objectives

At the outset, this demonstration project had three major objectives. Listed in order of priority, they were to

1. Determine the effectiveness of the part-time carpooling concept for increasing carpool placement rates and, if possible, measure long-term attrition rates and the maintenance effort required to keep these carpools together;
2. Identify the nature of the market for part-time carpooling, especially in terms of the characteristics and attitudes of the "customers" (i.e., those who adopt the concept); and
3. Identify the elements that contributed most to the success of the project and are transferrable to replications elsewhere.

General Approach

A "part-time carpool" was defined as a two-person carpool operating 2 days per week for a 3-month trial period. Commuters would be asked to make only this minimum commitment. Of course, it was entirely permissible for carpools to exceed the minimum requirements. The idea was to promote a concept that offered maximum flexibility in order to overcome the initial objections of those who believed conventional carpooling was too inflexible. As will be seen later, some of these minimums were voluntarily exceeded.

The target market was defined as commuters with strong needs for flexibility, especially in trip chaining but also with regard to schedules. ("Trip chaining" refers to the common practice of making several trips in sequence; for example, going from work to the grocery store to home.) Special needs must be known at least 1 day in advance so that carpool arrangements can be altered if necessary.

Compatibility of social factors must also be taken into account, as is true with other forms of carpooling. The demonstration would include personalized matching for at least some of the applicants so as to take into account the many subjective factors that can affect the viability of a carpool arrangement.

CHRONOLOGY OF EVENTS

The project officially began in October 1982, but external factors did not permit activities to begin until February 1983. The project concluded in September 1984. A brief summary of major project actions follows. Further details about these activities are contained in the Project Status Reports, available from ESEA.

- February 1983: First project meeting. Theme development discussed. Idea of "twofers" (two people ridesharing 2 days a week) arose. Concepts and functions of posters discussed. It was decided that two teaser posters would be used throughout the plant to arouse curiosity followed by a regular poster announcing the program. Using paycheck stuffers and prizes to attract participants discussed.
- April 1983: Concepts developed for posters reviewed. Twofers concept chosen.
- May 1983: Artwork for two teaser posters and announcement poster approved. Teaser poster said "the twofers are coming" and "the twofers are coming/you two can make a difference." The announcement poster explained the project. Discussion of paycheck stuffers, "Do's and Don't's" list for participants, card thanking participants for interest, and free lunch. Development of artwork for paycheck stuffer begun.

Decision made to provide free lunch, as get-acquainted meeting, as prize to all matched participants and to hold a drawing (for participating matched employees) for dinner for two at a restaurant of the winner's choice ($100 limit). Lunches provided by Hughes SCG at facility cafeteria, dinner provided from project funds.

• June 1983: Approval of artwork for paycheck stuffer, Do's and Don't's list, participant interest cards, and lunch tickets. Schedule set for delivery of materials. Costs: graphic artist, $1,322 and printing of posters and paycheck stuffers, $1,904.

• July 1983: Distribution of teaser posters with assistance of 50 Commuter Services Representatives in divisions of SCG. First teaser poster displayed for 1 1/2 weeks. Second teaser poster displayed for 1 week immediately following first poster. Announcement poster displayed immediately following second teaser poster. Article in SCG newspaper explaining twofers program and paycheck stuffer and including registration form. Personalized matching stressed in paycheck stuffer; prizes also mentioned.

• August 1983: Registration forms received (212 in first 3 weeks). Each registrant was immediately sent a follow-up card explaining matching process and delay required for all registrations to be received.

• September 1983: Matching performed initially ignoring work schedule, which was not requested on registration form. Program applicants found to have more widely varying work schedules than had been thought to be the case for the entire work force.

Personalized matching begun with follow-up telephone calls to each registrant to obtain further information and to distribute names of prospective partners. Costs for hand matching and telephone follow-up survey: $1,398 (approximately 198 person-hours).

When a final match had been arranged, participants were contacted and the complete program was explained. Participants were asked to make a commitment to form a two-person carpool 2 days a week for 3 months. Follow-up correspondence was sent, including restatement of required commitment, name and telephone number of partner, ticket for get-acquainted lunch, "Twofers Do's and Don't's" commuting tips, and information on drawing for free dinner.

Get-acquainted lunches at SCG cafeteria (lunch tickets required both partners to appear together). Cost: $226 (borne by Hughes SCG).

• October 1983: Winner of free dinner drawn randomly from registrants. Winner's carpooling status verified before presentation of gift certificate for $100 at restaurant of his choice.

• May 1984: Second survey conducted to determine continued participation of program poolers and long-term effects on attitudes. Survey results tabulated.

• September 1984: Final report written. Project completed.

EVALUATION OF RESULTS

In this section the findings of the project are presented. In the first subsection, the tangible and quantitative results of the demonstration project are presented. The second and third subsections are about the results of the two surveys of participants, and both quantifiable results (e.g., carpool formation rates) and subjective findings (e.g., attitudes) are presented.

Matching Statistics

Of the 212 program registrants, 100 were matched and 112 were not. Because the small data base limited matching opportunities, several sources were used for matching, including the registrant file, Commuter Computer (the areawide ridesharing agency), and personal contacts.

Among the 100 people who were matched, 49 potential carpool groupings were identified. (Two of these had three people.)

Of the 112 registrants who were not matched, 40 lost interest between the time they filled out the form and the time the matching was done. Matches were not available for the remaining 72 registrants; or they were not reachable by telephone, had moved, were already carpooling, or just filled out the survey for the prizes.

There were several reasons why registrants who were still interested and reachable were not matchable. Some people lived close to work and wanted carpool partners who also lived close. Those who lived farther from work were more flexible on proximity, but matches were often not available. Differing work schedules and lack of flextime often precluded matching, even though proximity was good. There were a few instances in which work location was a problem because a small subset of SCG employees works at a building that is about 1 mi from the main building.

The small size of the matching universe proved to be a significant limitation on the matching opportunities available to project registrants. This problem may be avoidable in the future with larger programs. There were other problems, such as people losing interest and people applying only for the prizes, that are not so easily avoidable.

Results of Initial Survey

The initial survey was performed immediately after the matching was completed in September 1983. This survey provided a picture of the registrants' commuting patterns and attitudes at the beginning of the part-time carpooling program. A complete tabulation of the results of this survey is presented in the Appendix. A summary and an interpretation of the salient findings follow (recall that 100 registrants were matched and 112 were not).

• Exactly half of those who were matched commuted less than 10 mi (one way) to work in less than 30 min. The trip lengths of those who were not matched were somewhat longer in both distance and time.

• Only 3 percent of the matched registrants were commuting in a mode other than automobile at the time they registered, whereas 12 percent of the nonmatched registrants were doing so. The latter group included two vanpoolers, one bus rider, and five bicyclists.

• Half of the matched registrants and 60 percent of the nonmatched registrants had had no previous ridesharing experience. This appears to be a surprisingly high percentage, but it might be a result of the twofers program appealing to those whose minds had previously been closed to ridesharing because of perceived inflexibility. The overwhelming majority of those who had had previous ridesharing experience had had positive experiences.

• Of those who had had no previous ridesharing experience who cited a reason for not trying ridesharing, about one-quarter gave reasons that related to flexibility. This appears to conflict with the results of the previous question, and the reason is not clear.

• There was substantial variability in work hours among registrants, and nonmatched people had greater variability than matched people. (This is a cause not an effect.)

• About three-quarters of all registrants can be classified as executive or professional. This was more often the case for the nonmatched than for the matched and is consistent with the prevailing wisdom among ridesharing practitioners: executive and professional people are less likely to accept ridesharing than are secretarial and clerical staff.

• The nonmatched group is slightly older than the matched group. This may be an effect of job classification rather than a reason for unmatchability.

• An overwhelming majority of all registrants preferred to pool with nonsmokers. There are no similar statistics from the general population, but this appears to be a very high percentage. If this percentage is, indeed, high, it might be a result of the twofer program's appeal to those who wished personalized matching attention, which always includes factors such as smoking preferences.

• An overwhelming majority of both matched and nonmatched registrants said that they were motivated to try the twofer program because they preferred part-time carpooling.

• The paycheck stuffer appears to have been the most effective (most remembered) promotional technique. Perhaps there is some complex psychological explanation for this finding--something to do with positive feelings associated with anything accompanying a paycheck. Another plausible explanation is that people pay more attention to their paycheck than to other things.

RESULTS OF SECOND SURVEY

The second survey was performed in May 1984, approximately 8 months after the matching was completed. The purpose of the second survey was to determine the program participants' long-term commuting patterns and attitudes after the initial effects of the promotion had passed.

A complete tabulation of the results of the second survey is presented in the Appendix. A summary and an interpretation of the major findings are presented here. This survey was directed only to the 100 registrants who were matched, that is, who received names of potential part-time carpool partners. This second survey was performed by telephone during a 4-week period beginning on May 14 by a Hughes Aircraft employee who spent about 55 person-hours telephoning and tabulating data. Of the 100 persons called, 94 were reached and 6 were unreachable. All results pertain to the group of 94 persons who were reached.

• All 94 participants reached remembered the twofer program 8 months after the promotional efforts ended.

• Slightly less than half (44) said they began carpooling as a result of the twofer program, and slightly more than half (50) did not begin carpooling as a result of the program.

• Of the 50 who did not begin carpooling as a result of the program, one-third cited reasons of schedule incompatibility (27 percent) or home location too far away (6 percent). The remaining two-thirds of the 94 people gave a wide variety of reasons that exhibited no discernible patterns.

• Only 16 percent of the 50 noncarpoolers had a negative attitude toward carpooling. This percentage is almost identical to the 18 percent of the 100 matched registrants in the original survey. Although these two groups are not strictly comparable, there is not an obvious change of attitude. (Further analysis of the data could establish comparable groups.)

• Twenty-two percent of the 50 noncarpoolers did not contact their prospective carpool partners.

• Of the 44 people who did begin carpooling as a result of the twofers program, 8 people (18 percent) were still carpooling with their original partner at the 8-month mark and 82 percent were no longer carpooling or were carpooling but not with their original partner. This is a much higher attrition rate than is typical for conventional carpool-matching programs, for which the average duration of a person in a carpool is roughly 2 years (1).

This high attrition rate could be the result of the target market consisting of people whose flexibility needs make them harder to please, or it could simply be because two-person, part-time carpools are inherently less stable than conventional carpool arrangements. It is interesting to note that 89 percent of those who discontinued carpooling had carpooled for less than the promised 3 months.

The attrition rate is of some concern because it indicates that maintenance efforts for part-time carpooling will be considerably greater than for conventional carpool programs. The ongoing maintenance effort would likely include follow-up calls to help resolve carpoolers' problems, to find new partners when a carpool dissolves, and so forth.

• Further examination of the reasons why 36 people discontinued carpooling revealed that almost half (43 percent) stopped carpooling because schedule conflicts arose. Another 45 percent cited external reasons such as "personal problems," "partner quit company," "partner retired," and "partner transferred." Fewer than 12 percent cited reasons that indicated objection to the concept of part-time carpooling (e.g., "inconvenient," "had to wait for another person," "carpooling too restrictive"). This indicates that a strong maintenance effort could have sustained up to 88 percent of the carpools that ended.

• Further examination of attitudes of those who discontinued pooling revealed that 53 percent claimed that they "plan to resume part-time carpooling," and another 14 percent said maybe. This indicated strong approval of the concept and is consistent with the observation that most people discontinued part-time carpooling for reasons that were unrelated to the basic concept.

• Perhaps the most interesting and puzzling finding of this demonstration is that all eight of the persons still carpooling said that they are carpooling 4 or 5 days per week. In dramatic contrast, of those who are no longer carpooling only 28 percent were carpooling 4 or 5 days per week. There is a whole host of possible explanations for this curious result, but they are all speculative.

• The trip length for those eight persons still carpooling was quite long--26 mi average, one way--compared with the 19-mi average trip length of all who were matched. Perhaps the greater costs associated with the longer trip length contribute to carpool longevity. However, the sample of eight poolers is too small to allow firm conclusions to be drawn.

• The great majority of those who began to carpool met their carpool partners each morning at their respective homes.

• The distance between home locations differed dramatically between those still carpooling and those no longer carpooling. More than three-quarters of the latter group were separated by 1 mi or less, whereas only one-quarter of those still carpooling lived within 1 mi of their carpool partner's home. This is exactly the opposite of what would normally be expected.

However, roughly two-thirds of both groups said that they did not have to travel extra mileage for the carpool. Apparently, those who are still carpooling have partners who live along the route to work. This is illogical because more than 90 percent of the carpoolers said they alternated driving, and both carpool partners cannot be along the other's route to work. Two possible explanations are that most respondents did not perceive less than 3 mi as constituting "extra mileage" or that the farther partner always drove to the meeting point.

• Roughly one-half of all respondents cited some form of cost savings as the major benefit or advantage of part-time carpooling. Other categories of responses (altruism, reduced driving hassle, etc.) were much smaller and without a consistent pattern across the two groups.

• The great majority of both groups said that their feelings about carpooling had not changed as a result of trying the twofers program. Among the relatively small number of people whose feelings did change, there was no clear pattern in the responses to the question "How have your feelings changed?"

CONCLUSIONS AND RECOMMENDATIONS

Conclusions

From the outset, this demonstration project was targeted directly to those commuters who have not been attracted to conventional ridesharing arrangements. These are people with strong needs for commuting flexibility and also, apparently, for personal attention during matching. This group of commuters is normally outside the target market of traditional carpooling programs.

Of the 6,500 persons at the demonstration site who were exposed to some form of promotion, 212 elected to register. Because about 4,400 of those 6,500 were driving alone to work, the 212 applicants represent about 5 percent of the solo drivers at the site. Thus it appears that the typical market size for part-time carpooling is approximately 5 percent of the drive-alone commuters.

On the basis of preliminary evidence, the paycheck stuffer appears to be the most effective promotional technique. This does not imply, however, that other promotional techniques should not be used. It simply means that this is the technique that people most remembered.

There is a strong indication from this demonstration that the 212 registrants were indeed harder to please than the typical carpool program applicant. Their work hours were spread over a wider range compared with those of all employees on site. They exhibited some special needs, such as a very high percentage of nonsmoking preferences. This target market for part-time carpooling appears to contain an abnormally high percentage of "tough cases."

Only 100 of the 212 registrants were matched into potential carpool groupings. Of the 112 who were not, some had no matches available, some had moved or changed job locations, and some had lost interest after registering. Matching proved to be quite difficult because the small size of the data base produced limited matching opportunities.

Of the 100 who were matched, 44 persons actually began carpooling with their designated partner. This represents a placement rate of 21 percent (44/212), which is high compared with traditional carpool programs but in the normal range for personalized matching programs. Given that this market is tougher than the traditional carpool market, this high placement rate is encouraging.

Because of the hard-to-please nature of the commuters in this target market, it appears that personalized matching attention is important to the success of a part-time carpooling promotional effort. It is likely that such a high placement rate would not be achievable without personalized matching.

The high attrition rate (75 percent dropout in 8 months) was disturbing, but it should not come as a surprise. After all, these are the "tough cases" with special needs for flexibility and social compatibility and with high schedule variability.

The most curious conclusion, however, was that all eight of the persons remaining in carpools at the end of the project were carpooling 4 or 5 days per week. Strong conclusions should not be drawn from this because only four carpools are represented and this is a statistically unreliable sample. Even so, it appears that there is something to be learned from the fact that there were no 2-day carpools in operation at the end of the demonstration. Many explanations are possible, of course. One explanation is that, when their needs for personal attention and flexible arrangements are met, these particular commuters find that their commuting patterns are rather stable after all. Perhaps it is all a matter of perception.

Recommendations

Based on the results of this demonstration, it can be said that the part-time carpooling concept is a viable means of reaching a new segment of the solo-driver commuting market that is not generally reached by traditional carpooling programs.

Much was learned from this first effort at promoting this new concept. The results were encouraging enough to suggest that the project should be replicated elsewhere, with improvements based on what was learned from this demonstration. Several suggestions for such future efforts follow.

1. The special needs of this market segment indicate a clear need for personalized matching procedures. These procedures are much more labor intensive than the conventional matching process (distribution of printed match lists), but this higher level of investment appears to produce a higher placement rate. Future projects of this type, which may not have the unavoidable inefficiencies of a demonstration project, should attempt to measure the extent to which the higher placement rate justifies the higher level of investment in matching.
2. The high attrition rate demonstrates clearly that a part-time carpooling project will require a strong, ongoing maintenance effort to keep the carpools operating. (This type of maintenance effort would typically include follow-up calls to help resolve carpool problems and to help find new partners when carpools break up.) Such a maintenance effort was not part of this demonstration, and the effects are clear.
3. Future projects should try to screen out cheaters. Although this was not a big problem, there were a small number of people who were attracted by the prizes and registered even though they were already carpooling or were not really interested. The ground rules should be made clear to all registrants.
4. Future part-time carpooling efforts should attempt to operate on a larger scale to produce a larger base of registrants. The 212 registrants in this demonstration produced very limited matching opportunities, which made matching very difficult and left a sizable number of interested registrants with no available matches.

In summary, part-time carpooling is a promising technique for reaching beyond the commuter market segments traditionally served by conventional ridesharing programs. This market segment has unique needs, and the per capita level of effort required to satisfy this market segment is relatively high. However, as ridesharing programs begin to saturate their traditional market segments--as some already have--the part-time carpooling concept holds promise as a way of expanding into a new market and continuing to increase the effectiveness of ridesharing programs.

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The Space and Communications Group of Hughes Aircraft Company served as the demonstration site. Carol Gerard, Commuter Services Administrator for SCG, was in charge of all ridesharing activities including all project activities. Trish Rundie, of the SCG Presentation and Graphics Department, assisted with development of printed materials.

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APPENDIX

Initial Matching Survey Statistics

TABLE 1 Distance from Home to Work (one way)

Distance (mi)	Matched No.	Matched %	Nonmatched No.	Nonmatched %	Total No.	Total %
Less than 5	8	8.0	5	4.5	13	6.1
5-9	42	42.0	32	28.6	74	34.9
10-19	28	28.0	35	31.2	63	29.7
20-29	13	13.0	20	17.9	33	15.6
30-39	3	3.0	12	10.7	15	7.1
40 and more	6	6.0	8	7.1	14	6.6
Total	100	100.0	112	100.0	212	100.0

TABLE 2 Time to Commute (one way)

Minutes	Matched No.	Matched %	Nonmatched No.	Nonmatched %	Total No.	Total %
Less than 10	7	7.0	0	0.0	7	3.3
10-19	9	9.0	8	7.1	17	8.0
20-29	34	34.0	27	24.1	61	28.8
30-44	23	23.0	37	33.1	60	28.3
45-59	15	15.0	22	19.6	37	17.5
60 or more	12	12.0	18	16.1	30	14.1
Total	100	100.0	112	100.0	212	100.0

TABLE 3 Current Mode of Commute

	Matched No.	Matched %	Nonmatched No.	Nonmatched %	Total No.	Total %
Automobile	97	97.0	99	88.4	196	92.4
Bicycle	1	1.0	5	4.5	6	2.8
Bus	1	1.0	1	0.9	2	1.0
Motorcycle	1	1.0	3	2.6	4	1.9
Truck			2	1.8	2	1.0
Vanpool	—	—	2	1.8	2	1.0
Total	100	100.0	112	100.0	212	100.0

TABLE 4 Previous Positive or Negative Ridesharing Experience

	Matched No.	Matched %	Nonmatched No.	Nonmatched %	Total No.	Total %
Yes						
Positive	41	82.0	46	88.5	87	85.3
Negative	9	18.0	6	11.5	15	14.7
Subtotal	50	50.0	52	46.4	102	48.1
No	50	50.0	60	53.6	110	51.9
Total	100	100.0	112	100.0	212	100.0

TABLE 5 Reasons for Not Having Tried Ridesharing

	No. Matched	No. Nonmatched	Total
Unable to commit to 5 days	3	0	3
Children to school or sitter	1	0	1
Work schedule inflexible	1	6	7
Frequent company business	2	0	2
Required meeting attendance	0	1	1
Frequent overtime	0	1	1
Attends school	1	0	1
Lack of interest	4	3	7
Small car	1	0	1
Carpooling inconvenient	0	3	3
Prefer to drive self	4	1	5
Needs car for job	0	1	1
Has car problems	0	1	1
Likes having car handy	0	1	1
Short distance from home	5	2	7
New to company	7	2	9
Unable to find match	5	7	12
Not interested in 5-day carpool	1	0	1
Total	35	29	64

TABLE 6 Scheduled Hours of Work

Hours	Matched No.	Matched %	Nonmatched No.	Nonmatched %	Total No.	Total %
a.m. to p.m.						
6:00-3:00	2	2.0	3	2.7	5	2.4
6:30-3:00			5	4.5	5	2.4
6:45-3:15			8	7.1	8	3.8
7:00-3:30			2	1.8	2	0.9
7:00-4:00	18	18.0	23	20.5	41	19.3
7:00-6:00			2	1.8	2	0.9
7:30-4:30	6	6.0	10	8.9	16	7.5
7:45-4:45	2	2.0			2	0.9
8:00-5:00	26	26.0	14	12.5	40	18.9
8:15-12:15			1	0.9	1	0.5
8:15-5:15	36	36.0	26	23.2	62	29.3
8:30-5:30	8	8.0	9	8.1	17	8.0
9:00-6:00	2	2.0	8	7.1	10	4.7
p.m. to a.m.						
3:30-12:00	—	—	1	0.9	1	0.5
Total	100	100.0	112	100.0	212	100.0

TABLE 7 Job Title

	Matched		Nonmatched		Total	
	No.	%	No.	%	No.	%
Management/ administration	34	34.0	40	35.7	74	34.9
Professional/ degreed	26	26.0	39	34.8	65	30.7
Technical	12	12.0	20	17.9	32	15.1
Secretarial/ clerical	14	14.0	4	3.6	18	8.5
Production	0	0.0	9	8.0	9	4.2
Unknown	14	14.0	0	0.0	14	6.6
Total	100	100.0	112	100.0	212	100.0

TABLE 8 Age of Respondents

	Matched		Nonmatched		Total	
Years	No.	%	No.	%	No.	%
Under 20	0	0.0	0	0.0	0	0.0
20–29	29	29.0	23	20.5	52	24.5
30–39	12	12.0	21	18.8	33	15.6
40–49	21	21.0	36	32.1	57	26.9
50 or more	15	15.0	32	28.6	47	22.2
Unknown	23	23.0	0	0.0	23	10.8
Total	100	100.0	112	100.0	212	100.0

TABLE 9 Sex of Respondents

	Matched		Nonmatched		Total	
	No.	%	No.	%	No.	%
Female	43	43.0	38	33.9	81	38.2
Male	57	57.0	74	66.1	131	61.8
Total	100	100.0	112	100.0	212	100.0

TABLE 10 Smoking Preference

	Matched		Nonmatched		Total	
	No.	%	No.	%	No.	%
Smoker	17	17.0	19	17.0	36	17.0
Nonsmoker	83	83.0	93	83.0	176	83.0
Total	100	100.0	112	100.0	212	100.0

TABLE 11 Motivation for Participation

	No. Matched	No. Nonmatched	Total
Prefer 2 days	42	51	93
More flexible	2	0	2
Not locked into 5 days	0	2	2
Two days will fit schedule	1	4	5
Vanpool not as flexible	1	0	1
Works overtime	0	1	1
Works unusual hours	0	2	2
Unable to find 5-day carpool	0	1	1
Cost saving	6	6	12
Free lunch	1	0	1
Save company parking	0	1	1
Everyone else is doing it	1	0	1
Ecological	2	1	3
New idea, willing to try	2	0	2
Management asked them to	0	3	3
Liked advertising	1	4	5
Saw notice	6	0	6
Will reduce traffic	2	0	2

TABLE 12 Reasons for Willingness To Try Carpooling Now

	No. Matched	No. Nonmatched	Total
Just moved	1	0	1
New to company	2	0	2
Lost carpool partner	2	0	2
Never had opportunity	0	2	2
Look into any type of carpooling	0	4	4
No luck trying to find carpool	0	2	2
Tired of driving	1	0	1
Believes in carpooling	2	3	5
Twofer allows freedom	1	1	2
Will allow for school	3	5	8
Hoping it will lead to 5 days	1	3	4
Goes to doctor 1 day/week	0	1	1
In carpool, looking for more riders	0	1	1
Has car problems	3	0	3
Doesn't like to ride bus	1	0	1
Husband retired, now needs ride	1	0	1

TABLE 13 Best Marketing Strategies

	Matched		Nonmatched		Total	
	No.	%	No.	%	No.	%
Teaser poster 1	26	17.6	46	19.7	72	18.9
Teaser poster 2	21	14.2	36	15.5	57	15.0
Announcement poster	13	8.8	22	9.4	35	9.1
Paycheck stuffer	68	45.9	89	38.2	157	41.2
Company newspaper article	6	4.0	16	6.9	22	5.8
Other flyer[a]	13	8.8	24	10.3	37	9.7
Orientation package[b]	1	0.7	0	—	1	0.3
Total[c]	148	100.0	233	100.0	381	100.0

[a]No flyer was included in the promotional material to be posted or distributed.
[b]The orientation package given to new hires did not include any twofer promotion material; it contained only general commuter services information.
[c]Does not match total of study participants because some individuals gave more than one response.

