TRUTH IN TRANSPORTATION PLANNING

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ABSTRACT

Transportation engineers often use very precise numbers to report extremely uncertain estimates, and urban planners rely on these precise numbers to make bad decisions. This paper uses two handbooks published by the Institute of Transportation Engineers - *Parking Generation* and *Trip Generation* - to illustrate the problems created by using precise numbers to report statistically insignificant estimates.

TRUTH IN TRANSPORTATION PLANNING

How far is it from San Diego to San Francisco? An estimate of 632.125 miles is precise but not accurate because the correct answer is 460 miles.[1] An estimate of somewhere between 400 and 500 miles is less precise but more accurate. It's better to be roughly right than precisely wrong, but precision creates the impression of accuracy. If you had no idea how far it is from San Diego to San Francisco, whom would you believe: the person who confidently says 632.125 miles, or the one who tentatively says somewhere between four and five hundred miles?

Transportation engineers and urban planners often use precise numbers to report uncertain estimates. The Institute of Transportation Engineers (ITE) publishes two handbooks - *Trip Generation* and *Parking Generation* - that exemplify this inappropriate precision. These handbooks have enormous practical consequences for transportation and land use. The ITE's estimates of trip generation and parking generation have found their way into many transportation models, travel forecasts, planning decisions, municipal ordinances, and court rulings. Urban planners rely on the ITE's trip generation rates to predict the traffic impacts of development proposals, and they rely on the ITE's parking generation rates to establish minimum parking requirements. Yet a close look at the trip generation and parking generation rates for one common land use (a fast food restaurant) exposes the problems created by precise - but inaccurate - estimates of travel behavior.

TRIP GENERATION

Trip Generation shows the number of vehicle trips to and from each land use during a given period. The ITE estimates the trip generation rates from surveys conducted by transportation engineers, planners, and consultants. Figure 1 shows a typical page from the fourth edition of *Trip Generation* (1987).[2] It reports the number of vehicle trips at fast food restaurants. Each point in the data plot shows the result of a case study at a single restaurant. Trip generation rates at the eight restaurants range from 284 to 1,360 vehicle trips per day per 1,000 square feet of floor area. The R^2 of 0.069 for the fitted curve (regression) equation at the bottom of Figure 1 shows that variation in floor area explains less than 7 percent of the variation in vehicle trips.[3] Nevertheless, the ITE reports the sample's *average* trip generation rate -- which urban planners normally interpret as *the* relationship between floor area and vehicle trips – as *precisely* 632.125 trips per day per 1,000 square feet of floor area.[4] The trip generation rate looks accurate because it is so precise.

Figure 1

FIGURE 1

FAST FOOD RESTAURANT WITH DRIVE-THROUGH WINDOW (834)

