Comparison of Three Parameters of Nonresidential Trip Generation

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This paper attempts to answer the question, "What is the best type of land-use measurement from which to estimate trips?" This question is important not only for trip estimation, but also because it dictates what type of land-use surveys a transportation study must conduct, and these surveys are very expensive.

The estimating capabilities of the three most common measures of land use—land area, floor area, and employment—are compared. Using data collected by the Chicago Area Transportation Study, trip rates based on these three measures are examined for five nonresidential land-use categories using correlation and regression analysis. The resulting coefficients and equations are given.

The findings indicate that no one of these measures is best for all land-use categories. Floor area seems best for commercial, employment for manufacturing, and land area for public buildings, public open space, and transportation. Contrary to expectation, floor area does not seem consistently better than land area. Furthermore, floor area trip rates are not uniform throughout a metropolitan area, but increase as the density decreases.

The results suggest that further research on trip generation is needed; understanding of the subject is still quite fragmetary. Five specific approaches for deeper investigation are recommended. In addition, more comprehensive surveys of the three parameters are still required for research purposes.

•ONE OF the major theoretical bases of modern transportation planning is the concept that the distribution of trip ends is related to the land-use pattern. Because of this belief, transportation studies devote a large amount of effort to collecting land-use data, relating trip ends to land use, and estimating future trip ends from land-use forecasts. It is generally conceded that the consideration of land use is a major advance in the science of transportation planning.

However, the study of trip generation is still in its infancy. Actually, no one is yet quite sure how to relate trips to land use. Studies of the past decade have shown that different types of land use generate trips at widely varying rates. Furthermore, the same type of land use may generate trips at different rates depending on where it is located in the metropolitan area. No one has analyzed and explained the variation in trip rates sufficiently to formulate a package of reliable techniques suitable for widespread adoption.

This paper describes an attempt to answer the question, "What is the best type of land-use measurement from which to estimate trips?" The answer to this has a significance beyond determining what kind of trip rate to use for an estimating problem. It also bears on what type of land-use data should be collected in a transportation

study. In the absence of confidence about exactly what to measure, many studies decide to measure everything that might be of use. Later on, the researchers can select the factors which give the best results and ignore the rest of the data. This, of course, is very inefficient, and it is still possible that some pertinent data will not be collected.

It may be that some types of surveys now conducted are not really necessary and that some new types of surveys would assist more in accurate trip estimation. One point should be borne in mind: since the object of trip generation is to estimate trips for some future or assumed situation, trip rates must be based on a kind of data which can be forecast with reasonable accuracy.

Three measures of land use have commonly been used as bases for trip generation: land area, floor area, and employment. Probably land area is the most popular because it is the easiest to measure. This is what is measured in the typical land-use survey conducted by city planners, and a relatively large amount of land area data is available for large cities. However, floor area is thought to be a better basis for trip generation because it reflects the widely varying intensity of use of land. But floor area is rather difficult to survey thoroughly. It is customarily obtained from Sanborn maps which cover only densely built-up areas. Floor area can also be obtained by aerial photography or field survey, but both methods are laborious and expensive.

Detailed employment data are fairly difficult to obtain because employment is not a fixed physical object, clearly visible to a surveyor. An employment survey requires the cooperation of all employers. Furthermore, there are considerable problems in defining and measuring employment (for example, persons with two jobs and persons with part-time or sporadic employment).

ABOUT THIS STUDY

The data collected by the Chicago Area Transportation Study (CATS) in its 1956 surveys permit analysis of these three types of trip rates.[1] This paper compares the estimating capabilities of these three measures of land use for the five nonresidential land-use categories used by CATS. These categories are given in Table 1, together with the number of trips made to each.

Residential trip generation was excluded from this analysis because these three parameters are not customarily used for this land-use category. Residential trip-making is normally considered in terms of trips per capita or per dwelling unit. At CATS, an estimating equation was developed in which trips per capita was a function of auto ownership and net residential density.

The CATS measurement of these three types of data included a complete survey of land area for the entire study area. The floor area survey covered only those areas for which Sanborn maps were available—Chicago, a few close-in suburbs, and the downtown parts of several more distant suburbs. CATS made no direct survey of employment per se. However, first work trips were identified in the home interview survey and give an approximation of employment. In general, first work trips represent 70 to 90 percent of employment. However, the exact relationship between first work trips and employment is unknown; this makes rates based on first work trips somewhat questionable.

Within each land-use category, there is considerable variation in trip rates throughout the study area. Clearly something more than a land-use breakdown is needed to explain the variation adequately.

