Perspectives on Land Use and Transportation

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With changes in society come changes in land use. Today's transportation professional needs to understand these changes and how they influence transportation conditions and characteristics. This website is designed to make recent research findings on the dynamic relationship between land use and transportation broadly available. Research topics include but are not limited to trip generation, parking, internal capture, on-site circulation and site design.

Perspectives on Land Use and Transportation is a production of the Center for Urban Transportation Research at the University of South Florida, College of Engineering.

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Perspectives on Land Use and Transportation

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If so, we would like to hear from you. Just send us an email at: **perspectives@cutr.usf.edu**

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Land Use Regulation

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Access to Choice

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Advocates of New Urbanism and other similar planning theories claim that these land use alternatives reduce the need for travel by focusing on accessibility (the ability to reach valued destinations conveniently) rather than mobility (the ability to travel fast). These theories are controversial for a number of reasons, including the following:

- The implementation of these land use alternatives imposes limitations on people's choices about where to live and how to travel,
- Any perceived reduction in vehicle miles traveled (VMT) resulting from the implementation of these land use alternatives is deceptive because any reduction in VMT is actually caused by socio-demographic factors,
- Once self-selection based on travel preference is accounted for, the independent influence of urban form on travel behavior becomes insignificant, and
- The close proximity of origin and destination may actually lead to an increase in the frequency of trips and VMT due to the reduced cost of trip making. Randall Crane, a critic of New Urbanism, goes so far as to assert that New Urbanism and similar land use theories "might unintentionally cause more traffic problems than they solve." (See "Travel by Design" in the Spring 1998 issue of Access, also summarized here on this site),

In his article, "Access to Choice," Access, Spring 1999, Jonathan Levine contends that critics forget that the primary goal of New Urbanism and similar land use alternatives is to increase lifestyle and travel choices, not to reduce VMT. Critics ignore that these choices are currently constrained by regulations on land use alternatives.

Current regulatory codes that shape land development patterns and limit population density, originally established to reduce unhealthy urban living conditions, also restrict transportation and land use options and act as barriers to innovative metropolitan land use patterns. Although land development regulations are not the

only barriers to alternative land use forms, they are the tools used by planners and should, therefore, be examined more critically given their “potential choice-constraining effects.” The article argues that loosening these regulations would allow the market to determine which types of developments are viable.

Many planners and transportation researchers determine the effectiveness of alternative developments by their ability to reduce VMT, encourage transit usage, or increase walking. The article contends that although these variables are useful for testing transportation claims, “scientific evidence of their likelihood must not be a precondition for removing regulatory barriers to choice.” Even if alternative development forms cause congestion as Crane claimed in "Travel by Design," they should not be avoided because the free-flow of automobiles should not take precedent “over other competing goals such as encouraging pedestrianism, improving the effectiveness of transit, or expanding the range of land use and transportation choice.” In addition, the article argues that there is no evidence that New Urbanism increases VMT. Therefore, this speculative argument should not be used to exclude alternative land use arrangements where market demand supports them. Instead, the article claims that the absence of profit will do so much more effectively.

The article claims that concepts such as New Urbanism or transit villages are not useful as long as “transportation policy focuses on the singular goal of mitigating traffic congestion.” Instead, the article suggests that U.S. transportation policy should encompass broader objectives that include ensuring that “households are able to match

their land use and transportation environments to their needs and preferences." Ultimately, reducing the barriers to household choices would be a positive goal for U.S. transportation policy even if the benefits of reduced highway congestion were not assured.

To read the original article, click here or see the Spring 1999 edition of Access, published by the University of California Transportation Center or online here. For additional information, contact Dr. Jonathan Levine at the University of Michigan, Ann Arbor, MI 48109-2069 or by e-mail at jlevine@umich.edu *Adapted with permission.*

Travel by Design?

BY RANDALL CRANE

Over the past few decades, most questions about land use/transportation linkages have dealt with the influence of transportation infrastructure on development patterns. Analysts have examined how highways and mass transit contribute to urban sprawl, how they affect the local balance of jobs and housing, or how they affect population density. There also exists a long, if less traveled, history of viewing these linkages from the opposite direction: examining how land use influences urban travel.

Recent work of the latter sort goes well beyond estimating the number and types of car trips that various land uses generate. The so-called New Urbanists and Neotraditional planners are much more ambitious. Among other things, they argue that higher residential densities, more-open circulation patterns, and mixed land uses will remedy many traffic problems.

The appeal of such outcomes is hard to deny, but can these designs deliver? We don't know. There's surprisingly little knowledge about how urban patterns influence travel patterns. Existing evidence is either mixed, contrary, or difficult to interpret. The potential traffic benefits of New Urbanism reflect an interesting set of hypotheses, but they remain a weak basis for current transportation policy.

URBAN DESIGN AS TRANSPORTATION TOOL

The proposed urban and suburban developments—alternatively described as either Neotraditional (based on the look and feel of "traditional" small towns and neighborhoods) or New Urbanism (essentially Neotraditional plans with a somewhat more explicit social agenda)—are easy on the eye and self-consciously familiar. Their renewed emphasis on front porches, sidewalks, and common community areas, as well as the half-mile wide "village scale" of many such plans, are perhaps the most visible examples. The Florida resort town of Seaside, designed by Duany and Plater-Zyberk, is justly noted for the clapboard nostalgia of its houses and its weathered old-town style, although barely ten years old. Recent developments in Southern California and Portland also successfully feature side-garages, big front porches, fewer cul-de-sacs, and nostalgic building designs.

In addition to these aesthetic architectural elements, the new developments often feature a substantial transportation agenda. As Ruth Steiner notes in this issue, New Urbanists want residents to walk more and drive less. Few would quarrel with the idea of reducing traffic problems. Progress by traditional traffic engineering has seemed elusive; and, although planners are intensely receptive to new ways of reducing car use, their options are limited. The cost of mass transit is ballooning out of proportion to expected benefits, and conventional strategies, such as HOV lanes and higher parking fees, have not changed most people's driving habits.

The problem, New Urbanists argue, is that these incentive strategies ignore the more fundamental facts of how urban developments are spatially configured. They say the treatments attack the symptoms, not the disease. Their solution? Higher density, mixed land use, and grid-like circulation patterns that will discourage driving, shorten trips, and aggressively encourage walking and transit use. Although deceptively simple in many respects, the rationale and method of these proposals have found wide acceptance within the planning community. The idea that auto travel will decrease with more-compact land-use has proven so appealing that almost all discussions of the new designs report it as though it were a proven fact.

These and related ideas are finding their ways into many public policy documents aimed at improving air quality, reducing traffic congestion, and improving "sense of community." ➢

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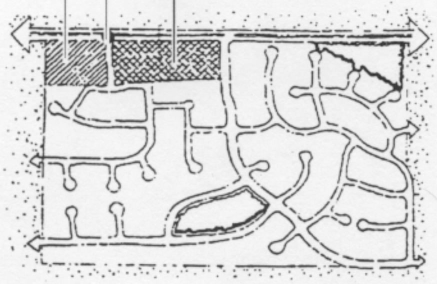
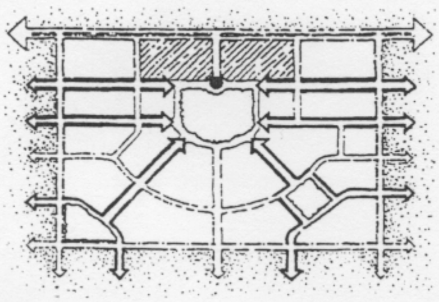


Suburban cul-de-sacs



Neotraditional grid design

Source: Calthorpe Associates, 1992

Recent plans for Los Angeles, Sacramento, and San Diego, among others, incorporate New Urbanist motifs. Prominent architect and Neotraditional planning evangelist Andres Duany recently claimed, in *Consumer Reports,* that the transportation benefits of these designs are their most important outcomes. The strong appeal of New Urbanism, then, is that it promises to achieve two very attractive objectives with one stroke—to create improved living environments and to reduce traffic. Unfortunately, research supporting the latter argument is both weak and flawed.

WHAT DO WE KNOW?

How *does* urban form affect travel behavior? The available evidence is difficult to interpret because the literature commonly addresses aesthetic, social, and transportation topics simultaneously. Only a few actual New Urbanist developments are fully built out at this time, and there are even fewer studies of their effects. Hence, even careful quantitative evaluations tend to be based either on hypothetical environments, as with engineering simulations, or on data obtained from older "traditional" communities that share some characteristics with proposed "Neotraditional" communities.

Simulation studies have asked whether grid-like street patterns lead to fewer vehicle miles of travel (VMT) than curvilinear patterns, essentially by reducing potential trip distances. Peter Calthorpe's assertions regarding the transportation benefits of his suburban designs depend heavily on a simulation by Kulash, Anglin, and Marks. Their study found grid streets make for 57 percent less VMT for trips within the neighborhood than do conventional suburban networks because grids bring origins and destinations closer together. So, for a given number of shorter trips, would people then drive fewer miles? The obvious answer is "yes." But what about secondary behavioral responses, such as changes of mode or changes in trip frequency? Most simulations assume away such responses, even though they promise to predict what will actually happen.

Empirical studies, in contrast, can't assume away behavior. They must explain it. The research strategy in most empirical analyses is to search for correlations among neighborhood features and observed travel—sometimes controlling for other relevant factors, sometimes not. Even then, Susan Handy and others report that outcomes are

Picket fences and front porches mark Seaside, Florida indeterminate—that traditional grid-based neighborhoods may be associated with either fewer or more automobile trips than neighborhoods with modern "loopy" street patterns, so that overall VMT might also either fall or rise.

Interpreting the range of results in any one case is also problematic because causal theory is not clearly established. What can we generalize about the factors that generate more car trips in one environment and less in another? While some studies based on observed behavior do attempt to control for different trip purposes (e.g., shopping versus commuting), trip lengths (e.g., neighborhood versus region), and demographic variables likely associated with trip demand (e.g., income, gender, and age), the approach is typically *ad hoc* and hence idiosyncratic. Further, the wide range of outcomes found in this work reveals little about whether Neotraditional designs can deliver the transportation benefits they promise.

One obstacle for planners and researchers alike is that travel behavior is extremely complex. It is difficult to explain even a quarter of the variation within either aggregate or individual travel data. This difficulty reflects the lack of a strong conceptual framework that would allow empirical results to be compared or interpreted in a standard manner. While recent studies (e.g., Cervero and Kockelman) make great strides in measuring and characterizing land use variables, they rarely possess even rudimentary behavioral foundations. Instead they employ various measures, such as accessibility, pedestrian friendliness, and density as control variables in *ad hoc* regression specifications.

Nearly all empirical studies also ignore the truncated nature of the data. People who live in one type of neighborhood (defined by street pattern, density, or level of access) cannot reliably be directly compared with people who live elsewhere. They are self-selected, and their choice of residence reflects their travel preferences as revealed by the travel options available to them at that site. People who want to walk, bike, drive, or travel by train seek houses where they can do that. For example, those who live near commuter rail stations may take the trains more often than others, perhaps because they deliberately chose to live near a station. The fact that station-area residents ride trains is not evidence, by itself, that additional station-area residential development would improve rail ridership. Sample data reported in comparisons of this kind are systematically biased.

In sum, given the problems with available data and the generally weak behavioral content of otherwise careful empirical studies, credible information on the effects of Neotraditional planning is quite rare.

NEW EVIDENCE

In recent articles and a forthcoming book, Marlon Boarnet and I contend that we can overcome many of these problems by systematically isolating the separable influences of urban design characteristics on travel. We try to clarify which results directly follow from the designs and which may or may not. We want to know how confident our forecasts can be and to check exactly which hypotheses are to be tested against the data. We then seek more-reliable tests of these hypotheses.

Any analysis of trip frequency and mode choice requires a discussion of the *demand* for trips. Nevertheless, even rough estimates of demand are typically absent from planning and land use studies. Demand analysis permits us to ask behavioral questions, such as whether differences in trip distance influence an individual's desire and ability to make trips by any particular mode. ➢

Individuals make choices based on their *preferences for the benefits* obtained by travel and on the *relative costs* of making different trips and of taking different modes. Preferences reflect attitudes and tastes that vary with the purpose of the trip and with the experience of driving versus walking. They probably also correlate with demographic and with idiosyncratic personal characteristics. But the decision whether to take a trip to the coffee shop by car or by foot depends not only on how one feels about those options, but also on external factors, including the cost of using one mode versus another. One may prefer to drive, but if gasoline or parking expenses are high enough, walking may be preferable. Thus the demand for walking trips is explained not only by one's preferences across modes but also on the cost of walking relative to the cost of driving. Remarkably, past empirical work about the influence of neighborhood design on travel has neglected the role of costs in choosing among trips and modes.

This simple framework has several direct and immediate implications for our study. In particular it suggests that while introducing some design elements, such as traffic calming (i.e., slowing cars down by narrowing lanes, adding speed bumps, and eliminating through traffic), probably does reduce car travel, such changes may also produce unknown effects. Some may even *increase* driving in these settings. For example, an open circulation pattern that makes for short trip distances can also stimulate trip taking; shorter trips take less time and therefore cost less. For example, people may shop more often if stores are nearby, and they may make so many shopping trips that they drive more miles. This bears repeating, since this outcome is rarely recognized: *Shorter car trips can mean more trips and more miles.*

Table 1 summarizes this range of plausible results of different neighborhood design features on travel behavior. The first two columns restate the results just summarized for shorter trips in a grid-type or more-open street network, or for slower trips through

TABLE 1

Qualitative Effects On Car Travel of Different Neighborhood Design Features

TRAFFIC MEASURE	DESIGN ELEMENT			
	Grid (Shorter trips)	Traffic Calming (Slower trips)	Mixing and Intensifying Land Uses	All Three
Car trips	Increase	Decrease	Either Increase or Decrease[2]	Either Increase or Decrease[3]
VMT	Either Increase or Decrease[1]	Decrease	Either Increase or Decrease	Either Increase or Decrease
Likelihood of walking rather than driving	Either Increase or Decrease	Increase	Either Increase or Decrease	Either Increase or Decrease

[1] Depending on how sensitive trips by each mode are to trip length
[2] Depending on trip purpose, trip length, and induced congestion
[3] Depending on relative mix of elements

traffic calming. The third column considers the range of effects from mixed land use. Owing to their countervailing effects on the relative costs and benefits of each trip, these also have ambiguous net effects on travel. With the exception of traffic calming, Neotraditional design features have unknown outcomes for car travel, either alone or in combination. Their actual outcomes depend on the specific details of their implementation in each location, not on their intrinsic traffic-affecting properties.

Thus we can understand the ramifications of Neotraditional planning only by observing actual behavior. Many problems associated with empirical studies can be corrected or otherwise statistically finessed. To see the specific effects on neighborhood travel behavior of street configuration and land use variables, Richard Crepeau and I looked into detailed travel-diary and street-pattern data. The travel data for over 2,000 individuals are from the 1986 Travel Behavior Surveys developed jointly by the San Diego Association of Governments and the California Department of Transportation. We added several measures of land use near each residence in the study, as well as data on the local street network.

Our model hypothesized that trip frequency and mode are explained by several carefully identified price, taste, and land use variables. This attention to straightforward behavioral factors remains unique in this literature. Following a regression analysis of these data for nonwork travel, we found *no evidence that the neighborhood street pattern affects either car-trip generation or mode choice.* This is true whether we consider only short trips or long trips, or only trips for specific purposes such as for shopping.

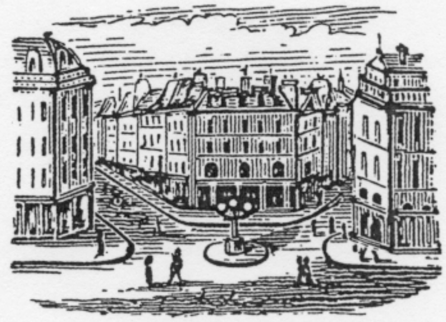
In a separate study, Boarnet and Sarmiento deal with the self-selection problem by explicitly modeling the set of joint choices: where to live and how to travel. Correcting for this bias, they also find that land use variables do not influence travel in their Southern California sample. Our forthcoming book integrates these approaches and data, again finding no evidence that land use patterns explain individual travel patterns when data on other relevant factors are statistically controlled.

Results in other regions may vary, and that is exactly our point: Transportation benefits of Neotraditional designs are neither certain nor self-evident.

CLOSING COMMENT

I find much to like in New Urbanist designs, and regret I lack the space here to elaborate why. In brief, they offer a generally thoughtful and attractive alternative to what many consider ugly or banal about conventional suburban development. However, there is no convincing evidence that these designs influence travel behavior at the margin. They remain a wobbly foundation indeed for current transportation policy.

We have much to learn. Improved understanding of how, and if, urban form affects individual and aggregate travel could help transportation planners immensely. Better measures of land use, supplemented by statistical specifications relating those measures to travel costs and benefits, are key to improving empirical work on these questions. Meanwhile it's prudent to recognize that neither every component of New Urbanism, nor every claim, is necessarily a good idea—a possibility largely ignored in the literature. We must strive to avoid new urban and suburban developments that, although pretty and ambitious, might unintentionally cause more traffic problems than they solve. ◆



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Travel Benefits of New Urbanism?

(To view and print pdf files, use Adobe Acrobat Reader available at this link.)

Much discussion and research has focused on how land use influences travel patterns. Proponents of Neotraditional Planning and New Urbanism theory argue that higher densities, mixed land uses, and grid-like circulation patterns reduce traffic problems experienced in more common development forms by shortening trips and encouraging walking and transit use. However, challenges of these generally accepted principals of New Urbanism have begun to be heard.

In a 1998 article in the University of California Transportation Center's journal Access entitled "Travel by Design," Randall Crane argues that despite the claims of the New Urbanists there is "no convincing evidence that these designs influence travel behavior." In fact, the existing research supporting the affect of Neotraditional design on traffic reduction appears to be "both weak and flawed." The article points out that only a limited number of studies have been conducted that solely focus on traffic patterns in Neotraditional developments, perhaps because there are so few in existence.

Most studies are based either on simulations in hypothetical environments or on relationships in existing older "traditional" communities that exhibit design principles on which New Urbanism is based. The article argues that using these studies as a basis for determining affect of Neotraditional design theories on traffic patterns can lead to erroneous conclusions.

Results from simulation studies support the principal that grid-like street patterns yield changes in travel behavior through the reduction of potential trip distances, in turn leading to fewer vehicle miles traveled (VMT) than more curvilinear street patterns. The criticism of this approach argues that these simulation studies fail to consider whether secondary behavioral responses such as changes in mode of travel or trip frequency affect will in fact negate the anticipated reduction in VMT. For example, shorter trip distances and reduced travel times to local shopping may induce more frequent shopping trips than is currently the case. As a result, instead of finding a decrease in VMT, overall VMT may be unaffected or even increase. Critics argue that most simulation studies seem to assume away such secondary behavioral responses.

Unlike simulation studies, empirical studies do attempt to address secondary behavioral responses and usually search for a correlation between neighborhood features and observed travel behavior. Unfortunately, empirical studies have there own set of difficulties. Those empirical studies that have been conducted on this subject have produced a wide range of outcomes ranging from findings that traditional grid-based neighborhood traffic patterns produce fewer automobile trips and lower VMT than modern street patterns to findings that indicate the exact opposite relationship.

Interpretation of these results is problematic because of the difficulty in controlling for other influences on the relationship such as trip purpose and demographic variables related to trip demand. All that can be clearly stated is that the empirical studies that have been conducted thus far have been unable to clearly reveal whether Neotraditional designs reduce VMT and deliver the transportation benefits that they promise.

One approach to overcoming the limitations experienced in the empirical studies conducted thus far is by observing actual behavior. In a study conducted in San Diego, Crane and Richard Crepeau examined detailed travel-diaries and street-pattern data involving over 2,000 individuals and hypothesized that trip frequency and mode choice are explained by price, taste and land use variables – variables that are usually not factored into traditional empirical studies.

Regression analysis of these non-work travel data found “no evidence that land use patterns explain individual travel patterns when data on other relevant factors are statistically controlled.” However, these results must be cautiously interpreted because they may vary in other regions, highlighting the original point of the article that “transportation benefits of Neotraditional designs are neither certain nor self-evident.”

Although New Urbanist designs provide a “generally thoughtful and attractive alternative” to the banality of modern suburban communities, there is a lack of substantive data to support the argument that these designs influence transportation behavior. More research must be conducted to validate and/or dismiss the many components of New Urbanism efore incorporating these designs into transportation policy.

To read the original article, click here or see the Spring 1998 edition of Access, published by the University of California Transportation Center. For additional information, contact Dr. Randall Crane at the University of California, Los Angeles, CA 90095-165 or by e-mail at rdcrane@uci.edu. *Adapted with permission.*

Access to Choice

BY JONATHAN LEVINE

A LONG TRADITION IN URBAN PLANNING seeks land use arrangements that reduce the need for travel, especially drive-alone travel. Current variations on this idea in the United States include jobs-housing balancing (locating jobs and housing nearby one another), transit villages (dense, mixed-use urban development with medium to high-rise housing concentrated near transit stops), and New Urbanism (a less dense, neighborhood form focusing on pedestrianism, transit, and mixed land uses).

Despite differences among these approaches, their common cornerstone for land use transportation policy is a focus on accessibility (the ability to reach valued destinations conveniently) rather than mobility (the ability to travel fast). Where valued destinations are nearby or accessible by transit, the reasoning goes, they can be accessible even without rapid and unconstrained travel. Thus traditional roadway construction and widenings, with attendant increasing travel distances and low densities, are de-emphasized in favor of development in areas of high accessibility, even at the cost of reduced travel speeds.

These ideas are controversial on two grounds. First, critics argue that implementation of these land use alternatives imposes undue limitation on people's choices about where to live and how to travel. Second, they suggest that transportation payoffs from these alternative development forms are illusory, because any major reduction in vehicle miles traveled (VMT) is caused by household sociodemographic factors, not urban design. Moreover, they argue, it is reasonable to believe that households select residences to match their travel preferences. Once self-selection is accounted for, they say, the independent effect of urban design on travel behavior becomes virtually undetectable. In addition, where origins and destinations are close together, the reduced cost of trips may lead people to take more frequent trips, leading to an increase in VMT.

Randall Crane summed up these policy implications of New Urbanism in the Spring 1998 issue of ACCESS, calling this alternative "a wobbly foundation indeed for current transportation policy." Crane goes so far as to say, "We must strive to avoid new urban and suburban developments that, although pretty and ambitious, might unintentionally cause more traffic problems than they solve."

I contend that critics of these land use alternatives are ignoring existing regulatory constraints on choice. They forget that the primary aim of these proposals is to expand households' choices in how to live and travel, not to reduce VMT. Nevertheless, neighborhood self-selection, an expression of expanded choice, can actually work to reduce VMT. ➢

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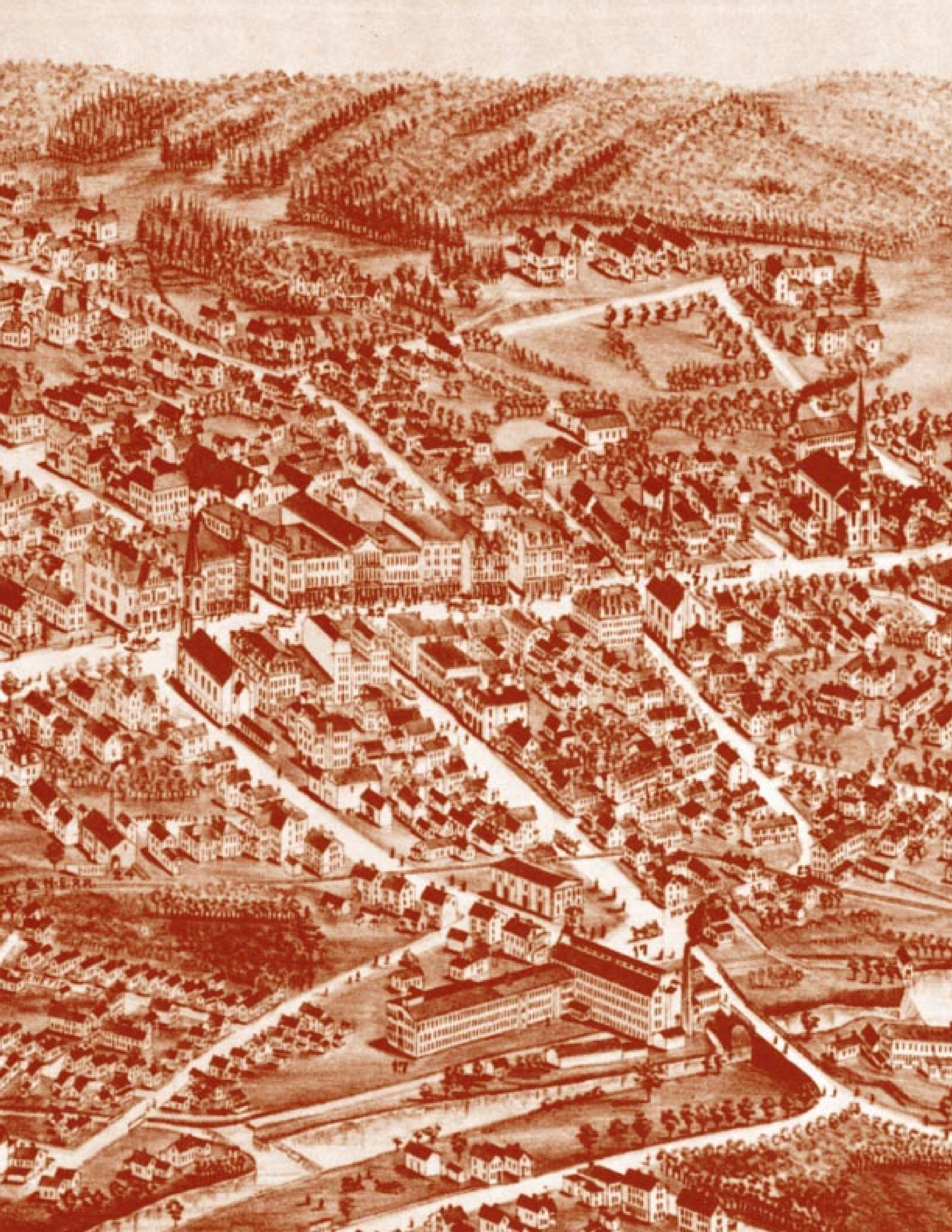

Expanding Choice

Researchers seem to agree that local government regulation works to shape metropolitan development patterns. Local policies include zoning that limits densities and mandates land use separation, transportation standards that call for wide streets and generous parking requirements, and fiscally motivated practices that restrict development of alternatives to the large lot and single-family house. But there is less acknowledgement of one implication of this regulatory regime: these policies prevent some households from getting the transportation and land use options they prefer.

Advocating accessibility-based land use alternatives does not mean more regulation forcing these designs on an unwilling market. Instead, local government regulations that currently preclude these alternatives need to be loosened, permitting the market to provide them where economically viable. Local government can prevent, allow, or facilitate higher-density development, but it is ultimately unable to *require* such development. A city council may desire development of a transit village at a particular site, but without a developer who sees the potential for profits the development will not occur.

Current municipal planning practice typically seeks to lower development densities.

Higher density development forms are typically portrayed as the products of planning and regulation of the land market, but the reality is actually the opposite: current municipal planning practice typically seeks to lower development densities. Reducing regulatory constraints is a prerequisite to the accessibility-based land use alternatives discussed here.

This argument is not intended to criticize land use regulation per se. Such intervention arose from early reformist activism aimed at unhealthful urban conditions, a concern that remains relevant today. But, reformist roots aside, the tools are broadly misused to exclude some development forms (and the population groups that would inhabit them) from selected neighborhoods. Moreover, they preclude innovation in metropolitan land use patterns. They are not the only barriers. But, as tools implemented by the planning profession, these regulations and their potential choice-constraining effects deserve more critical scrutiny by transportation and land use researchers than is currently evident.

VMT Reduction?

Many land use and transportation researchers judge alternative development forms by their capacity to reduce VMT, spur transit use, or encourage walking. These yardsticks seem reasonable tests for evaluating specific transportation claims, and such outcomes would be welcome side benefits from developing these land use forms. But scientific evidence of their likelihood must not be a precondition for removing regulatory barriers to choice.