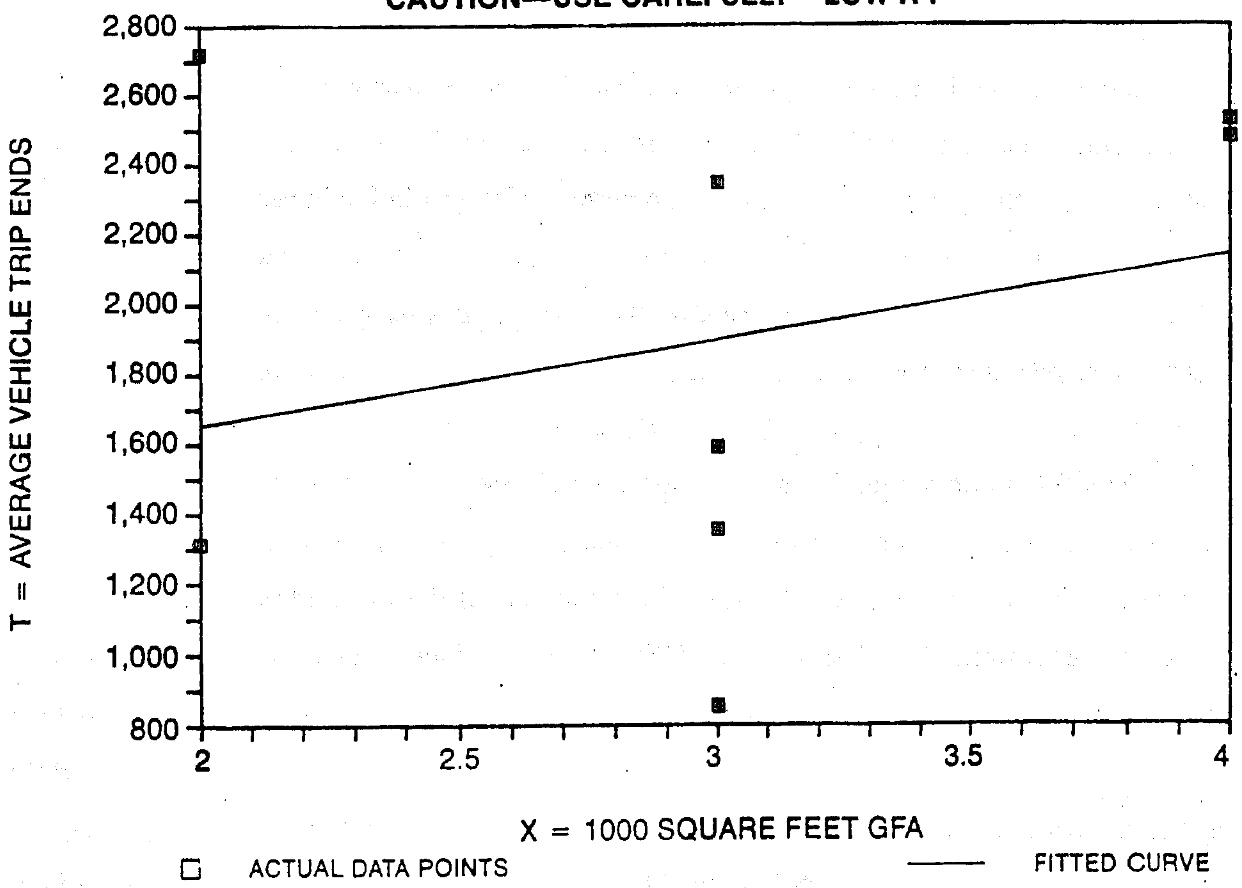
Average Vehicle Trip Ends vs: **1,000 SQUARE FEET GROSS FLOOR AREA**
On a: **WEEKDAY**

TRIP GENERATION RATES

Average Weekday Vehicle Trip Ends per 1,000 Square Feet Gross Floor Area				
Average Trip Rate	*Range of Rates*	*Standard Deviation*	*Number of Studies*	*Average 1,000 Square Feet GFA*
632.125	284.000–1359.500	*	8	3.0

DATA PLOT AND EQUATION

CAUTION—USE CAREFULLY—LOW R^2.



Fitted Curve Equation: $T = 242.75(X) + 1168.0$

$R^2 = 0.069$

DIRECTIONAL DISTRIBUTION: Not available.

The fitted curve equation at the bottom of Figure 1 suggests that a fast food restaurant generates 1,168 trips plus 242.75 trips per 1000 square feet of floor area. But the 95-percent confidence interval around the coefficient of floor area in the regression equation ranges from -650 to +1,141 trips per 1,000 square feet.[5] Since the confidence interval around the floor-area coefficient contains zero, the data do not show that floor area affects the number of vehicle trips. The ITE warns "Caution – Use Carefully – Low R^2," but how can one carefully use a trip generation rate estimated from data that do not show a statistically significant relationship between floor area and vehicle trips? Despite its precision, the *average* trip generation rate (623.125) is really too uncertain to use for transportation planning.

PARKING GENERATION

The ITE parking generation rates suffer from the sarne uncertainty. *Parking Generation* shows the peak parking demand at each land use, and Figure 2 shows the page for fast food restaurants from the most recent edition of*Parking Generation* (1987). Parking generation rates in the 18 studies range from 3.55 to 15.92 peak parking spaces occupied per 1,000 square feet of leasable floor area. The R^2 of 0.038 for the fitted curve equation at the bottom of Figure 2 shows that variation in floor area explains less than 4 percent of the variation in peak parking demand. It would be hard to find two variables that are more unrelated than floor area and parking demand in this sample.[6] Nevertheless, the ITE reports the *average* parking generation rate for a fast food restaurant as *precisely* 9.95 parking spaces per 1,000 square feet of floor area.[7]

Figure 2

The fitted curve equation at the bottom of Figure 2 suggests that a fast food restaurant generates a peak parking demand of 20 spaces plus 1.95 spaces per 1,000 square feet of floor area. The 95-percent confidence interval around the coefficient of floor area in the regression equation, however, ranges from -3 to +7 spaces per 1,000 square feet. Since the confidence interval around the floor-area coefficient contains zero, the data do not show that floor area affects parking demand.[8] The *average* parking generation rate of 9.95 spaces per 1,000 square feet is caused almost entirely by the intercept of 20 parking spaces, which is independent of floor area.