TABLE 1

ALL NONRESIDENTIAL PERSON TRIP DESTINATIONS IN CATS STUDY AREA

Land Use	No. Trips	Percent
Commercial	2,449,468	53.2
Public buildings	781,960	17.0
Manufacturing	779,340	16.9
Public open space	314,833	6.8
Transportation	280,270	6.1
Total	4,605,871	100.0

[1] The data used in this analysis were taken from unpublished tabulations of the results of the land-use and travel surveys made by CATS. These surveys are described in Final Report: Volume 1, Chicago Area Transportation Study, December 1959.

In this analysis, the rates have been related to net residential density (NRD). NRD tends to indicate (a) the intensity of use of land in an area, and (b) the accessibility of an area, i.e., the number of trip-makers located within a given radius of the site. NRD tends to indicate the intensity of use of nonresidential land as well as residential land. Of course, NRD declines with increasing distance from the central business district (CBD).

The CATS study area was divided into 44 districts, and statistics for the districts formed the data for this analysis. The two districts which include the CBD were omitted because (a) this is a special situation where general rules often do not apply, and (b) NRD figures for these two districts are artificial. NRD was measured in occupied dwelling places per 100,000 sq ft of residential land. Because land was classified according to first floor use, in the downtown area many buildings containing dwelling places were classified as nonresidential land.

In addition, two districts were not included in the floor area survey. In a few cases, none of the thing being measured was found in a district. In three cases, a few districts with very small amounts of land area or floor area were omitted from the calculations because they had highly aberrant rates which overly influenced the correlation.

ANALYSIS OF TRIP RATES

The three types of trip rates are expressed in the following terms:

1. The land area rate represents person trips (internal and external) per acre;
2. The floor area rate represents person trips (internal and external) per 1,000 sq ft of floor area, and only trips made to areas included in the floor area survey were counted; and
3. The first work trip rate represents the ratio of all person trips to first work trips (since the first work trips do not include external trips, the latter were also left out of the numerator).

Trips mean trip destinations, and the numbers are totals for a 24-hr period, an average weekday.

Table 2 shows the overall study area rates for the five land uses. These rates do not necessarily agree with the mean rates given later in the paper because the latter do not include the two CBD districts and are unweighted averages (i.e., they are the averages of district averages).

Table 3 gives the results of the correlation analysis of trip rates and NRD. Simple linear correlation was used for the land area and first work trip rates, and for floor area, the correlation was between the rate and the logarithm of NRD. The standard errors are adjusted for degrees of freedom. The variation coefficient is the ratio of the standard error to the mean, expressed as a percentage. Regression equations derived from the same data are also given in Table 3 for each type of land use.

Commercial

This is the most important category, since it attracts half of all nonresidential trips and has by far the highest land area and floor area trip rates. The floor area rate seems to be the best estimator, with a correlation of -0.93 and a variation coefficient of only 23 percent. The first work trip rate is almost as good.

Curiously, the land area rate has almost no relationship to NRD—it does not show a decline with movement from the CBD to the suburbs. This is the only land-use category for which this is true. Apparently the greater trip attraction per unit of floor area in the suburbs is bal-

TABLE 2

OVERALL TRIP RATES FOR CATS STUDY AREA

Land Use	Land Area Rate	Floor Area Rate	First Work Trip Rate
Commercial	181.42	5.87	3.54
Public buildings	52.82	3.82	4.70
Manufacturing	49.35	2.16	1.09
Public open space	4.28	—	17.49
Transportation	8.64	2.27	1.59

TABLE 3
RESULTS OF CORRELATION ANALYSIS OF TRIP RATES AND NRD

Land Use	Type of Rate	No. Districts	Correlation Coeff.	Mean Rate	Std. Error	Var. Coeff. (%)	Regression Equation[a]
Commercial	Land area	42	-0.024	153.82	59.60	38.7	$Y_1 = 155.355 - 0.0293X$
	Floor area	40	-0.927	11.02	2.54	23.0	$Y_2 = 33.800 - 14.642 \log X$
	First work trip	42	-0.781	4.96	1.18	23.8	$Y_3 = 6.549 - 0.0304X$
Public buildings	Land area	42	+0.711	75.69	30.03	39.7	$Y_1 = 43.085 + 0.6225X$
	Floor area	40	-0.674	5.37	2.80	52.2	$Y_2 = 14.657 - 5.971 \log X$
	First work trip	42	-0.624	7.94	3.75	47.2	$Y_3 = 11.141 - 0.0611X$
Manufacturing	Land area	42	+0.791	55.61	30.32	54.5	$Y_1 = 13.488 + 0.8042X$
	Floor area	38	-0.472	2.61	1.22	46.9	$Y_2 = 5.044 - 1.542 \log X$
	First work trip	42	-0.520	1.19	0.21	17.6	$Y_3 = 1.332 - 0.0026X$
Public open space	Land area	38	+0.560	12.61	12.47	98.9	$Y_1 = 4.354 + 0.1732X$
	First work trip	41	-0.532	25.71	15.01	58.4	$Y_3 = 36.087 - 0.1939X$
Transportation	Land area	42	+0.555	12.37	7.93	64.1	$Y_1 = 6.675 + 0.1087X$
	Floor area	34	-0.706	4.26	3.65	85.6	$Y_2 = 19.795 - 9.411 \log X$
	First work trip	42	-0.421	2.87	3.10	108.0	$Y_3 = 4.420 - 0.0296X$

