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DIRECTIONAL BIAS IN WORK TRIP FLOWS

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In the present century characteristics of person trips within urban areas in the United States have dramatically changed. Perhaps the most fundamental change has been the overall increase in travel mobility. The reductions in cost and effort of overcoming urban space have permitted a more flexible choice of residential and employment locations. Although these two locational decisions are less interdependent today than in the past, they are of course not totally unrelated. Rather, it has been generally observed that the friction of distance does not become severe until some critical distance is reached, whereupon the frictional effect is of increasing significance [2, 10]. Several studies have pointed out the varied responses among socioeconomic groups to the friction of distance, the most common conclusion being that the higher the socioeconomic status the greater the ability to overcome distance [11].

One important characteristic of person trips which has received much less investigation than travel distance is changing directional bias.¹ Directional bias actually implies either a differential frictional effect by direction or a different spatial distribution of trip end opportunities. Both are reasonable hypotheses, as it is readily observed that travel ease in a city may not be equal in all directions, and, even more clearly, the relative location of destination opportunities may cluster, resulting in directional travel bias. Socioeconomic groups may have different directional biases, a consequence of residential patterns, trip end distributions, or mobility differentials.

Traditional trip distribution modelling, typically the gravity and intervening opportunity models, has ignored direction, assuming distance friction to be equal in all directions. These models consider the locations of origins and destinations simply as a function of intervening distance or travel time--not direction [3]. For example, the distance exponent in the gravity model reflects "average" distance decay rates over all directions. The gravity model thus omits the critical spatial variable of direction, which is especially significant for travel behavior in urban areas.

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¹Directional bias is a term most used in migration studies and in models of spatial diffusion, in which diffusion patterns take on a directional spread as well as an overall distance decay. For examples, see Wolpert [12], Adams [1], and Moore [9].

Only a small number of studies have specifically focused on direction in trip behavior. Based on shopping behavior, Brennan [4] mapped the trade area of urban shops in Wolverhampton, England. He found the trade areas were pulled farthest out away from the center of town. "Brennan's Law" has been supported by Lee [7] and seems to be accepted in many situations by urban scholars. In fact, principles of spatial competition would predict that the market areas will be elongated away from the dominant source of competition when urban nodes compete over space for markets. Since many activities are concentrated in the urban core, "Brennan's Law" of elongation away from the center seems to have a theoretical base.

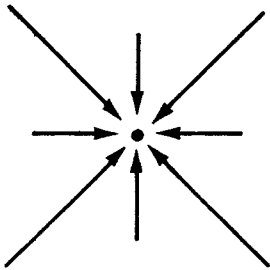
Further support for "Brennan's Law" comes from a different direction, the literature of social psychology. Here the degree of familiarity and reward at trip ends is noted as an explanation of directional bias. The build-up of satisfactions at the city center has an effect "on the perceptual process, causing a foreshortening of perceived distances in the inward direction, perhaps on an increasing gradient, and affecting judgments and behavior which might otherwise be quite independent of the city center" [8]. "Brennan's Law" is thus found to be a special case of the more general principal that the perception of distance depends on the favorability of the destination stimuli.

Empirical evidence of directional bias in travel behavior is mixed. Using Chicago data, Boyce [3] found a significant directional bias for transit trips, although such a bias did not exist for arterial trips by automobile. Boyce was led to conclude that despite the importance of central Chicago "the impact of the center on the travel pattern suggests the need for a revised approach in theoretical studies of urban structure." Deskins [5], studying work trips of blacks in Detroit, found bias toward the CBD prior to 1953 and mixed patterns of directional bias since then.