We cannot conclude much from the ITE data about how floor area affects either parking or trip generation because the 95-percent confidence interval around the coefficient of floor area

FIGURE 2

FAST FOOD RESTAURANT WITH DRIVE-IN WINDOW (836)

Peak Parking Spaces Occupied vs: **1,000 GROSS SQUARE FEET LEASABLE AREA**

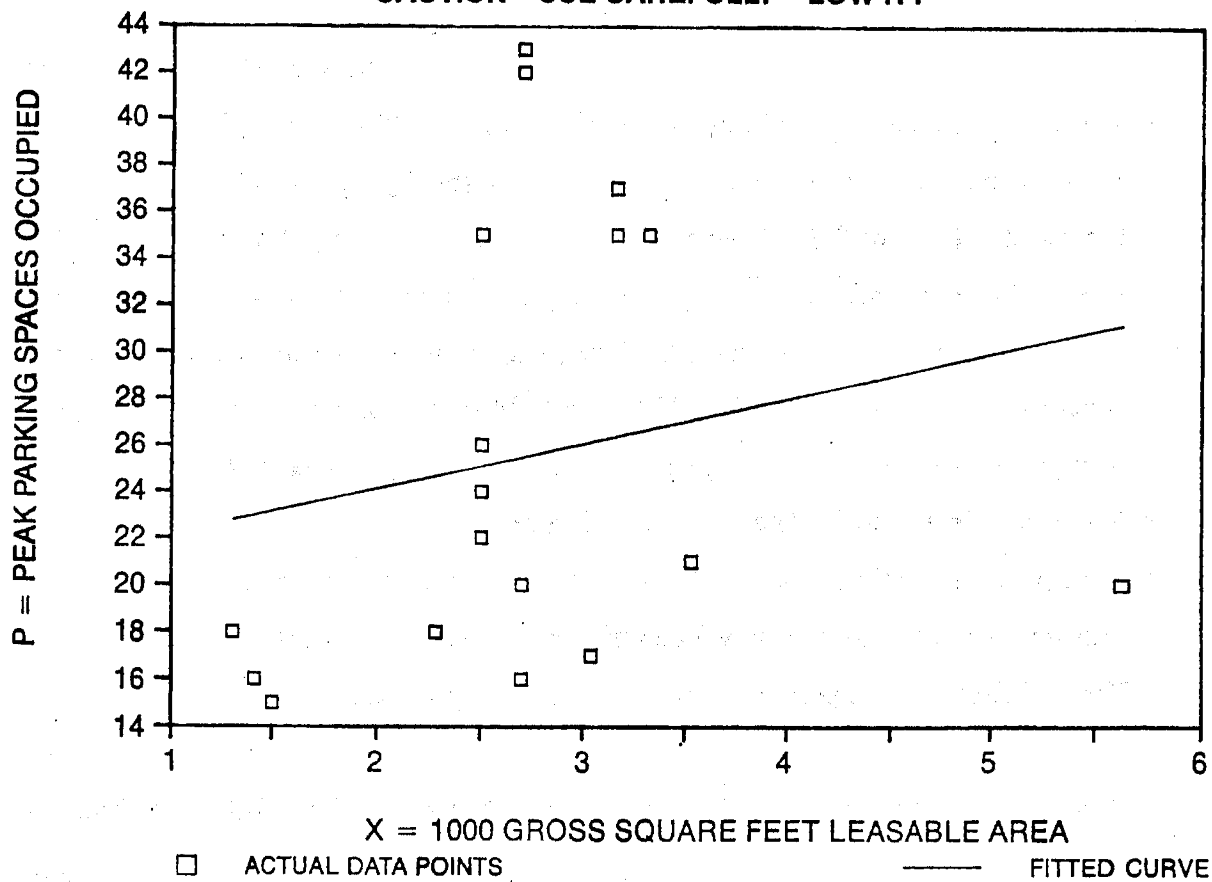
On a: **WEEKDAY**

PARKING GENERATION RATES

Average Rate	*Range of Rates*	*Standard Deviation*	*Number of Studies*	*Average 1,000 GSF Leasable Area*
9.95	3.55–15.92	3.41	18	3

DATA PLOT AND EQUATION

CAUTION—USE CAREFULLY—LOW R^2.



