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Truth in Transportation Planning

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Donald C. Shoup

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TRUTH IN TRANSPORTATION PLANNING

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ABSTRACT

Transportation engineers and urban planners often report uncertain estimates as precise numbers, and unwarranted trust in the accuracy of these precise numbers can lead to bad transportation and land-use policies. This paper presents data on parking generation and trip generation rates to illustrate the misuse of precise numbers to report statistically insignificant estimates. Beyond the problem of statistical insignificance, parking and trip generation rates typically report the parking demand and vehicle trips observed at suburban sites with ample free parking and no public transit. These parking and trip generation rates are therefore useful guides for planning a city where everyone will drive everywhere they go and park free when they get there.
TRUTH IN TRANSPORTATION PLANNING

Donald C. Shoup

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TRUTH IN TRANSPORTATION PLANNING

Beware of certainty where none exists
DANIEL PATRICK MOYNIHAN

How far is it from San Diego to San Francisco? An estimate of 632.125 miles is precise—but not accurate. An estimate of somewhere between 400 and 500 miles is less precise but more accurate because the correct answer is 460 miles. Nevertheless, if you had no idea how far it is from San Diego to San Francisco, whom would you believe: someone who confidently says 632.125 miles, or someone who tentatively says somewhere between 400 and 500 miles? Probably the one who says 632.125 miles, because precision creates the impression of accuracy.

Although reporting estimates with extreme precision suggests confidence in their accuracy, transportation engineers and urban planners often use precise numbers to report uncertain estimates. To illustrate this practice, I will use two manuals published by the Institute of Transportation Engineers (ITE)—Parking Generation and Trip Generation. These manuals have enormous practical consequences for transportation and land use. Urban planners rely on parking generation rates to establish off-street parking requirements, and transportation planners rely on trip generation rates to predict the traffic impacts of development proposals. Yet a close look at the parking and trip generation data shows that placing unwarranted trust in these precise but uncertain estimates of travel behavior leads to bad transportation and land-use policies.

TRIP GENERATION

Trip Generation reports the number of vehicle trips as a function of land use. Transportation engineers survey the number of vehicle trips to and from various land uses, and for each land use the ITE reports a “trip generation rate” that relates the number of vehicle trips to a characteristic of the land use, such as the floor area or number of employees at a site. The sixth edition of Trip Generation (1997) describes the data used to estimate trip generation rates:

This document is based on more than 3,750 trip generation studies submitted to the Institute by public agencies, developers, consulting firms, and associations. Data were primarily collected at suburban localities with little or no transit service, nearby pedestrian amenities, or travel demand management (TDM) programs.

The ITE says nothing about the price of parking at the study sites, but since parking is free for 99 percent of vehicle trips in the US, most of the study sites probably offer free parking. Half the 1.515 reported trip generation rates are based on five or fewer studies, and 23 percent are based on a single
The trip generation rates thus typically measure the number of vehicle trips observed at a few suburban sites with free parking but little or no public transit service, pedestrian amenities, or TDM programs. Urban planners who rely on these trip generation rates as guides to design the transportation system are therefore planning an automobile-dependent city.

Figure 1 shows a typical page from the fourth edition of *Trip Generation* (1987). It reports the number of vehicle trips to and from fast food restaurants on a weekday. Each of the eight studies is represented by a point in the figure showing the average number of vehicle trips per day (on the vertical axis) and the floor area at a restaurant (on the horizontal axis). Dividing the number of vehicle trips by the floor area at that restaurant gives the trip generation rate at that restaurant. A glance at the figure suggests that vehicle trips are unrelated to floor area in this sample, and the extremely low $R^2$ of 0.069 for the fitted curve (regression) equation confirms this impression. 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. The trip generation rate looks accurate because it is so precise, but the precision is misleading. Few transportation or land-use decisions would be changed if the ITE reported the trip generation rate as 632 rather than 632.125 trips per 1,000 square feet, so the three-decimal-point precision serves no purpose other than to give the impression of accuracy.