Follow-Up Survey Statistics

TABLE 14 People Not Contacted

Reason	No.
Left company	3
On vacation	2
Died	1
Total	6

TABLE 15 Answers to "Do You Recall the Twofers Program?"

	No.	%
Yes	94	94.0
No	0	0.0
Other (unable to contact)	6	6.0
	100	100.0

TABLE 16 Answers to "Did You Begin Carpooling as a Result of the Twofers Program?"

	No.	%
Yes	44	44.0
No	50	50.0
Other (unable to contact)	6	6.0
Total	100	100.0

TABLE 17 Reasons for Not Participating

	No.	%
Partner terminally ill	1	1.7
Never got in touch with partner	4	6.7
Unable to contact partner–bad telephone	1	1.7
Decided that hours not similar enough	16	27.0
Set up carpool only for emergency purposes	3	5.1
Wanted to drive alone	3	5.1
Wanted to have a car at noon	1	1.7
Partner lived too far out of the way	4	6.7
Take kids to school in morning	2	3.4
Ride bike to work	1	1.7
Frequently changed work locations	1	1.7
Jury duty	2	3.4
Wanted to ride more times per week	2	3.4
Was attending school	2	3.4
Partner not interested	3	5.1
Didn't live far enough away from work	2	3.4
Carpooled with someone else	2	3.4
Always had to drive	2	3.4
Never heard about it	1	1.7
Never set it up	2	3.4
Wife or husband was jealous	2	3.4
Moved	1	1.7
"I don't remember"	1	1.7
Total	59[a]	100.0

[a]Does not equal total of study participants because some individuals gave more than one response.

TABLE 18 Attitude Toward Carpooling of Those Not Participating

	No.	%
Positive	30	60.0
Undecided	12	24.0
Negative	8	16.0
Total	50	100.0

TABLE 19 How Partners of Those Not Participating Were Contacted

	No.	%
By telephone	19	38.0
In person	7	14.0
Unknown	13	26.0
Was not contacted	11	22.0
Total	50	100.0

TABLE 20 Answers to "Are You Still Carpooling?"

	No.	%
Yes	8	18.0
No	36	82.0
Total	44	100.0

TABLE 21 Answers to "Are or Were There Any Additional People in the Carpool?"

	Not Still Carpooling		Still Carpooling	
	No.	%	No.	%
Yes	2[a]	5.6	2[a]	25.0
No	34	94.4	6	75.0
Total	36	100.0	8	100.0

[a]One additional person per carpool.

TABLE 22 Answers to "How Long Did You Carpool or Have You Carpooled?"

	Not Still Carpooling		Still Carpooling	
	No.	%	No.	%
1 week or less	3	8.3	0	0.0
> 1 week but < 1 month	9	25.0	0	0.0
1 month to < 3 months	13	36.1	0	0.0
3 months to < 6 months	8	2.3	0	0.0
6 to 9 months	3	8.3	8	100.0
Total	36	100.0	8	100.0

TABLE 23 Reasons That Carpools Ended

	No.	%
Personal problems	1	2.4
Found a more suitable partner	1	2.4
Partner just quit	3	7.1
Inconvenient	2	4.7
Schedule conflict arose	18	43.0
Not saving enough mileage to justify the hassles	2	4.7
Had to wait for another person	1	2.4
Partner retired	1	2.4
Started school	3	7.1
Didn't feel comfortable with partner's driving	1	2.4
Moved	3	7.1
Used more gas taking partner's children to school	1	2.4
Partner's vehicle unsafe	1	2.4
Partner left company	1	2.4
Decided that carpooling was too restrictive	1	2.4
Partner transferred work location	2	4.7
Total	42[a]	100.0

[a]Does not equal number of participants because some individuals gave more than one response.

TABLE 24 Answers to "Do You Plan to Resume Part-Time Carpooling?"

	No.	%
Yes	19	52.8
No	12	33.3
Possibly	3	8.3
If the situation is right	2	5.6
Total	36	100.0

TABLE 25 Answers to "How Many Days a Week Are or Were You Carpooling?"

	Not Still Carpooling		Still Carpooling	
Days	No.	%	No.	%
1	0	0.0	0	0.0
2	15	41.7	0	0.0
3	11	30.5	0	0.0
4	8	22.2	4	50.0
5	2	5.6	4	50.0
Total	36	100.0	8	100.0

TABLE 26 Answers to "Where Did or Do You Meet Your Partner?"

	Not Still Carpooling		Still Carpooling	
	No	%	No.	%
Respective homes	28	77.8	8	100.0
Street corner near respective homes	8	22.2	0	0.0
Total	36	100.0	8	100.0

TABLE 27 Distance Between Home Locations

Miles	Not Still Carpooling No.	%	Still Carpooling No.	%
Less than 1/2	17	47.2	2	25.0
1/2 to 1	11	30.6	0	0.0
> 1 to 3	7	19.4	4	50.0
> 3 to 5	1	2.8	2	25.0
More than 5	0	0.0	0	0.0
Total	36	100.0	8	100.0

TABLE 28 Answers to "Do or Did You Have To Travel Extra Mileage for the Carpool?"

	Not Still Carpooling No.	%	Still Carpooling No.	%
Yes	9	25.0	3	37.5
No	27	75.0	5	62.5
Total	36	100.0	8	100.0

TABLE 29 Extra Miles Traveled in Carpool

Miles	Not Still Carpooling No.	%	Still Carpooling No.	%
Less than 2	4	44.5	1	33.3
2 to < 4	2	22.2	0	0.0
4 to < 6	2	22.2	2	66.7
6 or more	1	11.1	0	0.0
Total	9	100.0	3	100.0

TABLE 30 How Driving Is or Was Shared

	Not Still Carpooling No.	%	Still Carpooling No.	%
Alternate days	18	50.0	6	75.0
Alternate weeks	15	41.7	2	25.0
One driver	3[a]	8.3	0	0.0
Total	36	100.0	8	100.0

[a]No money was exchanged.

TABLE 31 Perceived Advantages to Part-Time Carpooling

	Not Still Carpooling No.	%	Still Carpooling No.	%
None	10	16.1	0	0.0
Save on gas	13	21.1	0	0.0
Save on wear and tear on car	7	11.3	1	6.7
Conservation	4	6.5	1	6.7
Not having to drive	5	8.1	3	20.0
Save money	1	1.6	0	0.0
Learned ways to get home faster	2	3.2	0	0.0
Cuts down on traffic	1	1.6	0	0.0
Allows flexibility for overtime	1	1.6	0	0.0
Didn't have car; provided transportation	1	1.6	0	0.0
Fewer parking hassles	2	3.2	1	6.7
Keeps one on schedule	1	1.6	1	6.7
More relaxed due to not having to drive	1	1.6	0	0.0
Saves time	2	3.2	0	0.0
Frees car for my family	1	1.6	1	6.7
Conversation	10	16.0	1	6.7
Economics	0	0.0	6	40.0
Total	62[a]	100.0	15[a]	100.2[b]

[a]Does not equal number of participants because some individuals gave more than one response.
[b]Total is greater than 100% because of rounding.

TABLE 32 Answers to "Have Your Feelings Toward Carpooling Changed Because of This Program?"

	Not Still Carpooling No.	%	Still Carpooling No.	%
No	27	75.0	7	87.5
Yes	9	25.0	1	12.5
Total	36	100.0	8	100.0

TABLE 33 Reasons for Negative Responses in Table 32

	Not Still Carpooling No.	%	Still Carpooling No.	%
It works out well with three people	0	0.0	1	12.5
Have always been positive about it	7	22.5	6	75.0
Carpooled before and liked it	0	0.0	1	12.5
Save gas, time, and money	3	9.7	0	0.0
Good to share company	1	3.2	0	0.0
I like to do it	0	0.0	0	0.0
Good in right situation, otherwise it is a hassle	1	3.2	0	0.0
If one lives close to work, there are inconveniences	2	6.5		
Twofer was a catalyst	1	3.2	0	0.0
Like it if it is flexible	1	3.2	0	0.0
Great if it fits your lifestyle	1	3.2	0	0.0
Gives one a chance to rest	1	3.2	0	0.0
Good idea	3	9.7	0	0.0
Favor it	2	6.5	0	0.0
If situation were different would do it	2	6.5	0	0.0
Partner must be able to handle it	1	3.2	0	0.0
Pain but worth it if live far away	2	6.5	0	0.0
Good because there is too much traffic	1	3.2	0	0.0
Have to make a commitment	1	3.2	0	0.0
Conservation	1	3.2	0	0.0
Total	31[a]	100.0	8[a]	100.0

[a]Total does not equal number of negative responses in Table 32 because some people gave more than one answer.

TABLE 34 Reasons for Affirmative Answers in Table 32

	Not Still Carpooling No.	%	Still Carpooling No.	%
Would not carpool if had a second car	0	0.0	1	50.0
Would not carpool if it were not economically advantageous	0	0.0	1	50.0
Thought there would be problems, but it is easier	1	5.6	0	0.0
Feel positive	2	11.1	0	0.0
Didn't like bus, but like carpooling	1	5.6	0	0.0
Skeptical at first, but like it now	3	16.7	0	0.0
Look at it more realistically now	2	11.1	0	0.0
Now know what it is all about	2	11.1	0	0.0
Stopped feeling guilty for not carpooling	1	5.6	0	0.0
More pro carpooling, before wouldn't even consider it	1	5.6	0	0.0
Saves money	1	5.6	0	0.0
Helps cut down traffic	1	5.6	0	0.0
It is bad if one has an irregular schedule	1	5.6	0	0.0
It is convenient	1	5.6	0	0.0
It helps save time	1	5.6	0	0.0
Total	18[a]	100.4[b]	2[a]	100.0

[a]Total does not equal number of affirmative responses in Table 32 because some people gave more than one answer.
[b]Total is not 100% because of rounding.

TABLE 35 Original Commuting Mode (information obtained from first survey)

Mode	Not Contacted No.	Not Contacted %	Nonparticipant No.	Nonparticipant %	Still Carpooling No.	Still Carpooling %	Not Still Carpooling No.	Not Still Carpooling %
Bus	0	0.0	0	0.0	0	0.0	1	2.8
Motorcycle	0	0.0	0	0.0	0	0.0	1	2.8
Bicycle	0	0.0	1	2.0	0	0.0	0	0.0
Commuter van	0	0.0	0	0.0	0	0.0	0	0.0
Truck	0	0.0	0	0.0	0	0.0	0	0.0
Automobile	6	100.0	49	98.0	8	100.0	34	94.4
Total	6	100.0	50	100.0	8	100.0	36	100.0

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Survey and Analysis of Vanpooling in Metropolitan Washington, D.C.

JON WILLIAMS

ABSTRACT

It is difficult to use traffic-counting programs in Washington, D.C., to accurately monitor vanpool occupancies because of the high speeds, high occupancies, and vision-restricting "privacy windows" of vans. A survey of vanpool operators was conducted to develop occupancy factors for traffic monitoring and also to collect other data of general interest. Because many of the vanpools in the Washington area are owner operated, a comprehensive survey of the entire population was not feasible through employers or third-party providers. Thus a license-plate survey technique was developed; it led to a mail-back survey that had a 57 percent response. A sample of the nonrespondents was contacted by telephone to correct for bias. Survey findings cover the following topics: number of vanpools, origins and destinations, occupancy rates, travel times and trip lengths, traffic assignment, collection-distribution characteristics, vehicle ownership, preferential treatment and parking, assistance from ridesharing agencies, and operators' concerns.

In the Spring of 1982 the Metropolitan Washington Council of Governments (COG) undertook a mail-back and telephone survey of operators of vanpools that had been spotted on major arterials in the morning peak period. The survey was conducted to develop average vanpool occupancy factors to be used in traffic volume and occupancy studies that are conducted by COG. Accurate monitoring of vanpools and their occupants is an important concern in the Washington, D.C., area because public agencies have implemented policies to encourage high-occupancy vehicle use in commuting, including restriction of certain highway lanes to carpools, vanpools, and buses. The immediate reason for the survey was the apparent rapid growth in vanpooling, coupled with difficulties in monitoring that result from high speeds, high occupancies, and dark passenger "privacy windows" of vans.

To perform such a survey and produce representative occupancy data, it was necessary to develop a method of sampling the total vanpool population. Many of the Washington, D.C., region's vanpools are known to be privately owned and operated, and these could not be located through employers or third-party vanpool providers. Thus the survey technique selected was license-plate monitoring in traffic, which led to a mail-back survey of vanpool operators. Because mail-back surveys are sometimes associated with nonrespondent bias, a telephone survey of a sample of the mail-back nonrespondents was also planned.

Although vehicle occupancies and traffic-count factors were the first concern of the study, it was

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recognized that the survey presented an exceptional opportunity to collect other data on vanpooling in Washington. Vanpool operators were therefore asked questions that explored such travel characteristics as route, trip distance, origin and destination, and parking cost. Inquiry was also made about some related topics: vehicle ownership, preferential treatment, assistance received from ridesharing agencies, and operators' concerns.

The occupancy factors developed from this survey have been previously documented in the 1983 Metro Core Cordon Count of Vehicle and Passenger Volumes (1). The purpose of this subsequent paper is to document the method and present and analyze the complete findings of the 1982 Washington vanpool survey.

SURVEY METHOD

The method was designed to survey a sample of the population of all vanpools in metropolitan Washington, D.C. The basic components of the method were

1. Identifying those links of the arterial highway system carrying the greatest concentration of vanpools;
2. Designing questionnaires for two surveys, the main mail-back and the follow-up nonrespondent;
3. Sending survey teams to selected highway links to record the license-plate numbers of vanpool-style vans, including vans with privacy windows that prohibited visual determination of occupancy;
4. Identifying addresses of van owners, using records of the Department of Motor Vehicles (Virginia), the Motor Vehicle Administration (Maryland), and mailing questionnaires to van owners;
5. Calling a sample of the mail-back survey nonrespondents to check and correct for nonrespondent bias; and
6. Reducing and analyzing data.

This process is detailed in the following subsections.

Site Selection

Highway links were selected for survey by a desk-top traffic assignment process that took into account vanpools for which origins and destinations were known. These vanpools and their trip ends were identified with assistance from third-party providers, van-leasing firms, and employers. The assignment technique was especially needed in Maryland because, in 1982, the vast majority of vanpools in Northern Virginia were known to be operating on the Shirley Highway high-occupancy vehicle lanes.

The technique was to identify the origin and destination for each known vanpool and, using professional judgment, to select the series of highway links most probably traveled by that van. An accounting system was devised to keep track of the links. When the process was completed, most of the known vanpool traffic was found to be concentrated on a small number of highway links, for part of their travel. Nine links in Maryland and three in Virginia (Table 1) were selected for survey.

A preliminary visit was made to each highway link, and survey station locations were identified. The criteria for locating stations were

1. Surveyor safety: there had to be a substantial barrier between the traffic and the surveyor and
2. Visibility: because much of the traffic to be monitored was traveling at high speeds, the surveyors needed to be as close as possible to the traffic to accurately read license plates.

Except for two sites, it was possible to locate surveyors close to the traffic flow without compromising safety. The exceptions were Stations M7 and M8 (Baltimore-Washington Parkway and US-50 in Maryland); monitoring of these was done with field glasses from an overpass.

Questionnaires

Mail-Back Survey

The questionnaire for the main (mail-back) survey was designed to address the original principal concern of the survey--development of factors for use in the COG's traffic-counting programs. Thus the first questions determined the surveyed van's occupancy and whether it had privacy windows. Following, in order, are the topics explored by the questionnaire:

- Occupancy,
- Privacy windows,
- Van ownership,
- Trip purpose,
- Parking fee,
- Preferential treatment at employment,
- Home origin,
- Assembly method,
- Work destination,
- Major highway links used,
- Total trip length (time and distance),
- Home-end circuity (time and distance),
- Assistance received from ridesharing agencies, and
- Issues of concern to vanpool operators.

The survey questionnaire was designed to reflect the date and highway link associated with the field

TABLE 1 Vanpool Survey Stations

State	Station No.	Facility	Location	Direction	Date Surveyed
Virginia	V1	George Washington Parkway	Abingdon Lane	Northbound	5/19/82
	V2	I-395 HOV lanes	Ridge Road	Northbound	5/18/82
	V3	George Washington Parkway	Spout Run Parkway	Southbound	5/18/82
Maryland	M1	I-270	North of MD-124	Southbound	5/21/82
	M2	I-270	Montrose Road	Northbound	5/21/82
	M3	I-270	Montrose Road	Southbound	5/21/82
	M4	I-495 (Beltway)	Connecticut Ave.	Westbound	5/20/82
	M5	16th Street	D.C. line	Southbound	5/18/82
	M6	Georgia Avenue	Thayer Street	Southbound	5/20/82
	M7	Baltimore-Washington Parkway	South of I-95	Southbound	5/20/82
	M8	US-50	East of I-95	Westbound	5/19/82
	M9	MD-5	MD-337	Northbound	5/19/82

work that identified the van. Using word-processing, questionnaires were custom-tailored for each survey site. The purpose of this was to determine actual van usage and occupancy on the survey date at the survey site. It was thought that more generalized survey approaches (i.e., "How many people are in your vanpool?" or "On a typical day, how many people ride in your vanpool?") might result in overestimation. Thus this questionnaire asked for van occupancy on a specific day at a specific place.

Nonrespondent Survey

This was a telephone survey; its concern was whether the van was operating as a vanpool and what its occupancy was. The occupancy question did not refer to the date on which the van was monitored because, by the time the nonrespondent survey was conducted, that would have been too far in the past for accurate memory. Instead, the respondent was asked for occupancy "The last time your van made this same trip in the morning."

Implementing the Mail-Back Survey

License-Plate Monitoring

Three teams of surveyors received training in reading license plates, using a typical high-speed road. Each team consisted of two persons, a spotter and a recorder. The spotter's job was to read and call out the license-plate number of any vanpool-style van that either had seven or more passengers or had privacy windows restricting determination of occupancy. The recorder's job was to accurately write down the license-plate number. Teams were also responsible for keeping tallies of vans the license plates of which could not be monitored. All monitoring work was completed in 4 days, May 18-21, 1982, for the 12 sites given in Table 1.

Mail-Out

Identification of van owners and distribution of questionnaires were handled differently for stations in Maryland and Virginia.

In Maryland, the Motor Vehicle Administration (MVA) agreed to allow COG staff on-line access to its registration records. License-plate data were therefore carried directly from the field to an MVA field office. There, van owners' names and addresses were manually transcribed and carried back to the COG offices where they were typed onto envelopes, and the questionnaires were mailed out, usually on the same day that monitoring took place.

In Virginia, the Department of Motor Vehicles (DMV) in Richmond required key-punching of the license-plate data to produce vehicle owner addresses. However, the DMV was also able to produce address labels for the mail-out. Thanks to excellent cooperation from DMV, and good courier work between Washington and Richmond, the turn-around time was minimal and all questionnaires were mailed within less than a week from the time of monitoring.

Implementing the Nonrespondent Survey

Any mail-back survey has the potential for nonrespondent bias (i.e., the survey respondents may have significantly different values than the nonrespondents for parameters that are being measured). A sample survey of nonrespondents was designed to check and correct for this possible bias. When the COG stopped receiving mail-back questionnaires, it was possible to compile a list of nonrespondents (199 in all). From this list a sample was randomly selected and stratified by each of the two home-origin states, Maryland and Virginia. Sample sizes were 37 for Maryland and 37 for Virginia, or 74 in all. The sample was roughly scaled to predict the percentage of the main survey nonrespondents who were owners of vans used as pools with an absolute error of estimate of ±0.07 at the 90 percent confidence interval.

Telephone numbers were obtained for the 74 nonrespondents from phone books and from listings of vanpoolers obtained from third-party leasing agencies. Two surveyors worked in both the daytime and evenings to contact as many of this second sample as possible. The surveyors succeeded in interviewing 67 of the 74. Six of these reported that they did not own vans, and were thus relegated to a "data error" category because they evidently represented an incorrectly read license plate in the field survey. Thus the final response was 61 out of 68, or a 90 percent response rate.

It was discovered that the percentage of vans in the vanpooling mode was significantly different for respondents to the mail-back survey.