Fitted Curve Equation: $P = 1.95(X) + 20.0$

$R^2 = 0.038$

includes zero in both cases. I do not suggest that parking demand and vehicle trips are unrelated to a restaurant's floor area. Common sense tells us that there is some relationship, but we should recognize that the ITE data do not show a statistically significant relationship between floor area and either parking demand or vehicle trips.[9]

Urban planners consult the ITE parking generation rates to establish parking requirements in zoning ordinances. The ITE's stamp of authority relieves planners from any obligation to figure things out for themselves – it's all right there in the book. For example, the median parking requirement that planners have set for fast food restaurants is 10 spaces per 1,000 square feet – almost identical to the ITE parking generation rate.[10] When the ITE speaks, urban planners listen. After all, planners expect parking requirements to meet the peak demand for parking at every land use, and the ITE's parking generation rates report this peak demand precisely!

STATISTICAL SIGNIFICANCE

The low R^2 for many of the fitted curve equations in the second edition of *Parking Generation* (1987) and the fourth edition of *Trio Generation* (1987) raises an important question: How many of the parking and trip generation rates are statistically significant?

The fourth edition of *Trio Generation* (1987) does not state a policy regarding statistical significance. It shows the data plots and regression equations for most land uses with more than two studies, but it doesn't show them for some land uses with more than 10 studies. For example, the page for recreational land uses (Land Use 400) reports 14 studies of trip generation, and gives the average trip generation rate as 3.635 trips per acre on a weekday, but says "No Plot or Equation Available – Insufficient Data." The trip generation rates in the 14 studies range from 0.66 to 296.296 trips per acre, a ratio of 4,489 to 1. Given this wide range of trip generation, reporting the average trip generation rate as precisely 3.635 trips per acre seems exceptionally misleading.[11]

The ITE first stated a policy regarding statistical significance in the fifth edition of *Trip Generation* (1991):

> Best fit curves are shown in this report only when each of the following three conditions are met:
>
> - The R^2 is greater than or equal to 0.25.
> - The sample size is greater than or equal to 4.
> - The number of trips increases as the size of the independent variable increases.[12]

Figure 3 from the fifth edition of *Trip Generation* (1991) shows how this policy affects the report of trip generation at a fast food restaurant. Figure 3 shows the same eight studies as in Figure 1 (from the 1987 edition), but it omits the regression equation and the R^2. Although the R^2 remains 0.069 because the data remain the same as in 1987, the warning "Caution-Use Carefully – Low R^2" has disappeared. The fifth edition is, however, more cautious about using unnecessary precision to report rough estimates: the average trip generation rate is truncated from 632.125 to 632.12 trips per 1,000 square feet of floor area.[13]

Figure 3

The ITE revised its reporting policy in the sixth edition of *Trip Generation* (1997). Regression equations are shown only if the R^2 is greater than or equal to 0.5, while the other two criteria remain the same (the sample size is 4 or more, and the number of trips increases as the independent variable increases).[14] Figure 4 shows the sixth edition's report of trip generation at a fast food restaurant. It shows that the number of studies increased to 21, and that the average trip generation rate fell to 496.[12] The R^2 is below 0.5, but we don't know what it is.[5] Given that both the previous rate (632.12) and the new rate (496.12) were derived from data that show no relationship between floor area and vehicle trips, it seems unlikely that vehicle trips to and from fast food restaurants really fell by 22 percent between 1991 and 1997.[16]

Figure 4

The first two criteria that must be met before the ITE will show a regression equation are troubling at best, and the third criterion is notably unscientific. For example, suppose the R^2 is 0.7 and the sample size is 21 (the first two criteria are met) but vehicle trips *decrease* as floor area increases (the third criterion is not met). In this case the ITE would report the average trip generation rate (which implies that vehicle trips increase as floor area increases), but would not show the regression equation or the R^2. The policy is therefore to conceal evidence that disconfirms the predicted relationship.

DENYING UNCERTAINTY

The ITE creates serious problems when it uses precise numbers to report statistically insignificant results, because many people rely on the *Trio Generation* and *Parking Generation* handbooks. When estimating traffic impacts, for example, developers and cities often battle fiercely

FIGURE 3

Fast Food Restaurant With Drive-Through Window (834)