Crane's article in Access shows how land use policies designed to bring origins and destinations closer together might actually increase VMT as the total cost per trip is reduced. Alternative development forms might well cause some congestion, if for no other reason than that population density can lead to automobile density. Is that sufficient reason to avoid them? Only if one thinks free-flow automobility should take precedence over other competing goals such as encouraging pedestrianism, improving the effectiveness of transit, or expanding the range of land use and transportation choice.

Moreover, the claim that New Urbanism might increase VMT is only speculative in the absence of empirical evidence, and it should not be employed to exclude such alternatives in areas where market demand might support them. In areas where insufficient demand exists, one hardly needs policy to keep these development forms out; the absence of profits will accomplish this much more effectively.

Neighborhood Self-Selection

Some researchers have been concerned that processes of neighborhood self-selection might lead to overestimates of the effects of urban form on travel behavior. They say that people who already wish to drive less may choose to live in areas where that is easier to do. If one accounts for this tendency in statistical analysis, it appears to be the major cause for changes in travel behavior. That is, urban design by itself seems to have little effect and should therefore not be credited.

In contrast, I want to argue that such self-selection is the prime process by which alternative development forms might affect travel. Aiming to use urban design tools to induce unwilling auto-oriented households to drive less is probably futile. It is much more promising to accommodate people whose preferences for less auto-dominated environments have been inhibited by zoning and other exclusionary regulations.

Consider, for example, the elderly household with the capacity to drive but a preference for alternatives to the car. Where transit-oriented neighborhoods are not available, this household has no choice but automobile dependence; but were transit-based settlements allowed to develop, they could reduce car use.

Thus self-selection is hardly a problem invalidating the transportation relevance of alternative development forms. On the contrary, transportation planners should hope for the greatest possible self-selection into transit-oriented neighborhoods to expand the desired effects on VMT and transit use.

Of course we should try to estimate self-selection effects, but they should be interpreted differently. Where prospects of alternative development forms are restricted by regulation, reducing the regulation and thus allowing those forms will enable people with preferences for transit use, walking, or limited automobile reliance to exercise their preferences. The relevant question is not how much transportation-behavior modification can be forced by means of mandated land use changes, but rather what travel-behavior changes can occur once barriers to land use and transportation choices are lowered.

Conclusion

The debates I refer to have been shaped by the broadly held view that alternative land use and transportation proposals can be realized mainly through governmental regulation and control and are to be justified (if at all) by demonstrable reduction in VMT. But, to adopt this view, one must ignore the intricate latticework of current governmental land use and transportation regulation that imposes a development template inimical to alternative accessibility-based land use forms. Where the workings of the market might generate the sorts of land use arrangements the proponents seek, those inhibiting regulations preclude them.

Accessibility-based land use policies should be assessed in a different light. Are such approaches a "shaky foundation" for transportation policy? To the extent that transportation policy focuses on the singular goal of mitigating traffic congestion, concepts like New Urbanism, jobs-housing balancing, or transit villages will probably be of little assistance. But transportation policy should be aimed at broader objectives. Among other goals, policy should seek to ensure that households are able to match their land use and transportation environments to their needs and preferences. With or without benefits of reduced highway congestion, lowered barriers to household choice would be a worthy aim indeed for U.S. transportation policy. ◆

FURTHER READING

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The Greening of Brownfield Sites

(To view and print pdf files, use Adobe Acrobat Reader available at this link.)

The decline in steel production and other manufacturing-intensive industries has left Pennsylvania with thousands of acres of “abandoned steel mills and manufacturing facilities deemed undesirable for development.” By using “sound land use and transportation strategy implementation,” Pennsylvania (particularly the Philadelphia region) has become one of the leaders in brownfield redevelopment.

In a July 2002 ITE Journal article, “Brownfield Redevelopment and Transportation Planning in the Philadelphia Region, Kevin L. Johnson, Chad E. Dixson, and Scott P. Tochterman examined the redevelopment of two brownfield sites in the Philadelphia region. The key elements leading to the successful redevelopment of these two brownfield sites, were “the integration of land use and transportation planning, the formation of public-private partnerships and the development of innovative funding strategies.”

http://www.noaa.gov

The first brownfield site discussed in the article is the French Creek Center in Chester County, Pennsylvania. Still in the pre-construction phase, this site houses a steel mill that was abandoned in 1992. In 1996, a private development group purchased the property and proposed a neo-traditional development with office space, townhouses and apartments as well as a recreation trail, thereby bringing jobs and revenue to the area.

An important component of the redevelopment of the French Creek Center is the accessibility of public transportation. This site will be located near train stations for the region’s proposed rail transit system that will link major cities such as Reading and Philadelphia. In addition, a parkway will be construed to link the Center to the main state road. The parkway, a “two-lane one-way couplet,” will run through the center of the development. Design functions for an urban environment include “minimum lane widths, low design speed, and provisions for on-street parking and pedestrian access activity.” Local roads, as well as the parkway will have traffic calming measures that include on-street parking and pedestrian crossings.

The transportation planning for this private redevelopment project involved administrative coordination and financial support from several state, federal and local agencies including the Pennsylvania Department of Transportation and the Federal Highway Administration. The state and federal agencies provided considerable public funding to make the redevelopment financially feasible, including a grant for the recreation trail and a loan to assist with the parkway design and engineering.

http://www.epa.gov

The second brownfield site described in this article is the Atwater development project, Chester County. This project, which is in the construction phase, is administrated and funded in coordination with nearby townships. The development is being built on a former limestone quarry that is approximately 150 years old. This second development will consist of a corporate center with Class A office space and a large hotel.

The Atwater business park is expected to generate 10,000 new jobs. Upon completion, this project will be one of the largest business parks in southeastern Pennsylvania and one of the largest brownfield projects in the northeastern United States.

The environmental benefits of the Atwater project include a scenic lake on 80 acres of land located at the center of the park and 40 acres of nearby land donated to a local conservancy for hiking trails and bird watching. The environment will also benefit from advanced drainage measures that enhance the fresh water flow to a trout stream and a fishery situated near the development.

To effectively deal with the current and potential traffic congestion in the surrounding residential area, a traffic impact study was conducted. The study recommended the widening the main state corridor along with the addition of turning lanes, traffic signs, and “the modification of existing signals at key intersections.”

http://www.noaa.gov

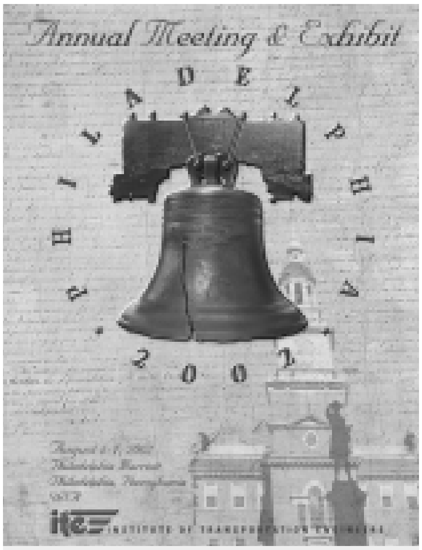
In addition, a “slip ramp” was proposed by the Pennsylvania Turnpike Commission (PTC) to allow Atwater employees to avoid the main state road as they enter and exit the business park, thereby reducing traffic on this already congested section of the state highway. An extensive public involvement process with environmental groups and the local business community was implemented to reach a consensus on the design of the slip ramps.

The environmental benefits of the transportation planning for the Atwater project include a significant reduction in vehicle miles traveled which in turn will reduce gasoline consumption and vehicle emissions. Also, the slip ramp will decrease the number of motorists that cut-through residential areas.

The redevelopment of brownfield sites requires extensive intergovernmental coordination because several state and federal agencies are responsible for the complicated environmental issues surrounding these projects. Despite the regulatory challenges associated with accessing public funds for developing the infrastructure for Brownfield sites, private developers and their municipal partners should not be deterred from seeking “state and federal assistance to alleviate the costs associated with site assessment, remediation, preparation and infrastructure development.”

To view this article in full, see the August 2001 edition of the ITE Journal or online here. For further information, contact Kevin Johnson at 610-326-3100 by phone or at KJohnson@trafficpd.com by e-mail. (*© Institute of Transportation Engineers Adapted with permission*.)

Brownfield Redevelopment and Transportation Planning in the Philadelphia Region



The successful redevelopment of Brownfields sites depends upon the integration of land use and transportation planning, the formation of public-private partnerships and the development of innovative funding strategies. All three components are necessary to place these sites on equal footing with vacant land from a development perspective. Effective transportation planning was paramount to the success of two high-profile Brownfields redevelopment projects in Chester County, located within the suburbs of Pennsylvania. Both the French Creek Center and the Atwater Redevelopment Project required the implementation of extensive transportation improvements while being sensitive to land use and environmental issues. Philadelphia, PA, USA, is the site of the ITE 2002 Annual Meeting and Exhibit.

BY KEVIN L. JOHNSON, CHAD E. DIXSON AND SCOTT P. TOCHTERMAN

THE DECLINE IN STEEL production and several other manufacturer-based industries in Pennsylvania has left thousands of acres of abandoned steel mills and manufacturing facilities deemed undesirable for development. Sound land use and transportation strategy implementation has enabled the state, and in particular the Philadelphia region, to become one of the leaders of Brownfields redevelopment in the United States. Both the Growing Greener legislation in Pennsylvania and the Brownfields legislation passed by Congress were signed into law by then-Governor Tom Ridge and President George W. Bush at Brownfields sites in the Philadelphia region in recognition of the role this region has played in this effort.

The successful redevelopment of Brownfields sites depends upon the successful integration of land use and transportation planning, the formation of public-private partnerships and the development of innovative funding strategies. All three components are necessary to place these sites on equal footing with vacant land from a development perspective.

Due to the limited opportunities to expand and provide the type of infrastructure needed to support the redevelopment of these sites in Pennsylvania's major cities, several innovative Brownfield redevelopment projects are underway in suburban areas and smaller boroughs. Several Brownfield sites have been approved or are in the planning stages in the Philadelphia region, including two in Chester County.

THE FRENCH CREEK CENTER

Phoenixville Borough, Chester County, PA

The French Creek Center is a classic Brownfields project involving the redevelopment of an abandoned steel site once home to Phoenix Steel, one of the region's largest employers. The site is bounded by French Creek to the south and west, the Schuylkill River to the east and the former Reading Railroad tracks to the north.

Phoenixville Borough is located in the western suburbs of Philadelphia, approximately 18 miles [29 kilometers (km)] to the northwest of the city. For almost 150 years, Phoenix Steel (later to be renamed Phoenix Pipe and Tube) was the economic core of the greater Phoenixville community.

However, by the 1980s, the economic climate in the United States was changing at a rapid pace. By the middle of the decade, Phoenix Steel was in economic peril and shut down the vast majority of its operations in 1986. After briefly attempting to reinvent itself as Phoenix Pipe and Tube Co. in 1987, the company officially closed its doors to the general public in 1992 and abandoned the site (Figure 1). The economic effects of this event were staggering. While Chester County and most of Pennsylvania were buoyed by the economic prosperity that transcended this country during the 1990s, Phoenixville remained one of the few communities in the commonwealth that was noticeably left behind.

REDEVELOPMENT PLAN: FRENCH CREEK CENTER

Beginning in 1996, the property was acquired by the Phoenix Property Group, an entity with the strategic vision for the potential of this site to change the character of downtown Phoenixville. The new Phoenix Property Group development team was focused on a comprehensive approach for redeveloping this property and transforming the 123-acre [0.5-square kilometer (km^2)] site into the new town center, complete with a mixed-use office and residential development plan, public recreational trail along the French Creek, linear park system and intermodal transportation network.

As a product of this extensive public involvement program, the conceptual Master Plan (Figure 2) for the French Creek Center, which has received unanimous approval from the Phoenixville Borough Council, includes the following components:

- 1 million square feet (ft^2) [92,903 square meters (m^2)] of first-class office space in multiple-rise structures;
- 20 acres (0.1 km^2) of high-density corporate apartments;
- 8 acres (0.03 km^2) of assisted and independent senior living units;
- 150 townhouse and apartments located next to an intermodal facility;
- 85,000 ft^2 (7,897 m^2) of village retail space;
- A new recreational trail along the northern and southern side of French Creek;
- The integration of several existing historic structures;
- Retention of existing scenic vistas from bluffs overlooking the French Creek;
- Intermodal transportation center;
- Neotraditional development with an existing downtown; and
- The integration of several existing historic structures—such as the Superintendents Building, the Foundry Building and the Phoenix Column Bridge—the latter two of which are being restored by the Phoenixville Area Economic Development Corp.

The economic impacts of the French Creek Center will be tremendous. The center will create employment opportunities and an increase in local and state tax revenues. More than 5,000 jobs will be created within the center with another 3,000 spin-off jobs in the region. Combined, these jobs will produce an annual payroll in excess of $103 million, which will generate $3,914,000 in new local and state tax revenues each year.

The development of the French Creek Center has emphasized the need for access

Figure 1. Existing condition of former Phoenix Steel Site.

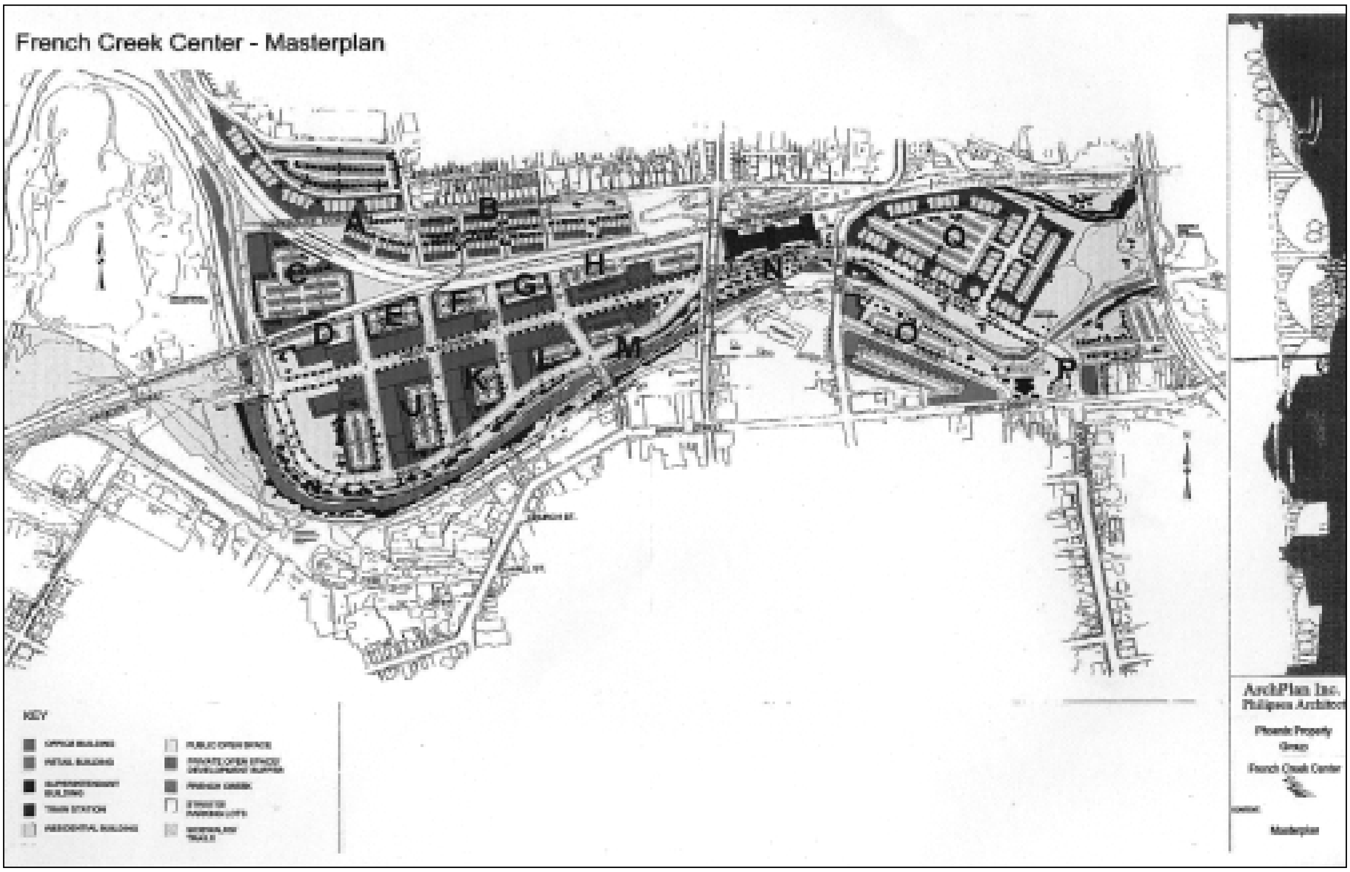


Figure 2. French Creek Master Plan, including French Creek Parkway.

to public transportation. The site is located adjacent to the proposed alignment of the Schuylkill Valley Metro (SVM), a 62-mile (100-km) long rail transit system linking the cities of Reading and Philadelphia and the former industrial-dominated towns between those two cities in Southeastern Pennsylvania. This pubic transportation initiative proposes an intermodal transportation center located within the French Creek Center along the north side of French Creek. Located along the south side of French Creek is downtown Phoenixville. The SVM will provide an alternative means of transportation to employment opportunities along the Schuylkill River Corridor and the City of Philadelphia for the residents of the Phoenixville area. The SVM will also facilitate the increasing reverse commute from Philadelphia to job opportunities located within the French Creek Center. This is one of the reasons why ridership projections for the SVM project is to be one of the most heavily used transit systems in the country.

The site will also include linkages to regional trail networks. Currently planned through the Congestion Mitigation and Air Quality (CMAQ) Program is a linear trail network referred to locally as the French Creek Trail system. The French Creek Trail will also provide a new connection from the extension of the Schuylkill River Trail to the French Creek and the development of the Phoenix Iron Canal Trail along the northeastern portion of the site. The interconnection with the Schuylkill River Trail is significant, as this trail currently extends from Center City Philadelphia to Valley Forge Park. This trail linkage within the French Creek Center site is part of a 19-mile (31-km) extension of the current trail from Valley Forge Park along the Schuylkill River and adjacent to Phoenixville to a terminus in Berks County, PA.

In addition to providing access to the French Creek Center through the SVM, access improvements via the regional highway system had to be analyzed. The French Creek Parkway will provide vehicular access for the center. To provide direct access from the existing state highway system, the French Creek Parkway will be constructed to link State Route 23 from the west to State Route 29 to the east. This new road will be the major collector through the project site and will also relieve traffic congestion at other intersections in downtown Phoenixville.

For more information on the ITE 2002 Annual Meeting and Exhibit, please see pages 9–12 of this issue of *ITE Journal* or visit www.ite.org and click on the ITE 2002 Annual Meeting and Exhibit icon.

The parkway will be designed as a two-lane one-way couplet to minimize street widths. The French Creek Parkway consists of about 14,350 linear feet [4,374 meters (m)] of new roadway and three new bridge structures over French Creek. The design of the roadway will be consistent with the urban setting with minimum lane widths, low design speed, and provisions for on-street parking and pedestrian access activity. The French Creek Parkway will run in a general east-west direction through the center of the Phoenix Steel site. From east to west, it will begin at Bridge Street (State Route 29) opposite Starr Street and will connect with State Route 23 at its western terminus point. The estimate for the design, right-of-way and construction of the French Creek Parkway is $16,320,151.

Traffic calming measures will be incorporated into the design of the parkway and local roads. The traffic calming measures will include on-street parallel parking, chokers, speed tables, Belgian block pedestrian crossings and 25-mile-per-hour (40-km-per-hour) speeds controlled through progressions established by a closed-loop signal system. All off-street parking will be provided to the rear of buildings with access from a series of local roads and alleys. An urban streetscape design will provide a vibrant setting for downtown business development: street furniture and pedestrian scale lighting will be provided along a tree-lined sidewalk, and pedestrian friendly places will be created throughout its length.

PUBLIC-FUNDING STRATEGY

Transportation planning for the French Creek Center required coordination between several state, federal and local agencies, including the Delaware Valley Regional Planning Commission, Pennsylvania Department of Transportation (PennDOT), Federal Highway Administration (FHWA), Federal Transit Administration (FTA), Department of Environmental Protection (DEP) and the Pennsylvania Department of Communities and Natural Resources (DCNR). Without an administrative and financial commitment among these entities to leverage resources and maximize technical expertise, the redevelopment of a blighted property of this size could never be accomplished. Of course, the development and implementation of a public-funding strategy to alleviate the costs associated with a project of this magnitude brings forth its own set of unique challenges.

The results of an effectively implemented public-funding strategy can be significant, and in many instances, Brownfields projects are not financially feasible without the injection of grant and subsidized loan financing. In the case of the French Creek Center, which is still in the preconstruction phase, the reaction from the state and federal government with respect to funding requests on behalf of the project has been nothing short of phenomenal:

- $200,000 grant for French Creek Recreational Trail (DCNR);
- $4,800,000 grant for construction of the French Creek Parkway (Penn DOT);
- $1,250,000 grant for transit-related improvements (FTA);
- $220,000 grant for Phase I preconstruction activities for the French Creek Corridor Restoration and Streambank Stabilization Project (DEP);
- $242,000 grant for Phase II preconstruction activities for the French Creek Corridor Restoration and Streambank Stabilization Project (DEP);
- $1,963,600 state infrastructure bank loan for French Creek Parkway engineering and design (Penn DOT); and
- $1,250,000 grant for public sewer (Infrastructure Development Program).

Today, the French Creek Center is an illustration of a successful public-private partnership whereby the private developer has reached out to municipal, county, state and federal officials, and stakeholders to build a consensus for the development of a master plan for the site. The success of this partnership has allowed the collection of resources to leverage public funding.

ATWATER REDEVELOPMENT PROJECT

East Whiteland and Tredyffrin Townships, Chester County, PA

One Brownfields redevelopment project in Chester County that has already reached the project construction phase (Figure 3) is the Atwater redevelopment project, which is reusing a 388-acre (1.6-km^2), 150-year-old limestone quarry in East Whiteland and Tredyffrin Townships located approximately 4 miles (6 km) south of Phoenixville. The project is being advanced through a public-private partnership between the property owner and developer—Trammell Crow Co.—and Tredyffrin and East Whiteland Townships.

Atwater is located to the north of the Great Valley Corporate Center, which employs approximately 25,000 people within an area of 1 square mile (2.6 km^2). Atwater will be designed to preserve approximately 80 acres (0.3 km^2) of the former quarry for a scenic lake located at the center of the business park with another 40 acres donated to a local conservancy. The redevelopment of this site into the Atwater Business Park will result not only in one of the largest business parks in southeastern Pennsylvania, but also in one of the largest Brownfield implementation projects in the Northeastern United States.

The proposed redevelopment plan focuses on the conversion of this property into a new corporate center that will include 2.5 million ft^2 (232,258 m^2) of Class A office space and will generate 10,000 new jobs at full build-out. Targeted and anticipated tenants for Atwater will include high-tech, pharmaceutical, financial-services and general-services users. Atwater's size will provide space for consolidation/headquarters facilities for both in-state and out-of-state users. The site will also include a large, full-service hotel to accommodate demand and ancillary retail uses to reduce traffic demand on the local road network. Commitments are in place for the leasing of the first phase of office construction, with the goal of occupancy in 2002.

Figure 3. Existing Atwater site under construction.

ENVIRONMENTAL BENEFITS

Included in this quarry revitalization was the design and construction of various complex stormwater and overflow drainage structures, in association with the surrounding development. These advanced drainage measures allowed the quarry reuse and contributed to the enhancement of fresh water flow to Valley Creek, a Class-A trout stream and a cold water fishery with the highest Commonwealth use designation—"Exceptional Value," and preserved the trout habitat and spawning areas in the creek from the ravages of floods associated with each storm in Chester County.

Equally as important, by redeveloping the 250 acres (1 km^2) of the site surrounding the 80-acre (0.3-km^2) lake instead of an equivalent amount of undeveloped area elsewhere in the county, 250 acres (1 km^2) of open space have been preserved for future generations to enjoy and for wildlife habitat. Additional environmental benefits include 60 acres (0.2 km^2) of undeveloped land adjacent to the site that will be preserved as open space by the Open Land Conservancy of Chester County for hiking trails, bird watching and education programs. Approximately 2 miles (3.2 km) of a former rail line were donated to Tredyffrin Township to connect this site with the Chester Valley Trail.

TRANSPORTATION CHALLENGE

The Atwater project required extensive transportation planning and public involvement to implement the roadway improvements needed to accommodate existing and future traffic volumes in the project area along State Route 29 and Yellow Springs Road. Traffic congestion was a concern for the municipalities even without the addition of 10,000 employees from Atwater Business Park.

To respond to this issue, a comprehensive traffic impact study was completed for a 10-intersection study area, including the State Route 29 corridor, which will provide direct access to the Atwater site, to determine necessary roadway improvements. A \$10 million roadway improvement was recommended to widen the existing State Route 29 corridor to two through travel lanes in each direction with additional turning lanes, traffic signal installation and modification to existing signals at key intersections along the corridor.

To meet this aggressive schedule and maintain the economic viability of the project, a private public-funding strategy has been developed to secure grant assistance for the substantial infrastructure costs that must be incurred over the next 12 to 18 months. Due to the size of this transportation challenge, and the presence of an existing traffic problem without any development at the Atwater site, a public-funding strategy was developed and implemented to share the cost between Trammell Crow, Chester County, PennDOT and the Pennsylvania Turnpike Commission (PTC). The culmination of a multiyear transportation phasing plan resulted in a \$4.8 million private-sector financial commitment, a \$2.6 million commitment of federal transportation dollars to improve State Route 29 and a commitment of \$2.6 million by the PTC to increase the span of Route 29 to permit

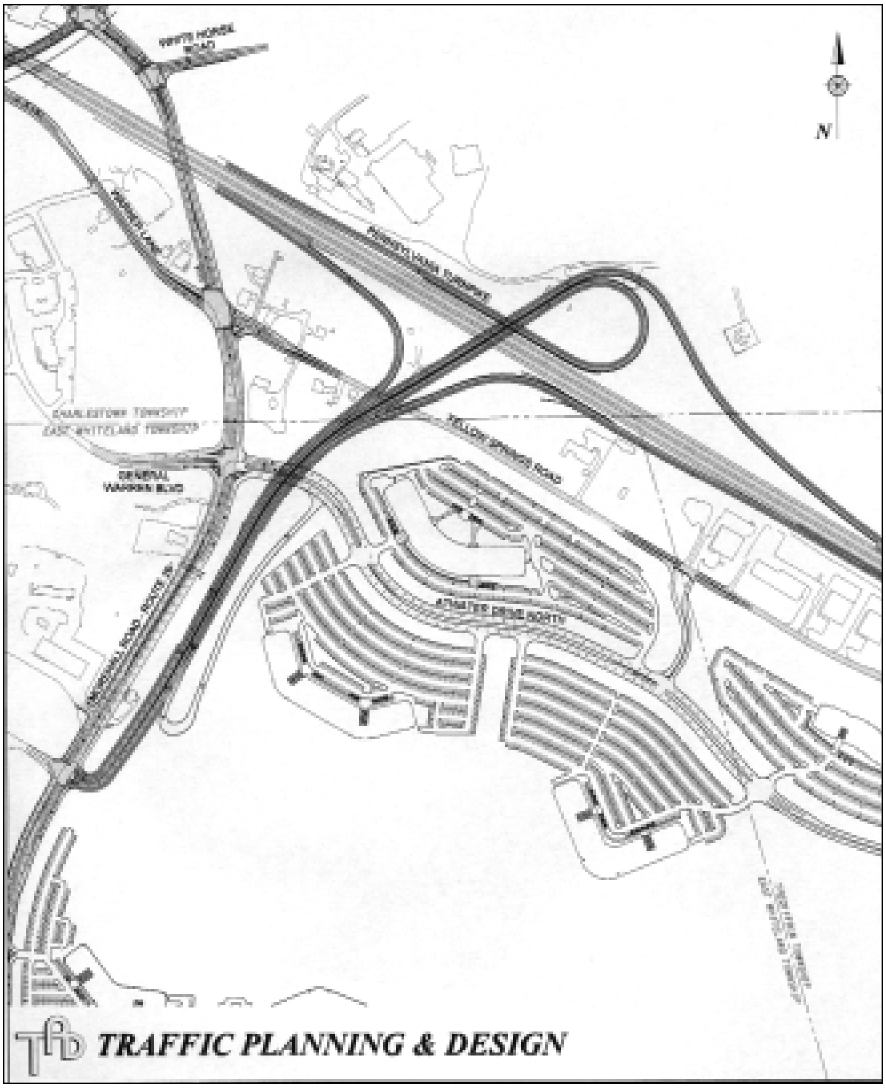


Figure 4. Currently planned configuration of proposed Pennsylvania Turnpike slip ramps with direct access to the Atwater Business Park

widening from a two-lane to a five-lane cross section under the bridge.