The equation at the bottom of Figure 1 suggests that a fast food restaurant generates 1,168 trips (the intercept) plus 242.75 trips per 1,000 square feet of floor area (the coefficient), but the 95-percent confidence interval around the floor-area coefficient ranges from −650 to +1,141 trips per 1,000 square feet. Since this confidence interval contains zero, the data do not show that vehicle trips are related to floor area. Reporting the average trip generation rate implies that larger restaurants generate more vehicle trips, but the figure shows that the smallest restaurant generated the most trips, and a mid-sized one generated the fewest. The data plot does contain the warning "Caution—Use Carefully—Low $R^2$," which is good advice, but how can one carefully use a trip generation rate derived from data that show no relationship between vehicle trips and floor area? Despite its precision, the average trip generation rate (623.125 vehicle trips per day per 1,000 square feet) is far too uncertain to use for transportation planning.
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

<table>
<thead>
<tr>
<th>Average Trip Rate</th>
<th>Range of Rates</th>
<th>Standard Deviation</th>
<th>Number of Studies</th>
<th>Average 1,000 Square Feet GFA</th>
</tr>
</thead>
<tbody>
<tr>
<td>632.125</td>
<td>284.000–1359.500</td>
<td>*</td>
<td>8</td>
<td>3.0</td>
</tr>
</tbody>
</table>

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.

Trip Generation/Fourth Edition/Institute of Transportation Engineers/1987/page 1199
A comparison with medical research shows the uncertainty of this trip generation rate. If, for example, Figure 1 showed blood cholesterol level (on the vertical axis) as a function of the number of aspirin tablets per day taken by sample of eight patients (on the horizontal axis), the data would not convince anyone that the aspirin dosage affected the outcome. But when it comes to transportation planning, the data seem to convince many people that each 1,000 square feet of floor area generates 632.125 vehicle trips per day.

PARKING GENERATION

Parking generation rates (which report peak parking occupancy as a function of land use) suffer from similar uncertainty. The ITE's second edition of *Parking Generation* (1987) describes the data used to estimate parking generation rates:

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.9

Half the 101 parking generation rates are based on four or fewer studies, and 22 percent are based on one study. The parking generation rates thus typically measure the peak parking demand observed at a few suburban sites with ample free parking but little or no transit ridership. Urban planners who use these parking generation rates to set minimum parking requirements therefore shape a city where everyone will drive wherever they go and park free when they get there.

Figure 2 shows the page for fast food restaurants from the second edition of *Parking Generation*. Each point in the plot represents one study (based on the observations at one site on one day). For example, if parking occupancy was observed at one restaurant for five days, this would be five studies.10 Dividing the peak parking occupancy observed in a study by the floor area at the restaurant gives the parking generation rate for the study. The parking generation rates in the 18 studies range between 3.55 and 15.92 spaces per 1,000 square feet of leasable floor area. The largest restaurant in the sample generated one of the lowest peak parking occupancies, while a mid-sized one generated the highest. The near-zero $R^2$ of 0.038 for the equation at the bottom of the figure confirms the visual impression that parking demand is unrelated to floor area in this sample.
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

<table>
<thead>
<tr>
<th>Average Rate</th>
<th>Range of Rates</th>
<th>Standard Deviation</th>
<th>Number of Studies</th>
<th>Average 1,000 GSF Leasable Area</th>
</tr>
</thead>
<tbody>
<tr>
<td>9.95</td>
<td>3.55-15.92</td>
<td>3.41</td>
<td>18</td>
<td>3</td>
</tr>
</tbody>
</table>

DATA PLOT AND EQUATION

CAUTION—USE CAREFULLY—LOW R².

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

\( R^2 = 0.038 \)
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. Again, the precision is misleading. 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, but the 95-percent confidence interval around the floor-area coefficient ranges from -3 to +7 spaces per 1,000 square feet. Since this confidence interval contains zero, the data do not show that parking demand is related to floor area. The *average* parking generation rate of 9.95 spaces per 1,000 square feet is due mainly to the intercept, which is independent of floor area. Predicting a parking demand of 26 spaces for every restaurant in this sample—regardless of size—produces about the same average error as predicting a parking demand of 9.95 spaces per 1,000 square feet.