[a] Y_1 = land area rate;
Y_2 = floor area rate;
Y_3 = first work trip rate; and
X = net residential density.

anced by the lower ratio of floor area to land area (parking lots and more horizontal buildings).

Public Buildings

There is not a great deal of difference among the three estimators, and none is especially good. The land area rate appears to be best, since it has the highest correlation coefficient and the lowest variation coefficient.

The ratio of all trips to first work trips is rather high because a large proportion of the trips to public buildings were made to schools, and trips by students heavily weight the nonwork trips. It seems reasonable that trips to schools might be based on enrollment, rather than any of the measures presented here. Unfortunately, CATS did not collect any enrollment data. Probably schools should be treated as a separate land-use category.

Manufacturing

The best predictor of the entire study is the equation relating all manufacturing trips to first work trips. Although the correlation with NRD is not high (-0.52), the initial variation in the trip rates is so low that the standard error is only 17.6 percent of the mean. It is logical that manufacturing trips are closely related to manufacturing employment because there are relatively few nonwork trips to manufacturing.

Public Open Space

There are no floor area rates for public open space, since normally this type of land contains no buildings. In the CATS survey, buildings located on public open space were usually classified under public buildings.

The results for this category are poor, undoubtedly because of the wide range in intensity of use of public open space. Hundreds of acres of forest preserve may attract almost no trips, whereas a small beach or playing field may attract thousands.

The first work trip rate appears to be better than the land area rate, since its correlation coefficient is almost as high and its variation coefficient is much lower. However, it might still be advisable to use the land area rate. Few people work on public open space and, therefore, first work trip rates are very high. It is probably difficult to measure employment accurately, and a small error in measuring employment would be magnified many times.

Transportation

The land area rate seems to be best for this category, which includes communications, utilities and other nonmanufacturing industrial uses. This is not surprising, since this category includes many extensive land uses in which floor area is not too significant. However, the variation coefficient is 64.1 percent—rather high—and this is a troublesome category. Fortunately, there are relatively few trips made to this land use.

COMMENTS ON RESULTS

No one of the three types of trip rates appears to be consistently superior. As measured by the variation coefficients, land area rates are best for two land uses, floor area rates for one, and first work trip rates for two. In three cases the land area rate has the highest correlation; in two cases, the floor area rate has the highest.

It is interesting that the floor area rate is substantially better than the land area rate only for commerical land use. (For manufacturing, the floor area rate has a slightly lower variation coefficient but a much poorer correlation. For transportation, the floor area rate has a slightly higher correlation, but a poorer variation coefficient.) This is contrary to expectations since, in theory, floor area is supposed to be a better basis for trip generation.

Attention is also directed to the sign of the correlation coefficients. All of the land area correlations have positive signs except commercial, where the correlation is practically zero. This is according to theory: where the density is higher, land is used more intensively and more trips are made to it.

All of the floor area rates have negative correlations, meaning that more trips are made to a unit of floor area in the suburbs than in the central city. This is puzzling. It was theorized, before the CATS survey was made, that floor area rates would be about the same everywhere. Why they are not is not yet fully understood. One hypothesis is that in the denser areas, walking trips are substituted for auto or transit trips, and walking trips are not included in person trips. Another explanation is that in the low density areas, only part of the floor area was measured in the survey, and that part was usually in the CBD's of suburban cities. If all suburban land use were measured, the floor area trip rates might drop considerably. A third possibility is that the supply of nonresidential floor area in the suburbs has not caught up with the demand for it (or had not as of 1956). People living in the suburbs make more trips per capita than those living in the central city. In time it would be expected that the amount of floor area would increase to absorb this greater trip-making, but perhaps there is a time lag. This would mean that nonresidential construction in the suburbs does not keep up with residential construction. These hypotheses may be invalid, but it does not seem logical that floor area is more intensively used in the suburbs when land area is more intensively used in the central city.