Data Reduction

The procedures for data reduction for this survey were somewhat complex. This was, in part, because it could not be known until after the survey which portion of the sample was actually vanpools and, in part, because of the necessity of factoring in the results of the nonrespondent survey. Until a number of data reduction procedures were performed, there could be no estimate of the volume or occupancy of vanpools and no means of factoring the survey data by strata. These procedures are documented here in a general way.

A total of 463 questionnaires were mailed out, and 264 were returned--a response rate of 57 percent, which is high for a mail-back survey and considered adequate for analysis purposes. The surveyors were asked to note vanpool-style vans the license plates of which they could not read. These are lumped with vans carrying out-of-state tags, vans the questionnaires about which were returned by the post office as undeliverable, and respondents who claimed that they did not own a van (this was assumed to be license-plate reading error). There are 382 of these "other vans." Counting the 463 surveyed vans and the 382 "other vans," the survey population was 845 vans. It should be remembered that these were not all vanpools; they were a collection of vans that could be seen to have seven and more passengers along with a number of vanpool-style vans with privacy windows that restricted visibility into the passenger area of the van.

To calculate total vanpools and develop weights for the survey data, the following steps were necessary:

- Estimate how many nonrespondent vans were vanpools and
- Estimate how many unsurveyed vans were vanpools.

When this had been done, Table 2 was produced.

In Table 2, Row J, Total vanpools, is calculated by adding together E (Surveyed nonresponding owners of vanpool vans), H (Unsurveyed owners of vanpool vans), and I (Surveyed respondent owners of vanpool vans). The result yields an estimate for total vanpools at each site and for the region (667). This

TABLE 2 Calculation of Total Vanpools

	Item	Virginia Subtotal	Maryland Subtotal	Total
A	Mailed questionnaires	262	201	463
B	Returned questionnaires	155	109	264
C	Nonresponding van owners (A – B)	107	92	199
D	Nonresponse factor (from survey of nonrespondents)	0.77	0.60	
E	Nonresponding owners of vanpool vans (C x D)	82	55	137
F	Unsurveyed vans	258	124	382
G	Vans to vanpools factor	0.83	0.72	
H	Unsurveyed owners of vanpool vans (F x G)	214	90	304
I	Respondent owners of vanpool vans	136	90	226
J	Total vanpools (E + H + I)	432	235	667

estimate is discussed further in the section on findings.

All data in the section on findings have been weighted. The method for developing the weights was to divide vanpool population by respondents for each station. The purpose of the weighting procedure is to factor the sample data back to a proportionate estimate of the total vanpool population.

Discussion of Sampling Methods and Confidence Levels

Sampling Methods

For the main, mail-back survey, the vans to be surveyed were not selected by a purely random or systematic procedure. The surveyors were instructed to read all the appropriate van license plates, which they could see and record, at each of the 12 survey stations. Technically, this approach should be described as "haphazard" and could be associated with bias. Because the sample selected (463 vans) was more than 50 percent of the population (845 vans), this potential problem is thought to be minimal, with one exception. On busy facilities, the rate at which vans were sampled is known to be lower during the peak hour of travel than during the balance of the peak period. Thus vans traveling during the peak hour are somewhat underrepresented by the sample.

For the nonrespondent survey, the sample was selected by an automated random sampling procedure.

Confidence Limits

Considering the "vanpool occupancy" parameter, at the 90 percent confidence interval, the mail-back survey has a 0.19 bound on the error of the estimate. For the nonrespondent survey, the bound for vanpool occupancy is 0.55, also at the 90 percent confidence interval. Combining results for both surveys, the bound for occupancy is 0.24. Thus, 90 percent of the time, the estimate of occupancy, 11.7, will fall into a range of from 11.46 to 11.94.

FINDINGS

This section contains the findings of the survey. The following topics are explored:

- Number of pools,
- Origins and destinations,
- Occupancy rates,
- Travel times and trip lengths,
- Traffic assignment,
- Collection and distribution characteristics,
- Ownership,
- Preferential treatment and parking,
- Assistance from ridesharing agencies, and
- Pool operators' concerns.

All data have been weighted to the total estimated population.

Number of Vanpools

A basic output of this survey is an estimate of the number of vanpools operating in metropolitan Washington, D.C., in spring of 1982. This figure is 667 vanpools. As explained previously, this estimate is a sum of the unsurveyed vanpools, nonrespondent vanpools, and surveyed vanpools.

This total may be checked against another data source, the 1980 Census. In 1980 a 16 percent sample of the census questionnaires included questions on work travel (2). These questions included information on mode and vehicle occupancy. The total number of persons living in the Washington, D.C., standard metropolitan statistical area (SMSA) and traveling to work in a vehicle with seven or more occupants in 1980 was 6,828 (Census Tape STF4A). Assuming that these are vanpool occupants, and that the average vanpool membership is 13.8 persons (to be discussed later), an estimate of vanpools originating in the SMSA would be 6,828/13.8 = 495. This census-derived number is probably understated because the STF4A tape does not include person-trips that originate outside the Washington region and travel into the region for work. Moreover, the census was taken 2 years before the vanpool survey. On the basis of professional experience, it is judged that vanpooling in the Washington area increased substantially between 1980 and 1982. It would thus appear that the 1980 Census estimate, 495 vanpools, serves as a rough, order-of-magnitude verification of the survey estimate, 667 vanpools.

Origins and Destinations

The survey questionnaire asked for the vanpool's community of origin and employment area destination. Using these data, it is possible to geographically distribute vanpools by origin and destination. Destinations are compressed into two major categories: core (downtown) and noncore (elsewhere). Core destinations include downtown Washington and the Virginia employment areas, Rosslyn, Crystal City, and the Pentagon. Van origins are summarized by home state.

Table 3 gives vanpools cross-tabulated by home state and core or noncore destination. It can be seen that 64 percent (429) of all vanpools originate in Virginia. Moreover, the Virginia-originated vanpools are almost entirely oriented toward the core, whereas the Maryland pools are destined for both core and noncore locations.

Figure 1 shows all core-destined vanpools distributed by major travel corridor. Most of the core-

TABLE 3 Vanpools by State of Origin and Core or Noncore Destination

	Destination		
Origin	Core	Noncore	Total
Maryland	122	113	235
Virginia	425	4	429
West Virginia	—	3	3
Total	547	120	667

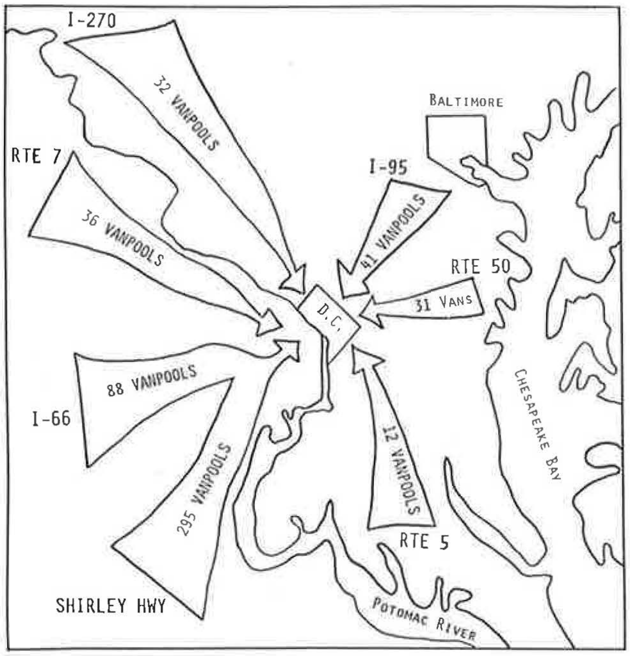

FIGURE 1 Vanpools destined for downtown employment area by travel corridor, Washington, D.C., 1982.

oriented vanpools travel in these seven corridors. The role played by the I-95 and I-395 Shirley Highway high-occupancy vehicle (HOV) lanes in promoting vanpooling is obvious, with 295 vanpools in that corridor. Considering home community, the highest concentrations of vanpool origins in the region are in Woodbridge and Lake Ridge (92 vanpools) and the contiguous Dale City (54 vanpools); both of these sites are in close geographic association with Shirley Highway. Many other vanpools benefit from the HOV lanes--the exact number will be investigated in the section on traffic assignment.

Core-destined vanpool passengers were disaggregated by destination employment district or area. Passengers, instead of vanpools, were selected for this procedure because it was discovered that a number of vanpools discharged in two or more different areas, a phenomenon that is discussed further in the section on collection and distribution characteristics. A total of 6,400 vanpool passengers were found to be destined for 14 distinct employment areas. Of the 14 areas, Southwest, Federal Triangle, and Farragut Square had the most disembarking passengers. Approximately 4,400 vanpoolers were traveling to these three employment areas, or almost 70 percent of the total destined for the core.

Occupancy Rates

An original aim of the vanpool survey was the production of occupancy factors to be used in converting raw field data. An important consideration in calculating these factors or rates was the hypothesis that survey nonrespondents would have different occupancy characteristics than respondents. It was for this reason that the sample survey of nonrespondents was conducted. This survey showed that

1. A lower percentage of nonrespondent than respondent van owners had vanpools and
2. The nonrespondent vanpools had a lower occupancy rate than did the respondent vanpools.

A weight-averaging technique was used to compute the average vanpool occupancies for vanpools monitored in Maryland, Virginia, and the region. The technique blends results from the main survey with those from the nonrespondent survey. Resulting occupancies are

- Maryland average vanpool occupancy = 12.2,
- Virginia average vanpool occupancy = 11.4, and
- Regional average vanpool occupancy = 11.7.

These occupancies reflect travel on an average day--the day vanpools were monitored in the field. It is important to distinguish between vanpool average occupancy and membership, which would include all persons who have that vanpool as their principal means of transport to work. Most prior surveys apparently have produced data on average membership. Average occupancy would differ from this by excluding people who did not travel on the survey date. However, the two measures can be made roughly equal. The 1968 Home Interview Survey conducted in the Washington area showed that, on the average workday, 85 percent of employed persons travel to work (3). The following calculations convert vanpool average occupancies to membership:

	Avg Occupancy		Avg Membership
Maryland	12.2/0.85	=	14.4
Virginia	11.4/0.85	=	13.4
Region	11.7/0.85	=	13.8

It is interesting that, after this adjustment, the average Maryland pool membership, 14.4, is close to the 14.2 figure reported in the 1980 Maryland vanpool survey (4).

An attempt was made to associate occupancies with trip length, and travel time, and parking cost. This was done for both core and total destinations, using appropriate measures of association. No strong correlation was discovered between occupancy and these variables.

Travel Times and Trip Lengths

Data provided by the survey respondents were used for travel times and trip lengths. No independent verification was attempted.

Figure 2 shows a frequency distribution of travel distances for all vanpools. The histogr shows that most of the pools fall in the 20- to 50-mi one-way travel distance range.

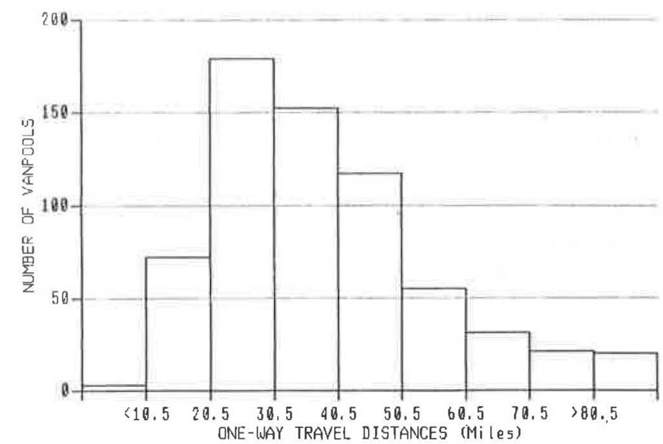

FIGURE 2 Frequency distribution of vanpool travel distances.

The average reported one-way vanpool travel distance was 36.3 mi. This may be compared with the reported distance of 33.8 mi from the 1980 Maryland survey of vanpool markets (5). The average reported one-way travel time was 58.8 min (0.98 hr). This is almost identical to the travel time reported in the 1980 Maryland survey, 59 min (4). It is possible to compute an average speed, using travel time and distance. The formula is

Rate = Distance/Time

and, substituting values,

Rate = 36.3/0.98 = 37.0 mph

It is useful to compare these travel time, distance, and speed values with the average for all commuters in the Washington area. Table 4 gives a comparison of the values from the 1982 vanpool survey with those for all persons commuting in automobiles or trucks in 1977. From Table 4, it can be seen that, compared with the general population of automobile-commuters, vanpoolers have longer travel distances, greater travel times, and higher average speeds. The higher speed may be due either to a greater proportion of the vanpool trip being on uncongested roads or to a greater proportion of the vanpool trip being on high-speed arterials.

TABLE 4 Comparison of Commuting Travel Characteristics, Vanpoolers Versus All Commuters Using Automobiles or Trucks in Metropolitan Washington

	Vanpoolers	All Commuters in Automobiles or Trucks[a]
One-way travel distance	36.3 mi	9.3 mi
One-way travel time	58.8 min	24.2 min
Speed	37.0 mph	23.1 mph

[a]Median values taken from Salopek *(6)*.

The consideration of travel times, distances, and speeds offers another interesting comparison. This is between core-destined vanpools using the Shirley Highway HOV lanes and all other core-destined vanpools. It would be expected that Shirley Highway vans would have a significantly higher rate of speed because the HOV lanes offer free-flow travel from the Capital Beltway to the Potomac River. However, the Shirley Highway vans had an average speed of 36.3 mph (average distance = 34.6 mi, average time = 0.95 hr), and other core-destined vans had an average speed of 35.5 mph (average distance = 37.3 mi, average time = 1.05 hr). Thus the difference is less than 1 mph. This represents an approximate travel time savings of a little over a minute, assuming an average trip of 35 mi. Yet, it is known that vehicles using the Shirley HOV lanes save >15 min in travel time, compared with vehicles using parallel radial arterials.

To check whether the speeds were being skewed by some very long trips, the estimate for each trip type was refigured by computing the speed for each individual vanpool and averaging these values. The results were little different: Shirley Highway vanpools = 35.5 mph; other vanpools = 35.3 mph.

This counterintuitive finding is based on reported travel times and distances. It is possible, but unlikely, that these data are systematically overstated in the Shirley corridor or understated in the other travel corridors. A more likely explanation is that radial arterials in the non-Shirley Highway travel corridors operate at a higher level of service than radial arterials in the Shirley Highway corridor. Thus the Shirley Highway HOV lanes do offer significantly higher speeds and lower travel times, but only in relation to contiguous facilities in the same travel corridor.

Traffic Assignment

Surveyed owners of vanpool vans were asked, "What major routes are used to make your trip to work?" Responses were coded according to highway and tabulated to determine which links carried the highest volumes of vanpool traffic. Respondents listed a total of 36 major highways used. Because of the somewhat general nature of the question, it was not possible to differentiate short links. Highways that carried more than 20 vanpools are given in Table 5, in order of volume.

TABLE 5 Highways with Highest Vanpool Volumes

Rank	Highway	Vanpool Volume
1	I-395 (Shirley Highway)	372
2	I-270	115
3	Virginia beltway	109
4	Maryland beltway	100
5	I-66 (outside beltway)	71[a]
6	US-50 (John Hanson Highway)	57
7	George Washington Parkway, Virginia	48
8	Baltimore-Washington Parkway	48
9	George Washington Parkway, Canal Road	33
10	Old Keene Mill Road	32
12	Dulles Access Road	24
13	US-1 (Jefferson Davis Highway)	23
14	Kenilworth Avenue	21

[a]I-66 inside the Beltway was not open in 1982.

Collection and Distribution Characteristics

The method by which vanpools assemble provides valuable information for further work on demand estimation. Early researchers believed that, predominantly, vanpools assembled by pickup at the door. This entailed a circuitous route and a stop at each passenger's house in both the morning and the evening. If at-home pickup were the principal assembly method for vanpools, vanpooling would have little success in low-density residential areas because the aggravation of assembly would incline most potential drivers and passengers toward other modes.

Respondents were asked how their vanpool assembled in the morning. Three possibilities were provided (passengers picked up at home, at a central meeting place, or at more than one meeting place), but multiple answers were permitted to describe combinations. Table 6 gives the results. The data in Table 6 indicate that exclusive pickup at home is a minor assembly method (6.8 percent). Although another 6.6 percent of vanpools mix home and meeting place pickup, the typical method of assembly is at one or more meeting places. It is assumed that most passengers arrive at these meeting places as automobile drivers or passengers.

There are two implications to this finding. First, vanpools can be formed in areas with a low density of trip home origins in relation to a particular work destination. Second, adequate commuter parking fa-

TABLE 6 Vanpool Methods of Assembly (home end)

Method	No. of Vanpools	Percentage
All picked up at home	45	6.8
All picked up at central meeting place	193	29.1
All picked up at several meeting places	381	57.5
Picked up at home and central meeting place	6	.9
Picked up at home and several meeting places	38	5.7
Total	663	100.0

cilities at the residential trip end are a necessity for the successful operation of this mode.

The survey also explored operational characteristics of pools at the work end. Respondents were asked to name employment areas where vanpools dropped off passengers. Many operators indicated that passengers came from multiple buildings in one general area. Some also specified that their vans distributed passengers in several different areas. The data in Table 7 indicate how many vans dropped off passengers in one, two, three, or four downtown districts.

TABLE 7 Core-Destined Vanpools by Number of Distribution Areas (work end)

No. of Distribution Areas	Vanpools	Percentage
1	389	71
2	136	25
3	20	4
4	3	1
Total	547	100

Ownership

Respondents were asked how the van was owned. The question also provides insight into the basic organization of the vanpool: employer sponsored, third party, or owner operated. Table 8 gives a summary of responses by state of origin.

From the table, it can be seen that ownership patterns are quite different in Maryland and Virginia. The predominant owner in Virginia is the van operator (82 percent). Here the Shirley Highway HOV lanes have evidently provided a powerful incentive for private individuals to form vanpools. In Maryland, more vans are owned by a leasing agency (52 percent) than by any other means. This may be because of the success of the various government-sponsored third-party programs that have aided the growth of vanpooling in Maryland. Overall, employers account for little vanpool van ownership (8 percent). This is in contrast to the national scene, where employer-sponsored programs are quite significant.

From comments written in the "Other" category, the survey discovered another method of ownership and operation: this is partnership, which accounts for 4 percent of vans in Virginia and none in Maryland.

Preferential Treatment and Parking

Van operators were asked whether they received preferential treatment at work because of vanpooling. Thirty-five percent of respondents reported that they received no preferential treatment; 37 percent reported one benefit; 22 percent reported two benefits; and 5 percent reported three benefits. Table 9 gives the number and percentage of respondents who reported receiving each type of preferential treatment. The table shows that receiving a reserved parking space or free or discounted parking were the benefits most frequently reported. Parking costs ranged from $0 to $120 a month. For respondents reporting a parking cost, the mean was $38.10 a month. Table 10 gives the frequency distribution of parking costs for all vanpools. It is interesting that, of the vanpools traveling to noncore destinations, 89 percent had no parking cost compared with 57 percent of those traveling to core destinations.

Assistance from Ridesharing Agencies

There are a number of agencies in the Washington area that offer assistance to vanpoolers. The survey asked which of these had been helpful in forming the vanpool. Table 11 is a listing that tallies the number of times agencies were cited; one vanpool may have cited more than one agency. The two agencies most cited were Virginia Vanpool Association (VVPA) and the COG Commuter Club. VVPA is a Virginia-based association of owner-operators. It has wide experience in vanpooling and provides extensive advice to would-be operators. It also directs potential riders to members with vacancies in their vans. The COG Commuter Club operates a regional computer-based pool-matching system. Applicants with similar origin-destination and work-time characteristics are advised of their compatibility via "matchletters." At the time of the survey, no special outreach for vanpoolers was taking place, but vanpoolers were clearly using the COG system to find riders.

It should be remembered that the survey was taken in the spring of 1982. Several of these listed agencies had, in 1982, been in business for only a short time.

Concerns of Vanpool Operators

The survey listed eight issues of concern to vanpoolers. Respondents were asked to score each issue,

TABLE 8 Means of Vanpool Vehicle Ownership by Home State

	Maryland		Virginia		Total	
Owner	Vans	Percentage	Vans	Percentage	Vans	Percentage
Myself or family member	55	23.4	355	82.1	409	61.3
Partnership			16	3.7	16	2.4
Leasing company	123	52.4	32	7.5	156	23.3
Employer	48	20.5	3	0.7	51	7.7
Private party outside my family	4	1.6	23	5.3	26	4.0
Other	5	2.1	3	0.7	8	1.2
Total	235	100.0	432	100.0	667	100.0

TABLE 9 Preferential Treatment of Vanpools at the Employment Site

	Yes		No	
Benefit	No.	Percentage	No.	Percentage
Reserved parking space	230	34	437	66
Closer parking space	97	15	570	85
Discounted or free parking	253	38	414	62
Subsidy of other vanpool costs	9	1	658	99
More convenient working hours	60	9	607	91

Table 10 Reported Monthly Parking Costs for All Vanpools

Cost ($)	No. of Vanpools	Percentage
0	416	62
1-20	101	15
21-40	57	9
41-60	24	4
61-80	33	5
More than 80	37	6
Total	667	100

TABLE 11 Assistance from Ridesharing Agencies in Forming Vanpool

Agency	No. of Vanpools Assisted
Virginia Vanpool Association	152
COG Commuter Club	131
VANGO	82
Prince William County Ridesharing Office	79
Montgomery County Ridesharing Office	45
Maryland Ridesharing Office	16
Fairfax County Ridesources	3
Silver Spring Share-a-Ride	2

using a scale of 1 to 5, where 1 = no concern and 5 = great concern. Table 12 gives the eight issues, along with the average score for each, and the total number of respondents who checked 5. It can be seen that the two issues of greatest concern to vanpool operators were increased HOV lanes and van insurance.

TABLE 12 Concerns of Vanpool Operators

Issue	Avg Score	No. of 5 Scores
More highway priority lanes for vanpools	3.58	103
Insurance	3.45	102
Priority parking at work	3.23	88
Van servicing	3.11	76
Finding new riders	3.05	62
Government regulation	2.59	49
Finding a backup van	2.58	42
Access to commercial parking garages	1.96	34

ACKNOWLEDGMENT

This paper uses data that were collected with the support of a grant from UMTA to the Metropolitan Washington Council of Governments. The paper is an abridgment of one written for a degree requirement at George Mason University. The author gratefully acknowledges the assistance of faculty advisor George Mouchahoir and readers Alice Andrews and William Mann.