Parking generation rates are hardly scientific, but the ITE’s stamp of authority relieves planners from the obligation to think for themselves—the answers are right there in the book. The ITE offers a precise number without raising difficult public policy questions, although it does warn, “Users of this report should exercise extreme caution when utilizing data that is based on a small number of studies.” Nevertheless, many planners USE the ITE’s parking generation rates to set minimum parking requirements in their communities. For example, the median parking requirement for fast food restaurants in the US is 10 spaces per 1,000 square feet—almost identical to the ITE’s reported parking generation rate of 9.95 spaces per 1,000 square feet. After all, planners expect minimum parking requirements to meet the peak demand for free parking, and parking generation rates predict this demand precisely. When the ITE speaks, urban planners listen.

### Parking Occupancy versus Parking Demand

There is a fine line but a big difference between “parking occupancy” and “parking demand.” Transportation engineers define parking occupancy as the number of parked cars. Economists define parking demand as the functional relationship between the price of parking and the number of parked cars, and they define the actual number of parked cars at any time as the “quantity of parking demanded” at a specific price. Economists would call the peak parking occupancy observed at a site that offers free parking “the quantity of parking demanded at a zero price at the time of peak parking demand.” These differing definitions show the confusion that can result when the ITE’s parking generation rates are loosely referred to as “parking demand.”
DOES SIZE MATTER?

We cannot say much about how floor area affects either vehicle trips or parking demand at a fast food restaurant, because the 95-percent confidence interval around the floor-area coefficient includes zero in both cases. This is not to say that vehicle trips and parking demand are unrelated to a restaurant's size, because common sense suggests some correlation. Nevertheless, factors other than the floor area explain most of the variation in vehicle trips and peak parking occupancy at these restaurants. Size does not matter much in these two samples of parking and trip generation, and it is misleading to publish precise average parking and trip generation rates based on floor area.

The breathtaking combination of extreme precision and statistical insignificance for the parking and trip generation rates for a fast food restaurant raises an important question: how many of the parking and trip generation rates for other land uses are statistically significant? The fourth edition of *Trip Generation* (1987) does not state a policy on statistical significance, but it does show the plots and equations for most land uses with more than two data points. Nevertheless, it fails to show the plots and equations for some land uses with more than 10 data points. For example, consider the report of trip generation at recreational land uses. The ITE reports 14 studies of trip generation at recreational land uses but says "No Plot or Equation Available—Insufficient Data." The trip generation rates in the 14 studies range from a high of 296 to a low of 0.066 trips per acre on a weekday, a ratio of 4,500 to 1. Given this wide range, reporting the average trip generation rate as precisely 3.635 trips per acre is exceptionally misleading.


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.

The third criterion is notably unscientific. For example, suppose the $R^2$ is greater than 0.25 and the sample size is greater than 4, but vehicle trips decrease as floor area increases (the first two criteria are met but the third is not). In this case the ITE would report the average trip generation rate (which implies that vehicle trips increase as floor area increases), but not the regression equation that would
cast doubt on this rate. The stated policy therefore conceals evidence that would contradict the presumed relationship.

Figure 3 from the fifth edition of *Trip Generation* (1991) shows how these three criteria affect the report of trip generation at a fast food restaurant. It shows the same eight data points from the fourth edition, but it omits the regression equation, the $R^2$, and the warning "Caution—Use Carefully—Low $R^2$." The omitted $R^2$ remains 0.069 because the data are unchanged from the fourth edition, but the fifth edition is more cautious about needless precision: it truncates the average trip generation rate from 632.125 to 632.12 trips per 1,000 square feet.\(^{20}\)

Figure 3

The ITE revised its reporting policy in the sixth (most recent) edition of *Trip Generation* (1997, 19). 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 vehicle trips increase as the independent variable increases). Figure 4 shows the sixth edition’s report of trip generation at a fast food restaurant. The number of studies increased to 21, and the average trip generation rate fell to 496.12 trips per 1,000 square feet. The $R^2$ is below 0.5, but we are not told what it is. Since the fifth edition’s rate was 632.12 trips per 1,000 square feet, anyone comparing the two editions might conclude that vehicle trips at fast food restaurants declined 22 percent between 1991 and 1997. But since both the previous rate (632.12) and the new one (496.12) were derived from data that show almost no relation between floor area and vehicle trips, this decline seems unlikely.\(^{21}\)