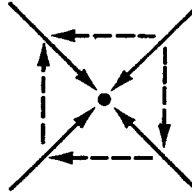
For cities in the past virtually all trips focused on the downtown because of the concentration of commercial and industrial activities (Figure 1.a). Gradually this downtown orientation began to weaken with the spread of jobs and activities away from the core. Lateral trips became important, i.e., trips in which the dominant direction was neither downtown nor toward the periphery (Figure 1.b). With continued decentralization of activities, reverse trips (toward the periphery) became more common (Figure 1.c). In addition there has been some growth in crosstown travel, in which the trip crosses through, or goes around, the congested downtown core. Thus the simplicity of the early travel patterns has been replaced by a confusing complexity, and the directional multiplicity of urban travel is the result both of the spread of activities throughout urban space and the reduction in the friction of travel.

Problem

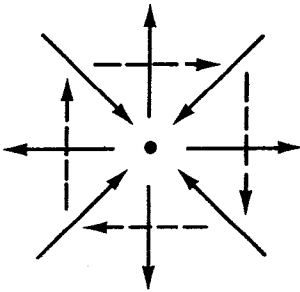
The purpose of this paper is to examine the role of several factors that may help explain some general features of directional bias in work-trip flows. First, variation in directional bias is measured by origin zones within the city and by occupational status. Second, the importance of employment locations



a.



b.



c.

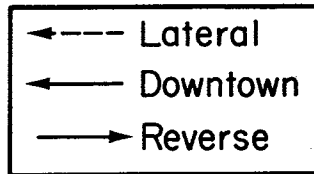


Figure I.

is examined, and a random coupling model is used to determine whether observed directional biases are due merely to employment patterns or to other factors influencing trip behavior, such as distance decay. Spatial competition as a theoretical basis for directional bias is thus tested, as competition for workers over space implies a lack of random coupling of home and work.

A schematic rationale is offered to conceptualize the process through which directional bias enters trip behavior (Figure 2). Although the discussion is framed in terms of employment destinations, it also holds for destination choice in general, even though work trips are "habitual" rather than "discretionary." The occupational status of a trip-maker exerts an influence on the choice of residential location, resulting in a spatial residential pattern characterizing the entire occupational group. For a given set of occupational skills, a spatial pattern of employment locations exists. The choice of a particular residence vis-a-vis employment depends on the trip maker's mobility preference, in part determined by income. In arriving at a choice of destination, the trip maker selects from the set of employment alternatives which he perceives as available to him. Given a residential location in the city, his mobility preferences are translated into perceived travel time or distance by direction away from his residential origin. Alternative destinations are both an influence on directional perception of mobility and a result of directional bias, through a time-dependent learning mechanism involving feedback between the two. On the basis of these perceptions, a choice of destinations is made. One characteristic of the ensuing trip is direction of travel, conceptualized here as both a result and an influence on the decision of destination choice.

Data and Approach

Data for this study are from a 1965 origin-destination survey of the five townships of the Lansing, Michigan, urban area, aggregated among sixty census tracts. Based on a five per cent household sample, each work trip (over 1,800) was classified into one of five categories, depending on the directional orientation of the trip. Downtown trips are those that focus in the direction of downtown (Lansing CBD), though not all actually terminated in the urban core. In direct contrast to this center orientation, reverse trips originate more centrally than they terminate. The crosstown trip is the third category, such a trip originating and terminating in opposite directions with respect to the CBD. These trips may actually pass through the CBD or take a circuitous, but perhaps faster, circumferential route. A crosstown trip may have characteristics of either a downtown or reverse trip (usually the latter), depending on whether the origin or destination, respectively, is farther from the CBD. Lateral trips have a "side-ways" orientation with regard to the center and periphery, with a smaller lateral than downtown or periphery angle between the home and work location. Finally, the fifth category is the intrazonal work trip. Only work trips starting from residence were analyzed. A small number of judgment decisions had to be made in classifying trips into these categories of directional orientation. Four occupational groups are studied: (1) professional-manager, (2) sales and clerical, (3) craftsmen-foremen and operatives, and (4) service and laborers. The use of four groups