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Abridgment

Interest-Free Vanpool Program: Experience in Connecticut

CHARLES S. BARONE and RAJENDRA JAIN

ABSTRACT

The Connecticut Department of Transportation has made a substantial commitment to vanpooling as part of its service development responsibility. There have been a number of programs, including a State Employee Ridesharing Program, a Vanpool Assistance Program, a Van Lease Program, and successful efforts to obtain legislation favorable to vanpooling, such as tax breaks and exemption from governmental regulations. In this paper is described a Connecticut Department of Transportation program to provide an alternative to existing, costly, third-party van-leasing arrangements. The program was developed and implemented with the cooperation of the Federal Highway Administration and the Rideshare Company. The state provides interest-free financing and mass acquisition of vehicles, and the Rideshare Company, an areawide nonprofit rideshare brokerage based in Hartford, markets, promotes, administers, and supervises the operational vans. This unique approach to providing vanpool vehicles to individuals and employers has resulted in the opportunity to acquire vans at the lowest possible cost. The program was implemented January 13, 1983. During the first 11 months, 27 vanpools were put into operation with 17 vans being run by individuals and 10 run by Connecticut employers. Participants who receive vans have to repay 100 percent of the vehicle cost during the van's projected life and pay all operating costs. The mechanics of the program are described and its transportation impacts are analyzed. This information should be useful to persons responsible for commuter transportation or new approaches to transportation financing.

Vanpooling in Connecticut had its beginning in 1976 when two state employers purchased several vans equipped to accommodate 12 passengers and made them available to their employees. During the past 10 years there has been substantial growth in ridesharing, especially vanpooling, in Connecticut (1-3).

Today there are more than 1,300 vanpools operating in the state saving each of the 14,300 commuters approximately $750 per year in commuting costs. This is perhaps the largest number of registered vanpools per capita of any state in the country. The operation of these vanpools directly or indirectly affects all segments of the state population through reduced consumption of energy, reduced traffic and congestion on roadways, reduced employer parking demands, reduced air pollution emissions, and reduced vehicle miles of travel on state highways.

In 1977, to demonstrate the benefits and the commitment of the state to ridesharing, the Department of Transportation developed two vanpool programs. One, the State Employee Vanpool Program, put its first van into operation in September 1978. At its peak there were 92 vanpools in operation; currently there are 72. The second, the Vanpool Assistance Program to Major Employers, became operational in April 1979. There were 29 vanpool vehicles distributed to Connecticut employers under the Vanpool Assistance Program. Many of the program's employers and other nonprogram employers have continued and expanded their vanpool programs on their own.

The Department of Transportation, together with private-sector employers, supported the development and implementation of two regional nonprofit ridesharing corporations in 1980. However, the third-party vanpool program administered by the brokerages experienced difficulties in starting vanpools in the first years. The main reason for this was high interest rates that were being included as part of the lease cost to the vanpool group.

To counteract the high monthly van-leasing rates created by the high interest charges, the ridesharing brokerage contacted the Department of Transportation for assistance in finding an alternative way to finance the purchase of vans. Finally, the decision was made to investigate the development of a van purchase program that would use federal funds and thereby avoid the high interest rates. The Federal Highway Administration had expressed willingness to use federal funds for the project pursuant to the Rural Secondary Funding-Federal Aid Highway Act of 1976 and the Surface Transportation Assistance Act of 1982. After review and coordination, the department's Office of Project Planning prepared and submitted a recommendation for the consideration of an interest-free van acquisition program. The Mass Transit Policy Committee of the Department of Transportation acted on the recommendation and requested the commissioner's approval to initiate a project including the expenditure of $750,000 to provide interest-free loans for the purchase of vanpool vehicles. At that time, the program cost, on a monthly basis for a van making a 40-mi round trip, was estimated to be $400 compared with $600 for the third-party van-leasing program.

Preliminary program activities were developed by the department with input from the ridesharing brokerages and resulted in the project being recommended to start in April 1981. The project was also required to be included in the Transportation Improve-

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ment Plan and A-95 Clearinghouse Certification process. Federal fund authorizations were received in October 1981, and the project was initiated the following month.

PURPOSE

The Interest-Free Vanpool Program was for the most part developed and implemented to increase ridesharing opportunities in the state. Vanpooling is highly cost-effective and yields many benefits. These benefits include reduced vehicle miles traveled, increased vehicle occupancy, reduction in the amount of air pollution emissions and gasoline consumption, as well as reduced traffic congestion and parking demands.

The program was cooperatively developed by FHWA, ConnDOT, and the Rideshare Company in order to provide an alternative to existing, more costly, third-party van-leasing arrangements. Several major companies have large carpooling and vanpooling programs, most of which have been in place since at least the mid-1970s. The Rideshare Co., Metropool Inc., and Rideworks Inc., are existing areawide nonprofit ridesharing brokerages that work with ConnDOT to promote ridesharing. These companies act as transportation brokers by matching local transportation suppliers with the local demand, actual and latent, for transportation. This allows the community to make effective use of available transportation services by fitting these services to meet the transportation needs of various population and socioeconomic groups.

Under the Interest-Free Vanpool Program, the state provides interest-free financing and mass purchasing of vehicles and maintains vehicle ownership throughout the van's program life (36 to 48 months), and the ridesharing brokerages market, promote, administer, and monitor the operational vans. By using state bidding procedures and exemptions from property tax and registration fees, vanpool vehicles could be made available for employee transportation for 20 to 40 percent less than under third-party operations.

DESCRIPTION OF PROGRAM

Approximately 90 12- and 15-passenger vanpool vehicles will ultimately be purchased by the state of Connecticut and made available for use in the program. The department pays 100 percent of the van's purchase cost on delivery of the van from the dealer. Twenty-five percent of the vehicle cost must be borne by the vehicle user and remitted to the Department of Transportation before or when possession is taken of the van. The remaining 75 percent of the vehicle cost must be paid to the department on a monthly basis over a 36- to 48-month period depending on the commuting mileage. Any Connecticut resident is eligible to receive one vanpool vehicle, and a Connecticut-based employer is eligible for a maximum of five vanpool vehicles.

The vehicle must be used in a vanpooling arrangement for the work trip. The vanpool group must consist of a minimum of eight passengers not including the driver. Seventy-five percent of the vehicle's monthly mileage must be for work trips. Personal use of the van is allowed at the expense of the driver or program participant at a nominal operating cost for gas, oil, and so forth. Failure to meet any of these criteria could result in termination of the operating agreement. Vehicle usage is monitored by the ridesharing brokerage via monthly vehicle usage reports.

All participants are required to provide insurance coverage for their vehicles in at least the amounts prescribed in the operating agreement. The participant is responsible for making certain that normal vehicle maintenance and other necessary repairs are carried out. Monthly fares are determined by the participant with assistance from the ridesharing brokerage.

Program participants can terminate their operating agreement before 100 percent payback and return the van in good condition to the ridesharing brokerage on 30 days written notice.

After the participant's obligation has been met under the operating agreement and the vehicle acquisition cost has been repaid to the department, the vehicle title is transferred to the participant. Registration fees and any applicable taxes are then passed on to the participant and all responsibility on the part of the ridesharing brokerage and the state is terminated.

PROGRAM ACCOMPLISHMENTS

On January 11, 1984, 27 interest-free vanpools were in operation. Thirty-six new vehicles were ordered for May 1984 delivery. These additional vans were later put into service. At present the program fleet consists of 63 vans. Eleven Connecticut employers are participating in the program. These employers have made 34 program vehicles available to their employees. In addition, 29 state residents, each utilizing one van, are also participating in the program.

BENEFITS

The various program benefits were estimated from the reports provided by the Rideshare Company and Metropool, Inc., two of the ridesharing organizations under contract with the department to administer and monitor the program. The following table gives the benefits derived from the program:

Benefit	Measure of Effectiveness
Vehicles removed from state highways	441 vehicles/day
Vehicle miles traveled reduction	6,615,000 mi/year
Air pollution reduction	1,000 tons/year
Energy use reduction	388,900 gal/year
Number of passengers carried	705 persons/day
Commuter cost reduction	$524,800 all riders/year
Parking demand reduction	441 spaces/day
Commuting trip cost per person	3.5 cents/mile
Commuter cost reduction	$744 each rider/year

CONCLUSIONS

The success of the program and the achieved results show the program to be beneficial to the state and the participants. The goals and objectives of the program are being met. The original objective of putting 27 vanpool groups in operation during the first year has been fulfilled. The anticipated resulting benefits of the vanpools are being demonstrated and the cost to the participants is lower than under third-party operations. The third-party vanpooler in a full 1984 van now pays $50.50 per month for a 67-mi round trip whereas the interest-free vanpooler pays $34.00 per month, approximately 32.5 percent less.

The concerns expressed about the possibility of a mass switching of people from the third-party program to the interest-free program did not materialize. It appears that the purchase option of the interest-free program appeals to a different group than does the lease option.

The second year of operation has shown that there is a vast untapped potential group of individual vanpool owner-operators. Twenty-nine of the 63 vans are being used by individuals. It is therefore anticipated that interest in owner-operator vanpooling in Connecticut will continue to grow.

FUTURE OF THE PROGRAM

With the additional vans put on the road during this year, the program currently supports 63 vanpools. With increased marketing and promotion of the program by the Rideshare Company, Metropool, Inc., and the Ride Works of Greater New Haven, the objective of 90 vanpools should be achieved by the end of next year.

ACKNOWLEDGMENT

This paper is based on work performed by the Ridesharing Unit of the Connecticut Department of Transportation's Bureau of Planning and Research. The authors would like especially to acknowledge the late E. Darrell Cram, Division Transportation Planner, of the Federal Highway Administration who was instrumental in providing guidance and support for the initiation of this unique program. The findings and conclusions are those of the authors.

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A Study of Staff and Faculty Commuters at the University of California, Los Angeles

ADELE PEARLSTEIN

ABSTRACT

The University of California, Los Angeles, Transportation Services Administration (UCLA/TSA) and Commuter Computer studied the transportation needs of UCLA faculty and staff to determine the market for ridesharing. Study results are to be used by UCLA/TSA and Commuter Computer to develop a campus ridesharing program. Survey results revealed that most respondents (74 percent) drove alone to campus, the average distance from home to UCLA was 11.5 mi, and commuting and parking costs were the primary transportation-related concerns. Driving time and stress were also mentioned frequently as concerns. Only 3 percent of the faculty and staff were registered for ridesharing. Although "need for a car" was one of the most common reasons given for not ridesharing, people used their cars an average of only 1.36 days a week for noncommuting purposes. Other rationales for not ridesharing included inflexible and irregular work schedules. Reduced costs, pool flexibility, and availability of a ridesharing coordinator were cited as factors that would encourage carpooling. Respondents also indicated that university-provided vans would encourage vanpooling.

During the past 6 months, the University of California, Los Angeles, Transportation Services Administration (UCLA/TSA) and Commuter Computer have been working together on a study to determine the market for ridesharing in the UCLA population. The objective of the survey was to determine the commuter transportation needs and characteristics of those people who travel to the UCLA campus. The results of the study are to be used by UCLA/TSA to plan and develop a ridesharing program for the Westwood campus. An analysis of the needs and characteristics of a university population will also help Commuter Computer develop a more targeted campus ridesharing program that will meet the specific needs of the university.

METHODOLOGY

The actual survey was designed through the mutual efforts of Patricia Ann Phillips, Ridesharing Coordinator for the UCLA Transportation Services Administration, Melissa Miller, Account Executive at Commuter Computer, and Adele Pearlstein, Planning and Development Division at Commuter Computer. The concept was devised in December 1983, and the actual design of the questionnaire was begun in January 1984.

The survey targeted faculty and staff members as the first groups to be evaluated. In early March, the original questionnaire was pretested on 150 faculty and 150 staff members. When the results were received, the questionnaire was revised; it was printed in late March. The survey questionnaire was then distributed to the selected sample through the intercampus mail system. A self-addressed return envelope was provided to encourage people to return the survey. Respondents were offered a copy of the results.

Commuter Transportation Services, Inc., 3550 Wilshire Boulevard, Suite 300, Los Angeles, Calif. 90010.

Sampling

The population for this survey was the faculty and staff at the UCLA campus. To determine the characteristics of this population, without actually surveying nearly 13,000 people, it was necessary to select a sample of the population. By using random sampling, it was possible to infer the characteristics of the entire faculty and staff by surveying less than 20 percent of the population.

The UCLA Administration Information Service selected the faculty and staff samples by computer and produced on-campus mailing labels. The entire faculty listing was used; it was systematically divided in two by assigning every other label to be included in the pretest sample; the remaining half was used as the final faculty sample. Every eighth staff person was selected by computer; a portion was given the pretest and the remainder received the final questionnaire.

A week after the surveys were distributed, a thank-you-and-reminder letter was sent out to all people who had received the survey. After several more weeks, another reminder was sent to those who had not yet returned the questionnaire.

When the surveys had been returned, the questionnaires were coded by UCLA/TSA and then returned to Commuter Computer for keypunching and analysis at the end of May. After the data were keypunched, a statistical analysis was run on the UCLA computer using the SPSS-X statistical package. This paper is a summary and analysis of the results of that statistical analysis.

Response Rates

The final questionnaire was distributed to 2,273 people, 1,154 staff and 1,119 faculty. Of the staff, 656 returned the surveys, a response rate of 57 percent; 527 of the faculty turned in their questionnaires, a response rate of 47 percent. The overall response rate was 52 percent. This is a somewhat higher response rate than is normally expected for a survey in which responses must be returned through the mail. However, follow-up letters and reminders are not always employed and may have encouraged more people to respond.

Another factor that may have affected the response rate is that the original letter accompanying the questionnaire mentioned that the survey was a tool to help build a ridesharing program at UCLA. Normally, the term transportation is used rather than ridesharing to avoid biases for or against ridesharing. People who were not interested in ridesharing or lived close to UCLA may have been less inclined to return their questionnaires. This may have led to underrepresentation of certain sectors in the sample, such as those who view ridesharing negatively or walk to campus and would not be in the market for a ridesharing program.

Sampling Error

Because the survey was administered to a sample of the entire population of faculty and staff, the findings are estimates rather than exact measures of population characteristics. Sampling error is the difference between the estimates shown in the sample and the actual number that would have been obtained from a census of the entire UCLA staff and faculty population. Random sampling errors occur because of the unlikelihood of obtaining the precise proportions of differences that exist in the general population.

For this survey the sampling error of the overall sample is ± 2.8 percent. This is, if the survey results show that 74 percent of the people surveyed drove alone to work, the actual percentage of people driving alone to work in the general population would be expected to be in the range of 74 percent ± 2.8 percent, or from 71.2 to 76.8 percent. The sampling error for staff is ± 3.8 percent; for faculty it is ± 4.3 percent.

Statistical Significance

It is important to note that apparent differences in the results of the survey may not actually exist in the overall population. For example, a difference may appear to exist between faculty and staff in the percentages of each who carpool to UCLA, but this difference may not actually exist in the overall UCLA population. A test for this is statistical significance. In this paper, results are reported as statistically significant or not at the 0.05 level. This means that, if a result is statistically significant, it is 95 percent certain that the differences found in the sample can also be found in the overall population and that the differences are not due to chance or to sampling error.

Weighting

Questionnaires were returned by 527 of the faculty and 656 of the staff to whom they were distributed. This gives a proportion of 44.5 percent faculty and 55.5 percent staff. This does not, however, match the actual breakdown in the university of 2,232 faculty (17.5 percent) and 10,552 staff (82.5 percent). To reflect this actual breakdown when reporting and analyzing the results, and to avoid biasing the results in favor of the faculty, the results were weighted in the statistical analysis. All results reported are weighted except the actual number of faculty and staff responses.

The target group for this survey was only the staff and faculty of UCLA, not all of the people who travel to UCLA. The two largest groups missing are students, who have been difficult to target for ridesharing, and the employees of the UCLA Medical Center. The results of this survey cannot be generalized to either of these populations. To determine their actual characteristics, these populations will also have to be surveyed, which will help in targeting each of them for ridesharing.

In the discussion of the survey results, the following topics are covered: travel patterns, ridesharing interest and commuter concerns, conclusions, and recommendations.

TRAVEL PATTERNS

Method of Travel

As can be seen in Figure 1, nearly three-quarters of the people surveyed (74 percent) drove alone to work. A total of 13 percent of the respondents carpooled. Nearly 15 percent of the staff carpooled, whereas only 9 percent of the faculty did. Most carpools were composed of two people (82 percent), with a mean of 2.3 people. Of the people who carpooled, most did so 5 days per week (63 percent); 14 percent carpooled an average of 4 days, 18 percent did so on 3 days, and 5 percent carpooled only 2 days per week. About one-tenth of those surveyed rode to work on the bus (9 percent). The remainder traveled in a number of different ways, including walking (3 percent), bicycling (0.7 percent), driving a moped or motorcycle (0.7 percent), vanpooling (0.1 percent), or using park-and-ride and then riding a public bus (0.1 percent).

Cross tabulation of mode by gender shows that the percentage of those who drove alone to work followed the split in the general UCLA population: 42 percent of those who drove alone were male and 58 percent were female. Of the women surveyed, 14 percent chose to carpool, 10 percent chose to ride the bus, but a higher than average 74 percent chose to drive alone. This is a statistically significant difference from the men, 72 percent of whom drove alone, 12 percent of whom carpooled, and only 8 percent of whom rode the bus.

Mode choice is clearly associated with distance traveled. Bus riders lived closest to campus, an average of 7 mi; carpoolers lived farthest, about 15 mi from UCLA on the average; solo drivers fell in between, traveling an average of about 12 mi.

Although at first glance there appeared to be a relationship between commute mode and salary, when employment classification (i.e., faculty or staff) was taken into account, the relationship only held true for staff. That is, as income level increased more staff tended to drive alone; conversely, at lower income levels, more staff carpooled and rode the bus. Only 64 percent of the staff earning $17,000 or less drove alone versus 73 percent of those earning from $17,001 to $27,000, 80 percent of those in the $27,001 to $37,000 range, and 84 percent of those earning more than $37,000. No clear-cut relationship between salary and mode choice existed for faculty.

Distance Traveled

Overall, respondents traveled an average of 11.5 mi to UCLA. Faculty traveled a shorter average distance of 10 mi compared with 11.8 mi for staff; the difference was statistically significant. As can be gleaned from Figure 2, about 50 percent of those

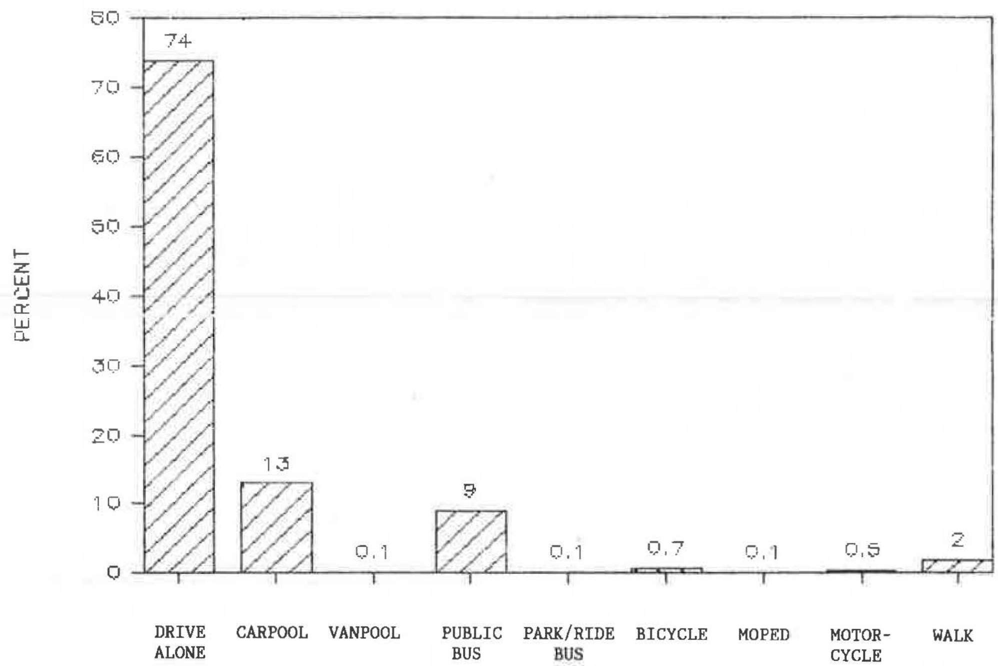

FIGURE 1 Mode of travel to UCLA (total sample population).

surveyed lived no more than 3 mi from campus, 75 percent lived within 15 mi, and only about 2 percent traveled more than 40 mi to get to UCLA. Faculty tend to commute shorter distances than do staff. Thirty-six percent of the faculty live within 5 mi of campus compared with 29 percent of the staff, and 72 percent of the faculty live within 10 mi versus 60 percent of the staff.

Travel Time

One-way travel time averaged 29 min. The staff average was 30 min, but faculty, who generally live closer, traveled for an average of 25 min; the difference was statistically significant (Figure 3). The breakdown of minutes traveled by mode was also statistically significant, with those who drove alone averaging a 28-min commute, those who carpooled 32 min, and those who rode the bus 38 min even though they live the closest. Nearly 90 percent of the people surveyed traveled 45 min or less to get to work, with most commutes (58 percent) taking between 15 and 30 min. The average ratio between time and distance traveled was 2.53 min per mile. When broken down by miles traveled, it is apparent that traveling shorter distances takes more time per mile. Those who traveled 5 mi or less averaged nearly 6 min per mile, whereas those who traveled more than 15 mi to campus averaged only 2 min per mile.

Work Schedules and Flexibility

Eighty-two percent of the people surveyed worked the same schedule each week, and 86 percent of the staff worked the same days and times each week. This is statistically different from the faculty, but a majority of the faculty (63 percent) stick to the

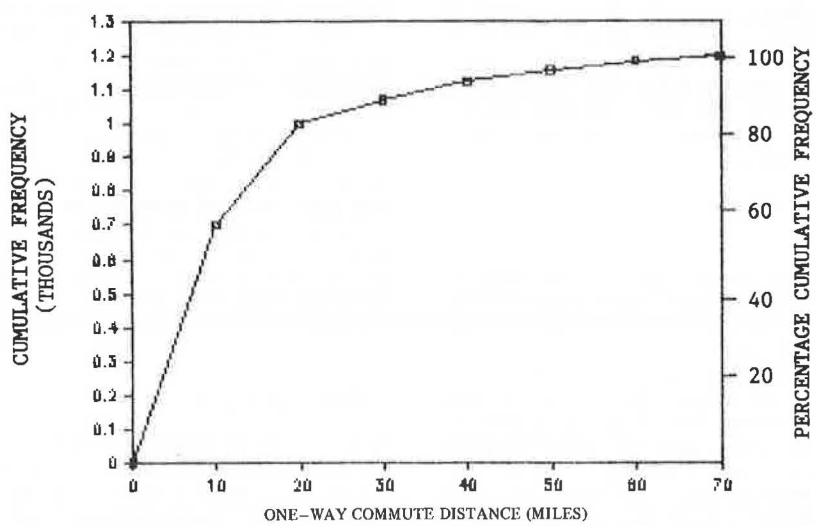

FIGURE 2 Distribution of distance to UCLA (total sample population).