Figure 4

The 1997 edition shows regression equations for only 34 percent of the trip generation rates, which means that 66 percent of the 1,515 trip generation rates fail to meet at least one of the three criteria. The statistical insignificance of most trip generation rates is not surprising, because they are merely a stripped-down version of the gravity model for travel forecasting. Gravity models predict travel between origin and destination zones in terms of zone characteristics and generalized travel cost, while trip generation rates predict the number of vehicle trips to and from one site as a function of floor area (or another variable) at the site, without reference to cost. In 1972, Berkeley economist Daniel McFadden revolutionized travel demand forecasting by shifting the analysis from travel between zones to travel by individuals. As McFadden says, "Zones don’t travel; people
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

X = 1000 Sq. Feet Gross Floor Area

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

<table>
<thead>
<tr>
<th>Average Rate</th>
<th>Range of Rates</th>
<th>Standard Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>496.12</td>
<td>195.98 - 1132.92</td>
<td>242.52</td>
</tr>
</tbody>
</table>

Data Plot and Equation

Fitted Curve Equation: Not given

Trip Generation/Sixth Edition/Institute of Transportation Engineers/1997/page 1401
Similarly, land uses don’t make vehicle trips, people make vehicle trips. The circumstances can vary enormously among different sites for the same land use (such as a fast food restaurant), and floor area is only one among many factors that influence vehicle trips. One should therefore not expect floor area (or any other variable) to predict the number of vehicle trips at any land use, but transportation engineers continue to report trip generation as a function of size because they have always done so. Floor area may not be the key variable—and is certainly not the only variable—that determines the number of vehicle trips to a site. Despite their precision, parking and trip generation rates are little more than rough and often unreliable ratios for predicting the relationship between land use and transportation, with a meager theoretical basis.

Although 66 percent of the trip generation rates fail to meet the ITE’s significance criteria, the ITE nevertheless publishes a precise trip generation rate for every land use. For example, consider the report of trip generation at truck terminals (see Figure 5). Two sites were studied, and the larger site generated fewer vehicle trips. Nevertheless, the ITE reports the average trip generation rate at the two sites, and plots a line which suggests that larger sites generate more vehicle trips. The precision defies common sense, but there is 81.90 vehicle trips per acre on a weekday.

Reporting statistically insignificant estimates with misleading precision creates serious problems because many people rely on the ITE manuals to predict how urban development will affect parking and traffic. When estimating the traffic impacts of development, for example, developers and cities often battle fiercely over whether a precise trip generation rate is correct. Given the uncertainty involved, the debates are ludicrous. Some cities even base zoning categories on trip generation rates. 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 1,000 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.”

The precise but uncertain ITE data thus govern which land uses the city will allow.

Parking and trip generation rates are difficult to challenge once they have been incorporated into municipal codes. Planning is an inherently uncertain activity, but the legal system of land-use regulation makes it difficult to acknowledge uncertainty in planning regulations. Admitting the
FIGURE 5

Truck Terminal
(030)

Average Vehicle Trip Ends vs: Acres
On a: Weekday

Number of Studies: 2
Average Number of Acres: 14
Directional Distribution: 50% entering, 50% exiting

Trip Generation per Acre

<table>
<thead>
<tr>
<th>Average Rate</th>
<th>Range of Rates</th>
<th>Standard Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>81.90</td>
<td>66.27 - 100.08</td>
<td>*</td>
</tr>
</tbody>
</table>

Data Plot and Equation

Caution - Use Carefully - Small Sample Size

Fitted Curve Equation: Not given

$R^2 = ****$

Trip Generation/Sixth Edition/Institute of Transportation Engineers/1997/page 66
flimsy basis of the parking and trip generation rates would expose land-use decisions to countless lawsuits from developers, neighborhood groups, and property-rights advocates, all of whom could rightly question the legitimacy of the “science” used to establish off-street parking requirements and to argue for either more or less parking. This desire for the appearance of certainty explains why transportation engineers, urban planners, developers, and elected officials rely on precise point estimates—rather than ranges—to report the highly uncertain parking and trip generation rates.