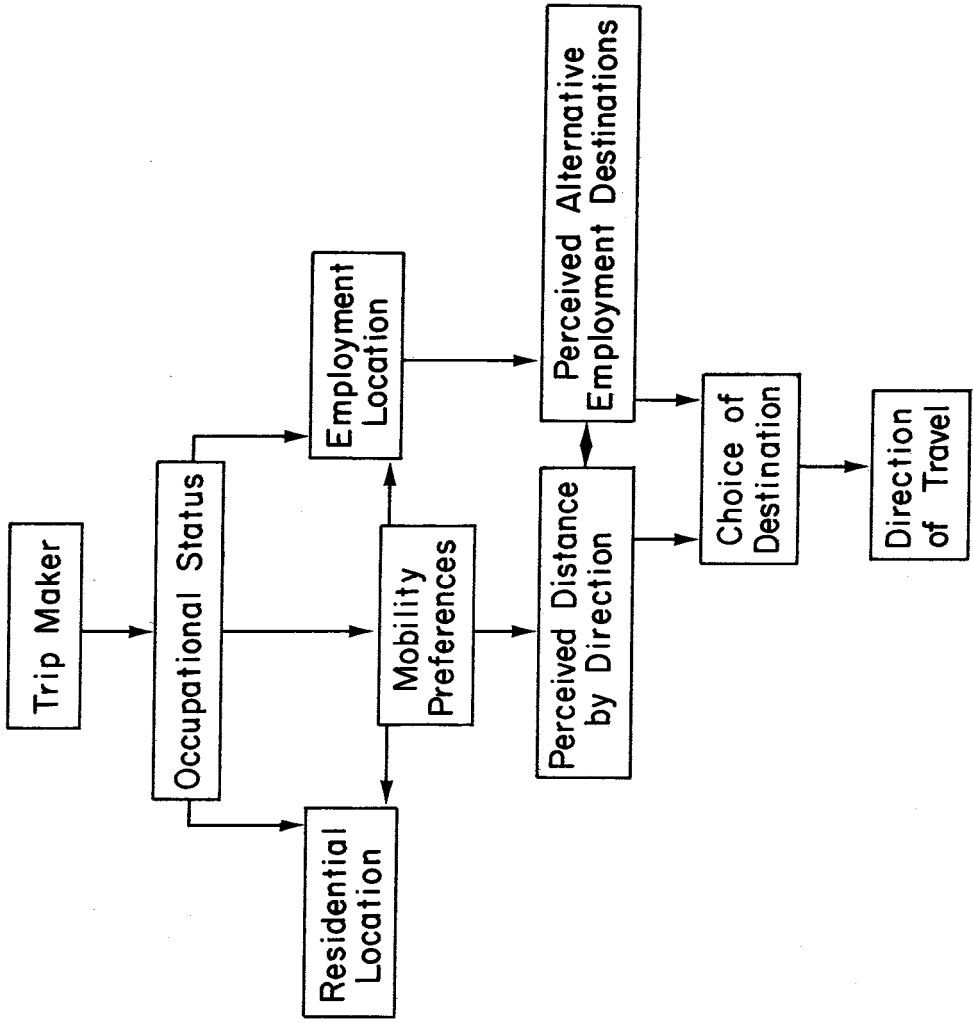


Figure 2.

was necessary to ensure a meaningful number of trips for each group.

Findings

It is obvious that origins in the urban area will have different probabilities of generating trips classified by the five types, downtown, reverse, lateral, crosstown, and intrazonal. For example, a central origin is more likely to originate a reverse trip than is a peripheral zone. An initial step in the investigation was therefore to calculate for each tract the percentage of trips in each category. Several features immediately became clear. The percentage of downtown trips increases in a fairly regular manner with distance away from the downtown, over sixty per cent in peripheral areas to under thirty-five per cent in tracts near the CBD. A second and related finding is that reverse trips predominate in a cluster of seventeen tracts encircling the CBD, where the number of these trips typically lies above one-fifth. Although the pattern of lateral and crosstown trips is less clear-cut, both trip types are areally concentrated in the intermediate zones between the downtown oriented peripheral tracts and the outward focused central tracts. Furthermore, tracts in this intermediate area are rather sharply divided by the dominance of either crosstown or lateral trips.