The total estimated cost of site improvements for Atwater is $28.2 million, although the true cost savings to residents of the area are difficult to quantify, due to realized increased tax revenue, the likely reduction in lost agricultural land, local economic boost provided by ancillary services and a more efficient transportation system. Because Trammell Crow and other agencies have supplied funding for the project, the taxpayers in this area will reap the benefits of a more desirable land use, an improved water management system and an improved transportation system, without paying a dime.

To address resident concerns that additional traffic generated by the Atwater Business Park would filter onto local residential roads, a traffic calming study was completed for Yellow Springs Road and Church Road, which border with the northern and eastern ends of the Atwater site. The traffic calming study recommended a series of multiway stop signs at intersections where warrants were met, Belgian Block crosswalks at pedestrian crossing locations and a series of strategies to improve police enforcement of traffic regulations along Yellow Springs Road.

THE PENNSYLVANIA TURNPIKE

The most significant roadway project to be implemented in conjunction with the Atwater Business Park is a "slip ramp" proposal by the PTC. In Pennsylvania, slip ramps are one-lane ramps supported solely with electronic toll collection. They are typically located between the existing interchanges located along the turnpike and are intended to give commuters a more direct route to their place of employment. The additional commuter options provided by slip ramps reduce congestion at the existing interchanges, which in this case are located 14 miles (22.5 km) apart. The Pennsylvania Turnpike intersects PA Route 29 just to the north of the Great Valley Corporate Center and the Atwater Business Park. Preliminary and final design is underway for slip ramps at this location to serve all directions of traffic between the Turnpike and Route 29. The slip ramps will be designed in a manner in which employees at Atwater will have direct access to the ramps from the business park (see Figure 4). Therefore, Atwater employees will be able to enter and exit the Pennsylvania Turnpike without using State Route 29, thereby reducing traffic congestion on an already heavily traveled component of the state highway system.

An extensive public-involvement process was needed to reach a consensus on the appropriate conceptual design for the slip ramps. Municipalities located in the vicinity of the proposed slip ramps were concerned with the traffic and land use impacts that could result from their construction. As part of the extensive public-involvement program, many presentations were given and meetings were held with public officials, the business community, environmental groups and citizens to develop a design concept that effectively addressed the roadway access needs of the business community, minimized traffic impacts to the local road system and was sensitive to local land use goals and objectives. The PTC formed a Community Advisory Committee (CAC) that represented these interests to build support for a design concept and to advance the project to the final design phase. The result of the CAC process led to an announcement by the PTC to commit $2.5 million for project design, with construction tentatively scheduled to begin in the spring of 2005 for this $25 million project.

ENVIRONMENTAL BENEFITS OF TRANSPORTATION IMPROVEMENTS

The transportation improvements themselves will also have several environmental benefits. The location of the site adjacent to the Pennsylvania Turnpike is important for several reasons. This proximity will enable the PTC to construct slip ramps that directly serve the site. Direct access to the turnpike will eliminate 2,400,000 vehicle miles (3,862,426 vehicle km) of travel each year for Atwater employees that otherwise would have been forced to find less direct routes to/from their homes. This reduction in vehicular miles of travel translates into 100,000 gallons (378,541 liters) of gasoline per year that will not be consumed as a result of the Turnpike Slip Ramp project. In addition, quality of life in the surrounding residential areas will be preserved as the slip ramps will eliminate the need for motorists to travel through residential areas to access the two existing turnpike interchanges located roughly seven miles in either direction from the site. The Route 29 improvements will eliminate the one to two mile back-ups that exist on Route 29 each day. As a result, CO, NO_x and HC emissions will also be significantly reduced as part of the congestion relief benefits from this project. Furthermore, as a member of the Chester County Transportation Management Association, the project owner, Trammell Crow, supports the operation of two local transit routes designed to provide a convenient transportation alternative to local residents and employees, which further reduces single occupancy vehicle usage and improves air quality in the region.

TRANSPORTATION PLANNING AND LEGISLATIVE POLICY

The redevelopment of a Brownfields site is an excellent example of the need for intergovernmental coordination. Many complex environmental issues are associated with this type of development project, which fall within the regulatory purview of several state and federal agencies. However, the amount of regulatory challenges associated with the use of public funds for infrastructure improvements should not deter private entities (and their municipal public partners) from pursuing state and federal assistance to alleviate the costs associated with site assessment, remediation, preparation and infrastructure development.

The effective integration of transportation and land use planning is paramount to the success of these two high-profile Brownfields redevelopment projects in Chester County. The transportation improvements planned for both the French Creek Center and the Atwater Redevelopment Project are consistent with several legislative and executive initiatives concerning effective land use that have been advanced by former Governor Ridge and the Pennsylvania General Assembly over the past six-and-a-half years. ■

KEVIN L. JOHNSON, *P.E., has 21 years of experience in the transportation engineering field and is the President of Traffic Planning and Design Inc. (TPD). Headquartered in suburban Philadelphia, TPD maintains offices in the mid-Atlantic area. Under Johnson's direction, TPD has worked on three Brownfields redevelopment projects in the past year and numerous projects involving public-private partnerships over the firm's 13-year history. He holds a B.S. in Civil Engineering from The University of Pennsylvania and a master's in Civil Engineering from Villanova University. Johnson is an Associate Member of ITE.*

CHAD E. DIXSON, *AICP, is a Project Manager at TPD. He holds a B.S. in Regional Planning from Indiana University of Pennsylvania. Prior to joining TPD's Regional Planning Team, Dixson spent four years with the Chester County Planning Commission. His TPD project-management experience includes numerous planning and traffic calming projects such as the 85-Intersection Kennett Area Regional Study in Chester County and the Village of Unionville Traffic Calming Study. Dixson is a Member of ITE.*

SCOTT P. TOCHTERMAN *is Principal of Government Relations at Delta Development Group. He holds a B.S. in Business Administration from Messiah College and a master's in Business Administration from Penn State University. Tochterman manages the firm's development projects and provides government relations support, which includes Brownfields redevelopment projects. His unique expertise includes securing public funding through federal, state and local government programs, building public-private partnerships and facilitating regulatory approvals.*

Putting on Their Parking Caps

(To view and print pdf files, use Adobe Acrobat Reader available at this link.)

In recent years, planners have focused on developing more pedestrian friendly, livable communities with affordable housing, accessible transit, improved water quality, and reduced congestion. The reduction of parking spaces provided by new developments is one strategy undertaken to achieve these livable communities because some planners hold the view that "parking is no exception to the rule that you can have too much of a good thing."

In "Putting on Their Parking Caps" published in Planning, April 2002, Adam Millard-Ball examined the strategies that some cities have adopted to reduce and/or restrict parking. Several cities including Eugene, Oregon; Cambridge, Massachusetts; and Gainesville, Florida have implemented policies that have limited parking. Cities such as San Francisco, California; Seattle, Washington; and Portland, Oregon have also adopted more restrictive parking policies.

Over the last half century, planners have specified minimum parking requirements for a variety of different land uses to ensure that developers provide ample off-street parking. The author notes that in his article, "Truth in Transportation Planning," Donald Shoup argues that this traditional parking policy has led to increased traffic congestion and lower development densities. A summary of Shoup's article entitled, "Trip and Parking Generation Rates: Truth or Fiction?" is available on this web site.

Gainesville senior planner, Dom Nozzi stated, "minimum parking requirements are truly drugs for cars. They ought to be a controlled substance. They breed car trips." As a result, Gainesville has established maximum parking requirements to limit automobile trips, encourage carpooling, the use of transit, bicycling and walking. Cities in suburban Portland use maximum parking requirements to meet regional air quality standards, increase densities, and reduce sprawl.

For Eugene, maximum parking requirements have raised densities and reduced the amount of paved land cover, thereby decreasing surface runoff and improving water quality. In Seattle, planners are considering maximum parking requirements and other measures to restrict parking around the planned light rail system stations. Although Cambridge has had maximum parking requirements for the last 20 years, recently the city adopted an ordinance requiring developers "reduce auto use to 10 percent below the 1990 average for that census tract, with a resulting decrease in the need for parking."

For the residents of San Francisco, minimum parking requirements have proven to be an obstacle to affordable housing and transit-oriented development. To remedy this situation, city planners have proposed eliminating the minimum parking requirements for developments close to highly used transit areas and other specific institutions. Maximum parking standards would be instituted varying from one space per unit in less developed areas of the city to .5 spaces per unit in densely populated areas where buses and streetcars arrive frequently during peak times. The city is also considering implementing a base standard of .75 spaces per unit in some downtown neighborhoods. If developers want one space per unit in these neighborhoods, they would have to apply for a conditional use permit. This process would "unbundle" the cost of parking from residents, thereby making tenants and homeowners pay for parking separately.

An example of a residential development with limited parking can be found in downtown Berkeley, California where an exemption from the minimum parking requirements allowed the construction of a seven-story complex with 91 apartments, 10,000 square feet of commercial space and only 41 off-street parking spaces. By reducing the 1:1 ratio of parking, the developer was able to use the savings in both finances and floor space to add amenities like a theater and to rent 20 percent of the apartments at below market rates to low-income households.

The regulation of on-street parking is an essential component when introducing maximum parking standards in order to prevent spillover parking which is the primary concern of communities. The strategy used to reduce spillover is the effective enforcement of meters, time limits, and on-street residential only parking permits.

A more controversial proposal in San Francisco would limit the number of on-street residential parking permits to be issued. Holders of the permits would be charged market rate for the parking space and the revenue channeled to paying for transit and neighborhood improvements. This policy favors households that do not own cars or are not willing to pay high costs for parking spaces "because car owners are not a protected class under state or federal law, this practice is perfectly legal." Some cities such as Eugene, Cambridge, and Portland have chosen to integrate maximum parking standards with existing minimum parking requirements to maintain low levels of spillover.

To ensure the success of maximum parking standards, Portland established advisory committees with bankers, environmentalists, developers, real estate brokers, and other business interests along with city officials. In Cambridge, city legislation reflected an anti-growth sentiment that encouraged developers to find ways of reducing traffic by providing less parking rather than lose space.

As noted by Shoup, the minimum parking requirements based on rates published in the informational manuals of the Institute of Transportation Engineers are drawn from survey data on the peak demand for parking and do not consider transit or the cost to the user. Shoup argues that cities should base their decisions to establish maximum parking standards after extensive research so as not replicate the mistakes of other cities. The article concludes by supporting Shoup's contention that minimum parking requirements should be abolished when there is no data on the parking needs, thereby allowing developers who have an interest in not overbuilding to be responsible for determining the parking supply which could lead to better planning than currently practiced.

The full text of this paper is available in Planning, April 2002, or online here. For additional information, contact Adam Millard-Ball at Nelson\Nygaard Consulting Associates or by e-mail amillard-ball@nelsonnygaard.com. *Adapted with permission.*

Putting on Their Parking Caps

By Adam Millard-Ball

Marshall Foster, San Francisco Planning Department

Affordable housing, transit-oriented development, smart growth, better water quality, reduced congestion, and more walkable, livable communities.

The connection?

All are issues that planners are seeking to tackle through parking policy, by limiting the number of spaces that may be provided as part of new development. Parking is no exception to the rule that you can have too much of a good thing. The past few years have seen cities such as Eugene, Oregon, Cambridge, Massachusetts, and Gainesville, Florida, adopt limits on parking.

San Francisco is poised to follow suit, while Seattle is considering extending its downtown parking restrictions to the areas around new light rail stations. In Portland, Oregon, maximum parking standards have been adopted on a regionwide basis by 30 cities and coun-

San Francisco's 1:1 parking requirement is said to reduce the number of residential units that can be built on a given parcel by 20 percent and add 20 percent to rent. A community advocate drew attention to the policy by moving into a makeshift "home" in a parking space (left). The city does not limit the number of residential parking permits sold.

Walk San Francisco

San Francisco Planning Department

ties, as mandated by Metro, the region's metropolitan government.

Such moves may signal a complete reversal of direction in planners' attitudes. For the last half century at least, planners have been specifying minimum parking requirements for a myriad of different land uses, from convents to massage parlors, in a bid to ensure that developers will provide sufficient off-street parking.

These minimum requirements are simply a recipe for more cars, says Donald Shoup, professor of urban planning at the University of California-Los Angeles, who has published extensively on the subject. In an effort to limit traffic overspill, he notes, minimum standards require developers to provide unlimited free parking, attracting more cars and resulting in lower development densities.

Shoup draws an analogy between minimum parking requirements and the 18th century practice of using lead to treat gunshot wounds, ulcers, and other ailments. While lead has local antiseptic properties, its toxic effects come at a high price to the rest of the body.

"Like lead therapy, minimum parking requirements produce a local benefit—they ensure that every land use can accommodate all the cars 'drawn to the site,'" Shoup wrote in a 1999 paper published in *Transportation Research*. "But this local benefit comes at a high price to the whole city." This price is paid in the form of traffic, congestion, and a less dense, auto-oriented city.

Drugs for cars

"Minimum parking requirements are truly drugs for cars," says Dom Nozzi, senior planner for the city of Gainesville, Florida. "They ought to be a controlled substance. They breed car trips."

Consequently, Gainesville has sought to turn the logic of parking standards on its head by introducing maximum parking requirements as a tool for limiting automobile trips, and persuading people to use carpools, tran-

Cambridge, Massachusetts, requires developers to reduce auto use to 10 percent below the 1990 average. Harvard Law School and the U.S. Postal Service share space at 125 Mount Auburn Street, developed by The Bulfinch Companies (bottom). A mix of office,

Catherine Preston, City of Cambridge, both photos

sit, bicycles, and their own two feet.

"Unless we have priced parking, which we generally don't, the only way to discourage people from driving is to restrict the supply," says Nozzi. "If we're really serious about reducing single-occupancy vehicle trips, and we don't have the political will to charge for parking, we need to control the supply."

Maximum parking standards also are being used to support a range of other objectives. Work on Portland's regional standards was initiated by the state Department of Environmental Quality in 1993 to help meet air quality standards for ozone. Subsequently, the work was moved forward by Metro as a tool to encourage compact development. Final standards were adopted in 1996.

Some suburban Portland cities, such as Beaverton, also see the parking standards as a way to raise densities, tackling sprawl and creating more compact, walkable neighborhoods. Beaverton's regulations target the amount of land devoted to parking, rather than the number of spaces provided, by allowing developers to build parking structures rather than surface lots, and thus exceed the maximum.

In Eugene, Oregon, the focus is as much on promoting greater densities and reducing the amount of land paved over for parking—and hence reducing surface runoff and improving water quality—as on reducing traffic.

And in Seattle, planners are now considering applying maximum parking standards outside the downtown core to bolster transit-oriented development around stations on the planned light rail system, where construction is due to start this year. "We see reduced parking as driving the success of transit," says Jemae Hoffman, strategic advisor for the city of Seattle.

"A lot of us would be really interested in switching to maximums," she continues. But even if they prove to be politically infeasible, she adds that the city will almost certainly take other steps to restrict the supply of parking.

Seattle is lucky to be considering these issues well in advance, rather than waiting for the first trains to start running, she notes, with station area overlay zoning ordinances in place since last July to prohibit auto-oriented uses. "I think that most other places with light rail are more reactive," Hoffman says.

Cambridge, Massachusetts, just outside Boston, has taken perhaps the most radical steps in limiting parking. While it has had parking maximums in place for around 20 years, a few years ago it adopted an ordinance forcing developers to reduce auto use to 10 percent below the 1990 average for that census tract, with a resulting decrease in the need for parking. The initial program was adopted in 1998 for an evaluation period of three years, but its success led to a reauthorization in fall 2001.

Under Cambridge's regulations, developers must draw up a transportation demand management (TDM) plan to achieve this 10 percent cut, pledging measures such as appropriate parking supply, subsidized transit passes, and parking charges. In addition, parking maximums for office and research and development uses were revised to reflect the 10 percent reduction.

retail, and residential occupy 600 Massachusetts Avenue, developed by Holmes Nominee Trust.

"It's a tough balance," says Catherine Preston, the city's parking and TDM officer. "We don't want to ratchet it down so much that there's overspill, but a surplus encourages people to drive."

Developers who don't meet the targets for car use can be fined. In a worst-case scenario, their parking facilities can be shut down by the city.

More parking means pricier housing

San Francisco is one of the most recent converts to maximum parking standards. While it has long maintained low maximum parking standards in the downtown core, in the rest of the city developers are generally required to provide at least one space per dwelling unit. Minimum standards also are set for commercial and industrial developments.

Here, the move to parking maximums is being driven in part by concerns over housing affordability. Even after the collapse of the dot-com boom, which many blamed for soaring home prices and rental vacancy rates of virtually zero, the San Francisco Bay Area is still suffering from an acute shortage of housing, particularly affordable housing.

"Parking requirements are a huge obstacle to new affordable housing and transit-oriented development in San Francisco," says Amit Ghosh, the city's chief of comprehensive planning. "Nonprofit developers estimate that they add 20 percent to the cost of each unit, and reduce the number of units that can be built on a site by 20 percent."

Pointing to census data and other studies that show low-income households tend to own far fewer cars than the parking requirements assume, he adds: "We're forcing developers to build parking that people cannot afford. We're letting parking drive not only our transportation policies, but jeopardize our housing policies, too."

San Francisco's current proposals, developed by the planning department and consultant Nelson\Nygaard, are to eliminate minimum parking requirements completely for projects within a half mile of rail stations or a quarter mile of major transit streets, and for all below market rate, elderly, and institutional units. These would be replaced by maximum standards, varying from one per unit for new housing in less developed parts of the city, to 0.5 in the central Market/Octavia neighborhood, where a bus or streetcar arrives every minute at peak times.

Interestingly, the link between restricting parking and encouraging new housing has caught the imagination of local residents, to the extent that spontaneous applause erupted at one neighborhood meeting when the parking plans were presented earlier this year.

Most innovative of all are the base standards of 0.75 per unit the city is considering in several downtown neighborhoods, with a slightly higher level of one space per unit allowed if developers apply through the city's conditional use permit process. The aim is to force developers and landlords to "unbundle" parking, by allowing tenants and homeowners to rent or purchase it separately from the housing itself.

The city's reasoning is that, with less than one space per unit, developers won't automatically add a parking space to the cost of an apartment, but will choose to unbundle instead. And if they want to provide one space per unit, unbundling parking and housing costs will be required as part of the conditional use permit.

"We want to get away from the situation where people are forced to pay for parking, regardless of whether they have a car," Ghosh says. "The true costs of car ownership need to be made visible to owners and renters."

Attacking the minimum

One concrete example of how to provide attractive housing with little or no parking is located across San Francisco Bay in downtown Berkeley. The $11 million, seven-story Gaia Building was completed in fall 2001 by a for-profit developer, Panoramic Interests. The building houses 91 apartments, 10,000 square feet of commercial space (including a theater), and just 41 off-street parking spaces.

Patrick Kennedy, founder of Panoramic Interests, is clear about the benefits of eliminating as much parking as possible. The savings made in both dollar terms and floor area have allowed the addition of amenities such as the theater, and for 20 percent of the apartments to be rented at below market rates to low-income households.

"That would never have happened if we'd provided 1:1 parking," he says. "This project would never have been built."

While Berkeley still has minimum parking requirements, the Gaia Building benefited from one of the exemptions granted by the city on a case-by-case basis. Kennedy would prefer to see these minimums abolished altogether, as the city is in fact considering in some neighborhoods as part of its new general plan, now being written.

A case-by-case approach gives far more scope for local objectors to stop the whole development on the grounds of lack of parking, Kennedy says. "Parking is one of the favored weapons of obstructionists."

Spillover can be avoided

The Gaia Building is located in downtown Berkeley, where on-street parking is metered or otherwise heavily controlled. This means there is little chance of spillover parking—that is, parking from a development that overflows into surrounding areas. Spillover parking can infuriate neighbors and other local residents. Communities that allow reduced parking or introduce maximum parking standards should pay attention to possible spillovers.

After all, avoiding spillover was the justification for specifying minimum requirements in the first place. Forget about setbacks and design guidelines. What the public wants to know is this: Will a new development increase traffic, and, above all, will it make it harder to find a parking spot?

For many planners, regulating on-street parking is an essential complement to the introduction of parking maximums. Seattle's Jemae Hoffman points to meters and time limits, as well as effective enforcement, as crucial to the success of parking restrictions around future light rail stations.

And then there are residential permit parking programs, which restrict on-street parking to local residents. "The program has really reduced spillover problems," says Teresa Bishow, senior planner with the city of Eugene.

In San Francisco, planners are considering radical surgery for the city's residential permit parking program, as a complement to maximum parking requirements. These changes would acknowledge that parking woes are often caused by the number of cars owned by residents themselves, not just the commuters that the program targets for restrictions.

The proposed legislation would restrict the number of permits issued to the number of on-street spaces, and—this is controversial—charge for them at market rates, with revenue channeled to neighborhood improvements and transit.

In some dense residential neighborhoods, planners estimate the price could rise from the current $27 per year flat rate to $200 per month. City officials are currently trying to determine whether the revised permit charges can be treated as a fee rather than a tax, and therefore avoid the state requirement for approval by a two-thirds popular vote.

Part of Ghosh's aim is to persuade people to clear the junk from their garages and use them for cars—and in the longer term to achieve a better match between households with cars and housing with parking. Market pricing of on-street parking means that automobile owners will be willing to pay extra for a garage, and at the same time help car-free households to find cheaper housing.

This matching of cars to parking spaces helps to explain the Gaia Building's success in

The $11 million, seven story Gaia Building in Berkeley houses 91 apartments, 10,000 square feet of commercial space, and a theater, but has only 41 parking spaces. At right, a parking garage with movable spaces allows more cars to be housed in less space.

The Gaia Building is able to rent 20 percent of the apartments at below-market rate to low-income households because Berkeley did not require a 1:1 ratio for parking. Berkeley still has minimum requirements, but will approve projects with less parking on a case-by-case basis.

attracting 237 residents with just 20 cars among them. "It's a matter of self-selection," says Patrick Kennedy. After all, how many car owners would want to live in a building marketed as a "car-free development" and on top of that pay $150 a month for one of the limited number of parking spaces?

There is nothing to stop developers and landlords giving preference to households that don't have a car, Kennedy adds. Because car owners are not a protected class under state or federal law, this practice is perfectly legal. Alternatively, as in some of Kennedy's other Berkeley developments, the city can prohibit residents from obtaining an on-street resident's parking permit.

Many cities, such as Eugene, Cambridge, and Portland, have elected to retain some minimum parking requirements alongside maximums, to alleviate concerns about spillover parking.

"It's a comfort zone," says Susan Christensen of Oregon's Department of Environmental Quality, which was instrumental in developing Portland's regional standards. "This was still a fairly radical idea when we introduced it, and the minimums gave the comfort of knowing there won't be parking in the neighborhoods."

Developers save money

One of the hallmarks of the Portland process for drawing up maximum parking standards was the involvement of developers and the wider business community. The state Department of Environmental Quality established three advisory committees, bringing lenders, developers, real estate brokers, and other private sector interests to the table, as well as city officials and environmentalists.

While it meant the standards took longer to create—a year and a half in the Portland case—the region is now reaping the benefits of including the business community, says Susan Christensen. "They're the ones that have to live with it. They're the ones that have to make this work," she says. "Our approach was to get buy-in before the ink was dry, rather than shove it down people's throats."

In many cases developers may realize major rewards from new parking standards that force them to think more creatively about the amount of parking they actually need. After all, substantial amounts are at stake, with each space in a parking garage in urban centers such as Los Angeles costing about $30,000.

"Developers assume a certain travel mode mix," says Eugene's Teresa Bishow. "If they understand the local area and its travel patterns, they can build less parking and save money."

In Cambridge, the new parking and transportation demand management (TDM) legislation has helped developers overcome public anti-growth sentiment by demonstrating that they were taking action to reduce traffic impacts. "There was a real surge of support in the community for measures to reduce traffic," says the city's Catherine Preston.

"Developers started to realize that they had to be part of the solution," she continues. "When push comes to shove, they would prefer to implement TDM programs and provide less parking than lose leasable space."

Nor have the new requirements risked pushed development to other parts of the Boston region, according to Preston. "Cambridge is a uniquely attractive place to do business," she says. Indeed, parking policies that reduce traffic and help raise densities will ultimately create a city more attractive to business, argues Gainesville's Dom Nozzi. "To the extent we build in a compact, walkable ambience, we're encouraging people to locate in the downtown because of the higher quality of life," he says. "We're saying to developers that we want to provide a walkable, human-scale community, and if you don't want to go along with that, we're not going to kill ourselves trying to keep you here."

Standards out of thin air?

Any city that seeks to introduce maximum parking standards should learn from the mistakes made in establishing minimums, advises Donald Shoup of UCLA. Often the minimums are simply copied from nearby cities, a practice that runs the risk of repeating someone else's mistakes.

Alternatively, they are based on parking generation rates published by the Institute of Transportation Engineers, which typically draw on survey data for peak demand at suburban sites that offer ample free parking and little in the way of public transit. Although demand is heavily influenced by price, the ITE takes no account of this—but simply assumes there will be no charge to the user, says Shoup.

Moreover, the sample sizes used to calculate these rates are often tiny; half are based on only four or fewer surveys, Shoup continues. "Without training or research, urban planners know exactly how many parking spaces to require for bingo parlors, junkyards, pet cemeteries, rifle ranges, slaughterhouses, and every other land use," he wrote in *Transportation Research*.

Rather than simply abolish these minimums and leave developers to determine how many spaces they want, however, many cities jump to replace them with maximums, even though they may still have little idea of demand. "Planners simply do not know how many parking spaces are needed," he says. "It's the old Soviet maxim: 'What is not required must be prohibited.'"

However, many cities—particularly Portland and Cambridge—have based their new maximums on significant research. And maximum standards are appropriate in many instances, Shoup argues.

But, he suggests, in the absence of hard data, a more sensible approach might be simply to take an intermediate step and abolish parking minimums. Leaving parking supply up to developers, who have a financial interest in not overbuilding, may lead to better planning than what's in place now, Shoup says.

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Resources

Reading. Donald Shoup's "Truth in Transportation Planning" is forthcoming in the *Journal of Transportation and Statistics*. His "The Trouble With Minimum Parking Requirements" was published in *Transportation Research* in 1999. See www.vtpi.org/shoup.pdf. "Reducing Housing Costs by Rethinking Parking Requirements," a policy paper from the San Francisco Planning and Urban Research Association, is at www.spur.org/spurhsgpkg.hmtl. "Parking Requirement Impacts on Housing Affordability," by Todd Litman of the Victoria Transport Policy Institute, is at www.vtpi.org/park-hou.pdf. *Planning*'s last story on residential parking was "Don't Park Here," October 2000.

Local ordinances. Information about the Portland region is at atwww.metro-region.org/growth and www.deq.state.or.us/nwr/eco/eco.htm. Contact Susan Christensen, Oregon Department of Environmental Quality, 503-229-5518; e-mail, christensen.susan@deq.state.or.us. For information about Cambridge, Massachusetts, see www.ci.cambridge.ma.us. The code for Eugene, Oregon, is at www.ci.eugene.or.us. And Gainesville, Florida's is at www.state.fl.us/gvl/index.new.html.

Models. The computer model created by the Non-Profit Housing Association of Northern California helps developers and planners to assess likely parking demand. The site also includes a policy briefing, "Rethinking Residential Parking." See www.nonprofithousing.org.

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 planning 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 measure the peak demand for parking and the number of vehicle trips observed at suburban sites with ample free parking and no public transit. Urban planners who use these parking and trip generation rates as guides to design the transportation system therefore implicitly assume that everyone will drive wherever they go and park free when they get there.

TRUTH IN TRANSPORTATION PLANNING

Donald C. Shoup

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.[1] 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 implies 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. Many transportation models also incorporate the trip generation rates. 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 planning policies.