PLANNING FOR FREE PARKING

The ITE’s parking and trip generation rates create serious problems when they are used for urban planning. Most ITE samples are too small to draw statistically significant conclusions, and the ITE’s method of collecting data skews observations to sites with high parking and trip generation rates. Larger samples might solve the problem of statistical insignificance, but a basic problem with parking and trip generation rates would remain: they measure the peak parking demand and the number of vehicle trips at suburban sites with ample free parking. This situation is troubling because the ITE rates greatly influence the outcome of transportation and land use planning, ultimately contributing to more traffic, lower density, and more urban sprawl.

How do the ITE’s parking and trip generation rates influence transportation and land-use planning? Consider the six-step process of planning for free parking in the US (see Figure 6). In step 1, transportation engineers survey the peak parking demand at a few suburban sites with ample free parking but no transit service, and the ITE publishes the results in Parking Generation with misleading precision. In step 2, urban planners consult Parking Generation to set minimum parking requirements. The maximum observed parking demand thus becomes minimum required parking supply. In step 3, developers provide all the parking that planners require, and the ample supply of parking drives the price of most parking to zero, which increases vehicle travel. In step 4, transportation engineers survey vehicle trips to and from suburban sites with ample free parking but no transit service, and the ITE publishes the results in Trip Generation with misleading precision. In step 5, transportation planners consult Trip Generation as a guide to design the transportation system with adequate capacity to bring cars to the free parking. In step 6, urban planners limit density so that development with ample free parking will not generate more vehicle trips than nearby roads can carry. This lower density spreads activities farther apart, further increasing both vehicle
travel and parking demand. The loop is completed when transportation engineers again survey peak parking demand at suburban sites that offer free parking but no transit service and—surprise!—find that more parking spaces are “needed.” Misusing precise numbers to report uncertain data gives a veneer of rigor to this elaborate but unscientific practice, and the circular logic explains why planning for transportation and land use has gone subtly, incrementally wrong.

Figure 6

The ITE manuals do not cause this circular process, which started long before the ITE began to collect data on parking and trip generation. In 1965, economist Edgar Hoover described the circular planning process in words that still apply today:

In practice, the separation of highway-building programs from parking programs (they are in different and quite independent bureaucracies or authorities) introduces a still further pernicious element. We know the story of the man who took another piece of bread in order to finish his butter, then another piece of butter in order to finish his bread, and so on till he burst. Similarly, every provision of new freeways into a congested area heightens the observed demand and the public pressure for more parking facilities; every additional downtown parking garage heightens the demand for more new freeways to bring people to it; and so on back and forth indefinitely. Each of the two independent public authorities involved can argue persuasively that it is merely trying to keep up with an undeniably strong and growing demand.25

The only change since 1965 is that transportation engineers and urban planners now have precise parking and trip generation rates to quantify the “undeniably strong and growing demand” for parking and highways. The interaction between engineers and planners in gathering and interpreting the parking and trip generation data help to explain why planning for parking in the US is really planning for free parking. With roads, the strategy is to “predict and provide,” while with parking it is to “predict and require.” Urban planners set requirements without taking into account the price charged for parking, the cost of constructing and maintaining parking spaces, the local context, or the wider consequences for transportation, land use, the economy, and the environment.

The ITE naturally deplores any misuse of its parking and trip generation rates, and it warns users to be careful when the $R^2$ is low (although it removed this warning from the plots of the trip generation rates in the two most recent editions of *Trip Generation*). The ITE also advises users to modify the trip generation rates in response to special circumstances:
FIGURE 6

THE SIX-STEP PROCESS OF PLANNING FOR FREE PARKING

**Step 1**
**Parking Generation Rates**
Transportation engineers survey the peak parking demand at suburban sites with ample free parking but no public transit. The ITE summarizes the data in *Parking Generation*, which reports a precise parking generation rate for each land use.