Given this spatial variation in the distribution of trip types by origin location, it is to be expected that variability among trip types may characterize occupation status groups because of differences in residential location, in employment location, or in mobility levels. Each trip type was grouped by occupation of trip maker, and Table 1 presents these data in percentage form. Downtown trips most characterize the two high status groups, especially sales and clerical workers. The proportion of reverse trips is inversely related to occupational status. Nearly thirty per cent of all trips by professional and managerial workers are lateral, a possible reflection of a higher mobility tolerance, since lateral trips go "across the grain" of traffic flow. Crosstown trips are more common among the low status occupations (principally due to those living on the northside who work at the Oldsmobile plant just south of downtown).

A test for independence between trip types and occupational groups was carried out with chi square analysis using trip frequencies. The null hypothesis that directional bias does not vary with occupational status was rejected at the .001 significance level ($\chi^2 = 63.6$, with 12 degrees of freedom). Departures from independence owe largely to variations among the downtown, reverse, and lateral trips.

Having found variation in directional bias both by location and occupational group, the question remains whether the variation is due simply to urban location or to occupational differences independent of location. The seventeen contiguous tracts surrounding the CBD having a predominance of reverse trips was examined. Trip frequencies were classified by directional orientation and by occupational group. Again the null hypothesis that there is independence or randomness between trip type and occupation was rejected ($\chi^2 = 39.3$, significant at the .001 level). Therefore, the greater number of reverse trips from the

TABLE 1: Trip Types by Occupational Groups (in percentages)

Occupational Group	Trip Types				
	Downtown	Reverse	Lateral	Crosstown	Intrazonal
Professional- Managerial	46.27	8.18	29.19	10.67	5.69
Clerical and Sales Workers	54.05	11.54	18.83	9.11	6.47
Craftsmen- Foremen and Operatives	41.58	16.16	22.85	13.74	5.67
Service Workers and Laborers	34.42	20.08	22.55	13.94	9.01
Total Workers	45.33	13.01	23.61	11.62	6.43

Source: Computed by author from Lansing Tri-County Regional Planning Commission data, 1965.

inner city is not due to the relative location of this area but rather to the different travel patterns of the occupation groups living there. A disproportionate share of workers in the lower two status groups are involved in reverse commuting, and a much higher than expected number of workers in the two higher status categories focus on downtown employment sites. It is not entirely central location that induces reverse commuting, as the high and low status groups react differently to downtown versus reverse work trips.

A similar test was undertaken for the sixteen tracts in the peripheral four township area, in which over sixty per cent of all trips are oriented downtown. The null hypothesis that there is no meaningful difference among occupations in directional bias (trip type) in these sixteen tracts was accepted. Thus service workers and laborers are about equally likely as professional and managerial workers to travel toward downtown workplaces. However, for the seven census tracts in the city of East Lansing, the same null hypothesis, when applied to the frequencies of downtown, lateral and other trips for the four occupations, was rejected (at the .05 level), showing variability among trips by occupation. The major deviation stems from a deficiency in downtown trips among service workers and laborers. The entire area of East Lansing is characterized heavily by lateral movement, but there is little variation in lateral trips among occupational groups. Finally, the same relationship between occupation and trip type was examined for a dozen tracts encircling the core at an intermediate distance; no statistically meaningful departure from independence was found to exist. Thus the findings are mixed on the issue of whether variations in directional orientation is the simple result of relative location within the urban area or the consequence of occupational status.