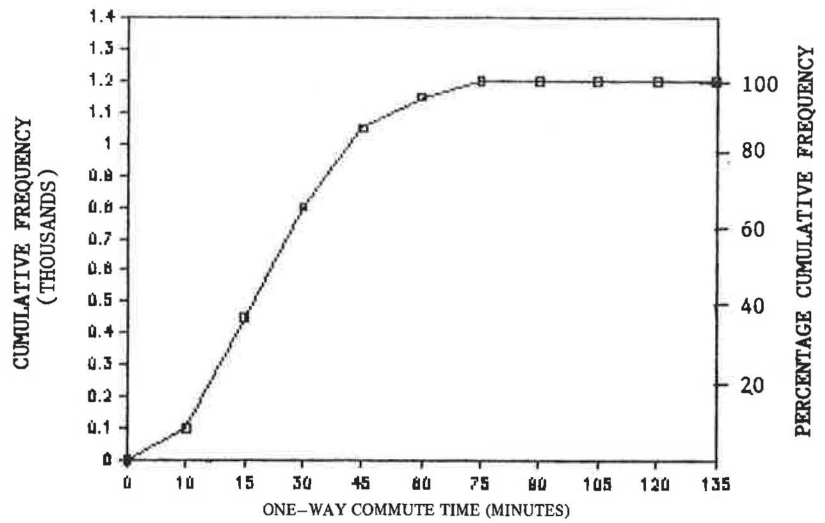

FIGURE 3 Distribution of time to UCLA (total sample population).

same schedule each day. However, faculty tend to have more flexibility in their work hours. Of those faculty who had regular schedules, only 11 percent needed to start at specific times, and 86 percent were flexible except for their class times and office hours. On the other hand, more than a third of the staff (35 percent) had no flexibility, and another 25 percent had only 15 min of leeway.

Figures 4 and 5 show the distribution of start and stop times for UCLA faculty and staff. Many people with regular schedules started at 8:00 a.m. (27 percent) and an even larger percentage got off at 5:00 p.m. (33 percent). The most common schedule was 8:00 a.m. to 5:00 p.m. (17 percent), with the rest of the sample working a variety of schedules. Faculty schedules varied tremendously, with no predominance of any one schedule. Staff, on the other hand, had more consistent schedules, with 19 percent working 8:00 a.m. to 5:00 p.m. and another 6 percent working 7:30 a.m. to 4:30 p.m. Faculty tend to arrive at UCLA later than staff; more than 50 percent indicated that they usually arrive at 9:00 a.m. or later. Staff usually arrive earlier (90 percent before 9:00 a.m.) and leave earlier (72 percent before 5:30 p.m.); only 54 percent of the faculty usually leave by this time.

Most staff (56 percent) had schedules that were consistent throughout the calendar year, but only 12 percent of the faculty did, a statistically significant difference. Faculty schedules appeared to vary mostly from one quarter to the next (38 percent), or on a daily or weekly basis (34 percent). The majority of the people worked a 5-day week, from Monday through Friday (77 percent). Only about 2 percent of the total worked either Monday, Wednesday, and Friday, or Tuesday and Thursday schedules. Of those who

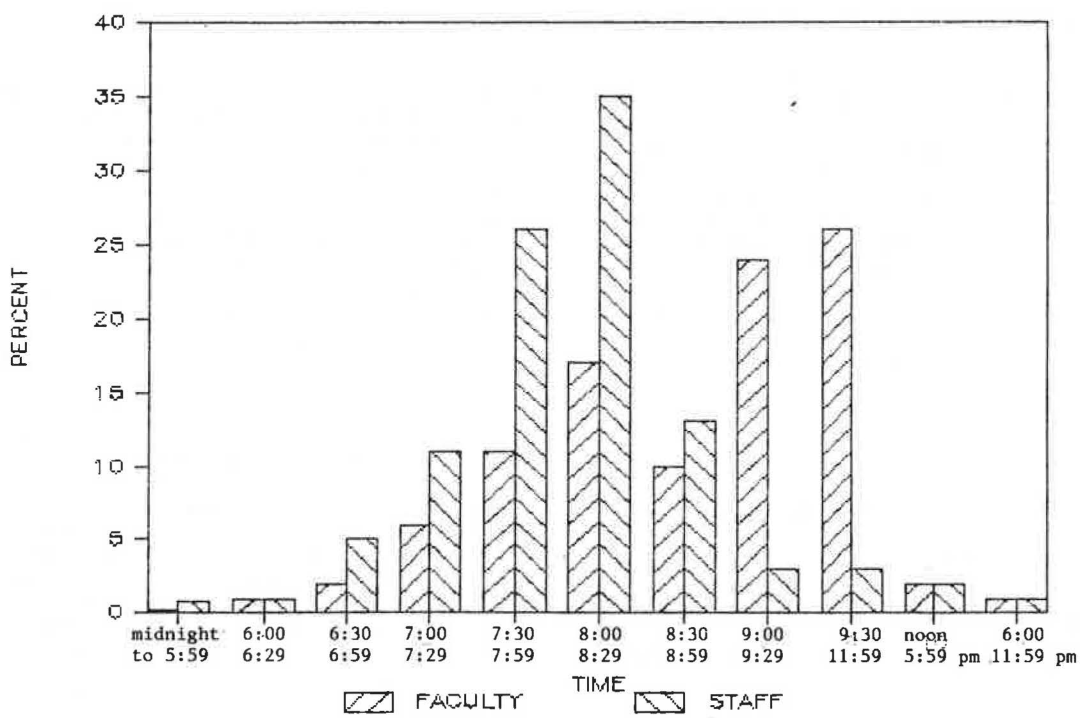

FIGURE 4 Usual time of arrival at UCLA for faculty and staff.

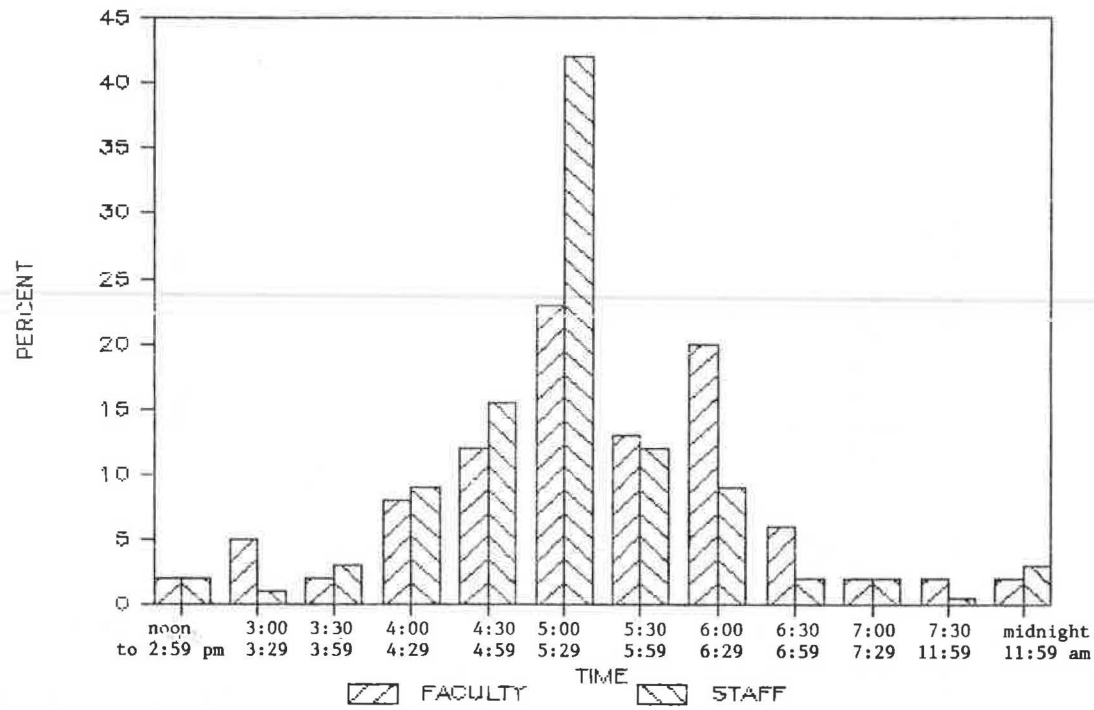

FIGURE 5 Usual time of leaving UCLA for faculty and staff.

carpooled, 89 percent worked Monday through Friday, as did 82 percent of those who drove alone.

Some faculty are perhaps unwilling to carpool because they have variable schedules. However, because they also have more flexibility, it might be possible to work around this potential problem. Staff, on the other hand, appear to be a better market for ridesharing because their schedules are consistent during the year and because they tend to have the same schedule from day to day. Also, they are a much larger market than the faculty.

Parking Permits

Most people (87 percent) had permits for parking on campus. A statistically significant higher percentage of faculty members had parking permits (92 percent) than did staff members (86 percent). Overall, those who did not have parking permits gave the following reasons: they preferred other transportation or did not drive (41 percent), they did not own a car (17 percent), UCLA parking permits were too expensive (15 percent), or they shared a parking permit (9 percent). Of those who did not have parking permits, 55 percent rode the bus to work, 15 percent drove alone and parked off-campus, 14 percent carpooled, and 8 percent walked to campus. Of those who did have permits, the majority drove alone (82 percent), 13 percent carpooled, and 2 percent rode the bus to campus.

INTEREST IN RIDESHARING AND COMMUTER CONCERNS

Registration for Ridesharing

Only 3 percent of the people surveyed were registered for ridesharing either through UCLA or Commuter Computer. More of the staff (3 percent) were registered than faculty (1 percent), a small but statistically significant difference. The most common reason given for not being registered was a lack of interest in ridesharing (41 percent overall); 52 percent of the faculty gave this reason as did 39 percent of the staff. Another important factor appeared to be that the people surveyed needed their cars before, after, or during work (30 percent). Of those surveyed, 11 percent were unaware of the services provided by the two ridesharing organizations, and nearly 7 percent were not registered because they were already ridesharing.

Commuter Concerns

The major concerns of commuters appeared to be centered around costs, both of general transportation (34 percent) and of parking (32 percent). Other factors that were of concern to a number of commuters were time spent driving (27 percent), stress caused by driving (20 percent), and that buses take so long (19 percent).

Those people who carpooled appeared to be slightly more concerned with parking costs (38 percent), with the time spent driving (35 percent), and with the stress associated with driving (32 percent). Those who rode the bus appeared to be most concerned with how long the bus took (25 percent) and that they had to transfer buses (20 percent). However, 45 percent of the bus riders had no serious concerns at all. People who walked to campus, as well as motorcycle riders, appeared to have fewer concerns, with 47 and 52 percent, respectively, responding that they had no concerns at all. Women were more concerned than men about personal safety walking to and from their vehicles; only 2 percent of the men believed that this was a factor of concern, whereas 12 percent of the women believed that it was. There were no other significant differences in concerns between men and women. Overall, the most important concerns appeared to be consistently centered around costs; incentives for ridesharing should take this into account.

Need for a Vehicle

About half of the faculty and staff commuters (52 percent) did not need their vehicles for noncommuting purposes at all. The average number of days people needed their vehicles was only 1.36 days per week. Of those who drove alone to work each day, 71 percent needed their vehicles fewer than 3 days a week for noncommuting reasons, and 44 percent did not need them at all. Of those who carpooled, 86 percent needed their vehicles fewer than 3 days a week for reasons other than commuting. Nearly half of those people who needed their vehicles needed them solely for personal reasons (48 percent), and 36 percent of the respondents who needed their vehicles used them for both personal and business reasons; only 16 percent needed them for purely business purposes. Most people needed their vehicles only 1 to 3 days a week (70 percent) even if they were needed for business purposes. Of those who needed their vehicles strictly for personal reasons, 56 percent needed them 1 to 2 days a week, and only 22 percent needed them 5 days a week.

When asked if the availability of an around campus/Westwood shuttle would alleviate the need for a vehicle, only 14 percent of the faculty and staff responded that it would. The shuttle would alleviate the need for a vehicle for only 8 percent of the faculty and 15 percent of the staff, a statistically significant difference. The market for ridesharing could be increased if people were made more aware that they need not rideshare every day.

Why People Were Not Ridesharing

The most common reasons given for not carpooling or vanpooling were need for a car before or after work (42 percent), lack of flexibility (39 percent), an irregular work schedule (35 percent), a dislike of relying on others (30 percent), and inconvenience (30 percent). A relatively low 17 percent of the people who were not carpooling or vanpooling reported that one of the reasons they did not rideshare was because they preferred driving alone. Although faculty members were most reluctant to pool because of irregular work schedules (51 percent) and a lack of flexibility (45 percent), staff members most commonly cited a need for their cars before or after work (44 percent), followed by a lack of flexibility (38 percent) and irregular work schedules (31 percent).

Those who drove alone to UCLA appeared to be most reluctant to pool because of a need for their cars before or after work (50 percent) and because of the lack of flexibility (45 percent). Those who took the bus to work did not pool because it was convenient to take the bus (62 percent), because they disliked relying on others (19 percent), and because of the lack of flexibility (18 percent). Those who walked or bicycled to work lived too close to pool (59 and 32 percent, respectively); those who motorcycled or rode a moped to UCLA were evenly divided among reasons for not pooling. Virtually no one cited the fear of losing his parking permit (4 percent) or the reasonable cost of UCLA parking (2 percent) as the reasons for their reluctance to pool. Another reason people may not rideshare to work is that 87 percent of those surveyed possess UCLA parking permits. The most common reasons for not pooling were the need for a car and a lack of flexibility. A good educational program would make people more aware that pools can be flexible and need not be used every day.

Incentives for Changing Travel Modes

When asked if they would seriously consider changing to carpooling under certain circumstances, 35 percent of the nonridesharers said they would. This included 23 percent of the faculty and 37 percent of the staff, a statistically significant difference. In addition, 19 percent stated that they would seriously consider carpooling during the Olympics. Although higher income employees were significantly less interested in carpooling, this relationship did not hold when faculty or staff work status was taken into account. Thus interest in carpooling is not really a function of income level but of whether a person is a faculty or a staff member.

Of those who drove alone, 43 percent stated that they would consider carpooling. Not surprisingly, people who lived farther were more receptive to carpooling; only 29 percent of those living 10 mi or less from campus would consider changing to carpooling, versus 44 percent of people living more than 10 mi from UCLA.

Overall, noncarpoolers would seriously consider carpooling under the following circumstances: if their carpool were flexible (i.e., they did not have to carpool every day) (29 percent), if a parking fee discount were offered (23 percent), if a ridesharing coordinator were available to assist them in finding people with whom to carpool (20 percent), during the Olympics (19 percent), if it cost less than driving alone (19 percent), and if an automobile insurance discount were available (18 percent). Only 2 percent of the respondents would change to carpooling because it would provide people to walk with them to their cars. Overall, half of the respondents (49 percent) indicated that they would not consider carpooling at this time; this sentiment was expressed by 60 percent of the faculty and 47 percent of the staff.

When asked about vanpooling, 32 percent of the nonvanpoolers responded that they were willing to consider vanpooling. Eighteen percent of the faculty said they were willing to consider vanpools, as were 34 percent of the staff. Of those who drove alone, 31 percent would consider vanpools, as would 40 percent of those who carpooled, and 35 percent of the bus riders. Across the board, interest in changing to vanpooling was greater among people living more than 10 mi from campus. These are the people who are being targeted for vanpooling at UCLA. Almost half (49 percent) of the people who lived more than 10 mi from campus responded affirmatively to at least one of the vanpool incentive questions, versus 22 percent of those living closer.

The strongest incentives for vanpooling, for respondents living more than 10 mi from campus, were being able to drive alone occasionally (41 percent), university-provided 15-passenger vans with costs shared among the riders (37 percent), lower cost than driving alone (34 percent), and a campus ridesharing coordinator to assist people in finding vanpoolers (29 percent). In addition, 19 percent of the nonvanpoolers stated that they would vanpool during the Olympics. Thirty-nine percent of the people living more than 10 mi from campus would not consider vanpooling at the time of the survey.

Questions were also asked about the respondents' willingness to change their travel modes to either taking the bus or riding a bike to work. On the whole, 31 percent said they were willing to consider taking the bus. This was the case for 31 percent of those who drove alone and 35 percent of those who carpooled. Those who used other modes did not appear to be particularly willing to change. The most common circumstances under which nonbus riders would change to taking the bus were if service were reliable and frequent (21 percent), if the route were near their home (16 percent) or direct (13 percent), if the buses were faster (14 percent), or during the Olympics (11 percent). The most common reasons given for not considering taking the bus were generally the reverse, with most people thinking that the bus takes too long (42 percent) or that it is too unreliable and inconvenient (21 percent). Only 11 percent would not consider changing because they needed their cars. Those most interested in changing to riding the bus lived between 5 and 15 mi from campus and accounted for nearly half of those willing to consider changing (46 percent).

Fewer people would consider changing their travel modes to riding a bicycle to work (19 percent). Eighteen percent of those who drove alone would consider changing, 13 percent of those who carpooled, 28 percent of those who rode the bus, and 50 percent of those who walked, a statistically significant difference among the various modes. Of the people who would consider changing, 71 percent drove alone. Not surprisingly, most of those interested in changing to riding a bicycle to UCLA lived less than 15 mi away; 51 percent lived within 5 mi of campus, and 38 percent lived between 5 and 15 mi away. The circumstances under which people would change to riding a bicycle were if there were a safe bike path to campus (47 percent), if they lived closer (12 percent), or during the Olympics (8 percent). As with changing to buses, the reasons for not changing were the reverse of the reasons for changing: 52 percent said that they lived too far away and 26 percent were concerned with traffic and safety. Only 3 percent would not consider changing because they need their cars.

Requests for Information

About 41 percent of the people surveyed wanted information on some aspect of ridesharing, and 21 percent were interested in finding out more about carpooling, 22 percent wanted to learn more about vanpooling, 11 percent wanted more information on public buses, and 8 percent wanted information on park-and-ride lots.

CONCLUSIONS

Carpooling

Ideally, the market for carpooling would be largely comprised of people who drive alone to work, nearly three-quarters of the faculty and staff commuters (74 percent). Also, except for those who rode the bus to campus (and were therefore already ridesharing), those who used other travel modes were less interested in changing to carpooling.

Generally speaking, people who live within 5 mi of their worksites are not inclined to carpool. However, because of the traffic and parking problems indigenous to the Westwood campus, this is not necessarily true at UCLA. People who are not within walking distance, even if they live only several miles from campus, can be targeted for carpooling.

At the time of the survey, about 35 percent of the nonridesharers indicated that they would seriously consider changing from their current modes to carpooling if circumstances were right. This was true for 43 percent of those who drove alone, 23 percent of the bus riders, and 14 percent of those using other modes. Of the 35 percent of the sample potentially interested in carpooling, 48 percent lived more than 10 mi from campus and might be better served by vanpooling if they lived near coworkers with similar schedules.

At the very least, the carpool market consists of the 18 percent of the commuters who stated an interest, if certain conditions were met, and lived 10 mi or less from campus; an additional 17 percent of the faculty and staff lived more than 10 mi from campus and were interested in carpooling; the majority of them also comprise the vanpool market. Notably, significantly more staff than faculty are interested in possibly switching to carpooling--37 and 23 percent, respectively. Because of the comparative stability of their schedules, staff would also be much easier to find carpooling partners for on the whole.

On the basis of the responses to the questions that dealt with what commuters were concerned about, why they were not ridesharing, and what might encourage them to carpool, it appears that the best incentives for carpooling center around reducing costs and allowing for flexibility. Need for a car and lack of flexibility were given by almost half of the nonridesharers as reasons for not ridesharing, but 29 percent said they would consider carpooling if the pool were flexible. One of the goals of the ridesharing coordinator might be to try and match people who need their vehicles several days a week or who need a carpool with a flexible departure time. Also, perhaps those who need a car during the day could be the ones whose cars are used for the carpool.

If people were made more aware that carpools do not need to be used every working day, perhaps it would be possible to capture some of the market that says they do not rideshare because they need their cars, especially because people only needed their cars an average of 1.36 days per week, and a campus/Westwood shuttle would apparently not alleviate the need for cars for most people.

Some people might be encouraged to carpool if they were made aware that pooling is less expensive than driving alone. If different people drive their cars each day for carpooling, then some cars are left at home, which reduces the wear and tear on the cars and, hence, repair costs. Costs of gasoline and the like are generally shared among poolers if driving is not shared. Also, some automobile insurance companies offer reduced rates to their customers who carpool.

These factors are important in encouraging carpooling because 34 percent of the people surveyed were concerned about transportation costs, 18 percent would consider carpooling if it would reduce their automobile insurance premiums, and 19 percent would consider changing if carpooling were less expensive than driving alone.

Another important incentive appears to be reduced parking fees for people who carpool to UCLA. Sixteen percent of the people surveyed were concerned with parking costs and 13 percent said that they would consider changing to carpooling if parking fees were reduced. Parking rates could be reduced for people who carpool to campus, or regular parking rates could be raised at the same time carpooling rates are established, in order to emphasize the incentive.

Vanpooling

Although as a general rule the market for vanpools is considered to be made up of people who drive more than 15 mi to work, the definition of the UCLA vanpool market has been expanded to include persons who live more than 10 mi from campus. The considerable social and environmental benefits resulting from high-occupancy vanpools, such as decreased congestion and parking demand, make the expansion of the market worthwhile at UCLA. As with carpooling, the market is also generally those who drive alone. In the UCLA faculty and staff survey, 13 percent drove alone more than 10 mi to campus and indicated an interest in switching to vanpooling for reasons other than the Olympics. Significantly more staff than faculty fell into this group--14 and 5 percent, respectively. Of the people traveling more than 10 mi each way, almost half (49 percent) were willing to consider vanpooling and 35 percent requested information on vanpooling.

The questions that dealt with commuters' concerns, reasons for not ridesharing, and what might encourage them to vanpool show that, like carpooling, the strongest vanpooling incentives center around costs and flexibility. Again, making people aware that pooling usually costs less than driving alone and need not be done every day should induce some people to try it.

Public Buses

No incentives that would get people to consider changing to riding public buses were suggested by the survey results. Most concerns about busing were centered around service, over which UCLA/TSA has little or no control. Many people thought that buses take too long (21 percent) or that they are not reliable or frequent enough (11 percent).

Perhaps the best suggestion for encouraging bus riding would be to make schedules and route information more easily available. It may be that people have not looked into taking the bus and do not really know how long it would take them to get to UCLA or how frequently the buses run.