**Step 2**
**Minimum Parking Requirements**
Urban planners consult *Parking Generation* to set minimum parking requirements for each land use. The maximum observed parking demand becomes the minimum required parking supply.

**Step 3**
**Ample Free Parking**
Developers provide all the parking spaces that planners require. Because the required parking supply is so large, the market price of most parking is zero, and drivers park free for most trips.

**Step 4**
**Trip Generation Rates**
Transportation engineers survey vehicle trips to and from suburban sites with ample free parking but no public transit. The ITE summarizes the data in *Trip Generation*, which reports a precise trip generation rate for each land use.

**Step 5**
**Transportation System Design**
Transportation planners consult *Trip Generation* to design the transportation system, which therefore provides enough capacity to satisfy the demand for vehicle trips to and from suburban sites with ample free parking but no public transit.

**Step 6**
**Urban Sprawl**
Urban planners limit density so that new development will not generate more vehicle trips than nearby roads can carry. The lower density spreads activities farther apart, further increasing vehicle travel and parking demand.
At specific sites, the user may want to modify the trip generation rates presented in this document to reflect the presence of public transportation service, ridesharing or other TDM measures, enhanced pedestrian and bicycle trip-making opportunities, or other special characteristics of the site or surrounding area. Nevertheless, the ITE does not suggest how a user might modify the rates in response to any special characteristics of a site or its surrounding area, and the price of parking is prominently not on the list of special characteristics that might affect trip generation.

The users of data should always ask themselves whether the data are appropriate for the intended purpose. Only users can misuse data, but the ITE invites misuse of its data when it reports statistically insignificant estimates as precise numbers. This spurious precision has helped to establish parking requirements and trip generation rates as dogma in the planning profession.

CONCLUSION: LESS PRECISION AND MORE TRUTH

Estimates of parking and trip generation respond to a real demand for essential information about the consequences of land use decisions. Citizens want to know how development 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. Politicians want to avoid complaints from unhappy parkers. These are all valid concerns, but reporting the parking and trip generation rates with needless precision creates false confidence in the data. To unsophisticated users, these precise rates look like constants, similar to the boiling point of water or the speed of light. When planners set parking requirements and engineers design the transportation system, they treat parking and trip generation like physical laws, and the ITE estimates like scientific observations. But parking and trip generation are poorly understood phenomena, and they both depend on the price of parking. Estimating parking demand without prices is planning without economics. Demand is a function of price, not a fixed number, and this does not cease to be true merely because transportation engineers and urban planners ignore it. Most cities are planned on the unstated assumption that parking should be free—no matter how high the cost or how small the benefit.

American motor vehicles consume one eighth of the world's total oil production, and ubiquitous free parking contributes to our automobile dependency. What can be done to improve this situation? Here are five easy recommendations.
The ITE should state in the report for each parking and trip generation rate that this rate refers only to suburban sites with ample free parking but no public transit, pedestrian amenities, or TDM programs.

The ITE should show the regression equation and the R² for each parking and trip generation report, and state whether the coefficient of floor area (or other independent variable) in the equation is significantly different from zero.

The ITE should report the parking and trip generation rates as ranges, not as precise point estimates.

Urban planners should recognize that even if the ITE data were accurate, using them to set parking requirements will dictate an automobile-dependent urban form with free parking everywhere.

Both transportation engineers and urban planners should ponder this warning from Lewis Mumford: “The right to have access to every building in the city by private motorcar, in an age when everyone possesses such a vehicle, is actually the right to destroy the city.”

Parking and trip generation rates illustrate a familiar problem with statistics used in transportation planning, and placing unwarranted trust in the accuracy of these precise but uncertain data leads to bad transportation and land-use policies. Being roughly right is better than being precisely wrong. We need less precision—and more truth—in transportation planning.
ENDNOTES

1. The airline 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.ndo.com/distance/>. “Accurate” implies fidelity to fact and freedom from error, while “precise” implies exactness.