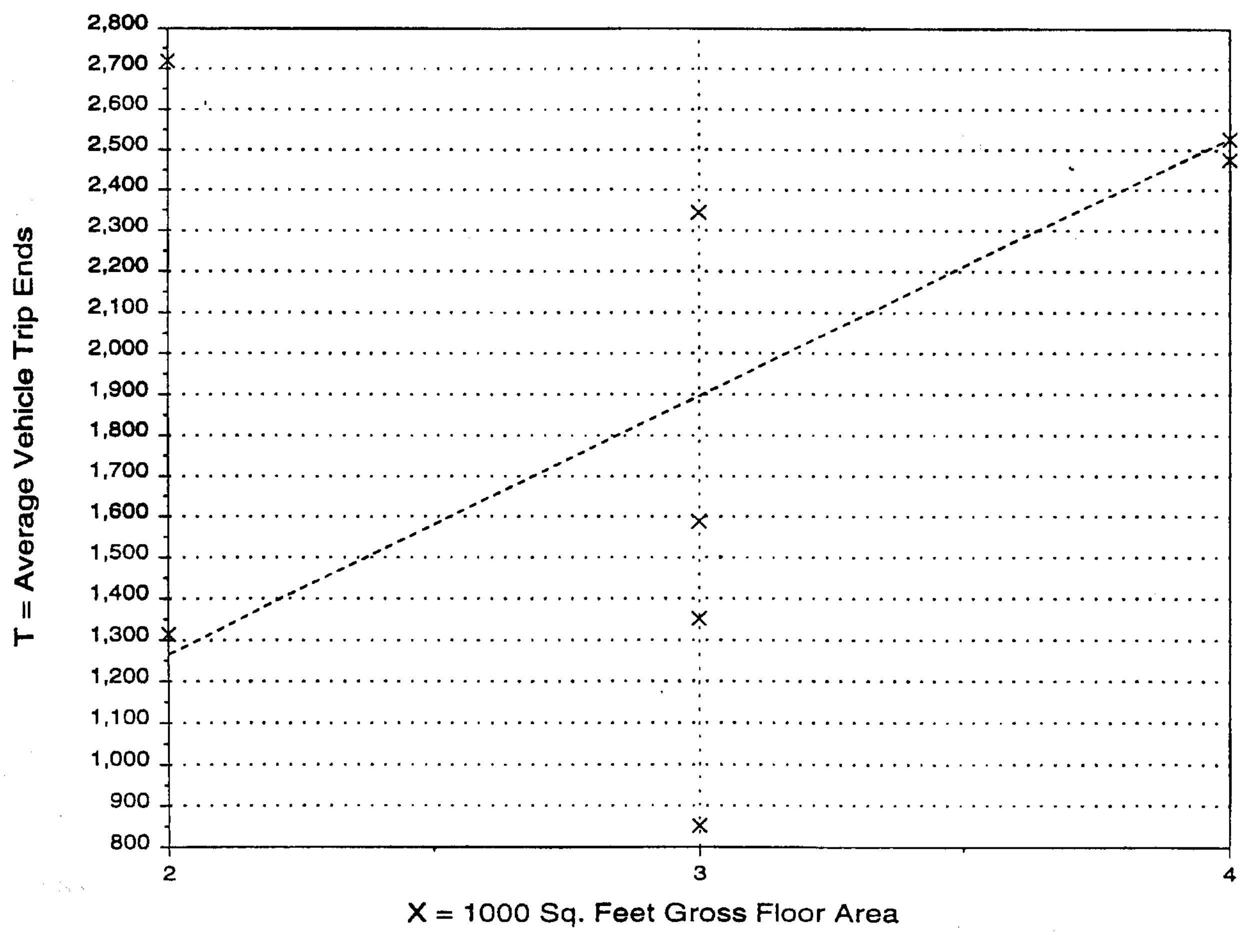
Average Vehicle Trip Ends vs: 1000 Sq. Feet Gross Floor Area
On a: Weekday

Number of Studies: 8
Average 1000 Sq. Feet GFA: 3
Directional Distribution: 50% entering, 50% exiting

Trip Generation per 1000 Sq. Feet Gross Floor Area

Average Rate	Range of Rates	Standard Deviation
632.12	284.00 - 1359.50	266.29

Data Plot and Equation



× **Actual Data Points** ------ **Average Rate**

Fitted Curve Equation: Not given R^2 = ****

FIGURE 4

Fast-Food Restaurant with Drive-Through Window
(834)