Bicycles

The best incentive for bicycling appears to be a safe bike path to the UCLA campus. Forty-seven percent of the people willing to consider bicycling would consider it if such a path were available; this is a total of about 7 percent of the working population.

RECOMMENDATIONS

On the basis of the results of the UCLA staff and faculty commuter survey, the following elements have emerged as having the greatest potential for structuring a successful commuter transportation program for employees at UCLA. The following points are important to an effective marketing plan for ridesharing:

1. Concentrate efforts on staff rather than faculty. Staff tend to be more interested in ridesharing, have more consistent schedules, and live farther from campus. They also comprise about 80 percent of the employee population.
2. Be responsive to employees' sensitivity to costs. Emphasize benefits of ridesharing such as shared expenses and resulting savings; develop incentives such as reduced parking fees for ridesharers; promote automobile insurance companies that give discounts to carpoolers.
3. Promote the flexibility of ridesharing. The top reasons for not ridesharing were the need for a car before or after work and a lack of flexibility. Yet people needed their cars fewer than 2 days per week on the average. Ridesharing need not be done every day of the week to provide commuters and the entire campus community with economic, social, and environmental benefits.
4. Promote the availability of UCLA's campus ridesharing coordinators. About a fifth of the nonridesharers stated that they would seriously consider carpooling if a coordinator assisted them in finding other faculty or staff to carpool with.
5. Encourage everyone seriously interested in ridesharing to register and regularly update their registration with UCLA/Commuter Computer. That way those people who are unable to find pooling partners on their own will have the greatest likelihood of contacting prospective poolers. The quality of the ridesharing data base--in terms of both numbers of people and accuracy of the information--is critical if Commuter Computer matchlists are to be useful to registrants. Fewer than half of the people who were not registered had not registered because they were not interested in ridesharing.

The survey results also indicate that university-provided vans would be instrumental in encouraging employees to vanpool. The ridesharing marketing program need not have bicycling and buses as priority elements, yet support for bike paths and facilities, and more easily available bus schedules and information, would be helpful to substantial segments of the employee population. Undoubtedly, these relatively low-cost transportation alternatives would be of interest to many students as well.

An integrated transportation program, which meets the needs of all segments of the campus community, can only be designed after the needs of students and Medical Center employees have been analyzed. This study of faculty and staff has been an excellent first step toward the development of a comprehensive ridesharing marketing program based on careful assessment of commuters' beliefs and behavior.

Circuity Factor Values in Ridesharing: A Detailed Update

JON D. FRICKER

ABSTRACT

The extra distance that a member of a carpool travels, compared with that person's drive-alone distance between home and work, is one of the negative aspects of ridesharing. It is also the key value in calculating the amount of fuel saved by those choosing this commuter mode. Among several proposed methods of quantifying this extra distance, or circuity factor (CF), the most commonly used is the ratio of ridesharing distance to drive-alone distance, which is called the circuity ratio (CR) in this paper. The CR-value most commonly used is the ratio 1.15, but this value is neither well documented nor up to date. A detailed examination of the CR-values experienced by 206 individuals who share rides in or to a small urban area is described in this paper. The CR-values were found to have a mean value lower than the long-accepted value (1.071 versus 1.15) and a standard deviation much smaller (0.154) than expected. These findings have several applications: (a) they permit more accurate calculations of fuel savings associated with mode shifts involving ridesharing under current conditions, (b) they define a standard against which circuity values in times of energy shortages can be compared, and (c) they provide data in sufficient detail to allow subsequent studies to examine and explain differences in circuity components found in other times and places.

Although the energy crises that gave ridesharing its biggest boost have become distant memories, that mode continues to play an important role in commuter transportation. In most metropolitan areas, either highway capacity cannot accommodate all those who want to drive to work alone or downtown parking supply and cost conditions make driving alone to the CBD impractical, or both. In these cases, public transportation and ridesharing are the primary recourses. In smaller urban areas, employment centers attract workers from a proportionally large surrounding area. The great distances (and travel costs) involved frequently motivate commuters from outlying towns and rural areas to form carpools and vanpools as economy measures.

In both large and small urban areas, travel cost is the major factor in choosing the ridesharing mode, but in large areas these costs are principally related to the capacity of facilities. In smaller areas, the key costs are distance related. It is both ironic and unfortunate that all published circuity factor (CF) values are drawn from large metropolitan areas (1-6). If a fuel shortage is the principal motivator and fuel conservation is the foremost social objective, modal CFs (7,8) for large standard metropolitan statistical areas (SMSAs) are appropriate for estimating fuel savings from ridesharing in those areas. However, such CFs are not well documented or up to date. For smaller areas or for other objectives, applicable information on circuity factors in ridesharing is not available.

This paper is based on Part I of a report (9) that investigated the individual's travel decision with respect to ridesharing and some techniques used to make the study of the distances involved easier. This paper has as its objective to disseminate and document the values of circuity factors found during a detailed analysis of the routes to work taken by 206 individuals in 64 carpools in and to an urban area of approximately 70,000 inhabitants, in a county with a population of 130,000. The results of this study should be informative to energy analysts, ridesharing brokers, and transportation planners.

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CIRCUITY FACTOR DEFINITIONS

There are numerous factors that figure in an individual's decision to join a carpool. Among the easiest to quantify, and the most important in calculating fuel saved by ridesharing, is the relative distance traveled. If a traveler's drive-alone distance from his home to his job is d_o, but he can join a car pool in which his home-to-work travel distance will be d_r, the pool's circuity factor (CF) for him could be measured as a circuity ratio (CR):

$$CR = d_r/d_o \qquad (1)$$

The measurement of circuity or route deviation has not been standardized, however. Among the many variations on, or substitutes for, $CR = d_r/d_o$ are those that follow.

- Circuity is "the mean fraction of the round trip length which must be covered to pick up one ride," with values thought to be between 0.2 and 0.4 (6).
- "One-day trip circuity per carpooler" is estimated to be a distance of 0.5 mi (2).
- A route deviation factor, d, can be defined as

d = Total passenger miles produced/Total passenger trip miles produced

where "a trip mile is produced when a traveler is carried one mile of the direct over-the-road distance between his trip origin and his trip destination" (10). This can be interpreted as the CR = d_r/d_o equation, especially because Kirby et al. use 1.0 $\leq$ d $\leq$ 2.0 in their examples.

• Richardson and Young (3) define home-end deviation "as the grid distance covered in traveling from the driver's home to each of the passenger's homes (in correct order) and then to the driver's work place." The work-end deviation is defined similarly. They take on mean values of 2.4 km and 0.9-1.7 km, respectively.

• Johnson et al. (1) say that a "fundamental question is: What is the total distance a van pool group may be willing to deviate from the direct route to the destination?" They "estimated the ratio of the maximum deviation to direct route length to be between one-fourth and one-third (depending on travel conditions)."

These variations will be given closer attention in a companion paper by Fricker and Habib in this Record, which describes how an individual's ridesharing decision is affected by various distance components. For now, the CF measurement methods CR = d_r/d_o, which is the most commonly used definition, and circuity distance, CD = $d_r - d_o$, which has the advantages of simplicity and familiar units (miles), will be used. A single CR value of 1.15 is often cited (7,8), but this value has an obscure basis, may be outdated, and gives no insight into an individual's decision to rideshare. The data collection, verification, and analysis steps that led to a complete distribution of CR values and form the basis for subsequent analyses are described in this paper.

DATA COLLECTION

In May 1982 a survey form was distributed by campus mail to 378 individuals who had requested the ridesharing matching services of Purdue University's Personnel Office. Although this was at the end of the spring semester and the beginning of a break before summer session for many, the survey response was impressive. Within 4 workdays, 197 survey forms were returned. Even those individuals who had not found satisfactory carpooling situations--147 of them--felt strongly enough about ridesharing to return the form with their reasons for not being in a pool (Table 1).

In addition to the apparent support for ridesharing on the part of respondents, the simplicity of the survey form helps to account for the high response rate. The form asked for the names and home addresses of carpool members and whether members were

TABLE 1 Reasons for Not Carpooling

Rank	Frequency	Reason
1	58	My schedule is too variable.
2	29	I can't find anybody in my area I would like to carpool with.
3	16	Driving alone is more convenient.
4	12	The extra distance is too great.
5	8	I need a car during the day.
6	6	I ride my bicycle or motorcycle.
7	6	I take the bus.
8	6	I ride with my spouse.
9	5	I have to drop my children off at babysitter/school/work.
10	4	I frequently have appointments after work.
11	3	I have moved since requesting a carpool match.
12	3	I'm no longer interested.
13	2	I walk to work.
14	2	It would be more expensive for me.
15	1	I have no car to offer.

picked up at their homes or at a rendezvous point, or had another arrangement. There was space on the survey form to record positive and negative aspects of carpooling, reasons for not participating in a pool, and suggestions for making the commute to Purdue more attractive. The simplicity of the form had its drawbacks, however.

Only a few of the 66 carpool members who responded to the survey provided enough detail to permit accurate d_o and d_r measurements. This was the result of a deliberate strategy to maximize the survey response rate, even if a large number of follow-up telephone calls had to be made to acquire the information necessary for the study. In the course of the following year, a lengthy series of follow-up phone calls was needed to acquire any information in the following list that was not clear from the responses to the original survey.

1. What is your exact home location?
2. Who in your carpool drives and how often?
3. Where are you picked up when others drive?
4. What is your drive-alone route?
5. What route or routes are taken by your carpool?
6. Where are you dropped off?
7. What is your exact work location?
8. Where do you park at work?
9. Are any of your carpool members "captive riders"?
10. Any suggestions to improve ridesharing to Purdue?

Without exception, the telephone interviewees were cooperative. A by-product of these conversations was the discovery of several other carpools, which eventually brought the size of the sample to 206 individuals in 63 carpools and 1 vanpool. (Note that, for the sake of convenience, all 64 pools in the sample will hereafter be referred to as carpools, unless the vanpool distinction is important.)

Early attempts at carrying out the d_o and d_r distance measurements on maps proved so tedious that a second survey form was developed and sent to carpoolers in April 1983. Respondents were asked to list the names of carpool members and indicate whether they were picked up at home, walked to a rendezvous point, or drove to a rendezvous point. In the latter two cases, the number of blocks walked or miles driven was to be indicated. The time (minutes) it took each person to walk from his dropoff point to the entrance of his place of work and the distance (miles) he would drive if he drove alone were also requested. In addition, the respondent was asked to record, for a single day, the odometer reading when the driver and each rider entered the vehicle, when each rider left the vehicle, and when the driver parked the vehicle.

The response rate was low and the information provided indicated that the respondents had trouble understanding the second form. In addition, an attempt was made to administer a survey of participants in the Tennessee Valley Authority (TVA) vanpool program. Although the survey form was carefully designed and successfully tested on a pilot basis, the results were not of sufficient quality to include in this study. These experiences vindicated the simplicity of the first form and justified the extensive telephone follow-ups it made necessary. Because a telephone follow-up to the second form or the TVA survey was not practical, given the nature of the information that was requested, a return to the tedium of map measurements was necessary. The second survey form did provide some useful information, however. In 19 of the 29 carpools covered in the survey's responses, changes in membership had taken place during the 11 months since the first survey: 9 new individuals had joined carpools, 13 had quit carpools, and 4 pools had disbanded. This small sample is further indication of the well-known volatility or flexibility of ridesharing arrangements.

The time required to process each carpool--and each individual's d_r and d_o values within it--varied with the number of members and the number of drivers but was surprisingly great. Processing the survey forms, making follow-up calls, and transcribing telephone notes into routes for map measurement took more than an hour for the typical carpool. The detailed over-the-road distance measurements were carried out using a mapwheel and took approximately another hour. This time was invested to guarantee the most accurate possible data set. However, this "ordeal" became a powerful incentive to develop and test distance estimation methods that provide sufficient accuracy with far less effort. This is the subject of the second part of the full report (9).

DATA VERIFICATION

Map Measurements

In all, more than 700 d_r and d_o route measurements were made with a mapwheel. Work of this sort lends itself to occasional errors, so a procedure was devised to search for anomalies in the data--data that would form the basis for all analyses to be conducted in the study.

A checking program was written to accept the following inputs for each individual:

1. The individual's over-the-road d_o (drive-alone) distance between home and work, as measured on the maps, and
2. The coordinates of the individual's home (x_h, y_h) and work (x_w, y_w) locations.

The checking program first converted these coordinates into an "airline distance,"

$$d_o^A = [(x_w - x_h)^2 + (y_w - y_h)^2]^{1/2} \quad (2)$$

Because d_o^A is the minimum possible (straight line or euclidean) distance between home and work, it acts as an absolute lower bound for the map-measured d_o. Next, the program calculated the individual's "Manhattan" (or rectangular or metropolitan) distance between home and work,

$$d_o^M = |x_w - x_h| + |y_w - y_h| \quad (3)$$

As Figure 1 is intended to illustrate, it is expected that the condition $d_o < d_o^M$ will hold in all but a few cases. Thus d_o^M was adopted as a suitable, but not absolute, upper bound on the map-measured d_o.

Table 2 gives a portion of the checking program's output. Note the asterisk used to indicate when a lower or upper bound was violated. Although $d_o < d_o^A$ never occurred, $d_o > d_o^M$ was true for 33.5 percent of the individuals. Checking these cases manually revealed that there were two possible reasons for violation of the upper bound, a violation that is usually equivalent to leaving the "box" formed by the two possible Manhattan paths shown in Figure 1. Either

1. $(x_w - x_h)$ or $(y_w - y_h)$ is very small, thereby forming a very narrow box that is likely to be left when following the road network or
2. There exists a more direct, shorter route between home and work along local roads that stay within the box, but a faster route along the major roads departs from the box.

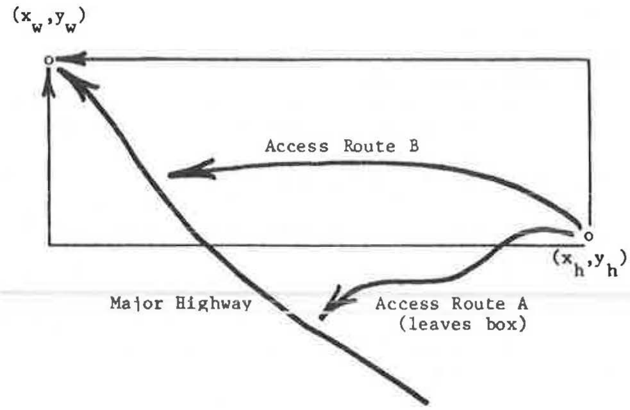

FIGURE 1 Box formed by the two possible Manhattan paths.

TABLE 2 Portion of Output from Checking Program

ID	County	Unweighted Airline Distance	Measured Distance	Manhattan Distance
1A	Montgomery	24.75	30.73	31.32
1B	Montgomery	24.91	31.08	31.40
2A	Clinton	28.28	33.80	34.21
2B	Clinton	25.05	30.62	33.69
2C	Clinton	26.65	31.37	36.14
2D	Clinton	23.84	27.64	32.04
3A	Tippecanoe	2.09	2.67	2.84
3B	Tippecanoe	2.03	3.21	2.84[a]
4A	Tippecanoe	4.23	5.69	5.64[a]
4B	Tippecanoe	4.52	6.30	6.38
4C	Tippecanoe	1.92	2.49	2.70
5A	Tippecanoe	3.16	3.90	3.52[a]
5B	Tippecanoe	3.12	3.80	3.21[a]
6A	Tippecanoe	3.58	4.08	4.84
6B	Tippecanoe	3.93	5.70	5.54[a]
6C	Tippecanoe	2.68	3.53	3.64

[a]Measured distance may be wrong; double-check.

This process was repeated for the map-measured d_r-values using Equations 2 and 3 to calculate d_r^A and d_r^M for each segment of the ridesharing trip and then summing these segment lengths. Each occasion in which $d_r > \Sigma\, d_r^M$ was reinspected. In both checking procedures, no measurement errors were discovered. The mean d_o-value for the 206 individuals was 19.80 mi, with a standard deviation of 12.57 mi.

For the reasons mentioned earlier, the second survey form did not fulfill its expectations as a checking instrument. Another checking step was to compute the daily and composite CR values (the weighted daily average, as defined in Equation 4) for each individual and reinspect those with suspiciously high or low values. In the case of carpool 13, member A had a CR of 2.895, whereas no one else in the sample had a CR greater than 1.69. This person (13A) turned out to be the only driver in his carpool, which included four fellow workers. Although individual 13A had to backtrack and drive an extremely circuitous route, he saw nothing unusual or arduous about helping his friends get to work in this way. CR-values less than 1.00 were not uncommon, and each was verified. An example of a CR less than 1.00 is given later in this paper.

As a result of these checks, the researchers are confident that the data acquired by the first survey form and its follow-up interviews have been correctly converted to the d_o and d_r distances presented in this paper.

Local Bias

Even after the accuracy of the d_o and d_r measurements has been verified, there is the question of how representative the data are. There are three questions to be addressed:

1. Is average occupancy in vehicles bound for Purdue University typical of work trips in most locations?
2. Is the distribution of occupancies for Purdue-bound vehicles similar to that for the non-Purdue-bound vehicles in this area?
3. For multioccupancy vehicles, is the distribution of carpool sizes (number of members) the same for the Purdue sample taken for this study, all Purdue carpools, and all non-Purdue carpools?

The following paragraphs describe the investigation of these questions.

• Average vehicle occupancy. A series of roadside observations along approaches to the campus was conducted in October 1984. Table 3 gives a summary of the findings. The average occupancy of 1.20 is somewhat smaller than the national average of 1.39 for automobile work trips, perhaps a reflection of the relatively mild congestion and parking problems on and near the Purdue campus.

TABLE 3 Vehicle Occupancy Rate at Purdue

		Vehicle Occupancy					
Date	Entrance	1	2	3	4	5+	Avg Occupancy
11/19/84	State at Andrew	354	57	7	0	0	1.17
	Fowler at Vine	254	52	6	0	0	1.21
11/18/84	Grant near Northwestern	286	43	3	0	0	1.14
	Stadium at Garfield	108	26	2	0	1[a]	1.29
11/19/84	SR-26 at Airport Road	207	52	4	1	0	1.24
Total		1,209	230	22	1	1	1.20

Note: Rate = number of adults in vehicles approaching campus during 36- to 60-min period, including 8:00 a.m.

[a]Eleven occupants in van.

• Distribution of vehicle occupancies. The roadside observations made in October 1984 included (a) the number of adults in each vehicle, (b) whether the vehicle was displaying a Purdue parking permit on the windshield, and (c) the state or Indiana county in which the vehicle was registered, determined from the numerical prefix on the license plate. Table 4 gives a summary of the first two items. A chi-square test indicated that the null hypothesis

> H_0: the distribution of vehicle occupancy is independent of whether the sample is drawn from cars with Purdue parking permits or those without

could not be rejected at the 5 percent level of significance (11). Inspection of the contingency table revealed very close agreement with each cell.

• Distribution of carpool sizes. The distribution of membership sizes in the survey of 63 carpools was

TABLE 4 Vehicle Occupancies by Destination

No. of Occupants	Purdue	Non-Purdue
1	1,209	490
2	230	105
3	22	8
4	1	0
11	1	0
Average	1.20	1.15

compared with that observed from the roadside (Table 5). This time the chi-square test indicated that the null hypothesis

> H_0: the distribution of adults in multioccupant vehicles is independent of whether the sample is drawn from cars with Purdue parking permits or those without

should be rejected at the 5 percent significance level. The average carpool size nationwide is 2.3 to 2.5 persons (12), yet the two subsamples (Columns 2 and 3 of Table 5) averaged 2.13 and 3.13. That the observed occupancies would be lower than those based on the first survey form is not unexpected. Normal absences from carpools, due to staying home or the need to have one's own car, can explain some of this difference.

TABLE 5 Purdue Carpool Sizes by Data Source

(1) No. of Members	(2) Roadside Observations of Purdue Permits	(3) First Form and Follow-Up	(4) Col. 3 with Pr{absence} = 0.20
2	230	26	24
3	22	12	15
4	1	16	11
5	0	9	3
7	0	0	1
9	0	1	0
11	1	0	0
Average	2.13	3.22	2.94

On the basis of information acquired from the Tennessee Valley Authority ridesharing agency (personal communication with Cheryl Hamberger of the Employee Transportation Branch of the TVA), it was estimated that the probability (π) that any individual pool member would be absent on a given day is approximately 0.20. Using a binomial probability model, the probability that a carpool with n members will have r riders on a typical day is

$$\Pr\{r \mid n,\pi\} = [n!/r!(n-r)!]\ \pi^r (1-\pi)^{n-r} \quad \text{for } r = 0, 1, 2, \ldots, n$$

Applying this model to Column 3 of Table 5 produces the values in Column 4. The evidence persists that the data gathered with the first survey form represent a greater proportion of larger pool sizes, especially at r = 4. This remaining difference may be an indication that husband-wife and coworker "spontaneous" carpools tend to be smaller than those made up of people who requested carpool matching services (which was the basis of the first survey form). The possible differences between spontaneous and third-party carpool characteristics is of great interest, but data on this question have been even more difficult to obtain than the basic inputs for map measurements.

Thus far, there is nothing to indicate that these data cannot be of value in other locales. The researchers have been unable to find data from other, similar locations in sufficient detail to verify this belief in the transferability of the data. This study can be the first step in that kind of investigation.

CIRCUITY FACTOR VALUES

The CR-value calculated for each individual in this study is actually the weighted average of CR-values experienced as that person's carpool cycles through its various daily arrangements:

$$CR(i) = \sum_{j=1}^{m} f_j \, CR_j(i) \qquad (4)$$

where

- i = the ith individual,
- m = the number of different driver and pick-up arrangements a carpool has,
- j = the jth of these arrangements,
- f_j = the fraction of the time the jth arrangement is used, and
- $CR_j(i)$ = the d_r/d_o ratio experienced by the ith member of the carpool during the jth arrangement.

The values for Equation 4 are based on d_o and d_r measurements assembled in the format shown in Figure 2. There is one such table for each of the 64 carpools. All 64 tables are included in the Appendix to the full report (9). In the table for carpool 4 shown, there are three members but only two drivers. When member A drives on day 1 (or in the first "arrangement"), she must travel 7.65 mi between her home and work locations in order to pick up and drop off members B and C. Because her drive-alone home-to-work distance is 5.69 mi, her CR on day 1 is 1.344. On day 2, member B drives. Somewhat surprisingly, rider A's CR on day 2 drops to 0.982. This is because A is dropped off at the doorstep of her workplace by driver B, which eliminates the rather lengthy walk from her drive-alone parking location. All distance components were included and weighted equally in this phase of the research. The relative importance of each of the distance components (walking, pickup, line-haul, dropoff, etc.) is discussed in the paper by Fricker and Habib in this Record.