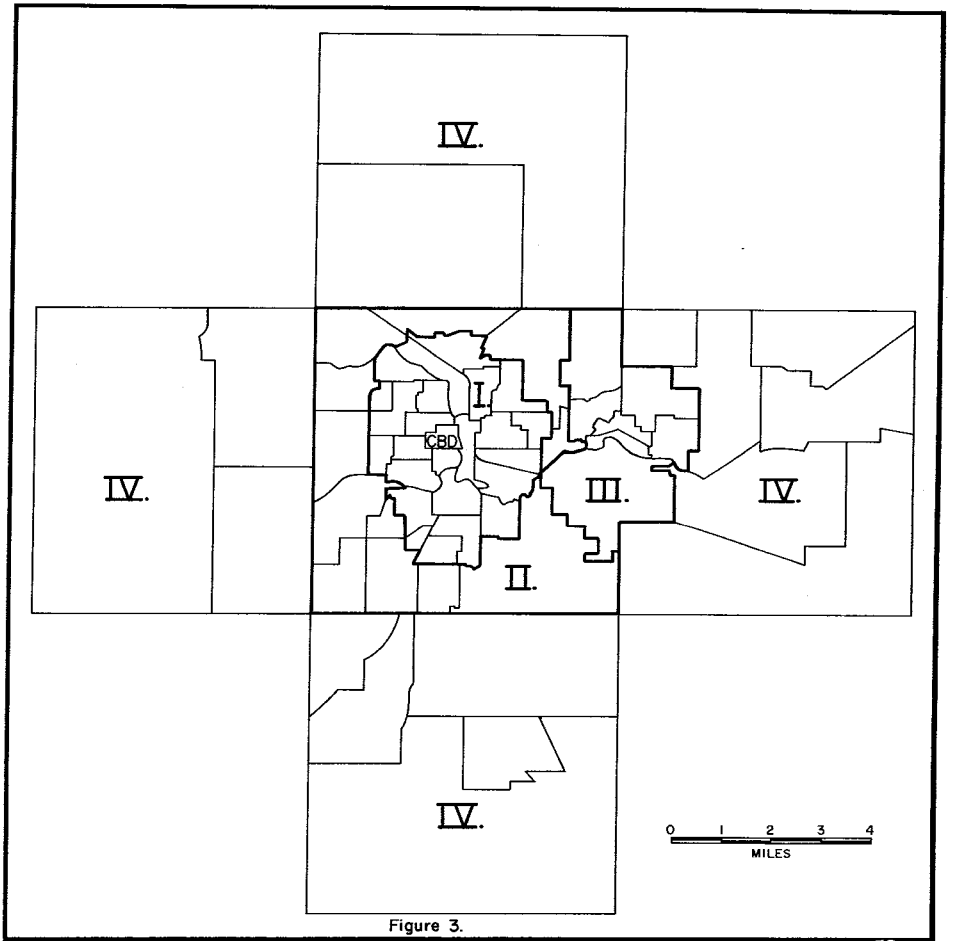
The question arising next is whether or not these mixed findings are due to different employment opportunities facing various occupational groups at different residential locations. Table 2 shows the mean distance of residential and employment location away from the CBD for the four occupational groups. Corresponding to the overall downtown bias of work trips is the higher average distance for residential versus employment distributions, the smallest difference being for service workers and laborers--those most highly engaged in reverse commuting. However, these average figures give only a generalized indication of possible directional bias, since a swarm of points representing residence may be linked with a swarm of employment points in a variety of ways, each of which may reflect differences in directional bias.

At another level of generalization, origin-destination measurement was made for each occupational group among four divisions of the urban area (Figure 3). The first is a cluster of twenty-five tracts surrounding the CBD. The second is a dozen tracts encircling the first area. East Lansing is used as the third area, since it acts as a secondary node within the urban area. The fourth division is the four peripheral townships. Chi square analysis showed a significant difference ($< .001$) among the occupation groups in the distribution of both residence and employment among the four urban divisions. East Lansing had considerably more in the professional-managerial class than expected and fewer in the craftsmen-foremen and operative group. These deviations from the expected held both for home and work distributions.

TABLE 2: Mean Distance from CBD for Residence and Workplace

Occupational Group	Mean Residence (miles)	Distance Workplace (miles)	Difference (miles)
Professional-Managerial	3.35	1.99	1.36
Clerical & Sales Workers	2.83	1.54	1.29
Craftsmen-Foremen and Operatives	3.02	1.51	1.51
Service Workers & Laborers	2.74	2.29	0.45

Source: Computed by author from Lansing Tri-County Regional Planning Commission data, 1965.