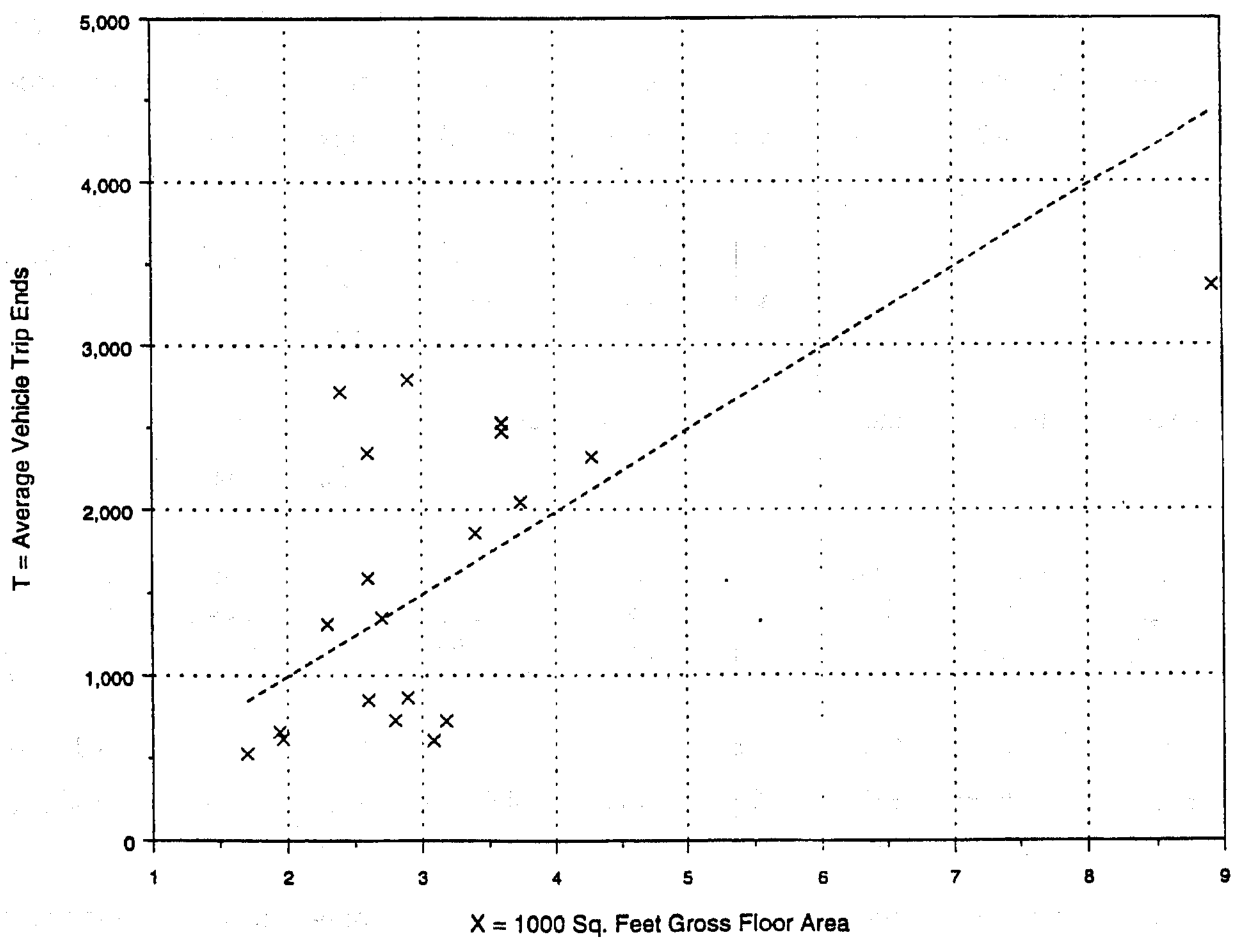
Average Vehicle Trip Ends vs: **1000 Sq. Feet Gross Floor Area**
On a: **Weekday**

Number of Studies: 21
Average 1000 Sq. Feet GFA: 3
Directional Distribution: 50% entering, 50% exiting

Trip Generation per 1000 Sq. Feet Gross Floor Area

Average Rate	Range of Rates	Standard Deviation
496.12	195.98 - 1132.92	242.52

Data Plot and Equation



× **Actual Data Points** ------ **Average Rate**

Fitted Curve Equation: Not given R^2 = ****

over which of two precise trip generation rates is correct. Given the uncertainty involved, the debates are ludicrous. But the legal system of land use regulation makes it difficult to incorporate uncertainty into decisions on permitted uses, traffic impact fees, and the like. Some cities even base zoning categories on the ITE trip generation rates. For example, consider this zoning ordinance in Beverly Hills, California:

> The intensity of use shall not exceed either sixteen (16) vehicle trips per hour, or 200 vehicle trips per day for each 1000 gross square feet of floor area for uses as specified in the most recent edition of the Institute of Traffic Engineers' publication entitled "Trip Generation."[17]

The precise but uncertain trip generation rates thus govern land use decisions.