TRIP GENERATION

Trip Generation defines the average number of vehicle trips observed at a site as its "trip generation rate." The sixth (and most recent) edition of *Trip Generation* (1997) describes the data base 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.[2]

The ITE says nothing about the price of parking at the survey sites, but parking is free for 99 percent of vehicle trips in the US, so the survey sites probably offer free parking.[3] Of the 1,515 trip generation rates, half are based on surveys at five or fewer sites, and 23 percent are based on surveys at only one site.[4] The trip generation rates thus typically measure the number of vehicle trips observed at a few suburban sites with free parking but no public transit, nearby pedestrian amenities, or TDM programs. Urban planners who rely on these trip generation rates as guides to design the transportation system are therefore planning for an automobile-dependent city.

Figure 1 shows a typical page from the fourth edition of *Trip Generation* (1987).[5] It reports the number of vehicle trips to and from fast food restaurants on a weekday. Each point in the figure shows the average number of vehicle trips per day and the floor area at a single restaurant. Dividing the number of vehicle trips by the floor area at a restaurant gives the trip generation rate at that restaurant. The rates range between 284 and 1,359.5 vehicle trips per 1,000 square feet at the eight restaurants. A glance at the figure suggests that vehicle trips are unrelated to floor area in this sample. The extremely low R^2 of 0.069 for the fitted curve (regression) equation at the bottom of the figure confirms this impression.[6] 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.[7] The trip generation rate looks accurate because it is so precise, but the precision is misleading.

Click here to view Figure 1

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 when we estimate the 95-percent confidence interval around the floor-area coefficient, it ranges from –650 to +1,141 trips per 1,000 square feet.[8] Since this confidence interval contains zero, the data do not show that floor area affects the number of vehicle trips. Reporting the average trip generation rate suggests that larger restaurants generate more vehicle trips, but the figure shows that the smallest restaurant generated the most trips, and a mid-sized restaurant generated the fewest. The data plot does contain the warning "Caution—Use Carefully—Low R^2," which is good advice because the data 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.

PARKING GENERATION

Parking generation rates suffer from similar uncertainty. *Parking Generation* defines the peak parking occupancy observed at each site as its "parking generation rate." The second (and most recent) edition of *Parking Generation* (1987) explains the survey process:

> 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 surveys, and 22 percent are based on surveys at one site.[10] The parking generation rates thus typically measure the peak parking demand observed at a few suburban sites with ample free parking and no public transit. Urban planners who rely on these rates to set off-street parking requirements are therefore planning for 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 most recent edition of *Parking Generation* (1987). Parking generation rates range from 3.55 to 15.92 spaces per 1,000 square feet of leasable floor area at the 18 sites. The largest restaurant generated one of the lowest peak parking occupancies, while a mid-sized restaurant generated the highest. The 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. 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.[11]

Click here to view Figure 2

Again, the precision is misleading. Although 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 floor-area coefficient ranges from –3 to +7 spaces per 1,000 square feet. Since this confidence interval again contains zero, the data do not show that floor area affects parking demand.[12] 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.[13] 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.[14]

We cannot say much about how floor area affects either vehicle trips or parking demand because the 95-percent confidence interval around the coefficient of floor area 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, we should recognize that these samples do *not* show a statistically significant relationship between floor area and either vehicle trips or parking demand.[15] Size does not matter in these two samples of parking and trip generation, and it is misleading to publish precise *average* parking and trip generation rates based on these data.

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."[16] Nevertheless, many planners recommend the parking generation rates as minimum parking requirements because they are the best data available. 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.[17] 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.

STATISTICAL SIGNIFICANCE

The breathtaking combination of extreme precision and statistical insignificance for the parking and trip generation rates at 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, the page for recreational land uses reports 14 studies of trip generation but says "No Plot or Equation Available—Insufficient Data." The trip generation rates at the 14 sites 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.[18]

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.[19]

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. The stated policy therefore conceals evidence that contradicts the predicted 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]

Click here to view 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). The sixth edition shows regression equations for only 34 percent of the reported trip generation rates, which means that 66 percent of the trip generation rates fail to meet at least one of the three criteria.

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 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, so this decline seems unlikely.[21]

Click here to view Figure 4

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 traffic impacts, 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."[22]

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 uncertain science, but the legal system of land-use regulation makes it difficult to incorporate uncertainty into decisions. Admitting the flimsy basis of these rates would expose land-use decisions to countless lawsuits. This desire for certainty explains why transportation engineers, urban planners, developers, and elected officials rely on precise point estimates—rather than ranges—to report uncertain parking and trip generation rates.

PLANNING FOR FREE PARKING

Not only are most ITE samples too small to draw statistically significant conclusions, but the ITE's method of collecting data also 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*.

Figure 5 shows the five-step process of planning for free parking. In step 1, transportation engineers survey the peak parking demand at suburban sites with free parking, 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, and the large supply of required parking drives the price of most parking to zero, which increases vehicle travel. In step 3, transportation engineers survey vehicle trips to and from suburban sites with free parking, and the ITE publishes the results in *Trip Generation* with misleading precision. In step 4, transportation planners consult *Trip Generation* as a guide to design the transportation system that brings cars to the free parking.[23] In step 5, urban planners limit density so that development will not generate more vehicle trips than nearby roads can carry. This lower density spreads activities farther apart, further increasing vehicle travel and parking demand. The loop is completed when transportation engineers again survey peak parking demand at suburban sites that offer free parking and—surprise!—find that more parking spaces are "needed." The maximum observed parking demand thus becomes minimum required parking supply. 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. Cities require off-street parking without considering parking prices, the cost of parking spaces, or the wider consequences for transportation, land use, the economy, and the environment.

Click here to view Figure 5

The ITE manuals do not *cause* this circular and cumulative process, and the ITE of course deplores any misuse of its parking and trip generation rates. The ITE does warn users to be careful when using data based on small samples, but 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:

> 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.[24]

Nevertheless, the ITE does not suggest *how* a user might modify the trip generation 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. Citizens want to know how development will affect parking demand and traffic congestion in their neighborhood. Developers want to know how many parking spaces they should 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 off-street parking requirements and 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. 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 of supplying it.

American motor vehicles alone consume one eighth of the world's total oil production, and ubiquitous free parking contributes to our automobile dependency.[25] What can be done to improve this situation? Here are five suggestions:

- 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 and no public transit service, nearby pedestrian amenities, or TDM programs.
- The ITE should show the regression equation and the R^2 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."

The ITE's 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 policy choices. 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.indo.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*."

4. This refers to the sixth edition of *Trip Generation* (1997).

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.

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 the 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.

9. ITE (1987a, vii-xv). The ITE does not report when the surveys were conducted, so it is unclear whether the observed peak occupancy refer to the yearly peak occupancy.

10. *Parking Generation* includes data for only 46 different land uses, but it reports more than one parking generation rate for some land uses. For example, it reports six parking generation rates for commercial airports (Land Use Code 021). Rates are reported for two bases (daily airplane movements and emplaning passengers) and for three time periods (weekday, Saturday, and Sunday).

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 sites 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 6.667 spaces per 1,000 square feet even if the coefficient of floor area were zero.

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

15. 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.

16. ITE (1987a, vii).

17. 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.

18. 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).

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. Oddly, all of the eight restaurants in the fourth edition (1987) and fifth edition (1991) were exactly 2, 3, or 4 thousand square feet, but none of the 21 restaurants in the sixth edition (1997) matched these three sizes.

22. Section 10-3.162(5) of the Beverly Hills Municipal Code. This provision refers to land 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. This 25-years-out-of-date reference in the municipal code suggests that urban planners are not always aware of the latest wrinkles in ITE methodology.

23. Transportation planners often use the Urban Transportation Modeling System (UTMS) to predict modal flows on links 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 4 of the five-step process of planning for free parking. Meyer and Miller (2001) explain the UTMS model.

24. ITE (1997, Volume 3, 1).

25. 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.

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Trip and Parking Generation Rates: Truth or Fiction?

(To view and print pdf files, use Adobe Acrobat Reader available at this link.)

Trip Generation, 6th Edition (and the previous five editions), published by the Institute of Transportation Engineers, contains expected trip generation rates for a variety of land uses. *Parking Generation, 2nd Edition* (and the previous edition), also published by the Institute of Transportation Engineers, contains parking generation rates for a variety of land uses. Planners and engineers rely on information provided in *Trip Generation, 6th Edition* and *Parking Generation, 2nd Edition* for a variety of transportation purposes ranging from estimating potential traffic impacts of a proposed project to establishing minimum parking requirements in local land development codes. Both of these documents are among the most widely used transportation resources in the country and around the world.

In the paper entitled "Truth in Transportation Planning," Dr. Donald Shoup of the University of California Los Angeles contends that the estimates of trip and parking generation rates, though stated as precise numbers in *Trip Generation, 6th Edition* (1997) and *Parking Generation, 2nd Edition* (1987), are in fact, highly uncertain. ITE's trip generation rates are based on surveys conducted by transportation engineers, planners, and consultants. However, these surveys often produce a wide range of results. For example, in *Trip Generation, 4th Edition* (1987), eight studies were used to determine the trip generation rate of a fast food restaurant. Results ranged from 284 trips to 1360 trips per 1000 square feet of floor area. The R2 (a statistical measure of the ability of the independent variable to predict the dependent variable) showed that floor area explained less than 4 percent of the variation in vehicle trips. Further analysis of the data revealed that no statistically significant relationship existed between floor area and vehicle trips. Yet ITE reported the average trip generation rate as "precisely" 632.125 trips per day per 1000 square feet of floor area with a caution about the low R2. Similarly, trip generation rates for other types of land uses were given in an equally precise manner.

In *Trip Generation, 5th Edition* (1991), ITE revised its policy regarding statistical significance. ITE decided to show best fit curves only when each of the following three conditions were met:

- The R2 is greater than or equal to .25

- The sample size is greater than or equal to 4
- The number of trips increases as the size of the independent variable increases

In *Trip Generation, 6th Edition*, ITE again revised its policy regarding statistical significance. The regression equations would be reported only if the R2 was greater than or equal to .5. The rest of their policy remained the same. In the 6th edition, the trip generation rate for a fast food restaurant calculated using 21 studies showed that the rate declined to 496.12 vehicle trips per 1000 square feet. The R2 was not reported. There is a significant difference between the previously reported 632.12 vehicle trips per 1000 square feet in *Trip Generation, 5th Edition* and the rate of 496.12 vehicle trips per 1000 square feet reported in *Trip Generation, 6th Edition*.

Under this policy, *Trip Generation, 5th Edition* reported the trip generation rate of fast food restaurants (using the same 8 studies discussed above) as precisely 632.12 vehicle trips per 1000 square feet, but omitted the regression equation and the low R2. While the policy was well intentioned, the paper contends that omission of the R2 actually encourages misuse of the data because the low R2 would warn planners to use the rate cautiously.

The rates for a fast food restaurant reported in *Trip Generation, 5th Edition* and *Trip Generation, 6th Edition* were generated from data that showed no statistically significant relationship between floor area and vehicle trips. The paper argues that it is, therefore, difficult to believe that the number of vehicular trips for a fast food restaurant could have declined so substantially between the two editions of ITE informational reports.

In *Parking Generation, 2nd Edition*, the paper suggests that parking generation rates "suffer the same uncertainty" as trip generation rates. Again using a fast-food restaurant as an example, 18

studies were used to determine the parking generation rate reported in *Parking Generation, 2nd Edition* . The range of results from the base data ranged from 3.55 to 15.92 parking spaces per 1000 square feet. Here again, the low R2 showed that floor area explained less than 4 percent of the variation, but ITE reported the average parking generation rate as precisely 9.95 parking spaces per 1000 square feet. While logic suggests that there is a relationship between the restaurant's floor area and parking demand or vehicle trips, there is no statistically significant relationship that has been proven by the data analyzed thus far.

Despite these admitted flaws in parking and trip generation rates, the paper notes that planners and engineers continue to consult the ITE resources because it relieves them of the obligation of conducting their own research. Most land use regulations are based on these precisely stated, but uncertain trip and parking generation rates. The rates are "deeply embedded" in municipal codes and case law so planners are reluctant to admit the "flimsy basis" of ITE's trip and parking generation rates because this could eventually lead to legal challenges.

Additionally, the parking and trip generation rates are calculated from land uses that offer free parking. To satisfy the community demand for free parking, planners establish minimum parking requirements that ensure enough parking spaces are available to meet the peak demand for free parking. The author's arguments regarding free parking are further explored in his article, "Instead of Free Parking," Access, November, 1999. A summary of that article entitled, "There is No Such Thing as Free Parking" is available on this web site.

The paper concludes by making five specific recommendations, including the following two:

- ITE should report parking and trip generation rates as ranges rather than point estimates, and
- ITE should show the regression equation and R2 for each land use in the parking and trip generation reports. In addition, ITE should state whether the coefficient of floor area (or other independent variable) in the equation is significantly different from zero.

The paper suggests that the precision of parking and trip generation rates as reported in the ITE informational reports causes transportation professionals to place misguided confidence in uncertain data that in turn results in poor policy decisions. This argument suggests that less precision would, in fact, introduce more truth into transportation planning.

The full text of this paper is available on the 80th Annual Meeting of the Transportation Research Board CD-ROM or online here. Also available on this site is Dr. Shoup's article, "Roughly Right or

Precisely Wrong" published in Access, no. 20, Spring 2002. For additional information, contact Dr. Donald Shoup at the University of California Los Angeles, CA 90095-165 or by email
shoup@ucla.edu *Adapted with permission.*

Instead of Free Parking

BY DONALD SHOUP

WE AMERICANS first learn about free parking when we play Monopoly. Players pay rent, buy houses, build hotels, or go to jail after a toss of the dice, and one toss out of forty lands us on "Free Parking." The odds of landing on free parking increase dramatically when we begin to drive cars because—notwithstanding the experience of commuters in some large cities—American motorists park free on 99 percent of all trips.

But there is no such thing as a free parking space. Someone must pay for it. If motorists don't, then who does? Initially, developers pay for parking when they provide spaces to meet requirements in zoning ordinances. Because the required parking spaces raise the cost of development, the cost of parking is then translated into higher prices for everything else, and everyone pays for parking indirectly. Residents pay through higher prices for housing, consumers pay through higher prices for goods and services, employers pay through higher office rents. Only in our role as motorists do we not pay for parking.

Where the cost of parking a car is included in higher prices for other goods and services, people cannot choose to pay less for parking by using less of it. Bundling the cost of parking into higher prices for everything else therefore distorts consumer choices toward cars and away from other options.

Minimum parking requirements in zoning ordinances promote free parking, but they often hinder development on sites where it is difficult to both construct a building and provide the required parking. They can also hamper adaptive reuse of existing buildings where the new use would require expensive new parking spaces. To mitigate these problems, some cities allow developers to pay a fee in lieu of providing the required parking. For example, Palo Alto, California, allows developers to pay the city $17,848 for each parking space that's not provided. The cities then use the fee revenue to provide publicly owned parking spaces in lieu of the privately owned parking spaces that developers would have provided.

A SURVEY OF IN-LIEU PARKING FEE PROGRAMS

I surveyed the in-lieu parking programs in forty-six cities—twenty-four in the United States, seven in Canada, six in the United Kingdom, six in Germany, two in South Africa, and one in Iceland. I examined the ordinances and supporting documents for the programs and interviewed the officials who administer them.

Officials in the surveyed cities contend that in-lieu fees have advantages for both cities and developers. The following five points summarize these advantages.

1. An Option. In-lieu fees give developers an alternative to meeting parking requirements on sites where providing all the required spaces would be difficult or extremely expensive.

2. Shared Parking. Public parking spaces allow shared use among different sites whose peak parking demands occur at different times. Shared public parking is more efficient than ºsingle-use private parking because fewer spaces are needed to meet the total peak parking demand. Parking that is shared among different establishments also allows motorists to park once and visit multiple sites on foot.

3. Better Urban Design. Cities can put public parking lots and structures where they do not deter vehicle and pedestrian circulation. Less on-site parking allows continuous storefronts without dead gaps for adjacent surface parking lots. To improve the streetscape, some cities dedicate the first floor of public parking structures to retail use. Developers can undertake infill projects without assembling large sites to accommodate on-site parking, and architects have greater freedom to design better buildings in a more pedestrian-friendly environment.

4. Fewer Variances. Developers often request variances from parking requirements. These variances create unearned economic windfalls, granted to some developers but denied to others. If developers can pay cash rather than provide the required parking, cities do not need to grant parking variances and can treat all developers equitably.

5. Historic Preservation. The in-lieu policy makes it easier to preserve historic buildings and rehabilitate historic areas by allowing for alternative locations of parking garages.

Officials in all the surveyed cities judged the in-lieu fees as successful, and they reported that the fees had become a form of administrative relief for developers who do not want to provide the required parking spaces.

WHO DECIDES?

Most cities allow developers the choice of paying the in-lieu fee or providing the required parking, but a few cities *require* developers to pay. Officials in these latter cities say mandated fees encourage shared parking, discourage proliferation of surface parking lots, emphasize continuous shopfronts, improve pedestrian circulation, reduce traffic congestion, and improve urban design.

Some cities also allow property owners to *remove* existing required spaces by paying in-lieu fees. This option can consolidate scattered parking spaces, facilitate reinvestment in older buildings, and encourage more efficient use of scarce land previously committed to surface parking.

IMPACT FEES IMPLICIT IN PARKING REQUIREMENTS

Many cities require developers to pay impact fees to finance public infrastructure—such as roads and schools. Parking requirements resemble impact fees because developers must provide required infrastructure—parking spaces—to obtain building permits. The cost of required parking is typically buried in the cost of development, but in-lieu fees expose the true cost of parking spaces and allow us to express the cost of parking requirements in terms comparable to municipal impact fees. When cities *require* developers to pay the fees rather than provide the parking, the in-lieu fees *are* de facto impact fees.

To compare the price of parking requirements with impact fees, we must first convert the required parking into a cost per square foot of building area. We can do this because the cities' in-lieu fees are their estimates of the cost of providing parking spaces. The in-lieu fees therefore reveal the impact fees implicit in the parking requirements themselves.

The *parking impact fee* depends on (1) the parking requirement (how many spaces per 1,000 square feet), and (2) the in-lieu fee (per parking space). Table 1 presents parking requirements and in-lieu fees for office buildings in the central business districts of twenty-nine cities. The last column shows the parking impact fees implicit in the parking requirements.

The first row shows that Palo Alto requires four parking spaces per 1,000 square feet of gross floor area for office buildings. Palo Alto's in-lieu fee is $17,848 per required parking space not provided, so the parking requirement is equivalent to an impact fee of $71 per square foot of office space (4 x $17,848 ÷ 1,000). A developer who does not provide any parking must pay the city a parking impact fee of $71 per square foot of office space.

The parking impact fees range from $71 per square foot in Palo Alto to $2 per square foot in Waltham Forest. The median parking impact fee is 2.5 times higher in the US cities than in the Canadian cities—$25 per square foot of office space in the US but only $10 per square foot in Canada. US cities have higher parking impact fees because they require more parking, not because they have higher in-lieu fees. The median parking requirement is almost three times higher in the US than in Canada—2.9 spaces per 1,000 square feet in the US but only one space per 1,000 square feet in Canada. The median in-lieu fee is lower in the US ($9,125 per space) than in Canada ($9,781 per space).

The average parking impact fee for the US cities is $31 per square foot of office space, which dwarfs the impact fees levied for all other public purposes. A 1991 survey of one hundred US cities found that the total impact fees for all purposes (roads, schools, parks, water, sewers, flood control, and the like) averaged $6.97 per square foot of office space. The average parking impact fee for office buildings is thus 4.4 times the average impact fee for all other public purposes combined. If impact fees reveal a city's preferences for public services, then it seems that many cities' highest priority is free parking.

Officials in most cities reported that they set the in-lieu fee below the cost of providing a public parking space because the fee would be "too high" if the city charged the full cost. When the cost of required parking is hidden in the cost of development, cost does not seem to matter. But when the cost of required parking is made explicit in cash, everyone can see that it is "too high."

REDUCE DEMAND RATHER THAN INCREASE SUPPLY?

Minimum parking requirements impose high costs, but reform is difficult because parking requirements are entrenched in cities' practice and legislated in zoning ordinances. Nevertheless, allowing developers the option to finance public parking rather than provide private parking suggests another promising in-lieu option: *Allow developers to reduce the demand for parking rather than increase the supply of parking.*

One way to reduce the demand for parking is to make public transit a more viable alternative. For example, employer-paid transit passes reduce the demand for parking at work, and a city can therefore reduce the parking requirements for developers who make a commitment to provide transit passes for all employees at their sites. Suppose that providing free transit passes to all employees at a site reduces parking demand there by one parking space per 1,000 square feet. In this case, a developer's covenant to provide free transit passes to employees at the site would be an appropriate alternative to providing one required parking space per 1,000 square feet.

Some transit agencies offer employers the option of buying Eco Passes that allow all their employees to ride free on all local transit lines. Eco Passes are priced according to their probability of use, and the price per employee is low because many employees do not ride transit even when it is free. Employers can therefore buy Eco Passes for all employees at a low cost. In California's Silicon

TABLE 1

Parking requirements for office buildings in city centers interpreted as impact fees, 1996 (US dollars)

CITY	IN-LIEU PARKING FEE ($/space)	PARKING REQUIREMENT (spaces /1,000 sq ft)	PARKING IMPACT FEE ($/sq ft)
Palo Alto, CA	$17,848	4.0	$71
Beverly Hills, CA	20,180	2.9	59
Walnut Creek, CA	16,373	3.3	55
Kingston upon Thames, UK	20,800	2.3	48
Carmel, CA	27,520	1.7	46
Mountain View, CA	13,000	3.0	39
Sutton, UK	13,360	2.7	36
Harrow, UK	14,352	2.3	33
Hamburg, Germany	20,705	1.5	32
Lake Forest, IL	9,000	3.5	32
Mill Valley, CA	6,751	4.4	30
Palm Springs, CA	9,250	3.1	28
Reykjavik, Iceland	13,000	2.2	28
Claremont, CA	9,000	2.9	26
Concord, CA	8,500	2.9	24
Davis, CA	8,000	2.5	20
Orlando, FL	9,883	2.0	20
Kitchener, Ontario	14,599	1.3	19
Chapel Hill, NC	7,200	2.5	18
Kirkland, WA	6,000	2.9	17
Hermosa Beach, CA	6,000	2.6	16
Berkeley, CA	10,000	1.5	15
Burnaby, British Colombia	7,299	2.0	15
Vancouver, British Colombia	9,708	1.0	10
State College, PA	5,850	1.3	8
Ottawa, Ontario	10,043	0.7	7
Calgary, Alberta	9,781	0.7	7
Port Elizabeth, South Africa	1,846	2.3	4
Waltham Forest, UK	2,000	0.9	2
MEAN	**$11,305**	**2.3**	**$26**
MEDIAN	**$ 9,781**	**2.3**	**$24**

TABLE 2

Eco Pass price schedule, Santa Clara Valley Transportation Authority (annual price per employee)

LOCATION	NUMBER OF EMPLOYEES 1–99	100–4,999	5,000+
Downtown San Jose	$80	$60	$40
Areas served by bus and light rail	$60	$40	$20
Areas served by bus only	$40	$20	$10

Valley, for example, the Santa Clara Valley Transportation Authority (SCVTA) charges from $10 to $80 per employee per year for Eco Passes, depending on an employer's location and number of employees.

Because frequent riders often buy conventional transit passes, transit agencies must price these passes on the assumption that riders will use them frequently. And because transit agencies price transit passes to cover the costs imposed by frequent riders, infrequent riders will not buy them. In contrast, Eco Passes are priced like employer-paid insurance that covers every member of a defined population, and the price of an Eco Pass is therefore much lower than the price of a conventional transit pass. For example, the SCVTA's price for its Eco Pass is only 2 to 19 percent of the price for its conventional transit pass ($420 per year).

COST-EFFECTIVENESS OF EMPLOYER-PAID TRANSIT PASSES

Minimum parking requirements increase the supply of parking, while providing Eco Passes increases the demand for transit. We can estimate the cost-effectiveness of providing Eco Passes in lieu of parking spaces by combining their cost with information on how they reduce the cost of meeting parking requirements.

Employers in Silicon Valley pay $10 to $80 per employee per year for Eco Passes. If there are four employees per 1,000 square feet of office space, Eco Passes will cost from 4¢ to 32¢ per square foot of office space per year. How does this cost of offering Eco Passes to all employees compare with the resulting reduction in the capital cost of providing parking spaces?

The SCVTA serves two of the surveyed cities that have in-lieu parking fees. The cost of providing the parking required for office buildings is $39 per square foot of office space in Mountain View and $71 per square foot of office space in Palo Alto. A survey of Silicon Valley commuters whose employers offered Eco Passes found that commuter parking demand declined by approximately 19 percent. A city might in this case grant a 19-percent reduction in the parking requirement for office developments that offer Eco Passes for all commuters. If the Eco Passes reduce parking requirements by 19 percent, they will reduce the capital cost of providing the required parking spaces by $7.41 per square foot of office space in Mountain View ($39 x 19 percent) and by $13.49 per square foot of office space in Palo Alto ($71 x 19 percent).

In this example, spending between 4¢ and 32¢ per square foot of office space per year to provide Eco Passes would reduce the capital cost of required parking by between $7.41 and $13.49 per square foot. We can convert this relationship into the potential return on each dollar spent for Eco Passes: spending $1 a year to provide Eco Passes will reduce the up-front capital cost to provide required parking by between $23 ($7.41 ÷ 0.32) and $337 ($13.49 ÷ 0.04). The annual cost of the Eco Passes ranges between 0.3 percent and 4.3 percent of the reduction in the upfront capital cost of the required parking. Eco Passes will also reduce the operating and maintenance costs for parking because fewer spaces are required. The low cost of reducing parking demand compared with the high cost of increasing the parking supply shows that Eco Passes are a cost-effective way to reduce the high cost of meeting parking requirements mandated by zoning ordinances.

CONCLUSION: THE HIGH COST OF MINIMUM PARKING REQUIREMENTS

The impact fees implicit in parking requirements dwarf the impact fees for all other public purposes combined. The evidence of high parking impact fees should make it hard for planners to ignore the high cost of minimum parking requirements. Given the high cost of required parking spaces, planners should not assume that the demand for parking automatically justifies minimum parking requirements.

Planners who set parking requirements rarely think about the price that motorists pay for parking. But demand depends on price, and most motorists park free. Planners who require enough spaces to satisfy the existing demand for parking make the mistake of requiring enough spaces to satisfy the demand for *free* parking, no matter how much it costs. In-lieu parking fees unveil the high cost of this mistake. ◆

FURTHER READING

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Donald Shoup, "The High Cost of Free Parking," *Journal of Planning Educaction and Research*, v. 17, no. 1, pp. 3-20, Fall 1997.

Donald Shoup, "In Lieu of Required Parking," *Journal of Planning Education and Research*, v. 18, no. 4, pp. 307-320, Summer 1999.

Willson, Richard, "Suburban Parking Requirements: A Tacit Policy for Automobile Use and Sprawl," *Journal of the American Planning Association,* v. 61, no. 1, pp. 29-42, 1995.

There's No Such Thing as Free Parking

(To view and print pdf files, use Adobe Acrobat Reader available at this link.)

Transportation professionals and policy makers strive to provide the most efficient, convenient and low cost transportation system possible. Regulatory measures are usually employed to achieve these goals and transportation professionals are commonly involved in determining the appropriate implementation tools to meet desired outcomes. Minimum parking requirements is such a tool. Found in zoning ordinances throughout the country, minimum parking requirements attempt to meet a perceived consumer demand for parking based on a particularly type and intensity of land use. But does this common regulatory requirement truly advance the goals of broader transportation policy? In an article entitled, "Instead of Free Parking" (Access, Fall 1999), Donald Shoup of the Institute of Transportation Studies at the University of California, Los Angeles considers the actual effect of minimum parking requirements and provides alternative approaches to meeting the transportation needs of the traveling public.

Current zoning practices promote free parking by enforcing minimum parking standards that ensure every development has ample parking, at no cost to the motorist. Although this has resulted in free parking for 99% of all trips in the U.S., there is no such thing as a truly "free" parking space. Typically, the developer bears the initial cost to purchase land, construct and maintain parking areas. These initial costs are then transferred to the consumer by way of higher prices for housing, office rent, goods, and other services.

Some communities have even noticed that these standards have hindered the adaptive reuse of existing buildings or the development of smaller properties where space is limited. In response, a handful of cities are beginning to allow developers to pay a set fee in-lieu of providing required parking spaces. The money is then set aside by the local government to fund public parking improvements.