The first work trip rate is definitely related to NRD, and in all cases the correlation is negative. There are probably two reasons for this. First, when people make more trips (as do suburban residents), the incremental trips tend to be nonwork trips. Second, walking trips may have something to do with it. Work trips (which tend to be the longest of any purpose) are seldom on foot, and even those working in dense areas tend to travel to work by auto or transit. Nonwork trips, however, are more apt to be on foot in dense areas, which would lower the first work trip rates there.

FURTHER RESEARCH

As is often the case, this investigation produced more questions than answers. To pursue this inquiry further, several things could be tried: (a) variables other than net residential density; (b) more sophisticated statistical techniques, such as multiple correlation; (c) a more detailed classification of land uses; (d) smaller geographical units; and (e) other parameters than the three discussed here. Some of these approaches were attempted with CATS data, but the results were not very rewarding. Land area rates

for public buildings and manufacturing were correlated with many different variables, using all types of correlation—simple and multiple, linear and curvilinear.

For both land-use categories, the variable giving the highest simple correlation was gross population density (population divided by total land area). The coefficients were +0.791 for public buildings and +0.845 for manufacturing—both slightly higher than the coefficients for net residential density. However, gross population density is not a very satisfactory variable because vacant land is included and can distort the ratios. The density can be greatly affected by where the boundaries of the districts happen to fall.

Other variables were found to have rather high correlations with trip rates. However, all of these were highly correlated with NRD and explained very little of the variation which was not explained by NRD. The goal was to find a variable with a sound logical basis which is highly correlated with trip rates and not particularly correlated with NRD. No such variable was discovered, so it appears that NRD is still the best variable to correlate with trip rates.

The comparison described here could not be carried out for a finer classification of land uses. Although CATS made such a classification (about 90 categories), land area was not so classified. However, some investigation was made of floor area trip rates for detailed commercial land uses. All of the detailed categories produced lower correlations than the overall category. Apparently, the detailed rates contained many variations which were washed out when the categories were lumped together. Besides, when the classification becomes finer, sampling variability becomes a greater problem.

It would be desirable to use smaller and more uniform geographical units. CATS districts admittedly were not ideal; they vary greatly in size, and some are very large (as much as 146 sq mi). The alternative was to use zones, of which there are 582. Then the volume of calculations becomes overwhelming, and machine assistance is required. It might be possible to get around this problem by using a sample of zones. A warning is also in order; when smaller units are used, the variation is liable to increase. This is similar to the effect obtained when moving from general to detailed land-use categories.

It would also be worthwhile to experiment with parameters other than land area, floor area and employment. Certain possibilities come to mind: enrollment (for schools), number of beds (for hospitals), and number of seats (for churches and auditoriums). These suggest themselves more readily for individual application to specialized land uses than for general adoption for all land uses. Therefore, the data collection will become more complex, rather than simpler.

This analysis was handicapped by lack of adequate data, which points up the need for some more comprehensive surveys, for research purposes at least. The only complete survey made by CATS was the land area survey. It would be valuable to make a complete floor area survey of a metropolitan area, including suburbs and rural areas as well as the central city. This would be a considerable undertaking, of course, and would mean going beyond Sanborn maps. It would also be desirable to make a comprehensive, detailed employment survey of a metropolitan area as part of a transportation study. This has probably never been done, although many studies have used gross employment estimates. The Census Bureau does make such surveys, but whether detailed data would be available to a transportation study is not known. Careful attention should be given to the design of such a survey to make the resulting data as comparable as possible to data from the travel surveys.

CONCLUSIONS

Although all generalizations about trip generation must be regarded as tentative, several conclusions can be drawn from this study:

1. Present evidence does not suggest that there is a single best parameter for non-residential trip generation. In the author's judgment, floor area rates are best for commercial, first work trip rates for manufacturing, and land area rates for public buildings, public open space, and transportation.

2. This indicates that, for the time being, transportation studies should continue to collect data for all three types. In fact, more comprehensive surveys of all three types would be beneficial.

3. Contrary to theory, it does not appear that floor area is necessarily a better basis for trip generation than land area.

4. It appears, from the limited data available, that floor area rates are not uniform throughout a metropolitan area but increase with decreasing density. This is also contrary to expectation.

5. As expected, land area rates decrease with decreasing density, except in the case of commercial land use where there is no relationship at all.

6. The ratio of total trips to first work trips is not stable throughout a metropolitan area but increases with decreasing density.

This has been a rather detailed investigation of a specialized subject. Nevertheless, it is of considerable importance because of the vital place that the land use-travel relationship occupies in the transportation planning process. So much has been made of this relationship, so much is ascribed to it, and so much is expected from it that it is a bit frightening to realize that as yet it is only dimly understood.

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