	Over-the-Road Distance		Manhattan Distance		Airline Distance	
Member	d(0)		d(0)		d(0)	
A	5.69		5.64		4.23	
Day	d(r)	CR(day)	d(r)	CR(day)	d(r)	CR(day)
1	7.65	1.344	7.96	1.411	5.76	1.362
2	5.59	0.982	5.64	1.000	4.32	1.021
Avg	7.44	1.308	7.73	1.370	5.61	1.327
Member	d(0)		d(0)		d(0)	
B	6.30		6.38		4.52	
Day	d(r)	CR(day)	d(r)	CR(day)	d(r)	CR(day)
1	6.20	0.984	6.38	1.000	4.52	1.001
2	7.04	1.117	7.22	1.132	5.55	1.227
Avg	6.28	0.997	6.46	1.013	4.63	1.023
Member	d(0)		d(0)		d(0)	
C	2.49		2.70		1.92	
Day	d(r)	CR(day)	d(r)	CR(day)	d(r)	CR(day)
1	2.49	1.000	2.70	1.000	1.92	1.000
2	2.49	1.000	2.70	1.000	1.92	1.000
Avg	2.49	1.000	2.70	1.000	1.92	1.000

FIGURE 2 Ridesharing distance for Pool 4.

A CR value of less than 1.00 computed this way is not unusual. Normally, it is due to the distance saved by being dropped off at the doorstep of one's workplace. In a few cases, one member prefers a longer (but faster, more comfortable, or more scenic) route when driving alone, but a more direct route may be taken by the carpool either because of the preference of the other members or because the members' home locations rule out easy access to the longer but faster route.

Member C is the nondriving member of carpool 4. She is picked up last, dropped off first, and would park next to her place of work (negligible walking distance) if she drove alone. Thus her CR of 1.00 on each day is neither a mathematical coincidence nor that unusual an occurrence in the computations.

In carpool 4, member A drives most of the time, such that $f_A = .90$ and $f_B = .10$. For individual 4A, Equation 4 produces

CR(A) = (.90*1.344) + (.10*0.982) = 1.308

Carrying out Equation 4 for each of the 206 individuals in the study produced a mean CR-value of 1.071 and a standard deviation of .154. The distribution of CR-values in histogram form is shown in Figure 3.

The mean CR-value of 1.071 is considerably lower than the commonly used 1.15 value (7,8). The distribution is positively skewed (the median CR is 1.039) and less spread out than expected. The low mean CR may be evidence of a reduced tolerance for circuity in the absence of a fuel shortage. The small standard deviation is an indication of fairly uniform behavior with respect to circuity among ridesharers, something that is discussed in the paper by Fricker and Habib in this Record. A preliminary step in that investigation is to display the computed CRs as is done in Figure 4. This is an attempt to detect any influence of carpool size (n) or drive-alone distance on CR-values. There is no obvious trend in this graphic display, which is summarized in Table 6. The somewhat larger mean and very large standard deviation for n = 4 in Figure 4 are due primarily to the individual (13A) with a CR of 2.894, described earlier. Without this outlying value, the mean and standard deviation for CR at n = 4 drop from 1.099 to 1.076 and from .250 to .111, respectively. Indeed, if 13A's CR is removed from the 206-member data set, the overall mean CR drops to 1.062 and the standard deviation becomes only .086. A number of suspected causes for variation in CR are studied in the paper by Fricker and Habib in this Record.

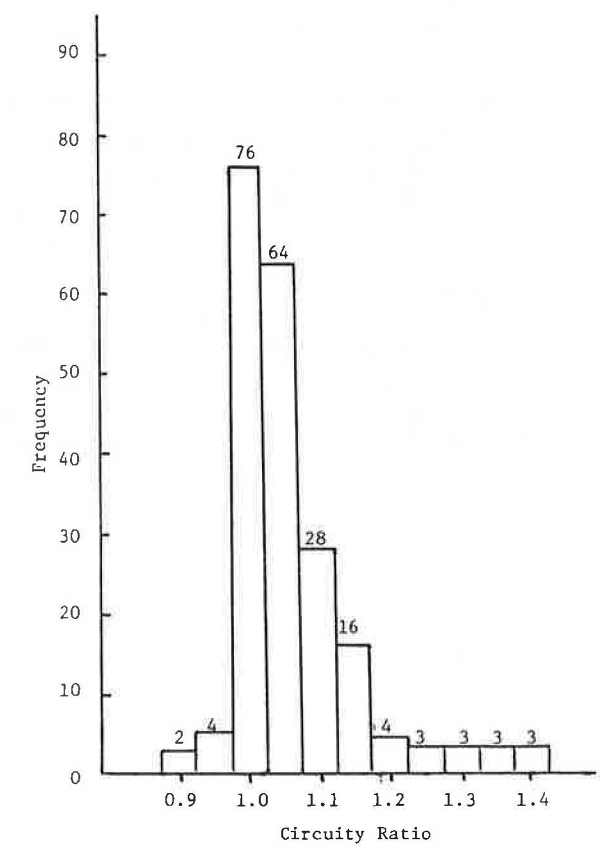

FIGURE 3 Distribution of circuity ratio values.

SUMMARY

In this paper are presented the circuity ratio (CR) values found for ridesharing among carpoolers at Purdue University. On the basis of analysis, the following information about ridesharing has been established:

1. The mean value of CR in the region around and including the small urban area studied is 1.071.
2. The distribution of CR-values is narrow, with positive skewness.
3. For subsamples based on the various carpool sizes in the sample (2, 3, 4, 5, and 9 people), the average CR-value ranges from 1.035 to 1.122.
4. The mean value of CR increases to some extent with an increase in the number of people in a carpool.
5. Some factors other than carpool size (n) might have greater influence on the observed values of CR.
6. No obvious trend exists between CR and d_o.
7. The most common carpool size is 2 persons--about 41 percent of the carpools.

The results obtained should be helpful in the evaluation of the energy-saving potential of carpooling in the journey to work. The results should also be of assistance in determining the acceptability of carpool structures generated by carpool-matching programs. The work done to date provides a good data base for subsequent investigations of distance estimation and clues to the acceptance of ridesharing as a commuter mode.

ACKNOWLEDGMENTS

The study described in part in this paper was carried out under a grant from the University Research and Training Program, Urban Mass Transportation Administration, U.S. Department of Transportation. The cooperation of Purdue University's Personnel Services Office--the office responsible for matching individuals who wish to share rides to campus--was necessary to get the study's data collection process started, for which the researchers are extremely grateful. The author expresses his appreciation to Ing and Chung-cha Liu, who processed the data that make up Table 1. The computer programming and helpful suggestions of Charles Oliva have been of great assistance. Md. Golam Habib deserves praise for the care and stamina he demonstrated in carrying out the approximately 700 measurements of drive-alone and ridesharing distances on which this paper is based. Most of all, the author is grateful to the ridesharers at Purdue who have answered, often with enthusiasm, his many questions about their carpool arrangements.

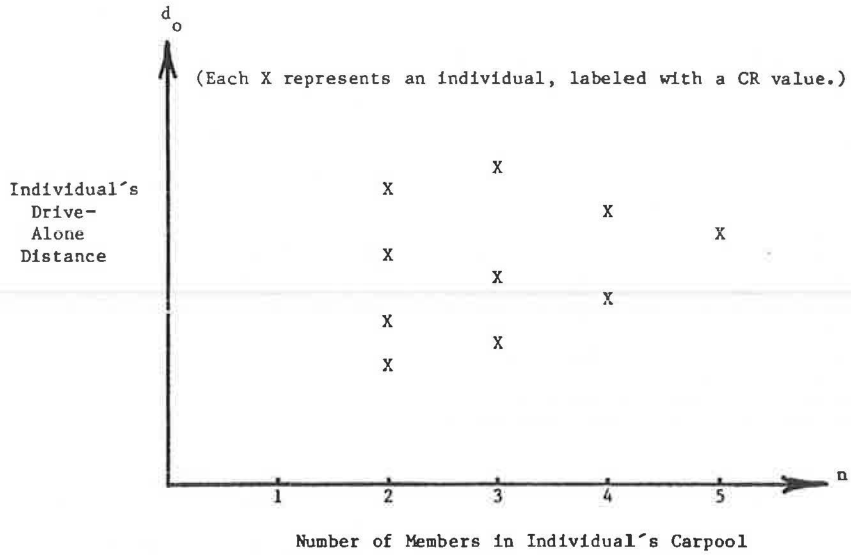

FIGURE 4 CR-value, carpool size, and distance to work.

TABLE 6 Summary of Figure 4

n	Mean CR	Standard Deviation
2	1.053	.088
3	1.035	.063
4	1.104	.250
5	1.061	.066
9	1.122	.082

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Analysis of the Influence of Certain Personal and Distance-Based Factors on the Tolerance of Circuity in Ridesharing

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ABSTRACT

An attempt is made to develop a regression model that will explain which factors influence the circuity associated with an individual's ride to work in a carpool or vanpool. The factors are of two types: those related to the trip and those that characterize the traveler. Although the resulting model was not extremely strong, certain of its elements indicate promise for variations and extensions of the work presented here. The factors included in the final model are reasonable and logically consistent. Trip-related factors, such as number of pickups, degree of common destination, and dropoff ride distance, emerge as more important explanatory variables than the personal variables, although job type also plays a useful predictive role. Application of this sort of model to ridesharing matching operations holds promise as a screening procedure for proposed matches.

Data collected for an earlier paper (see paper by Fricker in this Record) provided a rare opportunity to examine certain relationships that may exist between the distance traveled by carpoolers in excess of their drive-alone distance and (a) the personal makeup of the individuals involved and (b) the characteristics of the components of the shared-ride trip. The relationships between circuity and the personal and trip-related factors are investigated using a regression model. The idea is to construct a regression model

$$Y = b_o + b_1X_1 + . . . + b_mX_m \quad (1)$$

that makes possible the conversion of known or easily estimated X_j-values into a reasonable estimate of maximum tolerated circuity (Y). These X_j-values could be based on a proposed carpool matching. The Y-value that results from the use of Expression 1, when the b_j-values have been established, could serve as a measure of the probability of success for the proposed matching. In this paper are described the factors that were available in the data set, the relationships hypothesized, the analysis performed, and the prospects for possible application by ridesharing matching agencies.

CANDIDATE VARIABLES FOR REGRESSION MODEL

In this section, variables that describe the characteristics of individuals and their shared-ride work trips with respect to circuity in ridesharing are defined. Eighteen variables have been introduced for the analysis (Table 1). The variables can be classified as two basic types: trip-related or spatial variables and person-related or behavioral variables. The spatial types are those that mainly describe various components of the journey and their related measures--usually distances or counts. The variables "home-end walking distance" and "number of pickups" (defined later) fall into this group. The behavioral variables describe personal and qualitative aspects associated with each individual in the ridesharing context. "Sex," "sex mix," and "job type" are examples of behavioral variables in the analysis.

TABLE 1 Independent Variables for Regression Model

Symbol	Description
X_1	Drive-alone distance, d_o (mi)
X_2	Ridesharing distance, d_r (mi)
X_3	No. of pickups
X_4	No. of rendezvous points
X_5	No. of dropoffs
X_6	Carpool size, n
X_7	No. of sequences
X_8	Sex of carpoolers
X_9, X_{10}	Sex mix in carpool
X_{11}, X_{12}	Degree of common destination
$X_{13}, \ldots, X_{18}$	Job types
X_{19}, X_{20}	Job mix in carpool
X_{21}	Home-end walking distance (mi)
X_{22}	Pickup ride distance (mi)
X_{23}	Line-haul distance (mi)
X_{24}	Dropoff ride distance (mi)
X_{25}	Work-end walking distance (mi)
X_{26}	Circuity ratio, CR or Y_1
X_{27}	Circuity distance, CD or Y_2 (mi)

The contribution of each variable to the model requires careful interpretation. For example, consider the variable "pickup ride distance" in the circuity model. Spatially, as this distance goes up, the circuity is likely to go up because of the increased detour. But, from a behavioral point of view, this might not be true. Although a person may "suffer" more in the pickup distance, he may be compensated for it by some other components of the journey, which result in lower overall circuity. If this "compensation" were not possible, the overall circuity might be intolerable enough to cause the individual to

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forgo membership in the carpool. The individual's circuity threshold having been exceeded, this person would, of course, not be included in the ridesharing data set. This and other aspects of the search for an individual's maximum tolerable circuity are shown in Figure 1.

Figure 1 shows how an individual's circuity factor (CF) value changes from day to day as the driving responsibility rotates or the number of riders varies. If interest centers on the "circuity factor threshold" for an individual, the best available approximation is the maximum CF value experienced by that individual. For this reason, the Y- and X_i-values employed in the model correspond to the "max CF" day for each of the 206 individuals in the survey data. Because some individuals have two distinct days with the same maximum CF value, both days are included in the analysis, which brings the number of maximum CF observations to 215.

DEFINITIONS AND HYPOTHESES

The candidate variables and their contribution to the model must be viewed in a comprehensive way. The following subsections contain a description of each variable proposed for the current analysis, including a definition and hypothesized "circuity relationship" for each.

Y_1 or X_{26}, Circuity Ratio

The circuity ratio (CR) is the ratio of ridesharing distance (d_r) to drive-alone distance (d_o). This is the dependent variable Y_1 in the first CF model reflected in positive and negative coefficients.

Y_2 or X_{27}, Circuity Distance, $d_r - d_o$

This is the dependent variable in the second CF model. It is the difference between ridesharing distance (d_r) and drive-alone distance (d_o).

X_1, Drive-Alone Distance, d_o

This is the distance covered by an individual over his usual route from home to work when driving alone.

Drive-alone distance can be thought of as a proxy for various trip attributes, such as travel costs, travel time, and comfort. Individuals with large d_o-values could be considered prime candidates for ridesharing--to share travel costs, prevent boredom, provide company in remote areas, and so forth.

For smaller d_o-values, the net amount of detour (circuity distance, CD) to be tolerated by an individual in ridesharing is likely to be smaller, but the corresponding ratio measure of circuity (circuity ratio, CR) could still be about average or even larger. For large d_o's, the total deviation acceptable would be larger but, because it is the ratio of two large numbers, the CR is likely to be relatively close to unity. Hence, a positive slope for CD and a negative slope for CR when plotted against d_o.

X_2, Ridesharing Distance, d_r

This is the distance traveled by an individual in the journey to work as a carpool member. The distance components of the trip are home-end walking (X_{21}), pickup riding (X_{22}), line haul (X_{23}), dropoff riding (X_{24}), and work-end walking (X_{25}).

The effect of this variable on CD and CR is quite similar to that of d_o. It also gives an idea about the extent of various possible deterrents to ridesharing, such as extra distance and extra time. The variable d_r and its components might provide some clues about individual ridesharing decisions by revealing any strong correlations they might have with CR or CD, or both. Care should be exercised in using d_r, however. If d_o is already in the model, the definitions $CD = d_r - d_o$ and $CR = d_r/d_o$ make inclusion of d_r redundant and invite collinearity.

As d_r increases, CD is likely to increase, but CR may remain fairly stable. Hence, the coefficient of d_r would be expected to be positive when CD is the dependent variable but be approximately zero for CR.

X_3, Number of Pickups

This is the number of stops to pick up other carpool members experienced by a given individual from the time the individual in question enters the vehicle until the last person is picked up. In a five-person carpool, if person A drives and picks up members B, C, D, and E individually in that order, the X_3 count for person C on that day would be 2. For A, it would be 4. After E is picked up, the line-haul phase (X_{23}) begins.

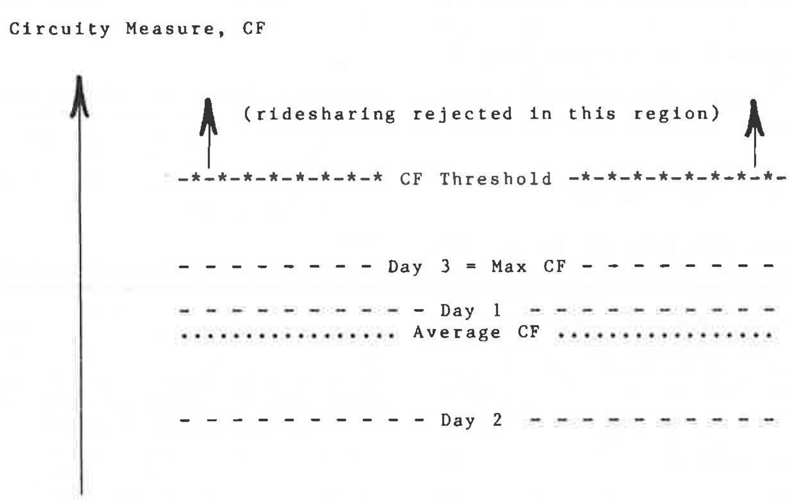


FIGURE 1 Seeking an individual's maximum tolerable circuity.

An increase in X_3 means reduced overall travel speed and may lead to unscheduled delays in excess of the standard boarding time or unnecessary extra distance if the person to be picked up is found to not be making the trip that day. Thus the variable X_3 is a measure of inconvenience (or ridesharing "cost") that is not reflected in distance values but may be a significant factor in the decision to rideshare. More stops mean more carpool members to be picked up and usually more detour. Hence, as the number of stops increases, both CR and CD are expected to increase, resulting in a positive coefficient for this variable in both the CD and CR regression equations.

X_4, Number of Rendezvous Points

Establishing a rendezvous point avoids the circuity associated with going door to door to pick up pool members. On the other hand, the typical rendezvous point involves the meeting of three or more individuals, each with his own potential for late arrival. It is expected that the use of rendezvous points leads to lower CR and CD values because purely distance values are involved. However, if rendezvous points are viewed quite negatively by a prospective carpooler, circuity elsewhere in the ridesharing route might have to be quite low to attract and retain that member. Thus only low-CF cases would appear in the data set when rendezvous points are involved. This notion of a CF threshold and its being influenced by rendezvous and other particular variables formed the basis for a subsequent analysis involving the individuals in the data set who use rendezvous points. (Note: a rendezvous point is not included in an individual's pickup count, X_3.)

X_5, Number of Dropoffs

This is the number of stops made to drop off other members before an individual's own dropoff point is reached.

The aversion to dropoffs may not be as severe as is that to pickups. There is little chance of unforeseen delay and, in most cases, the walk distance from dropoff point to workplace is much less than in the drive-alone case. Although CR and CD could be expected to increase with X_5, the coefficients should have smaller values than X_3. The hypothesis is that this variable is not a major factor and will not appear in the final model.

X_6, Carpool Size, n

This is the number of individuals who participate as members of a carpool on a particular day. In the data set, X_6 ranges from 2 to 6, with the one exception being a 9-member vanpool. The value of X_6 may change for a given carpool from day to day if, on a regular basis, some members ride only on certain days. For a given day, however, each of the n riding members of a given carpool is assigned the value $X_6 = n$.

Carpool size has both positive and negative ramifications. Larger carpools can mean greater savings in travel cost, with more persons to share costs that rise relatively little for each new member. If driving responsibilities are rotated, the number of days off between driving days increases as X_6 increases. For most people, this is desirable.

On the negative side, more members usually mean greater values for pickup and dropoff counts, pickup and dropoff distances, and the increased potential for incompatible personalities. The need for rendezvous points also becomes more likely. Again, if there were no threshold on the tolerance of various ridesharing characteristics, it could simply be hypothesized that CD and CF both go up with carpool size. However, the negative aspects just mentioned act in opposition to cost savings and relief from driving to complicate the relationship between X_6 and circuity. Examining the negative influences (X_3, X_4, X_5, X_{22}, and X_{24}) and their relationship to circuity separately may clarify the picture as the model is built. Until then, the expectation is that circuity increases with carpool size (i.e., the coefficient of X_6 will be positive).

X_7, Number of Sequences

This variable recognizes that a carpool may take on different configurations from day to day. On a regular basis, certain members may not participate on particular days of the week. Even if all members ride daily, the responsibility for driving may rotate, which in turn usually affects the sequence of pickups and dropoffs, as well as distance components associated with them. Each time some aspect of the carpool changes, there is a new sequence.

In a carpool in which the driving duty is uniformly rotated, an increase in X_7 means that an individual has more days as a rider, which is usually seen as desirable. However, more drivers increase the probability of one or more being unreliable, unsafe, or otherwise negatively viewed. Furthermore, any significant circuity may be less tolerated as a rider than as a driver. It is the hypothesis that the "signals" in the data may be so mixed that no significant relationship between the dependent variable and X_7 will be detected.

X_8, Sex of Carpooler

This is the sex of an individual in a carpool, indicated in the data set by introducing the dummy variables 0 and 1 for male and female, respectively.

Because there is no preconceived notion about whether men or women are more tolerant of circuity, the hypothesis states that there is no difference. The coefficient of X_8 will be tested to see if it can indeed be considered 0.

X_9, X_{10}, Sex Mix in the Carpool

This is the combination of the members of a carpool on the basis of sex.

A carpool could be formed by all males, all females, or a mix of the sexes. Indicator variables, given in Table 2, were used here. It is reasonable to expect that carpools of one sex, if due to common employment types and interests, would be more likely to form and be sustained. Although possible collinearity with X_8 is recognized, it is hypothesized that greater circuities will be tolerated by riders in carpools of one sex.

TABLE 2 Sex Mix in Carpools

Type	X_9	X_{10}
All male	0	1
All female	1	0
Mixed	0	0

X_{11}, X_{12}, Degree of Common Destination

The data in Table 3 indicate how indicator values X_{11} and X_{12} represent the degree of common destination for members of a carpool. Two or more riders share a common destination if they have the same dropoff points and work in the same (or adjacent) buildings.

TABLE 3 Degree of Common Destination

Destination	X_{11}	X_{12}
All same	0	1
Some same	0	0
All different	1	0

A ridesharing arrangement is more convenient if the participants have the same work place. Also, friendship and shared experiences at the work place could make for a more compatible membership. If this compatibility translates into a greater tolerated circuity at the (home) pickup end, it is to be expected that an increase in circuity would accompany an increase in the degree of common destination.

X_{13} Through X_{18}, Job Type

Each individual was placed in one of six categories on the basis of survey information and listings in the Purdue staff directory: faculty (X_{13}), administrative (X_{14}), clerical (X_{15}), maintenance (X_{16}), student (X_{17}), and other (X_{18}). In the input file prepared for data analysis, the indicator variables X_{13} through X_{18} represent these six categories by 10000, 01000, 00100, 00010, 00001, and 00000, respectively.

Job type may serve as a proxy for the socioeconomic variables about which information was not otherwise available. Higher income individuals may be less tolerant of circuity and less likely to appear in the data set at all. Also, the work hours for maintenance personnel are not the same as those for faculty members and are not likely to be as flexible. The tolerance of extra time spent in travel and the ability or willingness to accommodate someone else's schedule may not be the same for students and administrators.