Interviews with 46 cities from around the world (including Orlando, FL) that administer such in-lieu parking fee programs revealed that in-lieu fees can range from a few thousand dollars per space in some communities to upwards of $20,000 per space in other communities. The mean amount for all 46 cities was calculated at $11,305 per space. Officials in all of the surveyed cities believed that their in-lieu fee programs were successful and many noted the following advantages:

-

Provides developers with an alternative to meeting the parking requirements

- Promotes the use of shared public parking spaces

- Improves urban design by allowing planners to place public parking spaces in areas where vehicle and pedestrian circulation is not disturbed.

- Reduces the number of parking variance applications thereby treating all developers equitably

- Promotes historic preservation by allowing for alternative locations of parking garages

The survey also found that some communities require developers to pay an in-lieu fee rather than provide parking. In essence, when a community adopts such a program, the fees become de facto impact fees. Impact fees are charges assessed to developments to finance public infrastructure, such as roads, utility lines, and schools. While most of the communities that participated in the study do not require that a mandatory parking impact fee be paid, the study used the city’s in-lieu fee to calculate a hypothetical parking impact fee for each community for comparison purposes.

Using this methodology, it was found that parking impact fees ranged from $71 per square foot in Palo Alto, CA to $2 per square foot in Waltham Forest, United Kingdom. For the cities surveyed within United States, the average parking impact fee equivalent amounted to $26 per square foot, 4.4 times the average impact fee for all other public purposes combined. As noted in the article, “if impact fees reveal a city’s preferences for public services, then it seems that many cities’ highest priority is free parking.”

Given bureaucratic and political obstacles, implementing an in-lieu fee parking program, an alternative approach suggested in the article is to "reduce the demand for parking rather than increase the supply of parking" by making "public transit a more viable alternative." One method suggested in the article involves developers agreeing to offer employer-paid transit passes to on-site employees in order to reduce the demand for parking. Developers offering these passes could, in return, have their parking requirements reduced by the local municipality.

In California, a survey of Silicon Valley commuters whose employers offered passes that allowed employee to ride local transit lines for free found that commuter parking demand declined by approximately 19 percent from previous levels. Given the reduced demand for parking, a local jurisdiction could grant a comparable reduction of required parking spaces to developers that commit to offering transit passes to their on-site employees.

Transportation professionals and policy makers should be made aware of the high public cost of minimum parking requirements. Demand for parking depends on price and most motorists' demand free parking. Transportation professionals need ask themselves if requiring enough parking spaces to satisfying the demand for free parking advances broader community transportation goals.

To view this article, click here or see the Fall 1999 edition of Access or for additional information, contact Dr. Donald Shoup at the University of California, Los Angeles, CA or at shoup@ucla.edu. *Adapted with permission.*

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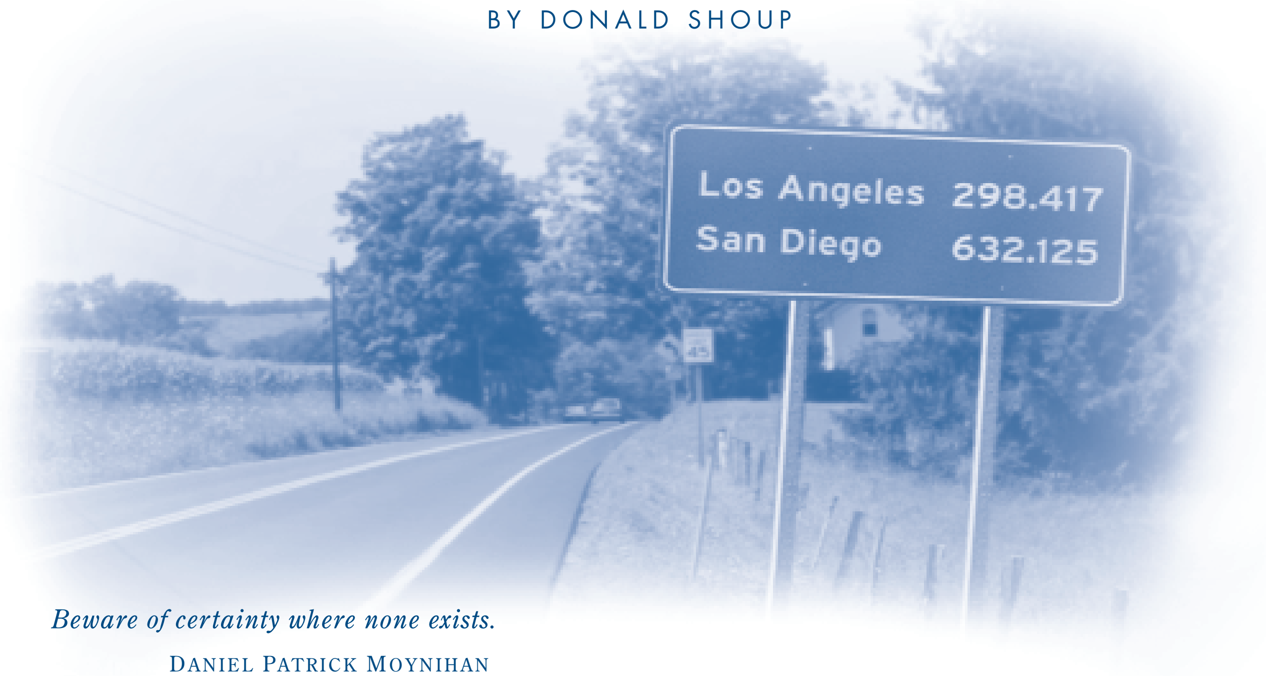
Roughly Right or Precisely Wrong

BY DONALD SHOUP



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 first, because precision implies certainty.

Donald Shoup is professor of urban planning at the University of California, Los Angeles (shoup@ucla.edu). This essay is drawn from a forthcoming article in the Journal of Transportation and Statistics, *vol. 5, no. 2, 2002.*

Although reporting estimates with extreme precision indicates confidence in their accuracy, transportation engineers and urban planners often use precise numbers to report uncertain estimates. To illustrate this practice, I will draw on 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 traffic effects of proposed developments. Many transportation models also incorporate trip generation rates. Yet a close look at the data shows that unwarranted trust in these precise but uncertain estimates of travel behavior can lead to bad transportation, parking, and land-use policies.

Trip Generation

Trip Generation reports the number of vehicle trips as a function of land use. The sixth (and most recent) edition of *Trip Generation* (1997) describes the data base 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.

ITE says nothing about the price of parking, but the 1990 Nationwide Personal Transportation Survey found that parking is free for 99 percent of vehicle trips in the US, so the surveyed sites probably offer free parking. Of the 1,515 trip generation rates, half are based on five or fewer studies, and 23 percent are based on a single study. Trip generation rates thus typically measure the number of vehicle trips observed at a few suburban sites with free parking but no public transit, no nearby pedestrian amenities, and no TDM programs. Urban planners who rely on these trip generation rates as guides when designing transportation systems are therefore reinforcing automobile dependency.

Figure 1 is a facsimile of a 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 point in the

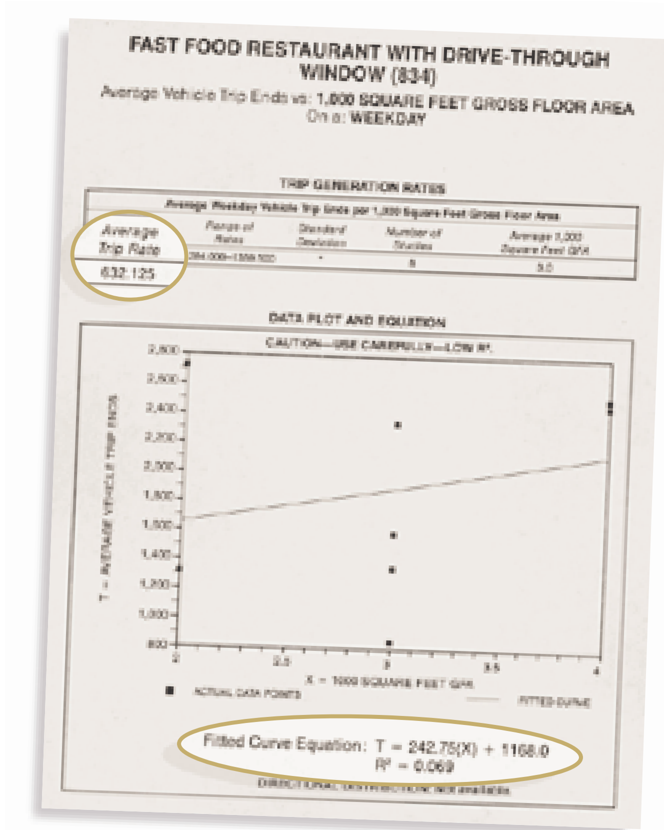


FIGURE 1

figure represents a single restaurant, showing the average number of vehicle trips it generates and its floor area. Dividing the number of vehicle trips by the floor area gives the trip generation rate for that restaurant, and the rates range from 284 to 1,359.5 trips per 1,000 square feet for the eight studies.

A glance at the figure suggests that vehicle trips are unrelated to floor area in this sample, and the equation at the bottom of the figure ($R^2 = 0.069$) confirms this impression. Nevertheless, 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. 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 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.

Reporting an *average* rate suggests that larger restaurants generate more vehicle trips—but according to the figure, the smallest restaurant generated the most trips, and a mid-sized restaurant generated the fewest. The page does contain the ➢

warning, "Caution—Use Carefully—Low R^2," which is good advice because the data show no relationship between vehicle trips and floor area. Nevertheless, the *average* trip generation rate is still reported at the top of the page as if it were relevant. Despite its precision, the number is far too uncertain to use in transportation planning.

Parking Generation

Parking generation rates suffer from similar uncertainty. *Parking Generation* reports the average peak parking occupancy as a function of land use. The most recent edition of *Parking Generation* (1987) explains the survey process:

> 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.

Half the 101 parking generation rates in the second edition are based on four or fewer surveys, and 22 percent are based on a single survey. Therefore, parking generation rates typically measure the peak parking demand observed at a few suburban sites with ample free parking and no public transit. Urban planners who use these rates to set off-street parking requirements are therefore planning a city where people will drive wherever they go and park free when they get there.

Figure 2 shows the page for fast food restaurants from the most recent edition of *Parking Generation* (1987). The equation at the bottom of the figure again confirms the visual impression that parking demand is unrelated to floor area in this sample. The largest restaurant generated one of the lowest peak parking occupancies, while a mid-sized restaurant generated the highest. Nevertheless, 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.

I do not mean to imply that vehicle trips and parking demand are unrelated to a restaurant's size. Common sense suggests some correlation. Nevertheless, we should recognize that these two samples do not show a statistically significant relationship between floor area and either vehicle trips or parking demand, and it is misleading to publish precise average rates based on these data.

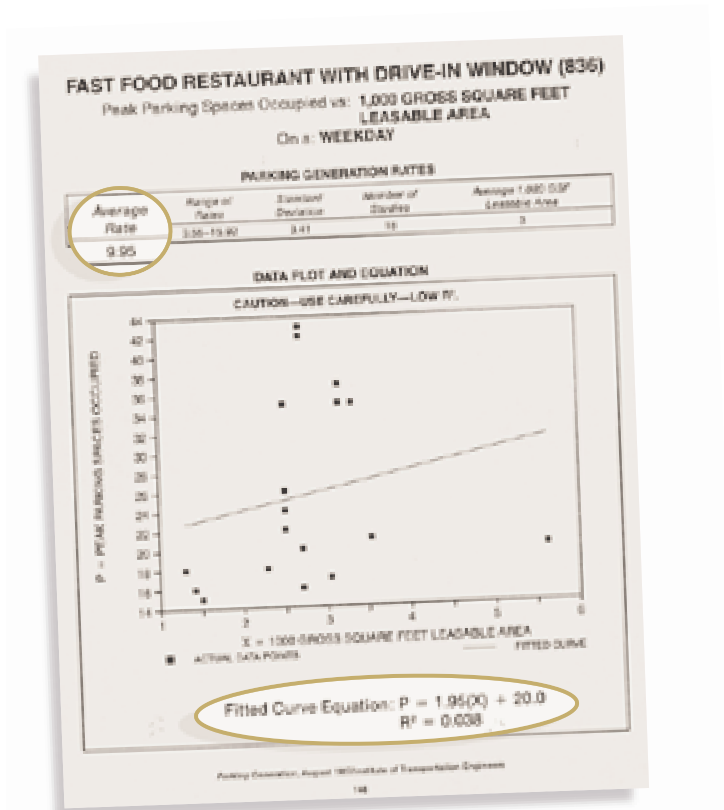


FIGURE 2

ITE's stamp of authority relieves planners from the obligation to think for themselves—the answers are right there in the book. 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 recommend using the parking generation rates as minimum parking requirements because they are the best data available. For example, the median number of parking spaces required by law for fast food restaurants in the US is 10 spaces per 1,000 square feet—almost identical to ITE's reported parking generation rate. After all, planners expect minimum parking requirements to meet the peak demand for free parking, and parking generation rates seem to have predicted this demand precisely! When ITE speaks, urban planners listen.

Statistical Significance

This breathtaking combination of extreme precision and statistical insignificance in the parking and trip generation rates at fast food restaurants raises an important question: how many rates for other land uses are statistically significant? Surely some of the rates must be suspect, but they are all reported to three-digit precision.

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 is 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 lacks a scientific basis. For example, suppose the R^2 is greater than 0.25 (which means that variation in floor area explains more than 25 percent of the variation in vehicle trips), the sample size is greater than 4, and vehicle trips decrease as floor area increases. The first two criteria are met but the third criterion is not. In such a case ITE would report the *average* trip generation rate (which implies that vehicle trips *increase* as floor area increases), but not the equation. The stated policy would therefore conceal evidence that contradicts the predicted relationship.

Figure 3, from the fifth edition of *Trip Generation* (1991), shows how this policy affects the report on fast food restaurants. It shows the same eight data points as the fourth edition, but omits the regression equation, the R^2, as well as the warning "Caution—Use Carefully—Low R^2." (The fifth edition is, however, more cautious about needless precision: it truncates the average trip generation rate from 632.125 to 632.12 trips per 1,000 square feet.)

ITE revised its reporting policy in the most recent edition of *Trip Generation* (1997). Now it shows the regression equation only if the R^2 is greater than or equal to 0.5, but the other two criteria remain the same. This edition reports regression equations for only 34 percent of the reported rates, which means 66 percent of the trip generation rates fail to meet at least one of the three criteria.

Figure 4 shows the trip generation report for a fast food restaurant from the sixth edition. The number of studies increased to 21, and the average trip generation rate fell to 496.12 trips per 1,000 square feet. 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 to fast food restaurants declined 22 percent between 1991 and 1997. But both the previous rate (632.12) and the new one (496.12) were derived from data showing almost no relation between floor area and vehicle trips, so this decline is uncertain.

Not including the equation is ITE's subtle way of pointing out that the information is statistically insignificant, but ➢

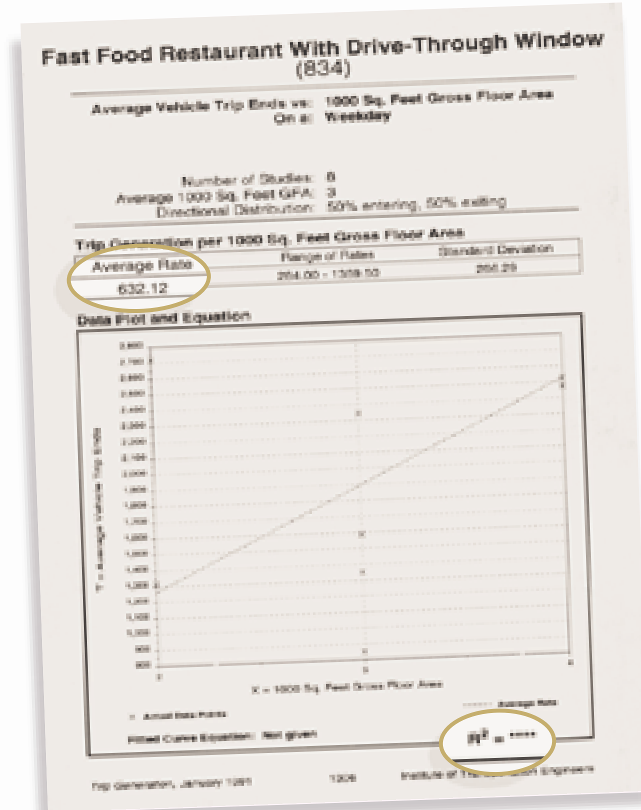


FIGURE 3

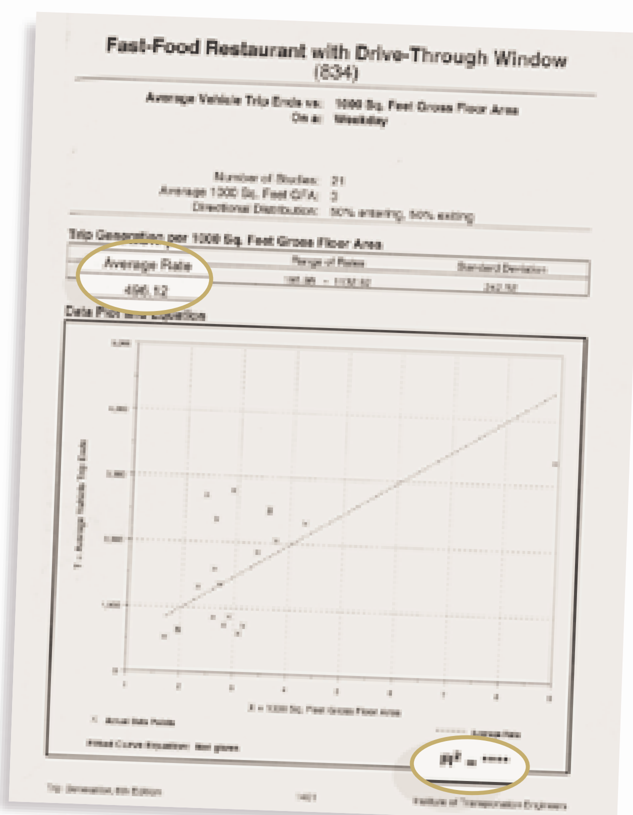


FIGURE 4

reporting the misleadingly precise averages anyway creates serious problems. Many people rely on ITE manuals to predict how urban development will affect parking and traffic. When estimating traffic impacts, 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. But few seem to pay attention to this; in fact, some cities base zoning categories on ITE's trip generation rates. Consider the zoning ordinance in Beverly Hills, California:

> The intensity of use will not exceed either sixteen (16) vehicle trips per hour or 200 vehicle trips per day for each 1,000 gross square foot 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 a city will allow. Once they have been incorporated into municipal codes, parking and trip generation rates are difficult to challenge. Planning is an uncertain activity, but it is difficult to incorporate uncertainty into regulations. Besides, admitting the flimsy basis of zoning decisions would expose them to countless lawsuits.

Planning For Free Parking

Not only are most ITE samples too small to draw statistically significant conclusions, but ITE's method of collecting data also 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 these rates would remain: they measure the peak parking demand and the number of vehicle trips at *suburban sites with ample free parking.*

Consider the process of planning for free parking:

1) Transportation engineers survey peak parking demand at suburban sites with ample free parking, and ITE publishes the results in *Parking Generation* with misleading precision.
2) Urban planners consult *Parking Generation* to set minimum parking requirements. The maximum observed parking demand thus becomes the minimum required parking supply.
3) Developers provide all the required parking. The ample supply of parking drives the price of most parking to zero, which increases vehicle travel.
4) Transportation engineers survey vehicle trips to and from suburban sites with ample free parking, and ITE publishes the results in *Trip Generation* with misleading precision.
5) Transportation planners consult *Trip Generation* to design the transportation system that brings cars to the free parking.
6) Urban planners limit density so that new development with the required free parking will not generate more vehicle trips than nearby roads can carry. This lower density spreads activities farther apart, further increasing vehicle travel and parking demand.

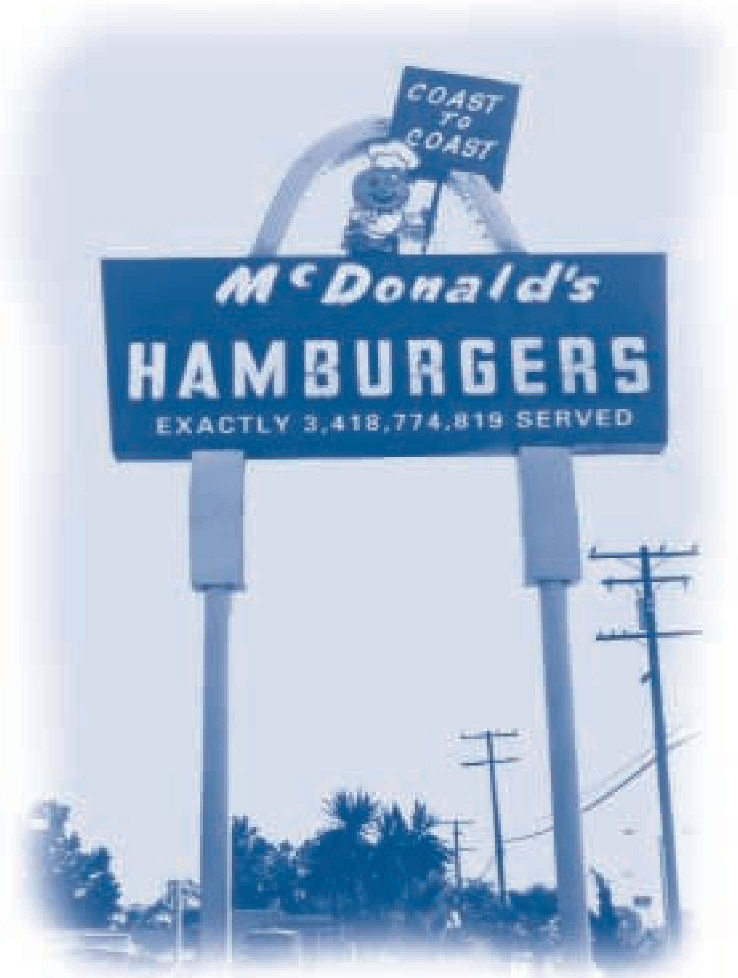
The loop is completed when transportation engineers again survey the peak parking demand at suburban sites that offer free parking and—surprise!—find that more parking is needed. Misusing precise numbers to report uncertain data gives a veneer of rigor to this elaborate but unsystematic practice, and the circular logic explains why planning for transportation and land use has gone subtly, incrementally wrong. Cities require off-street parking without considering parking prices, the cost of parking spaces, or the wider consequences for transportation, land use, the economy, and the environment.

ITE manuals do not *cause* this circular and cumulative process, and ITE of course deplores any misuse of its parking and trip generation rates. ITE warns users to be careful when the R^2 is low, but removed this advice from the data plots in the two most recent editions of *Trip Generation*. ITE also advises:

> 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, there is no suggestion about *how* a user might modify the rates, and the price of parking is prominently *not* on the list of special characteristics that might affect trip generation.

The users of any data should always ask themselves whether the data are appropriate for the intended purpose. Only users can misuse data, but ITE invites such misuse. The spurious precision of ITE's statistically insignificant estimates has helped establish parking requirements and trip generation rates as dogma in the planning profession.



Less Precision And More Truth

Parking and trip generation estimates respond to a real demand for essential information. Citizens want to know how development will affect parking demand and traffic congestion in their neighborhoods. Developers want to know how many parking spaces they should provide for their 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 false precision does not resolve them. To unsophisticated users, the precise rates look like constants, similar to the boiling point of water or the speed of light. Many planners treat parking and trip generation like physical laws and the reported rates like scientific observations. But parking and trip generation are poorly understood phenomena, and they both depend on the price of parking. 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.

American motor vehicles alone 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 four suggestions:

1) ITE should report the parking and trip generation rates as ranges, not as precise averages. This puts the information in the most accessible form for potential users who are not statistically trained.
2) ITE should show the regression equation and the R^2 for each parking and trip generation report, and state whether the floor area (or other independent variable) has a statistically significant relation to parking demand or trip rates.
3) ITE should state in the report for each parking and trip generation rate that the rate refers only to suburban sites with ample free parking and without transit service, pedestrian amenities, or TDM programs.
4) Urban planners should recognize that even if the ITE data were accurate, using them to set parking requirements will contribute to free parking and automobile dependency.

ITE's parking and trip generation rates illustrate a familiar problem with statistics in transportation planning. Placing unwarranted trust in the accuracy of these precise but uncertain data leads to bad policy choices. Being roughly right is better than being precisely wrong. We need less precision—and more truth—in transportation planning. ◆

Further Reading

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Perspectives on Land Use and Transportation

New Urbanism

Access to Choice

(To view and print pdf files, use Adobe Acrobat Reader available at this link.)

Advocates of New Urbanism and other similar planning theories claim that these land use alternatives reduce the need for travel by focusing on accessibility (the ability to reach valued destinations conveniently) rather than mobility (the ability to travel fast). These theories are controversial for a number of reasons, including the following:

- The implementation of these land use alternatives imposes limitations on people's choices about where to live and how to travel,
- Any perceived reduction in vehicle miles traveled (VMT) resulting from the implementation of these land use alternatives is deceptive because any reduction in VMT is actually caused by socio-demographic factors,
- Once self-selection based on travel preference is accounted for, the independent influence of urban form on travel behavior becomes insignificant, and
- The close proximity of origin and destination may actually lead to an increase in the frequency of trips and VMT due to the reduced cost of trip making. Randall Crane, a critic of New Urbanism, goes so far as to assert that New Urbanism and similar land use theories "might unintentionally cause more traffic problems than they solve." (See "Travel by Design" in the Spring 1998 issue of Access, also summarized here on this site),

In his article, "Access to Choice," Access, Spring 1999, Jonathan Levine contends that critics forget that the primary goal of New Urbanism and similar land use alternatives is to increase lifestyle and travel choices, not to reduce VMT. Critics ignore that these choices are currently constrained by regulations on land use alternatives.

Current regulatory codes that shape land development patterns and limit population density, originally established to reduce unhealthy urban living conditions, also restrict transportation and land use options and act as barriers to innovative metropolitan land use patterns. Although land development regulations are not the

only barriers to alternative land use forms, they are the tools used by planners and should, therefore, be examined more critically given their "potential choice-constraining effects." The article argues that loosening these regulations would allow the market to determine which types of developments are viable.

Many planners and transportation researchers determine the effectiveness of alternative developments by their ability to reduce VMT, encourage transit usage, or increase walking. The article contends that although these variables are useful for testing transportation claims, "scientific evidence of their likelihood must not be a precondition for removing regulatory barriers to choice." Even if alternative development forms cause congestion as Crane claimed in "Travel by Design," they should not be avoided because the free-flow of automobiles should not take precedent "over other competing goals such as encouraging pedestrianism, improving the effectiveness of transit, or expanding the range of land use and transportation choice." In addition, the article argues that there is no evidence that New Urbanism increases VMT. Therefore, this speculative argument should not be used to exclude alternative land use arrangements where market demand supports them. Instead, the article claims that the absence of profit will do so much more effectively.

The article claims that concepts such as New Urbanism or transit villages are not useful as long as "transportation policy focuses on the singular goal of mitigating traffic congestion." Instead, the article suggests that U.S. transportation policy should encompass broader objectives that include ensuring that "households are able to match

their land use and transportation environments to their needs and preferences." Ultimately, reducing the barriers to household choices would be a positive goal for U.S. transportation policy even if the benefits of reduced highway congestion were not assured.

To read the original article, click here or see the Spring 1999 edition of Access, published by the University of California Transportation Center or online here. For additional information, contact Dr. Jonathan Levine at the University of Michigan, Ann Arbor, MI 48109-2069 or by e-mail at jlevine@umich.edu *Adapted with permission.*

Mixed Feelings About Mixed-Land Use

(To view and print pdf files, use Adobe Acrobat Reader available at this link.)

Since the 1960's there has been a growing trend to develop residential neighborhoods that are located at a substantial distance from employment and service centers. This change in land use development has led to measurable increases in traffic congestion, pollution, and general unhappiness with suburban life. To reduce the dependency on the automobile and the associated problems, some developers and planners have recommended the development of neo-traditional mixed land use communities incorporating residences, employment, and goods and services so that residents could incorporate alternate forms of transportation such as short driving distances, biking and walking into their daily lives. Yet, despite the interest and claims of the advocates of these neo-traditional mixed land use communities, there has been no substantive data analysis to show a relationship between non-work travel patterns and mixed land use.