2. ITE (1997, Volume 3, pp ix and 1).

3. The 1990 Nationwide Personal Transportation Survey (NPTS) asked respondents, “Did you pay for parking during any part of this trip?” for all automobile trips made on the previous day. Ninety-nine percent of the responses to this question were “no.” Free parking at home does not explain the high percentage of trips with free parking because the NPTS asked the “did you pay for parking” question for all vehicle trips except the trips that ended at home.

4. This refers to the sixth edition of Trip Generation (1997). The ITE (2001, 10) notes that the warning, “Caution—Use Carefully—Small Sample Size,” is placed on each trip generation report if the sample includes five or fewer sites. At most sites, vehicle trips are observed during the course of only one day.

5. The fourth edition (1987) is shown because this is the date of the most recent edition of Parking Generation, to which Trip Generation will be compared. Vehicle trips were surveyed at McDonald’s, Dunkin Donuts, Burger Chef, and the like.

6. “The coefficient of determination \( R^2 \) is defined as the percent of the variance in the number of trips associated with the variance in the size of the independent variable” (ITE 1997, Volume 3, 19). An \( R^2 \) of 0 shows complete lack of correlation between two variables, and one would expect some correlation in a sample by chance. The significance test for the regression equation shows there is a 53-percent chance of getting an \( R^2 \) of 0.069 or higher even if there were no relationship between floor area and vehicle trips.

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

8. 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.


10. It appears that eight restaurants were observed for one day, one restaurant was observed for two days, and two restaurants were observed for four days. We are not told the hour(s), the weekday, or the month when parking occupancy was observed. The 18 studies of parking occupancy at fast food restaurants are an unusually large sample. In contrast, consider the report for Technical Colleges (Land Use 541). Parking occupancy was observed for one hour on one day at one site, and on this basis the parking generation rate for a technical college is reported as 0.82 parking spaces per
Parking occupancy was observed for only one or two hours for many of the studies in *Parking Generation*. Because only the peak occupancy at a site is needed to calculate a parking generation rate, the observer's main concern is to report the peak number of cars parked during the hour(s) of expected peak demand.

11. The significance test for the regression equation shows there is a 42-percent chance of getting an $R^2$ of 0.038 or higher even if there were no relationship between floor area and parking occupancy. The ITE (1987a, viii) divides the sum of all parking generation rates by the number of studies to calculate the unweighted average parking generation rate.

12. 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.

13. Because the intercept is 20 spaces and the average floor area is 3,000 square feet, the average parking generation rate would be 6.7 spaces per 1,000 square feet even if the coefficient of floor area were zero.

14. The average peak parking occupancy for the eight studies is 26 spaces.

15. ITE (1987a, vii).

16. 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.

17. Statistical insignificance does not imply that floor area has no effect on parking demand or vehicle trips, rather, it means that floor area does not reliably predict either variable.

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

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

20. 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.

21. 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. All of the eight study sites in the fourth edition (1987) and fifth edition (1991) were exactly 2, 3, or 4 thousand square feet, but none of the 21 study sites in the sixth edition (1997) matched these sizes.
22. McFadden (2002, 4). McFadden won the Nobel Prize in economics for his work on the theory and methods for analyzing discrete choice, and his research has been especially influential in transportation economics.


24. Transportation planners often use the Urban Transportation Modeling System (UTMS) to predict modal flows on links between zones in a network, and the first of the four major steps in the UTMS model is “trip generation.” The four-step UTMS model is thus used to carry out step 5 of the six-step process of planning for free parking. Meyer and Miller (2001) explain the UTMS model.


26. ITE (1997, Volume 3, 1)

27. Transportation accounted for 66.4 percent of US oil consumption in 1996, and highway transportation accounted for 78.3 percent of US oil consumption for transportation. Therefore, highway transportation accounted for 52 percent of US oil consumption (66.4% x 78.3%). The US also consumed 25.7 percent of the world's oil production in 1996. Therefore, highway transportation in the US consumed 13.4 percent (slightly more than an eighth) of the world's total oil production (52% x 25.7%). Highway transportation refers to travel by cars, trucks, motorcycles, and buses. See Stacy Davis (2000, Tables 1.3, 2.10, and 2.7) for the data on energy consumption for transportation in the US.
REFERENCES


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