Because we want to consider the traffic impacts of land use decisions, the denial of uncertainty is understandable. The ITE data are embedded in municipal codes and case law, so admitting their flimsy basis – no matter how obvious – would expose land use decisions to legal challenges. This is not to excuse current practice, but to suggest why planners, developers, and elected officials avoid acknowledging the uncertainty inherent in predicting parking and trip generation. Nevertheless, we need a *range* rather than a single figure to show what we know from the limited data, and a precise point estimate fails to acknowledge the uncertainty of parking and trip generation.

ESTIMATING THE DEMAND FOR FREE PARKING

Compounding the serious problems created by using precise numbers to report uncertain estimates, the ITE' 5 survey methods create further problems when urban planners use the parking and trip generation rates. The second edition of *Parking Generation* (1987) explains,

> A vast majority of the data... is derived from suburban developments with little or no significant transit ridership. . . . The ideal site for obtaining reliable parking generation data would . . . contain ample, convenient parking facilities for the exclusive use of the traffic generated by the site. . . . The objective of the survey is to count the number of vehicles parked at the time of peak parking demand.[18]

Half the 101 parking generation rates are based on four or fewer surveys, and 22 percent are based on a single survey. Parking is free for 99 percent of automobile trips in the United States, so parking is probably free at the sites where planners survey parking demand.[19] The ITE parking generation rates thus typically measure the peak demand for ample, convenient free parking observed at a few suburban sites that lack public transit.

Similarly, *Trip Generation* explains that "the [survey] site should be self-contained with adequate parking not shared by other activities."[20] Half the 1,912 trip generation rates in the sixth edition of *Trip Generation* (1997) are based on five or fewer surveys, and 23 percent are based on a single survey. The ITE trip generation rates therefore typically measure vehicle trips to and from a few sites that offer free parking.[21]

Much larger samples could solve the problem of statistical insignificance, but the basic problem with the ITE parking generation rates would remain: *they estimate the peak demand for free parking.* Because urban planners consult these parking generation rates to set minimum parking requirements, most new land uses provide at least enough parking spaces to satisfy the peak demand for free parking. The large parking supply drives the market price of most parking to zero, and ubiquitous free parking stimulates vehicle travel. The resulting trip generation rates become the guide for designing the transportation system that brings cars to the free parking. Peak parking occupancies observed at sites that offer free parking are then reported as parking generation rates, and the circle is completed. Using this circular logic, urban planners neglect both the price and the cost of parking when they set parking requirements, and they typically require at least enough spaces to meet the peak demand for free parking. Free parking is thus the tail that wags two dogs – transportation and land use (see Figure 5).

Figure 5

CONCLUSION: LESS PRECISION AND MORE TRUTH

Citizens, developers, and planners all want to know how proposed land uses will affect transportation. Citizens want to know how a project will affect parking demand and traffic congestion in their neighborhood. Developers want to know how many parking spaces to provide for employees and customers. Planners want to regulate development to prevent problems with parking and traffic. The ITE's estimates of parking and trip generation thus respond to a real demand for essential information.

Nevertheless, the ITE's methods of gathering and presenting information create grave problems. The ITE surveys the peak demand for free parking at a few suburban sites that lack public transit, and planners then use the ITE data to set minimum parking requirements. The ITE also gathers data on vehicle trips to and from sites that offer free parking, and planners use the ITE data

FIGURE 5

THE FOUR-STEP PROCESS FOR PLANNING TRANSPORTATION AND LAND USE

1. **Transportation engineers survey the peak parking occupancy at suburban sites that offer ample free parking and lack public transit. The ITE summarizes the data and reports the parking generation rate for each land use.**

⇩

2. **Urban planners use the ITE parking generation rates to set minimum parking requirements for all land uses. Because the required parking supply is so large, the market price of parking is zero. Most developments therefore offer free parking.**

⇩

3. **Transportation engineers survey vehicle trips to and from sites that offer free parking. The ITE summarizes the data and reports the trip generation rate for each land use.**

⇩

4. **Transportation planners use the ITE trip generation rates to design the roads and highways. The transportation system therefore provides enough capacity to satisfy the expected demand for vehicle trips to and from land uses that offer free parking. (Return to 1.)**

to design the road system. Therefore, transportation and land use are planned on the unstated assumption that parking will be free-no matter how much it costs.