In the study, "The Travel Impacts of Mixed Land Use Neighborhoods in Seattle," published by the Transportation Research Board (2001), Edward McCormack, G. Scott Rutherford and Martina G. Wilkinson collected empirical data about neo-traditional land use travel behaviors.

The authors investigated transportation characteristics of residents of mixed-use neighborhoods in Seattle, Washington, and compare them to data collected on the travel patterns of national households and residents who live in traditional suburban areas. For the purposes of the study, the researchers defined neo-traditionalism as characterized by more than one distinct land use, a gridded street pattern, a pedestrian friendly environment and frequent transit service.

This study compared the results of two data sets to find out if travel characteristics differed significantly between residents of mixed-use neighborhoods and residents of communities with homogenous land use. The researchers collected the first data set from three mixed-use neighborhoods considered neo-traditional. Participants completed a two-day travel diary that documented every trip taken. This yielded 15,600 trips from 1,620 individuals. The second data set, the PSRC's Transportation Panel Survey collected in 1989, provided the ability to compare the researchers' finding with county-level travel characteristics. This survey documented 12,00 trips from 663 households. Because this survey was collected first, the researchers modeled their neo-traditional travel diary on the PSRC's survey and had the same contractor randomly contact all households and administered both travel diaries.

The analysis of a variety of trip and household categories suggested that neo-traditional design may have an impact on reducing travel distances. Residents of neo-traditional communities travelled considerably fewer miles per day than suburban developments, especially the outer suburbs. The residents of mixed-use communities recorded more walking and neighborhood trips.

In addition, the data showed that travel time is a more appropriate measure than travel distance for mixed-used communities because transit and walking are slower means of travel. As a result, the reduction of travel for work and chores may simply allow time for other forms of travel that increase automobile usage, thereby confounding the benefits of mixed-use neighborhoods.

Future research on the positive aspects of neo-traditional design should focus on regional characteristics. The data showed that although mixed-use residents had more stops in their neighborhood than other groups studied, these stops comprised only 20 percent of their total trips. Since most trips are taken outside of neighborhoods, residential travel patterns appeared to be more influenced by regional employment and access issues that mixed-use design alone.

Nevertheless, neo-traditional design does appear to be associated with a reduction in travel distances. The neo-traditional movement must conduct further research to determine 1) if this relationship is a direct result of land use and 2) if this travel difference can provide a solution to the problem of increasing urban congestion.

Regression analysis of these non-work travel data found “no evidence that land use patterns explain individual travel patterns when data on other relevant factors are statistically controlled.” However, these results must be cautiously interpreted because they may vary in other regions, highlighting the original point of the article that “transportation benefits of Neotraditional designs are neither certain nor self-evident.”

Although New Urbanist designs provide a “generally thoughtful and attractive alternative” to the banality of modern suburban communities, there is a lack of substantive data to support the argument that these designs influence transportation behavior. More research must be conducted to validate and/or dismiss the many components of New Urbanism efore incorporating these designs into transportation policy.

The full text of this paper is available here or on the 80th Annual Meeting of the Transportation Research Board CD-Rom. For additional information, contact Dr. Edward McCormack at the Washington State Transportation Center, University of Washington, Seattle, WA 98155 or edm@u.washington.edu by email. *Adapted with permission.*

The Travel Impacts of Mixed Land Use Neighborhoods in Seattle

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ABSTRACT

In response to suburban transportation problems, developers and planners have suggested that mixing land uses can reduce automobile dependency by making more goods and services available within walking, biking, and short driving distances. This view has resulted in a neo-traditional planning movement that promotes neighborhoods designed with traditional characteristics including a mix of land uses. However, few studies have empirically explored the transportation implications of these neighborhoods. These research addresses this issue by using a travel diary collected in three greater Seattle area neighborhoods characterized by neo-traditional elements including mixed land use. This data was compared with an identical diary collected thought out the region. It was found that residents of the mixed land use study neighborhoods in Seattle traveled 28 percent fewer miles than adjacent areas and up to 120 percent fewer miles than suburban areas. This trend of lower mileage held across different socioeconomic characteristics. However, the differences among the areas for travel distance are not seen when considering travel time. The daily travel time was about 90 minutes per person (including walking) regardless of where that person lived and their socioeconomic status. One implication of this finding is if a neo-traditional development does make shopping and other chores less time consuming, there may simply be more time in the travel budget for additional regional travel. This suggests that travel from the neo-traditional neighborhoods needs to be examined in a regional context.

INTRODUCTION

Over the past 40 years, a notable change in land use has been the growth of residentially oriented suburban neighborhoods located some distance from employment and service centers. Linked with this growth are increasing levels of traffic congestion, pollution, and general disenchantment with suburban life *(1,2)*. These negative impacts have focused on the potential transportation benefits of traditionally oriented neighborhoods (i.e. neo-traditional) characterized by more diverse land use development patterns *(3,4)*. Developers and planners have suggested that mixing land uses can reduce automobile dependency by making more goods and services available within walking, biking, and short driving distances.

The new interest in mixed land use represents an about-face with regard to the basic assumptions that have shaped urban development patterns over the past 20 or 30 years and has resulted in a body of literature concerned with the relationship between land use and transportation. Much of this literature has been reviewed and analyzed previously and will not be repeated here (see for example, Rutherford, McCormack and Wilkinson *(5)*). In spite of this growing body of literature, the impact of the neo-traditional mixed land use on transportation remains to be demonstrated. For example, a recent study by Boarnet and Sarmiento failed to show a link between land use patterns and non-work travel *(6)*.

Handy in a 1991 article summarized (and anticipated) the complexity and ambiguity of this issue *(7)*. She noted the neo-traditional proponents claim fewer and shorter auto trips, more walking trips, and a greater sense of community in these developments. However, she found that critics and skeptics indicate these claims are not proven and that people may not want to live in these neighborhoods. She concluded that the entire debate over the neo-traditional issue "is greatly in need of substantive arguments, of testing and exploration of issues at a much greater depth than has occurred to date."

This research helps addresses this gap in the literature by using a two-day travel diary and demographic survey of 900 households collected *specifically* to explore the travel characteristics of mixed land-use neighborhood residents. This data set was then compared with identical countywide household travel data collected by the Puget Sound Regional Council (PSRC). The data were analyzed to see whether the travel behavior of residents of mixed-use neighborhoods differed significantly from the travel behavior of residents in areas with more homogenous land use patterns.

THE DATA

This research was based on a comparison of two data sets. The first data set, completed for this study, collected travel data in November of 1992 from three mixed-use land use neighborhoods in the greater Seattle area (King County). The mixed-use neighborhoods selected for the study had characteristics as identified by the neo-traditional movement as important for reducing automobile usage *(3,4,8)*. This included more than one distinct land use (residential as well as other uses such as commercial and recreational), a gridded street pattern, a pedestrian friendly environment, and frequent transit service.

Queen Anne, an older neighborhood located in the City of Seattle, is the smallest of the three study areas. The study area is roughly 0.5 mile by 0.7 mile, centered on a busy shopping street with supermarkets, banks, restaurants, and retail shops. The rest of the study area has many older single family residents, a few multi-family apartments, a handful of retail and office facilities, and several small parks. The streets in this neighborhood form a grid pattern and have sidewalks and on-street parking.

Wallingford is also an older neighborhood in the City of Seattle. The study area is approximately 0.75 mile by 1.25 miles long. The neighborhood's land use is diverse with parks, residences, and a variety of retail and commercial buildings. Two busy arterial streets with concentrations of retail activity cross the area. The area includes many small single-family houses but also a number of two and three story apartments. The streets in this neighborhood are gridded, and have sidewalks and on-street parking.

Kirkland is a suburban neighborhood across Lake Washington from Seattle and is the largest study area being approximately 2.0 miles by 1.2 miles. The area includes a renovated downtown and a mix of housing types. Kirkland's shopping and commercial facilities are somewhat more scattered than those of the other two study neighborhoods but there are concentrations along a major arterial and at a downtown 'core' where two major arterial streets intersect. The core area is notably pedestrian friendly and includes wide sidewalks with street furniture. While much of Kirkland is single family residential on large lots there are pockets of commercial and retail establishments as well as parks scattered throughout the area. Kirkland has a combination of a gridded street pattern and curvilinear streets with cul-de-sacs, which is different from the strictly gridded streets of Wallingford and Queen Anne. There is both on-street parking and parking lots in the area. Kirkland's land use pattern in many ways represents a transition between a mixed-use area and other suburban developments.

Individuals in each of the three mixed-use study neighborhood were initially contacted through a random dialing phone survey. After demographic information was collected, each family member over the age of 15 in the survey household was requested to fill out a two-day travel diary describing every trip taken over that period. Forty-three percent of the people contacted agreed to complete the travel diary and 76 percent returned a completed diary resulting in a data set including 15,600 trips from 1,620 individuals. A project report details the data collection methodology, characteristics of the study neighborhoods, and preliminary data analysis *(9)*.

The second data set, used for comparative county-level travel characteristics, was the PSRC's Transportation Panel Survey. This survey was a major effort aimed at collecting data on the effect of transportation conditions and demographic characteristics on household travel behavior in urban areas. PSRC collected demographic information that was combined with a two-day travel diary conducted on weekdays from September through November 1989. Since the PSRC data collection effort was started before the mixed-use survey project was initiated, the PSRC survey was used as the basis for the design of the mixed-use survey and the same contractor randomly contacted all the households and administered both travel diaries. Only part of the PSRC survey effort (the first wave conducted in 1989) was used for this study. The PSRC data used for this study involved 663 households in King County making almost 12,000 trips (see Murakami and Watterson *(10)* for detailed information on the survey methodology).

DATA ANALYSIS

For the data analysis the travel characteristics of the respondent of the mixed-use neighborhoods and the PSRC survey are compared. The measure of travel frequently used in this paper is *average daily travel mileage per person* (over age 15). This figure expresses the average per-person mileage of all trips made in one day, based on all the survey respondents fitting into the category of interest. Since the PSRC respondents were asked only to include trips five minutes or longer, only mixed-use respondent's weekday trips of more than five minutes duration are included in the comparisons.

Because this study was focused on the geographical location of households, the analysis frequently compared respondents and households from different zones (figure 1). The mixed-use survey neighborhoods of *Queen Anne*, *Wallingford, and Kirkland* made up three zones with 300 households each. The city of Seattle is represented by *north Seattle*. Since *north Seattle* encompasses the Queen Anne and Wallingford study areas but does not have the same mixed land use, these areas are frequently compared in this research. In the PSRC data 176 households were in north Seattle. Two analysis zones were also created based on when the cities or census places in the county were initially developed. One zone, which includes the Kirkland mixed use neighborhood, is an *inner ring*, and contains about 30 cities, surrounding Seattle that were developed in the 1940s, ‘50s and early ‘60s, and included 163 households. The *outer ring* includes both newer suburban developments and the remaining rural and unincorporated portion of King County, and included 248 households.

A summary of demographic characteristics of the mixed-use neighborhoods and the King County analysis zones are shown in Table 1. Overall characteristics for urbanized King County are also include. The two mixed-use neighborhoods within Seattle are similar. The third mixed-use neighborhood, Kirkland, has a higher median age and considerably lower residential density. With the exception of income, North Seattle is much like Queen Anne and Wallingford. Inner and outer King County are also similar to each other and have larger household sizes and higher auto ownership levels than areas in Seattle.

Travel Mileage

Because travel mileage is often a primary indicator of transportation activity, much of the analysis focused on comparing daily travel mileage by respondents in the analysis zones. During this analysis, an effort was made to control for sample bias, which was achieved by comparing travel mileage between similar socioeconomic categories. In some cases, because of small sample sizes analysis zones were at times aggregated.

The average daily mileage by mode for Queen Anne and Wallingford combined (the Seattle mixed-use neighborhoods), Kirkland; north Seattle; and the inner and outer areas (the King County suburban areas) is shown in figure 2**.** For all modes the following progression was observed: the Seattle mixed-use neighborhoods had the lowest mileage per day, north Seattle the next lowest, followed by Kirkland. The King County suburban areas had the highest daily mileage. Across modes, automobile use had the highest mileage. For transit users the difference in average mileage for the two mixed-use neighborhoods and the King County suburban areas was 14 miles per day. For automobile use, this difference was almost 16 miles a day.

The travel mileage data can be broken down in more detail by location. Figure 3 shows some of the same data as above, but disaggregated into the three mixed-use neighborhoods and the three King County zones. As with the previous figure, the Seattle mixed-use neighborhoods had the lowest daily person mileage, and the suburban King County areas had the highest. The Kirkland mixed-use neighborhood respondents had higher mileage than other mixed-use neighborhoods and north Seattle, but lower mileage than the King county suburban zones. This finding supports the idea that Kirkland is a transitional neighborhood between mixed land use and suburban land use.

Regional Work Trips

One concern when comparing the mixed-use and King County data were confounding effects due to differential accessibility to Seattle’s Central Business District (CBD). The CBD is a major employment center for King County, and as such it can be expected to attract a large number of work trips. Both Queen Anne and Wallingford are close to the CBD; Queen Anne is about two miles and Wallingford four miles away. This proximity raised concerns that any average trip length for these two neighborhoods would be shorter than other locations simply because work trips to the CBD would reduce the average trip length and could obscure some of the transportation effects related to mixed use.

As a means of investigating the CBD's capture of work trips, the location of each respondent's workplace was identified for both the mixed-use and King County data. The percentage of work trips that traveled to the Seattle CBD and to other zones was identified and it is apparent that the Seattle CBD is indeed a significant work trip destination for Queen Anne (31 percent) and Wallingford (25 percent). However, the CBD also attracts the same level of work trips from the north Seattle zone (31 percent). This finding is particularly relevant to this research because the north Seattle study area includes the Queen Anne and Wallingford neighborhoods. Because of the equal percentage of work trips traveling to the CBD from each of these areas, we conclude that differences in average trip lengths between these areas are probably not unduly influenced by travel to the CBD.

The analysis also indicates that Seattle's CBD is attracts relatively few work trips from King County's inner (13 percent) and outer zones (7 percent). As expected, most of the work sites for these two zones remained internal to the areas. The majority of the work locations for the Kirkland residents remain within the inner King zone.

Household Location and Commercial Establishments

On tenant of the neo-traditional movement is that a mixed land-use neighborhood promotes local trips because the nearby commercial establishments reduce the need to drive. Since each mixed-use household address was geocoded, it was possible to calculate the straight-line distance between each household and the nearest commercial street and quantify the accessibility of each household to commercial opportunities. Commercial streets were selected based on concentrations of establishments providing goods and services used on a routine basis, including grocery stores, convenience stores, restaurants, dry cleaners, and drug stores.

The ability of local opportunities to reduce the need to drive was then tested by comparing levels of walking for mixed-use residents living at different distances from commercial areas. Figure 4 shows the percentage of shopping trips that were completed on foot by households at five different distances from the commercial streets. This analysis includes only shopping trips that have at least one trip end within a census tract that includes the mixed-use neighborhoods. As expected, the figure indicates that the farther mixed-use inhabitants live from a commercial street, the less likely their shopping trips will be on foot (and more likely in an automobile). This trend is particularly noticeable for the Queen Anne and Wallingford data. Over 65 percent of the residents from Queen Anne and 50 percent of those from Wallingford, who also lived within 0.1 mile of a commercial street, walked to shop. In contrast, fewer than 25 percent of those respondents who lived more than 0.2 mile from commercial establishments walked. (These walk trips could be going anywhere—not just to the local commercial street).

The Kirkland data showed a less obvious trend because of low numbers of walk trips and small survey sample sizes. Kirkland also had a more dispersed pattern of commercial activity than did the other two mixed-use neighborhoods, rendering any patterns less obvious.

Trip Stops

Given the neo-traditional movement's emphasis on trips to locations near home, one factor of interest is how many trip destinations are within a short distance from home. An analysis of trip ends that were local (less than two roadway miles) from each respondent's household shows that the respondents in the mixed-use neighborhoods made almost twice (39 percent versus 18 percent) as many trips to local stops as did the King County respondents. The difference between the data sets is become even more evident for local stops within one mile of a household. Mixed-use residents made 17 percent of their stops locally whereas those living in King County made only 5 percent of their daily stops within one mile of their house.

Transit

Neo-traditional developments are often interchangeably labeled as transit-oriented-developments highlighting the potential role of transit in these areas (Audirac and Shermyen 1994). In an effort to further explore the use of transit, the survey respondents were classified as transit users if they used transit for any trip during a day. Those living in Queen Anne and Wallingford had the most transit users (16 percent of all respondents). North Seattle had slightly higher number of transit users at 18 percent. Kirkland percent of transit users (6 percent) was similar to inner (7 percent) and outer (6 percent) King County. These finding suggest neighborhood design may not be the most important factor influencing transit use. Other factors such as stop location and route frequencies may manner more.

Pedestrian Trips

One commonly stated goal of the neo-traditional movement is increased pedestrian activity. In the mixed-use neighborhoods 11.3 percent of all trips were by pedestrians while in King County 3.6 percent of all trips were by pedestrians. It should be recognized that these percentages may underestimate the number of daily walk trips since they include only trips greater than five minutes in duration. A distribution of walk trips by geographic area is shown in Table 2. The table clearly shows that the mixed-use neighborhoods of Queen Anne and Wallingford had the highest level of walking with around 18 percent of all trips on foot. North

Seattle and Kirkland had fewer walking trips with 7 to 9 percent of all trips on foot. In the suburbs of King County less than 3 percent of all trips were on foot. The most common purpose for walk trips is personal. This is reasonable since many personal trips include walking and running for exercise as well as recreational walking.

Number of Trips

The number of daily trips made by each survey respondent (Table 3) averaged about 5 trips per day for each location. Given that the mixed-use respondents travel fewer miles per day, this suggests that the mixed-use respondent's trips, while as frequent, are a shorter than the respondent's trips from other locations. This average of 5 trips per day holds up for different incomes. Households with children travel more trips per day, across all location than do other households. Females travel slightly more trips per day than do males across all locations.

Travel Time

As with travel mileage, the travel time for the survey respondents can be compared. Table 3 indicates that the great difference in travel mileage between the mixed-use neighborhoods and the King County area is not nearly as apparent as the difference in travel times. Travel time for all groups was about 90 minutes. These observations seem to be confirmed by other analysis. Hupkes summarized trip rates and travel times for the U.S. and European countries and reported the average daily travel per person to range from 65 minutes to 84 minutes *(11).* The U. S. travel time in Hupkes' paper was 83 minutes for 1965/66 and was an average of 44 urban areas. Purvis calculated an average for the San Francisco Bay Area of 82.5 minutes per person in 1990 *(12).* The Seattle area average of about 90 minutes compares fairly well with the Bay Area when you consider that the Seattle survey collected no travel data from those younger than age 15 and the Bay Area started with age 5. NPTS reports shorter and fewer trips for these younger people *(13)* and leaving them out raises the average travel time for those remaining.

Travel Speed

The average speed for each area shows notably lower travel speeds for the Queen Anne and Wallingford respondents compared to other areas (Table 3). Given that these areas had a higher use of the slower transit, bike, and walk modes, and higher levels of congestion, this finding is reasonable.

Travel and Socioeconomic Characteristics

A detailed, descriptive breakdown of the socioeconomic characteristics of the respondents by analysis zone is found in Rutherford, McCormack, and Wilkinson *(5)*. This study found patterns that indicated that travel characteristics of respondents varied depending if they lived in a mixed-use neighborhood or King County analysis zones but showed some stability across socioeconomic categories. Some of the more relevant travel patterns as controlled for by sex, income, and household categories are summarized in table 4. The four household categories used for this research were selected because of characteristics (age, children, number of adults) that are key determinates of travel behavior. For each of these socioeconomic categories, daily travel mileage increased from Seattle mixed-use zones to north Seattle to Kirkland to suburban King County. In most cases, the Queen Anne and Wallingford mixed-use respondents in various socioeconomic groups traveled half the distance per day than did those living in suburban King County.

Because of concerns that travel patterns could be associated with the resident's socioeconomic characteristics instead of the neighborhood location, it was important to further explore socioeconomic characteristics using an analysis of variance (ANOVA) *(14)*. The

ANOVA is a way of testing a null hypothesis that several group means are equal in the population by comparing the sample variance estimated from the group means to that estimated within the group. ANOVA was applied to the household categories and the results indicated that each household category had greater differences between the groups than within the groups (table 5). This was an indication that these categories were able to represent different socioeconomic elements in the survey data.

ANOVA techniques where then used to demonstrate the significance of the variations in travel measures between the analysis zones while also accounting for the household categories. The F-statistic in the table 6 indicates the level of variability of several daily travel characteristics within both zones and household categories. For travel mileage and transit use, the zonal effect is a stronger determinate (a greater F) of travel characteristics than is household characteristics suggesting the location of the household influences these travel characteristics more the household category. The household category had a greater influence on total trips and daily travel time but, as discussed above, these two characteristics had minimal variably across all travel zones suggesting the impact of either location or household is minimal.

CONCLUSION

Residents of the two mixed-use neighborhoods in Seattle traveled 28 percent fewer miles than the remainder of North Seattle, 73 percent fewer than the inner suburbs and 120 percent fewer than the outer suburbs. The trend of traveling fewer miles per day held across different socioeconomic characteristics. The mixed-use resident also walked more and traveled closer to home than other areas in King County. If one of these mixed-use neighborhood were somehow relocated to the outer suburbs would it's travel characteristics remain the same? It's doubtful, but indications from this research based on looking at various breakdowns of trip and household categories, suggest that substantial reductions in travel distances can be accomplished with appropriate urban design.

This paper also gives credence to the few researchers who have looked at travel time rather than distance as a principal measure. The large differences among the areas reported for travel distance are not seen when considering travel time. The travel time was about 90 minutes per person regardless of where that person lived. Variation by age and family life cycle stage was also remarkably small. This "travel time budget" of about 90 minutes is an interesting finding and compares favorably to previously cited studies.

This difference in travel distance for the mixed-use inhabitants, combined with the stability of the travel times, indicates that the mixed-use resident traveled at slower speeds than did inhabitants of other areas of King County. This is reasonable because this research found that the mixed-use inhabitants used slower modes of travel (mainly transit and walking). Gordon and Richardson in a review using Nationwide Personal Transportation Survey data pointed out that while work trip distances have increased, so have travel speeds, supporting the inverse relationship between travel time and speeds as found in this data analysis *(15).*

This slower travel speed in mixed-use neighborhoods combined with a "travel time budget" has an interesting implication for the neo-traditional movement. If a mixed land use does make shopping and other chores more convenient and quicker this may simply leave more time to be used for additional travel. Crane recognized this when he noted that the improved access associated with a mixed land-use neighborhood would reduce the cost of travel and could lead to travel by auto becoming more attractive *(16).* He noted that this could results in the benefits of mixed land-use neighborhoods being greatly overstated.

As Handy (1996) suggests the effectiveness of the neo-traditional movement depends on the travel and destination choices available *(14)*. The findings from this research suggest that this is true in the sense that travel from the neo-traditional neighborhoods need to be examined in a larger regional context. While this study's mixed-use neighborhoods did have four times as many stops within a mile of the neighborhood than did less mixed areas, this was still less than 20 percent of all stops. Clearly most trips taken by the mixed-use resident are out into the region. Thus access and opportunities in the region will have a notable impact on a resident's travel patterns - perhaps more so than neighborhood design by itself.

Based the findings in is study, it does appear that neighborhood characteristics can be associated with different travel. These differences highlight two challenges for understanding the neo-traditional movement. The first is to determine first if these changes can truly be linked to the land use. The second is to determine if these travel differences contain within them a potential solution to worsening urban congestion.

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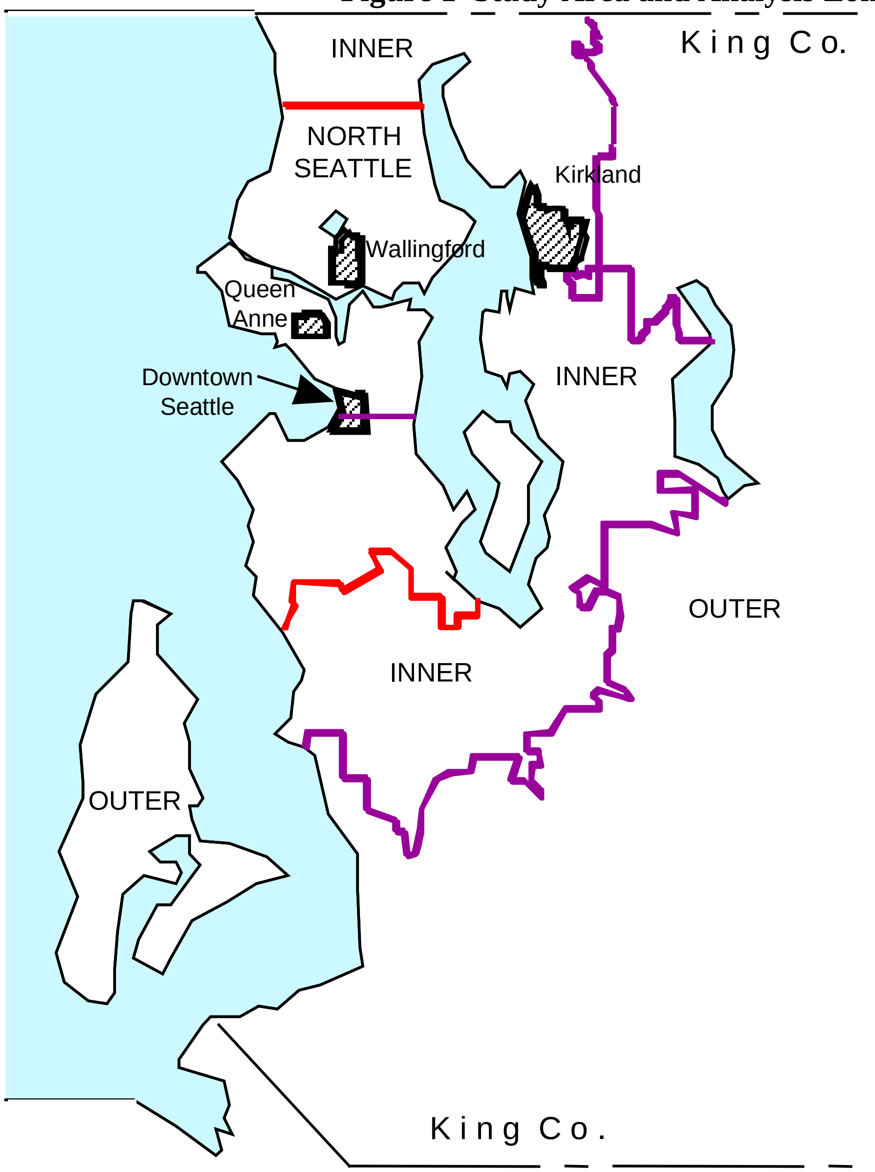
Figure 1 Study Area and Analysis Zones.



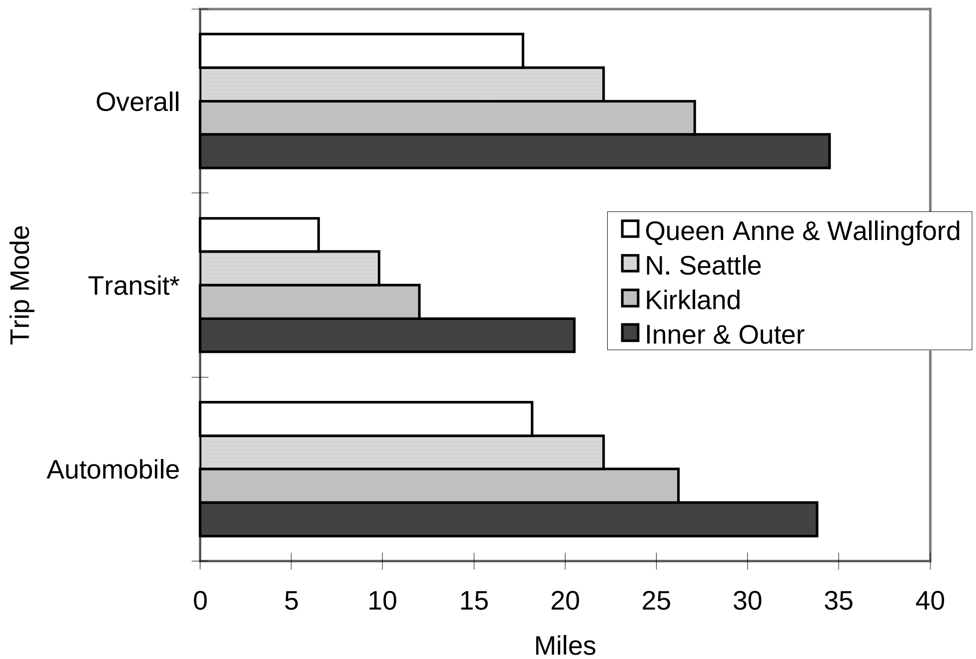


Figure 2 Average Total Daily Mileage by Mode.