Incompatibility in schedules would be minimized if all pool members held similar jobs. This may be picked up by the "common destination" and "mix of job type" variables. If the more flexible jobs also tend to be higher paying, the income effect may be detected as a lower circuity accepted when $X_{13} = 1$ or $X_{14} = 1$, and coefficients are approximately 0 for the variables X_{15} through X_{18}.

X_{19}, X_{20}, Mix of Job Types in Carpool

As mentioned previously, the mix of job types in a carpool may indicate the degree of work schedule compatibility among its members. The holders of similar kinds of jobs might also have a greater degree of compatibility in life-style, interests, habits, and values that would overshadow moderate increases in circuity (Table 4).

TABLE 4 Job Mix Variable Values

Type	X_{19}	X_{20}
All same	0	1
Mixed	0	0
All different	1	0

X_{21}, Home-End Walking Distance

This is the distance an individual must walk to reach the pickup point in the carpool.

Quite often this value is 0 because doorstep pickups at one's home are considered to involve about the same (insignificant) distance as does the drive-alone case. However, if $X_{21} >> 0$, this adds to the negative aspects of ridesharing. As the walking distance goes up, both the tolerated circuity and the actual associated d_r's might be expected to decrease.

X_{22}, Pickup Ride Distance

This is the distance traveled by a pool member from his point of pickup until the last member has been picked up.

Pickup distance adds to travel time and cost and involves the stops and starts described under the "pickup count" variable. Because line-haul portions of the d_r and d_o routes (X_{23}) are usually quite similar, the pickup and dropoff phases of the ridesharing journey contribute the most to circuity. Thus a close, positively signed relationship between X_{22} and circuity can be expected.

X_{23}, Line-Haul Distance

This is the roadway distance traveled between the last pickup at the home end and the first dropoff at the work end in ridesharing.

This is usually the largest component of the shared work trip. If the pickup and dropoff phases of a carpool are quite localized, the in-vehicle drive-alone distance will be close to the value of the shared-ride line-haul distance. For this reason a high correlation between X_{23} and d_o can be expected. If X_{23} remains in the model and the dependent variable is circuity ratio (CR), a reasonable hypothesis is that the ratio does not change with line-haul distance: $b_{23} = 0$. If circuity distance (CD) is the dependent variable, a strong positive correlation is expected.

X_{24}, Dropoff Ride Distance

This is the distance from the end of the line-haul segment at the work end (the first dropoff point) to the point of one's own dropoff.

The variable can be interpreted in two opposite ways. It could be said that, as X_{24} increases, so does circuity. However, if X_{24} is large enough to make a significant difference in circuity, it may also be significant enough to "drive away" a carpool member. Thus any high X_{24} values in the survey might have to be compensated by low values of other distance components, leading to a negative or zero coefficient for X_{24}. On the other hand, a positive coefficient might be evidence of increased tolerance of circuity as the work trip nears its completion.

X_{25}, Work-End Walking Distance

This is the distance one must walk after being dropped off from the carpool to get to one's work place.

As with home-end walking access distance (X_{21}), a doorstep dropoff is represented by X_{25} = 0. This zero value happens frequently and is the main reason for the surprising number of instances in which d_r is less than d_o. A doorstep dropoff eliminates a walk from the parking location used on drive-alone days. If this walking distance is greater than the circuity involved in the other shared-ride distance components, the $d_r < d_o$ case results. Because X_{25} is typically zero or small relative to other components, $b_{25} \approx 0$ can be expected in the final model.

METHODOLOGY AND ANALYSIS OF RESULTS

Statistical Analysis

In the previous section, the variables that affect circuity in the ridesharing trip to work were defined. They are either trip related, socioeconomic factors or related to subjective measures like comfort, convenience, and reliability. Through regression analysis, the effect of these factors on circuity factors (CFs)--circuity ratio (CR), and circuity distance (CD)--may be determined. An attempt is made to determine the factor or set of factors that best explains traveler response to this negative aspect of ridesharing.

Although not obvious from the scatter plots of Y versus the individual Xs listed in Table 1, subtle relationships between some factors and CF can be detected. By using analysis of variance (ANOVA), the consequences of certain demographic variables can be identified. This is done later in this section. In attempting to develop a meaningful regression model, it should be possible to determine whether CR or CD is the more useful measure of detour in carpooling.

Modeling of Circuity Factors

Simple Linear Regression and Scattergrams

CR and CD are the two candidates for the dependent variable. First, simple linear regression models for CR and CD versus each of the independent variables listed in Table 1 were formulated. At the same time, the scatter plots of all of the independent variables were generated and studied to detect any apparent trends (including nonlinearity) among the variables. The results of these procedures, especially with respect to the relationships hypothesized in the previous section, are summarized in Table 5. No noticeable nonlinear trend in any of the independent variables with respect to the circuity factors was found.

TABLE 5 Effect of Independent Variables on Circuity Factors (simple linear regression)

	b-coefficient				
	Sign				
Variable	Expected	Actual	Magnitude	R^2	Significance
For Circuity Ratio					
X_1	–	0	−0.002	.0151	.07
X_2	0	0	−0.0003	.0005	.75
X_3	+	+	0.034	.0758	.00
X_4	–	0	−0.013	.0014	.59
X_5	+/0	–	−0.020	.0198	.03
X_6	+	0	0.010	.0086	.17
X_7	0	0	0.001	.0002	.85
X_8	0	–	−0.050	.0205	.03
X_9	Large	0	−0.032	.0094	.15
X_{10}	Large	0	−0.088	.0003	.81
X_{11}	–	0	0.008	.00003	.93
X_{12}	Large	0	0.044	.0088	.17
X_{13}		0	0.012	.0003	.81
X_{14}		0	−0.060	.0101	.14
X_{15}		0	0.002	.00003	.93
X_{16}		0	0.021	.0017	.55
X_{17}		0	0.075	.0058	.26
X_{19}		–	−0.004	.0001	.89
X_{20}	Large	–	−0.019	.0032	.40
X_{21}	–	0	−0.224	.0062	.25
X_{22}	+	+	0.007	.0376	.00
X_{23}	0	0	−0.002	.0149	.07
X_{24}	+/-	+	0.023	.3160	.00
X_{25}	+	0	0.047	.0012	.61
X_{27}	–	+	0.048	.3903	.00
For Circuity Distance					
X_1	+	+	0.051	.1020	.00
X_2	+	+	0.068	.2037	.00
X_3	+	+	0.743	.2082	.00
X_4	–	+	0.676	.0208	.03
X_5	+/0	+	0.833	.2010	.00
X_6	+	+	0.318	.0544	.00
X_7	0	+	0.521	.1203	.00
X_8	0	0	−0.320	.0049	.30
X_9	Large	0	−0.290	.0046	.32
X_{10}	Large	0	−0.500	.0049	.30
X_{11}	–	0	0.274	.0042	.34
X_{12}	Large	–	−0.925	.0224	.03
X_{13}		0	−0.007	.0000	.99
X_{14}		–	−1.144	.0214	.03
X_{15}		0	−0.214	.0025	.46
X_{16}		0	0.135	.0004	.76
X_{17}		+	2.402	.0351	.00
X_{19}		0	−0.758	.0151	.07
X_{20}	Large	–	−0.978	.0517	.00
X_{21}	–	0	−4.102	.0122	.10
X_{22}	+	+	0.210	.2026	.00
X_{23}	+	+	0.060	.1073	.00
X_{24}	+/-	+	0.733	.1880	.00
X_{25}	+	0	−0.714	.0016	.55
X_{26}	–	+	8.137	.3903	.00

Multiple Linear Regression Analysis: Correlation Matrix

The presence of collinearity among the variables (a high correlation coefficient) was also a concern. For example, the variables "drive-alone distance" (X_1) and "ridesharing distance" (X_2) are quite highly correlated (r = 0.989), as might be expected. High correlation was also observed between "line-haul distance" (X_{23}) and "drive-alone distance" (r = 0.953) and "ridesharing distance" (r = 0.947), respectively. These variables, and other pairs with high r-values (r > 0.60 was used as the criterion), should not be placed in a regression model at the same time. A more detailed discussion of this topic is given elsewhere (1).

After repeated applications of the surviving variables, using stepwise multiple linear regression (2) to determine the impacts of adding and removing promising independent variables, certain models emerged as the most meaningful. They are given in Table 6. The resulting performance of the models (R^2 = 0.219 for CR and 0.467 for CD) is lower than is normally acceptable in regression analysis. However, it must be remembered that what is being examined is not the behavior of a physical specimen in a laboratory but rather the complex behavior of a group of individual travelers in a variety of trip-making environments. After the basic stepwise regression package (2) had been used to determine the impacts of adding and removing variables to identify the probable most explanatory independent variables, each of the variables listed in Table 6 was examined, before its inclusion in or exclusion from the model, for its effect on the overall model. The formula used to determine each variable's contribution to the F-value of the model was based on the

TABLE 6 Multiple Linear Regression Results After Stepwise Approach at 5 Percent Significance Level

Dependent Variable	Circuity Ratio, Y_1	Circuity Distance, Y_2
Variables not used	X_2, X_{23}, X_{27}	X_2, X_{23}, X_{26}
Variables in the model	X_1, X_3, X_8, X_{22}, X_{24}	X_3, X_{11}, X_{12}, X_{17}, X_{22}, X_{24}
Variables close to being accepted	X_{14}(0.07), X_{25}(0.08), X_{13}(0.08)	X_6(0.10), X_4(0.13), X_7(0.14)
R^2	0.219	0.467

partial f-test statistics (3) of the successive sets of variables:

$$\Delta F_{1,\nu} = \left[(R_p^2 - R_{p-1}^2)/1\right]/(1 - R_p^2)\nu \quad (2)$$

where

$\nu = n - p$,
n = data points, and
p = number of parameters in the model (4).

Table 7 gives a summary of the regression models that were developed by this method. The residual plots of the models showed no noticeable indications of nonnormality.

Despite the low R^2 values, the models are still useful. The standard deviation of circuity ratio values ($\sigma = 0.154$) is surprisingly small (see paper by Fricker in this Record), given (a) the large variability in the components that make up d_r and d_o and (b) the low R^2 values in the regression models developed. A plausible explanation is that the degree of tolerance of circuity in ridesharers is quite consistent from person to person, but the way in which the distance components and nondistance factors contribute to this tolerance level varies widely among individuals. Furthermore, factors not available in this study's data set--travel budgets, stage in life cycle, relative modal attributes, perspectives of nonridesharers--all have an important influence on the decision to join a particular carpool. Nevertheless, the well-behaved nature of the CF values indicates a consistent level of tolerance of circuity among current ridesharing participants.

Between the two measures of CF, CR and CD, CD produces far better results as far as R^2 is concerned. So, CD appears to be a more desirable definition of circuity factor, if an explanatory model of maximum individual CF values is desired.

Independent Variables Accepted and Model Performance

The variables accepted in the CF models are shown schematically in Figure 2. The variables "number of pickups" (X_3), "degree of common destination" (X_{11}, X_{12}), "pickup ride distance" (X_{22}), and "dropoff ride distance" (X_{24}) are common to both equations. Other variables included are, in CR: "drive-alone distance" (X_1), "sex of carpooler" (X_8), "administrator job type" (X_{14}), and "work-end walking distance" (X_{25}), and in CD: "number of sequences" (X_7) and "student" as "job type" (X_{17}). Note that, among the variables, trip-related factors dominate the list of common variables as well as the complete set of variables in both models.

The coefficients of the variables (b) and the relationships among them (sign) in the models are summarized in Table 7. Also presented there are the beta (β) coefficients and t-statistics for the respective variables (i.e., for each b-value) in the models. In the case of the CD model, the coefficients are satisfactory, with the exception that the value of X_7 is not close to zero. But, from the β-values in Table 7, X_7 is the least important variable in the model.

According to the beta coefficients in Table 7, X_3 and X_{22} are among the most valuable of the factors common to both models. For CR, X_1 is the most important variable, whereas for CD the strongest variable is X_{24}. Analysis of the beta coefficients indicates that the trip-related variables are the most important variable types in determining the level of circuity that is tolerated.

The F-test for the regression relation indicates whether the variables in the model have any statistical relationship to the dependent variable. The hypotheses are

$$C_1 : \beta_1 = \beta_2 \ldots = \beta_{p-1} = 0$$

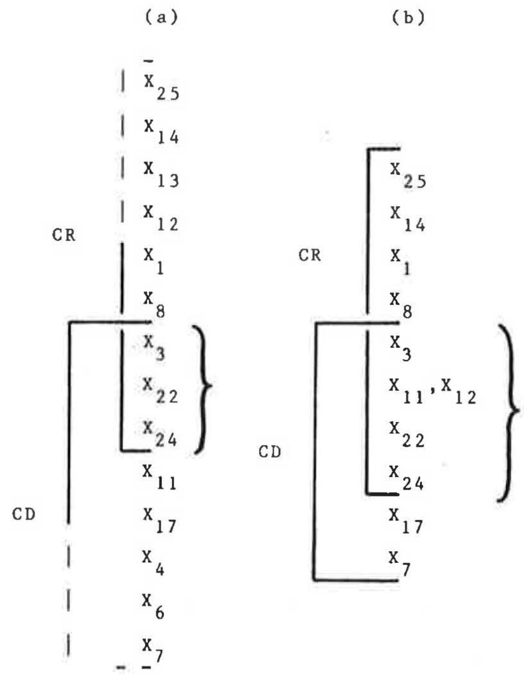
$$C_2 : \text{all } \beta_k \ (k = 1, \ldots, p - 1) \neq 0$$

The test results show that the hypothesis that the relationships among the variables in the model exist (C_2) cannot be rejected at an α-level of as low as 0.1 percent for both the CR ($F^* = 8.65$) and

TABLE 7 Regression Results for the Two Models

	CR (Y_1)			CD (Y_2)		
Independent Variable	β	b	t	β	b	t
Work-end walking distance, X_{25}	0.134	0.185	2.13	–	–	–
Administrative personnel, X_{14}	-0.14	-0.083	-2.24	–	–	–
Sex of the carpooler, X_8	-0.17	-0.060	-2.78	–	–	–
Drive-alone distance, X_1	-0.38	-0.005	-4.83	–	–	–
No. of pickups, X_3	0.27	0.033	4.11	0.30	0.485	5.18
Degree of common destination, X_{11}	0.12	0.04	1.78	0.20	0.832	3.35
Degree of common destination, X_{12}	0.19	0.089	2.66	0.14	0.896	2.41
Pickup ride distance, X_{22}	0.33	0.012	4.10	0.30	0.140	5.34
Dropoff ride distance, X_{24}	0.17	0.022	2.61	0.33	0.560	6.25
Student personnel, X_{17}	–	–	–	0.16	1.995	3.06
No. of sequences, X_7	–	–	–	0.12	0.185	2.06
Intercepts, b_0	–	1.094	32.93	–	-0.926	-2.78
Coefficient of determination, R^2	–	0.275	–	–	0.478	–

Note: In the CR model, $F^* = 8.65$ and $F(.001, 9, 205) = 3.10$; in the CD model, $F^* = 27.05$ and $F(.001, 7, 207) = 3.47$.



(a) Models after Stepwise Regression:

——— Variables included in the model

- - - Variables close to being included in the model

} Variables common to both models

(b) Final Models.

FIGURE 2 Schematic representation of the two models (CR and CD).

the CD ($F^* = 27.05$) models. Hence, valid regression relationships exist (Table 7).

The t-statistics in Table 7 offer the opportunity to test the statistical relationships individually for each variable in the model. The test is whether there exists any relationship between the dependent variable and the variable in question. The hypotheses in this case are

$$C_1 : \beta_k = 0$$

$$C_2 : \beta_k \neq 0$$

For the CR model, the hypothesis that the statistical relationship does not exist (C_1) cannot be accepted for all the b's at an α-level of 2 percent ($t = 2.33$) except for X_{25}, X_{14}, and X_{11}. X_{25} and X_{14} are significant at the 5 percent α-level ($t = 1.96$) and X_{11} is significant at 10 percent. For the CD model, except for X_7, the null hypothesis of $\beta_k = 0$ can be rejected at the 2 percent significance level, and for X_7 rejection at 5 percent is justified. Therefore, for all of the variables as a whole, C_2 cannot be rejected for both the CR and CD models at α-levels of 0.10 and 0.05, respectively. The variables in the CD model, therefore, can be accepted more confidently in the context of the statistical relationships tested by the t-statistic than by examination of the model's beta coefficients. In either case, the variables for the model, as portrayed in Table 7 and Figure 2, represent a reasonable basis for interpreting those aspects of ridesharing behavior that concern trip-related and person-related factors.

<u>Analysis of Variance (ANOVA)</u>

Although no well-defined trend in CFs was observed in the scatter diagrams mentioned earlier, some trends in the mean of the maximum values of CF ("Mean Max CF") could be detected as certain independent variables took on different values. Figure 3

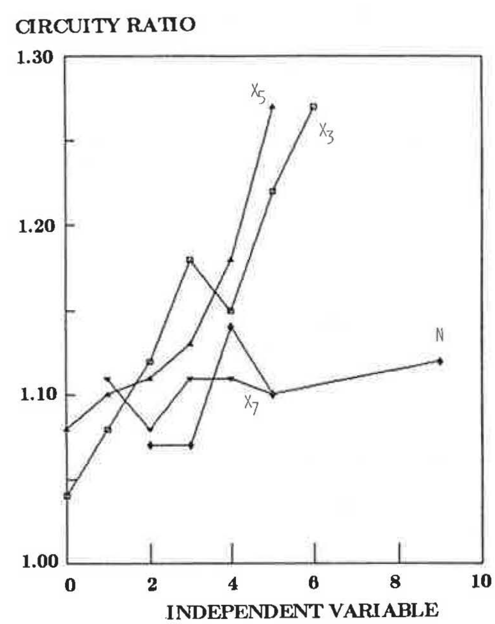


FIGURE 3 Mean of maximum circuity ratios.

TABLE 8 Effect of Job Type on the Mean of the Maximum Values of Circuity Ratio, Circuity Distance, Drive-Alone Distance, and Ridesharing Distance

Job Type	Sample Size	CR μ	CR σ	CD μ	CD σ	d_o μ	d_o σ	d_r μ	d_r σ
Faculty	10	1.11	0.10	1.73	1.43	29.77	21.25	31.50	21.60
Administrative	17	1.04	0.06	0.69	1.28	13.33	14.25	16.02	14.29
Clerical	124	1.10	0.19	1.65	2.06	19.29	11.15	20.94	12.09
Maintenance	24	1.12	0.15	1.86	1.88	18.54	6.33	20.40	6.40
Student	6	1.17	0.15	4.07	3.39	25.26	19.34	29.33	20.74
Other	34	1.09	0.10	2.10	2.43	23.15	17.53	25.25	18.33

contains several examples, each of which is associated in some way with carpool size. "Mean Max CR" is seen to grow as the number of dropoffs increases, but the relationship between each individual's Max CR and his X_5 value was not so well defined in the regression analysis: X_5 was excluded from the model. The trace for "number of pickups" straddles the "dropoffs" line in Figure 3 and has a dip at $X_3 = 4$. However, the relationship of X_3 with CR on an individual basis is among the strongest in the model. X_7, "number of sequences," exhibits almost no trend at all in Figure 3, as might be expected. The plot for "carpool size" has a peak at $X_6 = 4$, with lower values on either side of this point. This might be taken as an indication of optimal carpool size, but there is no pattern that can be seen in the scatter plot to support this view.

Perhaps more interesting at this stage of the analysis are the factors that are not easily quantified. Table 8 gives Mean Max CR values by job type. Although their small sample sizes make drawing conclusions risky, several job types attract attention. Although the faculty members have the largest mean d_o- and d_r-values in the table, their Mean Max CR and Mean Max CD values are not among the largest. Instead, the students are seen to tolerate the largest Mean Max CF values. This is not at all surprising. Meanwhile, administrative personnel tend to live closer and have the lowest Mean Max CF values. The other job types are not statistically distinguishable from one another.

In general, CD has demonstrated a greater ability than CR to establish statistically justified relationships with independent variables. While Mean Max CF was not sensitive to any of the qualitative variables, more detailed analysis of Mean Max CD revealed that carpools with "some common" job type mix have significantly longer mean maximum circuity distances than the mix types "common" and "different," which are statistically indistinguishable. The factor "sex" is insignificant for both circuity factors at an α-level of 0.05, as is the variable "sex mix."

CONCLUDING REMARKS

Summary

A regression analysis of the factors that may affect circuity in ridesharing was attempted for three reasons:

1. The existence of a data set of reasonable size and good accuracy built from the perspective of the individual ridesharing participant (see paper by Fricker in this Record);
2. The suprisingly small variance in the circuity values for individuals included in an earlier study; and
3. The potential for development of a screening model whereby potential carpool matches could be evaluated for likelihood of success or markets could be targeted for more intense promotion of ridesharing.

The results were mixed. The R^2-values for the regression models developed were lower than for "textbook cases," but they were not unreasonable for a first attempt at modeling a complex human decision-making process. The regression models that were developed were quite stable (Figure 2), with variables the behavior of which was compatible with logical expectations (Table 5).

Extensions

Several obvious alternatives and extensions to the work described in this paper are possible to better develop the relationship between easily measurable independent variables and dependent variables that represent the potential for a carpool's success. Some of these are:

1. More data. The data set used was developed with distance-based measures in mind. Some nondistance variables were easily generated, but acquiring others that would enhance model development would require a new survey. Also, it must be acknowledged that, although these data are representative in some ways of nationwide values (see paper by Fricker in this Record), data from other locations should be assembled.
2. Separate models for trip-related and person-related variables. Some independent variables may be positively correlated with Y out of the necessity of geography and geometry, and others deal more directly (but vaguely) with tolerances of circuity. The steps taken in the present statistical analysis could be expected to sort out these variable types, but a more explicit implementation of this philosophy may prove useful.
3. Instead of individuals' Max CF values, use their weighted average CFs or all of their daily CFs to develop a regression model. Although Max CF values were used here to seek a CF threshold (Figure 1), using a more central or exhaustive set of data might yield a model with greater explanatory power.
4. Focus on carpools using rendezvous points. Look at Figure 1 from a new perspective. Days 1, 2, and 3 differ only in who drives and, therefore, in the dropoff phase. Each day the same access routes and meeting point are used. This must be because a doorstep pickup arrangement for this group of individuals is intolerable to them. That is, any doorstep configurations would have CFs above the CF threshold level in Figure 1. If the best possible doorstep route or routes could be constructed, an upper bound on the elusive circuity threshold would be established. The Max CF day's level used in this paper can serve as the lower bound.

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