The ITE presents parking and trip generation rates so precisely (such as 632.12 vehicle trips per day per 1,000 square feet of restaurant space) that they appear to be constants, like the boiling point of water or the speed of light.[22] Unwarranted confidence in these precise numbers then leads to bad decisions. Planners treat parking and trip generation like physical laws, and they treat the ITE estimates like scientific observations. In reality, parking and trip generation are poorly understood phenomena, and they both depend on the price of parking. Demand is a function, not a number, and this simple fact doesn't cease to exist merely because urban planners and transportation engineers ignore it.

The ITE should not report parking and trip generation rates as precise numbers. More important, it should make clear that parking generation rates measure the peak demand for free parking, and that trip generation rates measure vehicle trips to and from sites that offer free parking. Urban planners should acknowledge that minimum parking requirements based on the ITE parking generation rates will satisfy the peak demand for free parking at suburban sites that lack public transit. We need less precision – and more truth – in transportation planning.

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ENDNOTES

1. The distance between San Diego and San Francisco is calculated from the latitudes and longitudes of the two cities. See "How far is it?" at <http://www.indo.corn/distance/>.

2. The 1987 edition is shown because this is the date of the most recent edition of *Parking Generation,* to which *Trip Generation* will be compared.

3. The significance test for the regression equation shows that there is a 53 percent chance of getting an R^2 of 0.069 or more even if there were no relationship between the two variables.

4. The ITE (1987b, 9) divides the sum of all vehicle trips by the sum of the floor areas to calculate the weighted average trip generation rate.

5. The confidence interval around the coefficient of floor area was calculated by re-estimating the regression equation from the eight observations in the data plot.

6. The significance test for the regression equation shows that there is a 42 percent chance of getting an R^2 of 0.038 or more even if there were no relationship between the two variables.

7. The ITE (1987a, viii) divides the sum of all parking generation rates by the number of sites to calculate the unweighted average parking generation rate.

8. The confidence interval around the coefficient of floor area was calculated by re-estimating the regression equation from the 18 observations in the data plot.

9. Statistical insignificance does not mean that floor area does not affect parking demand and vehicle trips; rather, it means that floor area does not reliably predict either variable.

10. The Planning Advisory Service (1991) surveyed the parking requirements in 127 cities. The median of 10 spaces per 1,000 square feet is for the cities that base their requirements for fast food restaurants on gross floor area.

11. In the fourth edition of *Trip Generation* (1987), Land Use 400 (Recreational Land Use) includes bowling alleys, zoos, sea worlds, lakes, pools, and regional parks (ITE 1987b, 537).

12. ITE (1991, 1-8). The ITE gives no explanation for showing the regression equation and the R^2 only when all three criteria are met.

13. Figure 3 (from the fifth edition) also differs from Figure 1 (from the fourth edition) in two other respects. First, the directional distribution of vehicle trips was "not available" in 1987, but for the same data became "50% entering, *50%* exiting" in 1991. Second, the standard deviation was not reported in 1987, but was reported as 266.29 in 1991.

14. ITE(1997,19).

15. The ITE does not explain why all of the eight restaurants in the fourth (1987) and fifth editions (1991) were exactly 2, 3, or 4 thousand square feet, but none of the 21 restaurants in the sixth edition (1997) matched any of these three sizes.

16. The 1997 trip generation rate of 496.12 is 22 percent lower than the 1991 rate of 632.12. If the eight studies from the fourth (1987) and fifth (1991) editions are included among the 21 studies reported in the sixth (1997) edition, the average trip generation rate for the 13 new studies must be well below 496.12 in order to reduce the average rate for the 21 studies to 496.12.

17. Section 10-3.162(5) of the Beverly Hills Municipal Code. This provision refers to uses permitted in the city's C-3T-2 Zone. The ITE changed its name from the Institute of Traffic Engineers to the Institute of Transportation Engineers in 1976.

18. ITE (1987a, vii-xv).

19. The ITE parking surveys contain no information about the price charged for parking at the survey sites, but the 1990 Nationwide Personal Transportation Survey found that parking is free for 99 percent of all automobile trips in the United States.

20. ITE (1987b, 23).

21. Many urban activities share their parking lots with other activities, so conducting surveys only at self-contained sites with adequate parking not shared by other activities leaves relatively few cases to observe. These cases probably overstate the trip generation rates at activities that do share their parking lots with other activities.

22. Even the boiling point of water and the speed of light are not constants. Air pressure affects the boiling point of water, and the speed of light depends on the medium through which light passes.