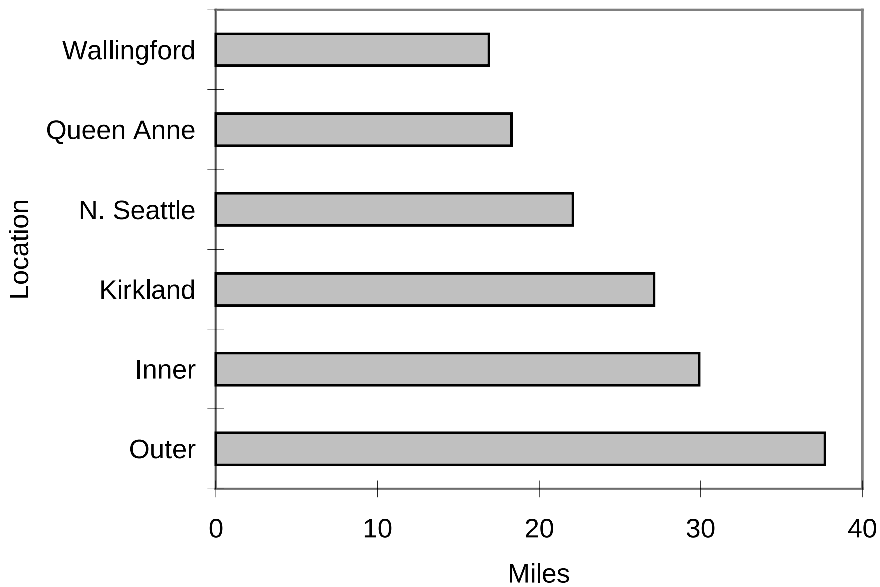


Figure 3 Average Daily Person Mileage by Household Location.

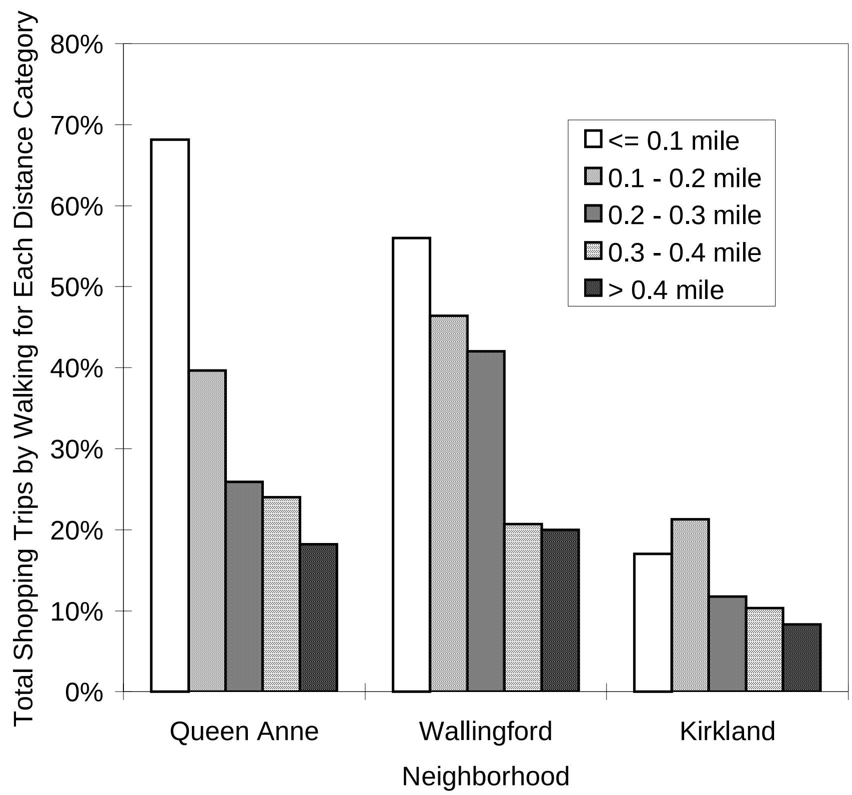


Figure 4 Total Shopping Trips by Walking Related to Household Distance from Commercial Streets.

TABLE 1 Summary of Household Characteristics

Location	Average House-hold Size	Average Number Employees/ Household	Average Number of Vehicles/ Household	Median Age of Persons over 15	Percent Household Income over $35.000	Gross Density-Households per Acre
Queen Anne	2.2	1.4	1.7	39	67%	7.6
Wallingford	2.1	1.3	1.6	37	56%	7.2
North Seattle	1.9	1.2	1.8	37	41%	5.4
Kirkland	2.0	1.0	1.9	47	61%	3.1
Inner	2.5	1.4	2.1	35	56%	1.2
Outer	2.7	1.4	2.2	37	55%	0.2
Urbanized King Co.	2.5	1.3	2.1	37	51%	2.0

TABLE 2 Walk Trips as a Percent of All Trips

	Percent of Walk Trips	Number of trips
Queen Anne	18.1%	610
Wallingford	17.7%	529
North Seattle	8.8%	246
Kirkland	7.8%	227
Inner	2.8%	90
Outer	2.0%	84

TABLE 3 Travel Characteristics by Location

	Average Daily Travel Minutes	Average Daily Travel Mileage	Average Travel Speed (MPH)	Average Daily Trips
Queen Anne	92	18.2	11.9	5.6
Wallingford	91	16.9	11.1	5.0
North Seattle	86	22.4	15.6	5.0
Kirkland	90	27.1	18.1	5.2
Inner	90	30.3	20.2	5.1
Outer	93	38.5	24.8	4.9

TABLE 4 Daily Travel Miles: Location versus Sex, Income, and Household Category

	Sex		Household Income		Household Category			
Location	Male	Female	< $35K	≥ $35K	with child (ren)	one adult	2 or more adults	Senior (65+)
Queen Anne	18.7	16.8	14.9	18.7	18.8	17.8	17.3	15.9
Walling-ford	16.8	16.2	15.3	17.0	17.0	18.8	15.8	14.6
North Seattle	23.5	20.7	20.3	24.3	26.0	19.3	22.5	16.3
Kirkland	28.1	25.9	22.4	29.3	29.1	25.3	29.8	21.5
Inner	31.4	28.7	27.6	32.2	32.0	32.2	29.9	21.6
Outer	39.1	36.3	36.7	37.4	39.6	33.4	37.0	35.4

TABLE 5 Characteristics of the Household Categories

	Household Categories			
	With Children	One Adult	2 or More Adults	One or more >65 years
Average Age*	37	41	40	71
Total Adults*	2.1	1.0	2.3	1.8
Employed*	73%	85%	78%	16%
Drivers license*	93%	95%	96%	88%
Bus Pass*	14%	24%	20%	50%
Income over $35,000*	75%	33%	71%	32%
* ANOVA =with F Probability less than .05				
Number of households	417	322	553	258

TABLE 6 Travel Characteristics: Household versus Analysis Zones

	Household category		Analysis Zone	
	F-statistic	Sig.	F-statistic	Sig.
Daily travel distance	10.6	0.00	118.6	0.00
Daily travel time	7.3	0.22	2.3	0.02
Transit use in day	5.9	0.00	8.1	0.00
Total daily trips	30.1	0.00	5.8	0.00

List of figures and tables:

Trip Generation At Traditional Shopping Centers

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Transportation planners continually strive to reduce traffic congestion and improve roadway efficiency. The most popular ways to achieve these goals have traditionally focused on improving existing roads, constructing new facilities, or encouraging transportation demand management practices. Neotraditional town planners also strive to reduce congestion by designing compact pedestrian-friendly "villages" where goods and services are easily accessible by walking, bicycling, or transit. These villages cluster development where retail shops and services are a short distance from nearby neighborhoods.

In a recent article in the University of California Transportation Center's journal Access entitled "Traditional Shopping Centers," Ruth L. Steiner investigated if a traditional neighborhood or New Urbanist design approach actually reduces automobile usage by promoting both walking and transit usage. The studies were based on six shopping districts that reflected principles of the New Urbanist approach. Located in the San Francisco Bay Area, each district offered employment opportunities and was surrounded by medium-density residential neighborhoods. All but one of the six shopping districts, an old suburban shopping mall, had a continuous sidewalk that abutted retail shops. Four of the six centers were within a half mile of a Bay Area Rapid Transit (BART) station. Studies found that two of these districts selling resident's daily needs were mostly frequented by locals. In other four shopping districts, two attracted almost the same percentages from the locality as from outside, while two that had adjacent BART stations, attracted most of its customers living outside the nearby neighborhood.

Outside visitors were attracted to the area by the charm of the traditional design and the quality of merchandise being offered. As pointed out in the article, “shopping in (these) areas have become popular largely in response to the quality of their goods...crowded streets and frenetic purchasing contribute to a carnival atmosphere that, in itself, serves to attract even more customers.” Although the traditional design encouraged walking from nearby neighborhoods, it simultaneously attracted visitors from the outside who predominantly arrived by automobile. In five of the six districts, it was found that 85 percent of the non-local shoppers drove.

Consistent with the principles of the New Urbanist movement, Steiner found that a considerable percentage of shoppers from the nearby neighborhoods walked to each shopping district, especially when only a short distance was involved. In five of the six districts, the article reported that between 25 and 50 percent of customers walked from the nearby neighborhoods. In three of those districts, almost 66 percent of the residents living within a mile of the shopping area walked. In the remaining district, which was home to the older suburban mall, only 10 percent of all customers walked. As expected, the closer a resident lived to the shopping district, the more willing they were to travel by foot. It was observed that customers who lived less than one mile from the shopping district were the most willing to walk, with the average distance of all walkers being a third of a mile. However, when the shopping trip involved the purchase and transport of groceries or other cumbersome goods, local residents often chose to drive.

Although each district was located near a BART transit center, only a small percentage arrived by BART or bus. Overall, only 5 percent of customers frequenting the retail shops arrived by any form of transit. Customers were more apt to use transit in the shopping districts where there was only a short walk between the BART station and the shops. In the case of one district, 15 percent of customers arrived by BART. In another district where a half-mile walk was involved, only 3 percent arrived by BART. Of those leaving the districts using BART, over a third walked to the BART station. To study whether walking and transit ridership reduced traffic congestion and parking demand, Steiner looked to Institute of Transportation Engineers (ITE) trip generation rates and parking requirements. ITE generation rates provided the number of car trips that each use in each district could be expected to generate. She compared the actual number of customers frequenting the shopping district to the number suggested should be there by the ITE trip generation rate. By counting the number of shoppers in each retail area, it was found that the totals exceeded those predicted by ITE in four of the six districts. In the remaining two districts, activity was less than predicted. Steiner attributed this to the fact that these areas “mostly serve adjacent residents during a short commute period each day.” After subtracting the number of shoppers who did not drive to the district, the remaining amount nearly equaled the ITE trip generation rate or in some cases doubled the rate, most notably on Saturdays. In other words, the traditional shopping districts generated the same or more vehicle trips than conventional shopping developments, even after taking into account shoppers who walked from nearby residential areas.

Parking continued to be in high demand in three of the shopping districts. Areas that attracted a number of residents from outside the neighborhood experienced a high demand for parking. Only one district, where a high percentage of visitors were from the nearby neighborhood, had sufficient parking.

Conclusion

As discovered during this study, many people living in the surrounding area of these traditional districts did indeed walk to the nearby shops. However, these districts also attracted numerous customers from outside the neighborhood who drove. As Steiner stated, "counts and surveys taken during average (not major) shopping days reveal levels of traffic and parking demand in excess of comparable standards for peak demand." Thus, the number of expected automobile trips generated by the retail uses did not decline as New Urbanist theory would suggest. Instead, automobile usage from outside visitors made up for the trips that locals would have completed had they chosen to drive instead of walk. Steiner suggests that placing more high density residences near the district would inevitably increase the number of customers who could walk to the shops. However, retailers in the district, whose business relies significantly on visitors who drive from out-side the immediate area, would still want to attract these types of customers. To do so, they must provide sufficient parking. As concluded in the article, "the New Urbanist's challenge is to incorporate enough parking into the site plan to attract customers without making the physical design unattractive. To design a shopping center only for walkers, or even primarily for walkers, might doom the investment from the start."

To read the original article please see Transportation Research Record 1617 (1998) by Transportation Research Board, or to view the Access article in full, see the Spring 1998 edition of Access, published by the University of California Transportation Center in Berkely, CA, or online *here*.

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Traditional Shopping Centers

BY RUTH L. STEINER

"The alternative to sprawl is simple and timely: neighborhoods of housing, parks and schools placed within walking distance of shops, civic services, jobs and transit—a modern version of the traditional town. The convenience of the car and the opportunity to walk or use transit can be blended in an environment with local access for all the daily needs of a diverse community. It is a strategy which could preserve open space, support transit, reduce auto traffic and create affordable housing."

—Peter Calthorpe

The New Urbanist goal to create pedestrian-friendly transit villages is hard to criticize. Transit villages promise reduced traffic congestion and heightened quality of life. Their formula is simple: Create clusters of houses, shops, jobs, and social services amidst neighborhoods where transit riders and pedestrians outnumber drivers.

Proponents' assert that such districts will change travel behavior and enhance daily activities, ultimately reducing traffic. First, they expect neighborhood retail shops will meet most shopping and service needs of nearby residents. Second, they expect higher density residential developments will attract enough people living within walking distance to support a variety of businesses. Third, they expect people living and working in such neighborhoods will make fewer and shorter automobile trips—that they'll choose walking, cycling, or transit riding more frequently than do residents of lower-density neighborhoods. New Urbanist designs attempt to recreate elements of traditional neighborhoods built prior to World War I. These are typically marked by mixed land use, grid street pattern, and higher than usual density. If possible, they are located at rail-transit stations.

As New Urbanists have become more vocal, so have their critics. They suggest that most people don't wish to live in high-density neighborhoods or near commercial areas. They observe that forecasts of rail-transit riders have been highly exaggerated. They note that where people do use transit, they do so mostly when going to and from work, seldom for routine shopping. Furthermore, they say that people choose to shop where they can readily find their preferred goods at acceptable prices, not simply at the nearest store. Finally, they contend, higher-density residential development will not eliminate traffic congestion because people will still own and use cars.

In an attempt to assess whether the New Urbanist predictions are plausible, I studied six shopping districts located in established, traditional San Francisco Bay Area neighborhoods that exemplify New Urbanist ideals. The districts incorporate the basic design attributes they deem important. Each has a variety of community services and office employment, and each is within walking distance of a neighborhood built on a grid-street pattern. With the exception of an old suburban shopping mall located adjacent to a Bay Area Rapid Transit (BART) station, each has continuous sidewalks fronting clusters of retail shops. Together, they represent the array of sizes and activities considered appropriate to transit villages or main street shopping areas. Each is surrounded by medium-density residential development ➢

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(thirteen to twenty-one persons per gross acre) with households having incomes near the regional median. Four centers are within a half mile of a BART station, offering a test of the transit-village model.

While each shopping district offers grocery stores, restaurants, and convenience services such as banks and pharmacies, they vary in scale and character. The smallest, Kensington, is a classic neighborhood center with twelve retail businesses, including a hairdresser and a video store, along with small medical and other offices. The largest, El Cerrito Plaza, is an old 1960s-style shopping mall directly across from a BART station, but separated from it by a large parking lot. The mall has deteriorated in recent years, especially following the closure of its only department store.

Between those extremes, Market Hall is an upscale neighborhood center immediately adjacent to a BART station. Lining a busy two-lane commercial street, it offers a variety of clothing, antique furniture, and specialty food shops, along with trendy restaurants and many convenience services. Apartments and offices are located on the floors above many of the retail stores. Less than half a mile away, the Alcatraz area is equally bustling, offering similar retail outlets, restaurants, large supermarket, and convenience services. There is no BART station in the immediate vicinity.

Slightly smaller, Elmwood has a quaint, old-town feel, offering a mix of folk art, gifts, clothing, convenience services, and casual restaurants. There is also a movie theater and a post office. The Hopkins area is similar in size, but contains a well-known produce market, specialty food shops, and a horticultural nursery that attract many visitors from outside the area.

I drew data describing the shops and offices and their users from a land-use inventory, formal surveys, open-ended interviews with merchants, and an intercept survey of 1,000 customers in the six shopping areas asking about travel and shopping behavior on the day of the survey. These were followed by a more specific survey that provided demographic and socioeconomic details, descriptions of usual travel patterns, and attitudes towards the shopping district. In addition, users of the BART stations near these shopping areas described their modes of access to BART and their uses of the adjacent shopping areas.

SOME SHOPPERS DO WALK

Consistent with New Urbanists' expectations, I found that significant numbers of customers in each of these shopping districts did indeed walk there. Excluding the old suburban shopping center, to which only about 10 percent of customers walked, 25 to 50 percent of customers reached the other five shopping districts on foot. Residents living within a mile of the shops were most likely to walk; almost 66 percent of residents of three neighborhoods did so. The average walk was a third of a mile; the longest, about two miles; 75 percent walked less than half a mile.

These numbers somewhat understate walking frequency, however, because they include visitors from outside the surrounding neighborhood who obviously couldn't walk. In five of the districts over 85 percent of these outsiders drove. About 15 percent of visitors to Market Hall came by BART, in conjunction with their commute trip; the station is only a crosswalk away. Two shopping areas selling goods primarily for residents' daily needs (Kensington and Alcatraz) attracted a majority of customers from the surrounding neighborhoods. But two others (Elmwood and Hopkins) attracted almost equal percentages from the adjacent neighborhood as from outside. In Elmwood, residents and nonresidents had distinctly different shopping patterns: residents stopped for convenience goods (dry cleaners, pharmacy, hardware) while nonresidents stopped at clothing and gift shops. Patrons at Hopkins were both residents and nonresidents, and primarily shopped for specialty foods. The two shopping areas attracting most of its customers from outside the neighborhood (El Cerrito Plaza and Market Hall) are adjacent to BART stations—even though one is a rundown shopping mall and the other, a trendy commercial center.

Despite the popularity of walking, a significant percentage of each neighborhood's residents drove to the adjacent shopping area. This was especially true in the two areas with adequate parking, where there were more than twice as many drivers as walkers. For those living within a half-mile of the shopping districts without adequate parking, up to 30 percent drove, especially if they were shopping at grocery stores or at several specialty food shops.

TRANSIT RIDING AND USE OF THE SHOPPING AREA

Over a third of BART riders walked to the train from adjacent neighborhoods. However, even though they walked to BART, they didn't stop at shops near the station. Less than 20 percent of BART riders stopped in the adjacent shopping area in conjunction with the transit trip.

Surprisingly few customers came to the shopping districts by public transit, and they made these trips mostly in the late afternoon and evening commute hours. Overall, only about 5 percent of shoppers used any form of transit, evenly split between bus and BART. On weekday afternoons about 20 percent arrived at Market Hall by BART, but BART riders didn't walk long distances after that. Only about 3 percent of customers arriving at Alcatraz had arrived by BART, less than half a mile away.

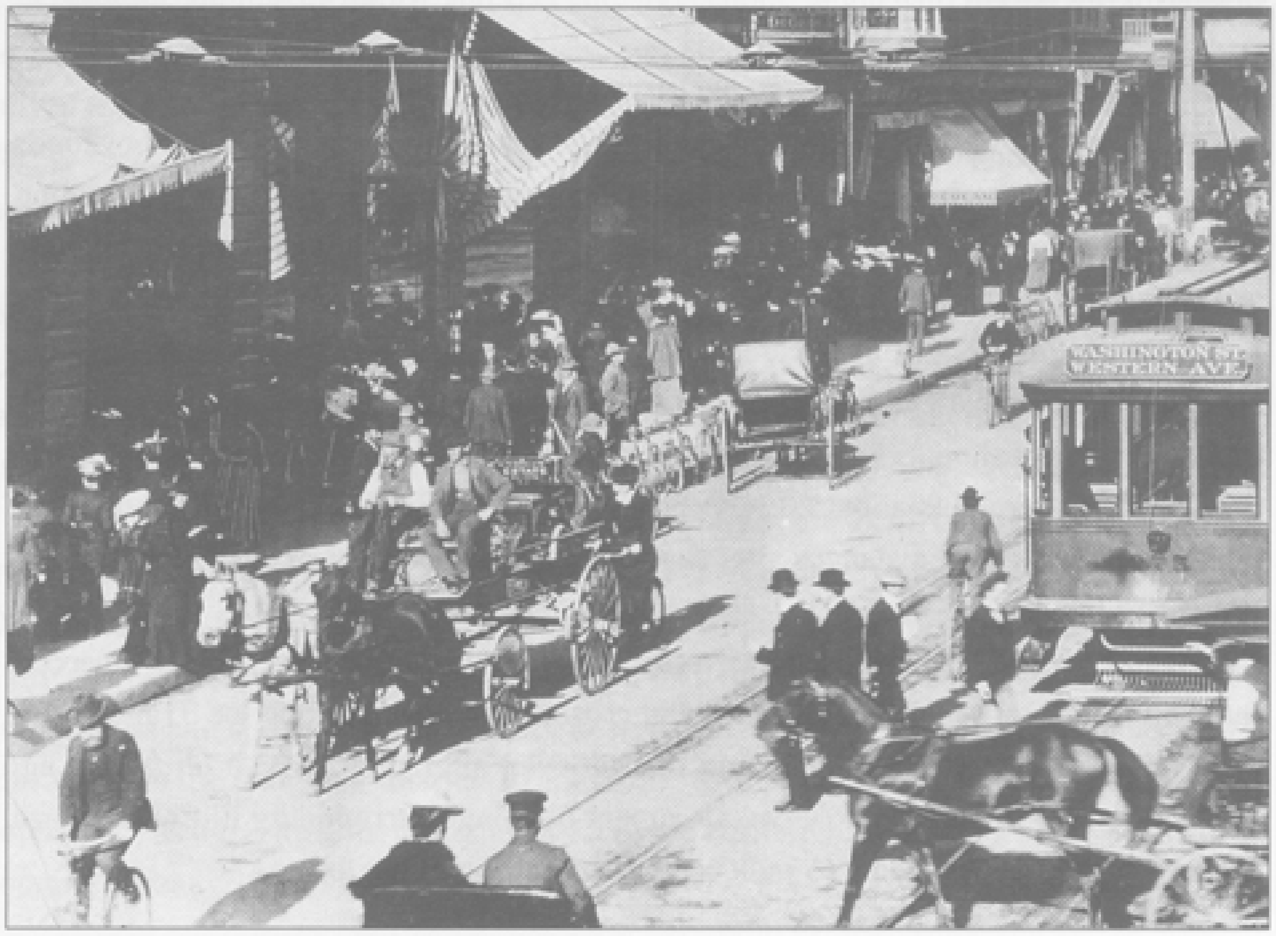
At El Cerrito Plaza, within a quarter of a mile of the BART station, only 2 percent came by BART on weekday afternoons and crossed the large parking lot. Transit users were unlikely to stop in the shopping district even after they arrived on transit and despite the large number of low-rise apartment buildings surrounding El Cerrito Plaza. It seems people are unwilling to walk across extensive parking lots. ➢

TRAFFIC AND PARKING

Thus New Urbanist claims are only partly fulfilled in these six traditional shopping districts. On one hand, a significant percentage of customers walk to these centers. However, because half or more the customers at four of the centers come by car from outside the neighborhood, overall traffic and parking effects are less clear. To estimate these effects, I computed trip-generation rates and hourly parking demand for each shopping area.

These trip-generation rates, based on formulas and categories comparable to those of the Institute of Transportation Engineering (ITE), are based on the square footage of shops in each area and are calculated for weekdays and Saturdays. When these results are compared to numbers of pedestrians actually walking around in these shopping districts on an average weekday, I find more shopping activity in four of these six shopping districts than the ITE method predicted. The other two districts, which show less activity than predicted—El Cerrito Plaza (the declining shopping mall) and Kensington (the small neighborhood center)—mostly serve adjacent residents during a short commute period each day. When trip generation rates are adjusted to account for persons who do not drive, the level of shopping activity more closely resembles the activity level predicted by the ITE method on weekdays. On Saturdays, the trip generation rates resemble the activity predicted by ITE in two of these four shopping areas. In the two other shopping areas, Market Hall and Hopkins, the level of activity is almost twice the comparable ITE trip-generation rates.

I then calculated parking requirements, based on the observed level of shopping activity and the turnover rate of parked automobiles. I compared calculated parking requirements with the ITE standards and with standards advocated by New Urbanists. The ITE standard recommends between four and five parking spaces per 1,000 square feet of retail floorspace. Many New Urbanists consider the ITE standards to be excessive and thus recommend three parking spaces per 1,000 square feet. In three of the



shopping areas (Hopkins, Elmwood, and Market Hall), average hourly parking demand exceeds the minimum recommended by New Urbanists. In one area (Market Hall) demand on Saturdays exceeds even the so-called excessive standards recommended by ITE's method. Interestingly, the number of parking places in each of these three shopping areas is currently at or below the minimum level advocated by New Urbanists. Two other shopping areas (El Cerrito Plaza and Kensington) generate fewer trips than expected. Alcatraz, with a high percentage of visitors from its neighborhood, has sufficient parking spaces.

These results are not surprising when one identifies the customers. Areas with high demand for parking not only attract a large number of customers, they also attract a high percentage of customers from outside the adjacent neighborhoods. Further, the type of shopping in these areas leads a customer to stay in a parking place for a longer time; customers shopping for comparison goods such as clothing, furniture, gifts tend to shop more leisurely than those buying food and other necessities.

CONCLUSION

As New Urbanists suggest, traditional shopping areas generate more walking than is usually associated with shopping trips. However, they also attract a significant number of customers who don't live in the adjacent residential area and who drive there. Even those living in adjacent residential areas may drive, especially if they're grocery shopping.

Despite this high frequency of walking, the promise of less automobile traffic is not realized. Counts and surveys taken during average (not major) shopping days reveal levels of traffic and parking demand in excess of comparable standards for peak demand. Simply put, some of these shopping areas have become popular largely in response to the quality of their goods. Crowded streets and frenetic purchasing contribute to a carnival atmosphere that, in itself, serves to attract even more customers. In turn, large crowds and high quality induce high levels of traffic. Customers come from outside the neighborhood, some from many miles away—in cars that must be parked.

Justification for revitalized Main Streets or transit villages may reside in the sheer physical attractiveness of their urban design in contrast to that of the commonplace shopping mall or retail strip. The transit village's advantage may lie not in reduced traffic, but in its improved retail environment. High density residences may be necessary if the objective is more walking, because people seem willing to walk only short distances.

Investors in shopping areas can't rely exclusively on walkers. So they face a dilemma: To pursue pedestrian-friendly urban design that will entice local residents into walking, they may install just a few parking spaces. But to attract customers from outside the neighborhood, they must provide ample parking. However, a design that incorporates large asphalt areas for cars might deter some from moving into the neighborhood because it would then seem uninviting—and unconducive to walking.

Of course, every shopping center developer and every shopkeeper is eager to attract lots of customers. They don't care whether they come by foot or car. But to attract large numbers they must provide plenty of parking. The New Urbanists's challenge is to incorporate enough parking into the site plan to attract customers without making the physical design unattractive. To design a shopping center only for walkers, or even primarily for walkers, might doom the investment from the start. ◆

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The Urban Network: A Radical Proposal

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As many states experience population growth along with significant migrations to suburban areas, some planners have found that the urban growth problem is only partially resolved by development focused on infill and redevelopment.

In his article, "The Urban Network: A Radical Proposal" published in Planning, June 2002, Peter Calthorpe proposes that "a new paradigm of growth on undeveloped sites" be developed in order to complement the land use forms that have emerged from the New Urbanism and Smart Growth movements. The old paradigm involves a grid of arterials with retail establishments at intersections and commercial strips at visible edges overlaid with a freeway system where malls and office parks are situated.