For each occupational group, a random coupling model [2] was used to determine the "expected" flow of work trips among the four divisions or zones, assuming no distance or directional bias.² The model assumes that the proportion of trips attracted from each zone equals the total proportion of trips terminating in each zone. Chi square analysis showed a significant difference between random coupling and actual flows, at the .001 level for the two white collar occupational groups and at the .01 level for the other two groups. The deviations from random coupling expectations reveal specific distance and to a lesser degree directional biases.

For all groups the most notable distance bias is seen in the higher than expected flows within zones three and four. For the professional-managerial groups, there are fewer reverse trips than expected from zone one to zones three and four; and from zone three there are fewer than expected trips to zones one and four. Clerical and sales workers also have smaller than expected flows out of zone three into zone one, but have a disproportionate share of reverse trips from the central zone into zones three and four. Evidence of directional bias among the other two occupational groups is not strong at this level of data aggregation, and even among the white collar workers there is less indication of directional bias than intrazonal, or distance, bias.

Conclusions

Directional bias varies among origin location in the city because of different relative access to trip end opportunities. Directional bias also is variable with occupation group. In both cases, it is the distribution of employment opportunities, relative to origins, that sets up the orientational bias in trip making. Although tests for random coupling were rejected statistically, rejection depended largely on the preponderance of intrazonal trips for zones three and four. Otherwise, the dominance of random coupling for all occupational groups suggests that observed differences in directional bias stem from differences in relative concentration of residences and workplaces.³ This statement is consistent with Black's finding that "distance to a workplace is not an important variable in the distribution of work trips from a given traffic zone . . ." [2]. Whereas directional bias is readily observed in urban travel, it is largely a function of random coupling of home and work and thus dependent upon the uneven spatial distributions of residence and workplace.

²The fourth zone, consisting of the four spatially separate townships, introduces a potential problem into the analysis. A trip going from the farthest northern to the most southern township, for example, would be counted as intrazonal, whereas a short trip just crossing a township line into zone three, for instance, would be considered an interzonal trip. However, very few such intrazonal trips took place.

³These conclusions are of course dependent upon the level of data aggregation used.

The existence of directional bias does not itself verify the operation of spatial competition. Spatial competition require that destinations "capture" trips as some function of trip distance and that trip making decisions are made because of trip end preferences which vary with distance. Directional bias, as with distance decay, seems to reflect different areal distributions of home and work. The results of this analysis then do not point toward the role of spatial competition as strongly as hypothesized. Rather, random coupling among urban zones for all occupational groups appears to be the major influence on observed directional travel biases. This statement is further consistent with the known increase in mobility levels, which have been rather similar for all occupational groups. In short, there is nothing very different about the way people travel, except that they start their work trips at different places and go to different destinations. Their choice of residence and workplace is probably more unrelated to each other today than generally recognized, especially in many models of urban location theory.

This research lends support to the growing emphasis on the perceived desirability of destinations. "Brennan's Law" is regarded as an empirical generalization which is a product of the historical evolution of urban spatial structure, rather than as a result of mobility preferences. As applied to work trips at least, this generalization sheds little light on factors influencing trip behavior. The directional biases observed in this study are attributed largely to aggregate home-work distributions. "Brennan's Law" is but a special case of directional bias in which trips have a downtown focus.

As suggested by Horton and Reynolds [6], directional bias may most characterize trip makers in early stages of gaining familiarity with an urban setting. Trips other than for a work purpose would probably best be understood in the context of spatial exploration, learning, and reinforcement. The explanation of directional bias lies more generally in knowing the utility mentally assigned each destination and in examining possible directional clustering of highly desirable trip ends. Thus an even spatial pattern of trip destinations may yield directional bias because of areal bunching of destination utility, and conversely an uneven distribution of destination opportunities may not lead to directional bias if preference is evenly spread over the urban area. It is thus to the examination of locational preferences that one must turn in future research to enhance the understanding of directional bias.

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