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.

School of Civil Engineering, Purdue University, West Lafayette, Ind. 47907.

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):

$$CR = d_r/d_o \tag{1}$$

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 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.

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.

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.

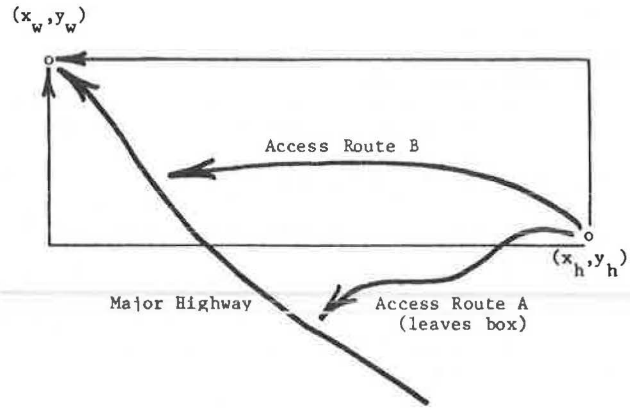

FIGURE 1 Box formed by the two possible Manhattan paths.

TABLE 2 Portion of Output from Checking Program

		Unweighted		
ID	County	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

Date	Entrance	Vehicle Occupancy 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:

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

where

- i = the ith individual,
- m = the number of different driver and pickup 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.

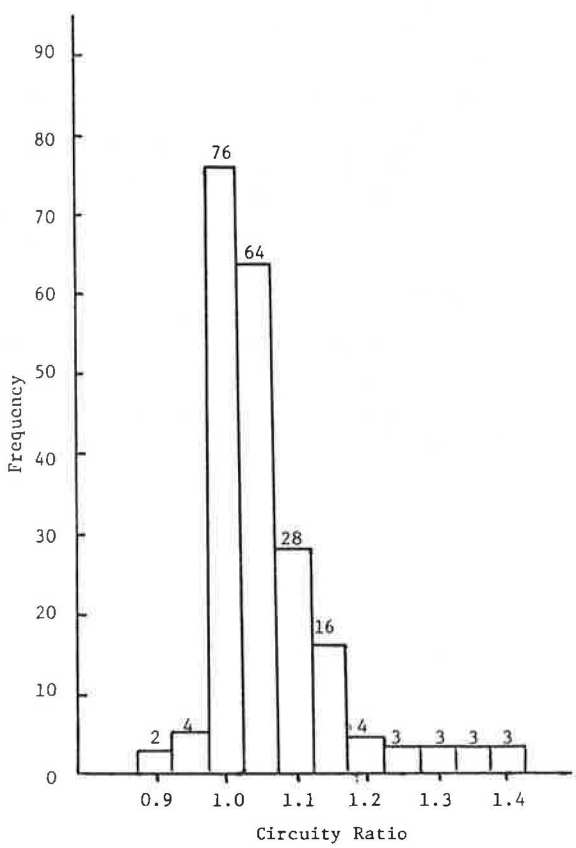

FIGURE 3 Distribution of circuity ratio values.

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.

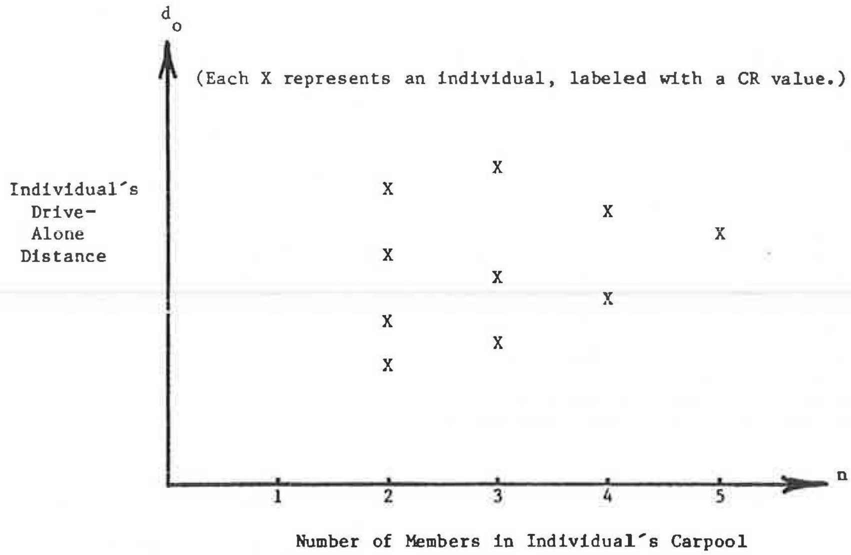

FIGURE 4 CR-value, carpool size, and distance to work.

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

REFERENCES

1. C. Johnson, A.K. Sen, and J. Galloway. On Tolerable Route Deviations in Van Pooling. Transportation Research, Vol. 13A, 1979, pp. 45-48.
2. F.A. Wagner. Evaluation of Carpool Demonstration Projects. Office of Highway Planning, FHWA, U.S. Department of Transportation, March 1978.
3. A.J. Richardson and W. Young. Spatial Relationships Between Carpool Members' Trip Ends. In Transportation Research Record 823, TRB, National Research Council, Washington, D.C., 1981, pp. 1-7.
4. L. Sherman. Interim Evaluation of the Minneapolis Ridesharing Commuter Services Demonstration. Research and Special Programs Administration, UMTA, U.S. Department of Transportation, Transportation Systems Center, Cambridge, Mass., March 1979.
5. D.A. Maxwell and D.V. Williamson. How Much Fuel Does Vanpooling Really Save? In Transportation Research Record 764, TRB, National Research Council, Washington, D.C., 1980, pp. 23-26.
6. A.B. Rose. Vanpool Energy Efficiency: A Reevaluation and Comparison with a Brokered Carpooling Concept. Transportation Energy Group, Energy Division, Oak Ridge National Laboratory, Oak Ridge, Tenn., 1980.
7. D.J. Kulash. Energy Efficiency: Which Modes, Which Programs? Proc., ASCE Specialty Conference on Transportation and Energy, Washington, D.C., May 22-24, 1978.
8. D.J. Kulash, R.R. Mudge, and D. Prywes. Urban Transportation and Energy: The Potential Savings of Different Modes. Congressional Budget Office, Dec. 1977.
9. J.D. Fricker and Md. G. Habib. Circuity Factors in Ridesharing: The Individual's Travel Decision. Final Report. University Research and Training Program, UMTA, U.S. Department of Transportation, June 1986.
10. R.F. Kirby, K.U. Bhatt, M.A. Kemp, R.G. McGillivray, and M. Wohl. Paratransit: Neglected Options for Urban Mobility. The Urban Institute, Washington, D.C., June 1974.
11. L.L. Lapin. Probability and Statistics for Modern Engineering. Brooks/Cole Engineering Division, Monterey, Calif., 1983, Section 13-1.
12. D.A. Bryant. Study and Evaluation of Computer Carpool Programs in Certain Metropolitan Areas. Report EPA-450/3-74-041. Environmental Protection Agency, April 1974.