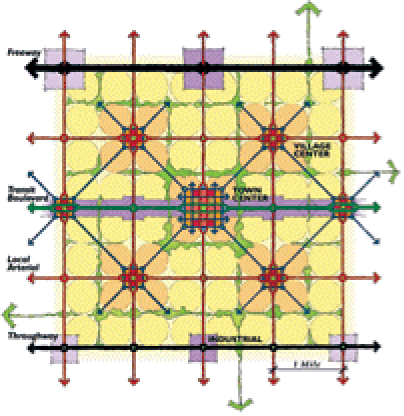
The proposed new network incorporates transit boulevards, throughways, and arterials that allows through-traffic, but does not necessarily bypass commercial areas. This network would make neighborhoods and urban areas accessible to pedestrian movement. Transit would be affordable and integral to the system. This alternative system would be comprised of "roundabouts and couplets of one-way streets" to keep traffic flowing and permit development close to or even within the intersection.

The centerpieces of this proposed network are transit boulevards that would support a variety of transportation modes. Like traditional boulevards, transit boulevards would support small businesses and pedestrian movement as well as transit systems such as the light rail or buses. The transit boulevards would pass through a "town center" every four miles then "split into two one-way streets set a block apart, creating an urban pedestrian-scaled streets." Roundabouts also play an important role in this proposed network. The roundabouts would be placed at one-mile intervals with "infrequent right-in, right-out curb cuts" instead of intersections in order to reduce delays at intersections.

Unlike traditional single function street types, streets would serve multiple purposes consistent with New Urbanist mixed land-use patterns. In addition, retail stores would anchor village centers "at major arterial intersections without being cut off from surrounding development." Couplets and diagonal connector streets would allow pedestrians, bicycles, and automobiles to move through the village center from nearby neighborhoods.

This new urban network proposes an innovative hierarchy of streets and intersection forms as well as land-use patterns that would provide New Urban developments practical mobility and access choices. The article concludes that for new development paradigms to succeed a newly re-designed circulation system with an integrated multi-use street network is needed.

The full text of this paper is available in Planning, June 2002, or online here. For additional information, visit http://www.calthorpe.com. *Adapted with permission.*



The Urban Network: A Radical Proposal

A pitch for a new kind of transportation network.

By Peter Calthorpe

California is expected to grow by 12 million people in the next 20 years. Many other states, while not growing as fast, are also experiencing major migrations to suburban areas as much as we may like development to focus on infill and redevelopment, such efforts will only solve part of the growth problem. Even Portland, Oregon, with its urban growth boundary and strong urban design policies, satisfies only 30 percent of its growth with infill and redevelopment.

There is a critical need for a new paradigm of growth on undeveloped sites — one that complements urban infill and revitalization. This paradigm would match a new circulation system with the new forms of land use now emerging through the New Urbanism and Smart Growth movements.

Our transportation network is still a suburban grid of arterials punctuated by freeways. On occasion, a transit line may overlay this auto-oriented framework, supporting transit-oriented development and the revitalization of some historic towns and cities. But short of that, New Urbanism and Smart Growth are forced to take place within a network designed for sprawl.

The old way

The old paradigm is simple: a grid of arterials spaced at one-mile increments with major retail located at the intersections and commercial strips lining its inhospitable but very visible edges. Overlaying the grid in rings and radials is the freeway system. The intersection of the grid and freeway is fertile ground for malls and office parks. This system is rational, coherent, and true to itself, even if increasingly dysfunctional.

To insist that we must build transit rather than freeways is simplistic, just as calling for infill development to the exclusion of new growth is unrealistic. This is not to say that transit and infill are trivial pursuits, but they are not and never will be the whole story.

We must develop a new circulation pattern that will accommodate cars as well as transit and will reinforce walkable places rather than isolating them. Bringing daily destinations closer to home is a fundamental aspect of urbanism, but it is not the complete solution to our access needs.

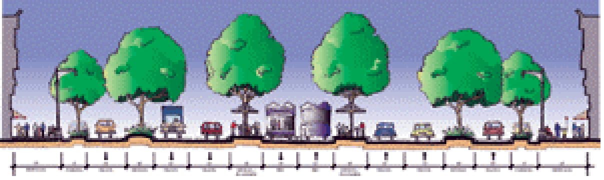
More than ever, regions define our lives. Our job opportunities, cultural interests, and social networks go beyond the borders of any single neighborhood or town. Even if we double the percentage of walkable trips in a neighborhood and triple transit ridership, there still will be massive growth in auto trips — not to mention an exploding quantity of truck miles. We need a system that accommodates all modes efficiently at the same time that it supports urbanism throughout the region.

New, diverse, and complex

The alternative transportation network proposed here is diverse and complex. It calls for a new hierarchy of arterials and boulevards that allow for through-traffic without always bypassing commercial centers — a road network that reinforces access to walkable neighborhoods and urban town centers without cutting them off from local pedestrian movement.

This new network must incorporate transit in a way that is affordable, appropriately placed, and integral to the system. It should reserve freeway capacity for long trips and provide alternate means for daily work commutes and shopping trips.

Our firm has developed such an urban network for Chicago Metropolis 2020, a private regional planning effort of the historic Commercial Club (the group responsible for the Burnham Plan of 1909). The plan for new growth areas around Chicago proposes three types of major roads to replace the standard arterial grid: transit boulevards, throughways, and arterials. The transit



boulevards combine semi-local trips with some form of transit, the throughways are limited-access roads for long trips, and the arterials are similar to our existing grid.

These alternative street types would breed a different set of intersections: roundabouts and couplets of one-way streets. They would replace the slow, over-scaled intersections of our standard, signalized arterials. The roundabouts would expedite traffic on through streets, and the couplets would allow urban development adjacent to and even within a major intersection.

Beautiful boulevards

The transit boulevards are at the heart of this new network. They are multi-functional arterials designed to match the mixed-use urban development they support. Like traditional boulevards, they have a central area for through-traffic and transit. Small-scale access roads support local activities and a pedestrian environment at the edges. The boulevard is a place where cafes, small businesses, apartments, transit, parking, and through-traffic mingle in a simple and time-tested hierarchy.

The transit boulevards would be lined with higher density development and approximately every four miles would run through a "town center." At that point, the boulevard would split into two one-way streets set a block apart, creating an urban grid of pedestrian-scaled streets.

No street would have more than three travel lanes, allowing pedestrian continuity without reducing auto capacity. This one-way system would also eliminate left turn delays, actually decreasing travel time through the area.

The transit system running along the boulevards and through the town centers could be light rail, streetcars, or bus rapid transit. BRT is the most financially viable system for widespread use, particularly with the new super-efficient natural gas engines and advanced bus designs.

In contrast to the boulevards, throughways are single-use roads that provide for truck traffic and longer distance auto trips, much as our older highways do today. They are a viable alternative to congested freeways or stop-and-go arterials.

In our scheme, roundabouts would be placed at one-mile intervals, supplemented by infrequent right-in, right-out curb cuts. The roundabout is particularly important to this system, as its average intersection delay is up to half that of a typical signalized arterial intersection.

The throughway would support truck and auto-oriented land uses, such as low-density manufacturing, warehousing, and light industrial development. In some areas, these roads could be lined with open space areas and greenbelts. The tendency for strip development along such roads would be offset by the availability of development opportunities on the boulevards and local arterials, and in village and town centers.

Local arterials would have frequent intersections — crossing the throughways and boulevards at one-mile intervals — just as our existing suburban system does. At major intersections, an urban couplet could support a village center. In some cases, the local arterials could get a parkway treatment and be lined by large-lot houses backed by alleys, as in the historic neighborhoods of many American cities.

Multi-use, multi-scale

This urban network would replace the old system of functional street types, where streets serve a single function in a linear hierarchy of capacities. The new street types combine uses, capacities, and scales.

The transit boulevards combine the capacity of a major arterial with the intimacy of local frontage roads and the pedestrian orientation that comes with the transit system. Local arterials are multi-lane facilities that transition into a couplet of "main streets" at the village centers. This approach is fundamental to the more complex mixed land-use patterns of the New Urbanism. Streets, like land uses, can no longer afford to be single-purpose.

The urban network integrates new and old forms of urban development in appropriate and accessible locations. Walkable town and village centers are placed at the crossroads of the transit boulevards and local arterials. Residential neighborhoods are directly accessible to these centers by way of local connector streets as well as the arterials. Industrial, warehouse, and other auto-oriented uses are close to the throughways.

Each urban land-use type has the appropriate scale and type of access. The town center is both pedestrian friendly and accessible to the boulevard's through-traffic and transit line. The villages are directly accessible by foot, bus, car, or bicycle from their surrounding neighborhoods, while the couplet streets bring the auto access needed for retail. Auto- and truck-oriented uses can locate at the intersections of the throughways away from the transit and mixed-use centers.

Making retail work

Retail uses within the village and town centers need adequate access and visibility and an appropriate market area. For example, it now takes a minimum of 10,000 people or just under two square miles of mixed-density housing to support a full-service grocery store.

In the urban network, village centers anchored by such stores could be located at major arterial intersections without being cut off from surrounding development. Diagonal connector streets provide direct access for pedestrians, cyclists, and cars from the surrounding neighborhoods, while the couplet allows comfortable pedestrian movement through the center. Surrounding the village are four neighborhoods, each defined by a quarter-mile walking radius and a mix of uses enhanced by access to the village center.

An example of a village center organized this way is San Elijo, about 30 miles north of San Diego. There, a site originally planned around a standard arterial intersection was redesigned to place a village green at the intersection of four one-way streets.

In one quadrant, the grocery store anchors the primary retail area; in others, housing and civic buildings line the streets. Two main streets lead up to the green and mixed-use buildings will surround it. In two of the quadrants, a school and community park complete the center.

A town center contains much more retail along with higher density housing, major office development, and a more extensive street system. Issaquah Highlands, 17 miles east of Seattle, is an example.

This center is placed at the intersection of a major new arterial (projected to carry some 50,000 drivers a day to a new freeway interchange) and the entry to a new community of approximately 3,500 units of housing. The Microsoft Corporation has also acquired part of the town center for a second major campus of approximately three million square feet.

Splitting the arterials into one-way couplets allowed an urban grid to organize the site and provided for a more pedestrian- scaled environment. Under the standard configuration, the primary intersection had a 166-foot pedestrian crossing. In contrast, one of the couplet streets is just 28 feet wide; the other is 40 feet. Traffic engineers found that the auto travel time through the village center was actually reduced by 11 percent when compared to the conventional intersection pattern.

The spacing and configuration of the urban network can and should bend to environmental constraints and existing development. In retrofitting existing suburban areas, selected arterials could be converted into transit boulevards and some intersections reconfigured into paired one-way couplets at redeveloping retail centers.

A radical departure

The urban network is a radical departure from the norm. It posits a new hierarchy of streets, new intersection configurations, and a new set of land-use types. Yet it uses much of the same technology and many of the same institutions that built and are building our current suburban infrastructure.

Road builders would still lay down asphalt; auto makers would still produce cars, and buses as well; developers would continue to build communities. Further, all the advantages of the New Urbanism — its compact, land-saving density, its walkable mix of uses, and its integrated range of housing opportunities — would be supported and amplified by a circulation system that offers real choices in mobility and access.

Smart growth and New Urbanism have begun the work of redefining America's 21st century development paradigms. Now it is time to redefine the circulation armature that supports them. It is shortsighted to think that significant changes in land-use and regional structure can be realized without fundamentally reordering our circulation system. Only an integrated network of urban places and multi-use street systems can support the change we need for the next century of growth.

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Trip and Parking Generation Rates: Truth or Fiction?

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Trip Generation, 6th Edition (and the previous five editions), published by the Institute of Transportation Engineers, contains expected trip generation rates for a variety of land uses. *Parking Generation, 2nd Edition* (and the previous edition), also published by the Institute of Transportation Engineers, contains parking generation rates for a variety of land uses. Planners and engineers rely on information provided in *Trip Generation, 6th Edition* and *Parking Generation, 2nd Edition* for a variety of transportation purposes ranging from estimating potential traffic impacts of a proposed project to establishing minimum parking requirements in local land development codes. Both of these documents are among the most widely used transportation resources in the country and around the world.

In the paper entitled "Truth in Transportation Planning," Dr. Donald Shoup of the University of California Los Angeles contends that the estimates of trip and parking generation rates, though stated as precise numbers in *Trip Generation, 6th Edition* (1997) and *Parking Generation, 2nd Edition* (1987), are in fact, highly uncertain. ITE’s trip generation rates are based on surveys conducted by transportation engineers, planners, and consultants. However, these surveys often produce a wide range of results. For example, in *Trip Generation, 4th Edition* (1987), eight studies were used to determine the trip generation rate of a fast food restaurant. Results ranged from 284 trips to 1360 trips per 1000 square feet of floor area. The R2 (a statistical measure of the ability of the independent variable to predict the dependent variable) showed that floor area explained less than 4 percent of the variation in vehicle trips. Further analysis of the data revealed that no statistically significant relationship existed between floor area and vehicle trips. Yet ITE reported the average trip generation rate as “precisely” 632.125 trips per day per 1000 square feet of floor area with a caution about the low R2. Similarly, trip generation rates for other types of land uses were given in an equally precise manner.

In *Trip Generation, 5th Edition* (1991), ITE revised its policy regarding statistical significance. ITE decided to show best fit curves only when each of the following three conditions were met:

- The R2 is greater than or equal to .25

- The sample size is greater than or equal to 4
- The number of trips increases as the size of the independent variable increases

In *Trip Generation, 6th Edition*, ITE again revised its policy regarding statistical significance. The regression equations would be reported only if the R2 was greater than or equal to .5. The rest of their policy remained the same. In the 6th edition, the trip generation rate for a fast food restaurant calculated using 21 studies showed that the rate declined to 496.12 vehicle trips per 1000 square feet. The R2 was not reported. There is a significant difference between the previously reported 632.12 vehicle trips per 1000 square feet in *Trip Generation, 5th Edition* and the rate of 496.12 vehicle trips per 1000 square feet reported in *Trip Generation, 6th Edition*.

Under this policy, *Trip Generation, 5th Edition* reported the trip generation rate of fast food restaurants (using the same 8 studies discussed above) as precisely 632.12 vehicle trips per 1000 square feet, but omitted the regression equation and the low R2. While the policy was well intentioned, the paper contends that omission of the R2 actually encourages misuse of the data because the low R2 would warn planners to use the rate cautiously.

The rates for a fast food restaurant reported in *Trip Generation, 5th Edition* and *Trip Generation, 6th Edition* were generated from data that showed no statistically significant relationship between floor area and vehicle trips. The paper argues that it is, therefore, difficult to believe that the number of vehicular trips for a fast food restaurant could have declined so substantially between the two editions of ITE informational reports.

In *Parking Generation, 2nd Edition*, the paper suggests that parking generation rates “suffer the same uncertainty” as trip generation rates. Again using a fast-food restaurant as an example, 18

studies were used to determine the parking generation rate reported in *Parking Generation, 2nd Edition* . The range of results from the base data ranged from 3.55 to 15.92 parking spaces per 1000 square feet. Here again, the low R2 showed that floor area explained less than 4 percent of the variation, but ITE reported the average parking generation rate as precisely 9.95 parking spaces per 1000 square feet. While logic suggests that there is a relationship between the restaurant's floor area and parking demand or vehicle trips, there is no statistically significant relationship that has been proven by the data analyzed thus far.

Despite these admitted flaws in parking and trip generation rates, the paper notes that planners and engineers continue to consult the ITE resources because it relieves them of the obligation of conducting their own research. Most land use regulations are based on these precisely stated, but uncertain trip and parking generation rates. The rates are "deeply embedded" in municipal codes and case law so planners are reluctant to admit the "flimsy basis" of ITE's trip and parking generation rates because this could eventually lead to legal challenges.

Additionally, the parking and trip generation rates are calculated from land uses that offer free parking. To satisfy the community demand for free parking, planners establish minimum parking requirements that ensure enough parking spaces are available to meet the peak demand for free parking. The author's arguments regarding free parking are further explored in his article, "Instead of Free Parking," Access, November, 1999. A summary of that article entitled, "There is No Such Thing as Free Parking" is available on this web site.

The paper concludes by making five specific recommendations, including the following two:

- ITE should report parking and trip generation rates as ranges rather than point estimates, and
- ITE should show the regression equation and R2 for each land use in the parking and trip generation reports. In addition, ITE should state whether the coefficient of floor area (or other independent variable) in the equation is significantly different from zero.

The paper suggests that the precision of parking and trip generation rates as reported in the ITE informational reports causes transportation professionals to place misguided confidence in uncertain data that in turn results in poor policy decisions. This argument suggests that less precision would, in fact, introduce more truth into transportation planning.

The full text of this paper is available on the 80th Annual Meeting of the Transportation Research Board CD-ROM or online here. Also available on this site is Dr. Shoup's article, "Roughly Right or

Precisely Wrong" published in Access, no. 20, Spring 2002. For additional information, contact Dr. Donald Shoup at the University of California Los Angeles, CA 90095-165 or by email shoup@ucla.edu *Adapted with permission*.

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We’re Going to Walk Around the Block Tonight!

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Recent research has focused on the link between land use and transportation behavior, bringing into question the nature of that relationship and the very components of trip making. Popular urban design theories such as neo-traditional design, transit-oriented development, and mixed-use development maintain that stimulated pedestrian travel results in traffic benefits such as reduced vehicular trip generation. It has also been suggested that non-work related trips constitute the bulk of the total number of daily trips made.

In a 2001 paper, Michael Greenwald and Marlon Boarnet state that, “taken together, these facts suggest a major component in testing the relationship between land use and transportation is measuring the degree to which land use characteristics influence pedestrian travel behavior for activities other than employment.” Their paper, entitled "The Built Environment as a Determinant of Walking Behavior: Analyzing Non-Work Pedestrian Travel in Portland, Oregon " and presented at the 80th annual meeting of the Transportation Research Board, sets out to test this suggestion.

A regression model (based on a non-work automobile trip generation model) was developed that could take into account the affect that various land use factors might have on non-work walking trip demand. Data used in the study was drawn from travel diaries maintained by residents in the greater Portland, Oregon metropolitan area; including standard socio-demographic data, trip speeds and distances, data on the nature of related activities. Factors integrated into the regression model included:

- A composite pedestrian environment factor based on the ease of street crossing, sidewalk continuity, street connectivity, and topography.
- A measure of the amount of grid street circulation patterns found within a one-quarter mile buffer area encircling each resident’s home.

A “local” population and retail employment density factor based data at Census Block Group level.

- A “regional” population and retail employment density factor based on data at the Zip Code level.

The regression model was applied several times in order to test whether the land use factors affected non-work walking trip generation. First, the model was applied without the benefit of land use factors. This was done in order to establish a base case against which model results taking into account land use factors could be measured against. In following model runs, variables were added to in an effort to demonstrate what effect land use variables would have on local and regional walking behavior.

After testing the models using no land use factors, local land use factors and regional land use factors, the following conclusions were made:

- To the extent that densities do impact walking decision-making, the effect is highly localized and not very important at a regional level (in contrast to previous research findings on non-work automobile trips where regional land use traits were found to be more important).

- Though the elements of New Urbanist practice (emphasizing such things as the mixture of residential to retail uses, jobs to housing balance, enhanced street design, etc.) appear to have some merit, at least in the generation of walking behavior, the relative contribution of the elements is not clear.

- With regard to trip costs, the most important determinant of walking behavior appeared to be trip distances. Shorter distances increased the likelihood of individual walking trips for non-work activities.

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    Because there are no known methodological equivalents for the pedestrian environmental factor or percentage of urban street grid orientation at the regional level, the ability of New Urbanist practices to generate benefits beyond the local level are unfounded, although the model results suggested that regional densities are not as important in determining individual walking behavior as at the local level and that individual trip costs become insignificant as a determinant of walking behavior.

The full text of this paper is available here or on the 80th Annual Meeting of the Transportation Research Board CD-Rom. For additional information, contact Michael J. Greenwald at mgreenwa@uwm.edu or Marlon Boarnet at mgboarne@uci.edu by email. *Adapted with permission.*

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The Built Environment as a Determinant of Walking Behavior: Analyzing Non-Work Pedestrian Travel in Portland, Oregon

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Abstract: Much has been written about the connection between land use/urban form and transportation from the perspective of impacting automobile trip generation. This only addresses half the issue. The theoretical advances in land use/transportation relationships embodied in paradigms such as the jobs housing balance, Neo-Traditional Design (NTD) standards and Transit Oriented Development (TOD) rely very heavily on the generation of pedestrian traffic in order to realize their proposed benefits. The analysis presented here employs similar models and data sets used in Boarnet & Greenwald for the Portland, Oregon area, but applies them towards analysis of non-work walking travel. The results suggest that whatever effects land use has on affecting individual non-work walking trip generation, the impacts take place at the neighborhood level.

The Built Environment as a Determinant of Walking Behavior: Analyzing Non-Work Pedestrian Travel Behavior in Portland, Oregon

Word Count: 4,619 words + 9 Tables * 250 Words/Table

INTRODUCTION

A great deal of time and effort has been expended in the popular planning literature investigating the connection between land use and transportation behavior. Most of this research has focused primarily on the linkages between land use and automotive travel, particularly with regards to commuting behavior (Cervero, 1989 (*1*); Cervero 1996 (*2*); Cervero & Wu, 1998(*3*)). Although this relationship is a large part of the theories guiding the current inquiries, it is still only part of the story. The theoretical advances in land use/transportation relationships embodied in paradigms such as the jobs housing balance, New Urbanism/Neo-Traditional Design (NTD) standards and Transit Oriented Development (TOD) rely very heavily on the generation of pedestrian traffic in order to realize their proposed benefits. In addition, recent evidence suggests work commutes and related activities make up a relatively small proportion of the total number of trips made and distance traveled (FHWA, 1995 (*4*)).

Taken together, these theories and findings suggest a major component in testing the relationship between land use and transportation is measuring the degree to which land use characteristics influence pedestrian travel behavior for activities other than employment. Yet precious little of this research has been done. This work helps to add a missing piece of the puzzle. The analysis presented here employs similar models and data sets used in Boarnet & Greenwald (*5*) for the Portland, Oregon area, but applies them towards analysis of non-work walking travel, using the same data sets from that research. This provides two advantages. First, as this work uses the same data to answer a different key question regarding the linkage between land use and travel behavior, the results here can be used as a starting point for drawing comparison based conclusions about a single population. Second, stemming from this first advantage, to the extent that Portland is representative of other major metropolitan environments, this research speaks to the ability of strategies such as NTD and TOD to achieve their goals of travel mode substitution in different urban settings.

PREVIOUS RESEARCH

Because the research presented here focuses quite heavily on testing the impacts of neo-traditional design, it is appropriate to begin with a brief description of what NTD (and it's related concepts) is. The basics of these strategies are not all that complex; retail and employment centers are to be constructed within walking distance (approximately 15 minutes travel time) of high density multi-family or single family attached housing. Atash (*6*) notes that this is reminiscent of traditional town planning practices of the late 19th and early 20th century. Depending on the specific application of NTD employed (standard NTD, or more specifically transit related TOD), rectilinear street orientation in conjunction with the high population densities plays a major role in promoting travel by means other than personal automobile by facilitating path finding. This focus away from the automobile is reinforced by the use of narrow street right of ways in NTD neighborhoods. Developers who practice NTD strategies point to commercially successful projects as examples that their perspectives are valid (e.g., Kentlands, Maryland and Seaside, Florida for Duany & Plater-Zyberk; Portland, Oregon and Sacramento, California for Calthorpe).

Although the ability to sell one's product in the marketplace can be an indicator in a capitalist society of popular support for the underlying social constructs on which it is based, it is not proof that the theories work in the manner NTD proponents suggest. Crane (*7*) demonstrated that NTD strategies reduced time costs for all modes of travel, and as such these strategies could lead to an increase in automobile travel if the orientation of land usage in these communities did more to reduce impediments to vehicle usage than promote pedestrian behavior. Could NTD backfire?

The initial research in the area of land use/transportation connection suggests that land use characteristics do little to influence individual non-work automobile travel behavior. Boarnet & Crane (*8*) and Boarnet & Sarmiento (*9*) both found that where land use influences travel behavior, the effect is indirect through influencing the non-monetary costs of travel (i.e. time in transit). This is consistent with NTD theory. However, these works also demonstrated that whatever relationship is present is not robust (and possibly highly endogenous with residential choice), as the statistical significance of land use measures changes between models employed. Though these findings are based on the Los Angeles County/Orange County/San Diego County metropolitan region, Boarnet & Greenwald (*5*) verified these results using similar models on the Portland, Oregon region. Yet these works speak only to the impact of land use characteristics on automotive behavior. Without a comparative discussion of impacts on pedestrian behavior, this body of literature is incomplete. It is to this task we now turn.

THE MODELS

Following Crane (*7*), we represent demand for non-work walking trips as

$$N = f(p, y; \mathbf{S}) \qquad (1)$$

where N = the number of non-work walking trips taken by an individual

p = the time cost (or price) of a non-work walking trip

y = individual income

S = a vector of sociodemographic shift (or taste) variables, which will be defined later.

In general, travel cost (p in Equation 1) includes both money and time cost. However, our sample is limited to individuals who are faced with similar money costs. Since all travel diary respondents are from the greater Portland area, we assume that there are no important variations in fuel cost across persons in our sample. Note that this assumption is reasonable, since the greatest variation in fuel costs occurs across rather than within urban areas. Hence the model is simplified to consider only the time cost of travel.

The time cost of travel varies across individuals depending on their respective values of time. Differences in individual time value are captured by income and other sociodemographic characteristics. Following Kitamura, et. al. (*10*), income squared (y^2) is included in the empirical model. Of the studies reviewed earlier, only Kitamura (*10*) gives any attention to the need to control for how the value of time spent driving will change as income levels change. This quadratic representation is intended to capture both the extent to which non-work trip-making is a normal good and the extent to which time spent driving is more valuable (and thus more costly) for persons with higher income.

Given the inclusion of prices (here, time cost) and income in the non-work walking trip generation model -- standard practice in any application of the theory of consumer demand -- the tricky question involves how land use might enter into a specification like Equation 1. Following Boarnet and Crane (*8*), we test two specifications.

Model 1: Price Variation that is Completely Determined by Observable Land Use Characteristics

Perhaps the differences in time costs of non-work trips can be completely explained by differences in land use patterns. In other words, land use might affect non-work pedestrian trip frequencies by directly affecting the price, e.g. time cost, of travel. This is shown below.

$$p = f(\mathbf{L}) \qquad (2)$$

where **L** is a vector of land use or urban design characteristics. Substituting Equation 2 into Equation 1 gives

$$N = f(\mathbf{L},y;\mathbf{S}) \quad (3)$$

The model in Equation 3 is a reduced form which reflects the assumption that differences in the time cost of travel are due to differences in land use and urban design at different locations. Yet if land use and design are measured incompletely, which is plausible given the difficulty of operationalizing and measuring the characteristics associated with, e.g., the New Urbanism, there might be differences in the time cost of travel even after the land use variables are introduced into a trip generation regression. Crepeau (*11*) addresses this point directly, saying the literature examining land use and transportation has up to this point been constrained by the use of proxy variables for land use such as population and retail densities at different levels of geography (e.g., zip code, census tract, or transportation analysis zone). According to Crepeau, though these variables are readily available and relatively easy to incorporate and interpret in existing models, they do not get to the heart of incorporating land use characteristics into travel behavior. This suggests the next model.

Model 2: Include both Price Variables and Land Use Variables in the Trip Generation Regression

Both the price variable, p, and the land use variables, L, can be used in a regression equation, as shown below.

$$N_a = f(p, y,; \mathbf{L}, \mathbf{S}) \qquad (4)$$

The time-cost variable p can be broken down into two components, trip distances and trip speeds. These variables can be more easily linked to policy, since urban designs have been proposed with the explicit intent of, for example, changing automobile trip speeds (e.g. traffic calming) or changing trip distances (e.g. mixed land uses or more direct, grid-oriented, street patterns). The result of representing the variable p by trip distances and trip speeds is shown below.

$$N = f(m, t, y; \mathbf{L}, \mathbf{S}) \qquad (5)$$

where m = non-work trip distance

t = non-work trip speed.

Following Crane and Crepeau (*12*), we use the median of non-work trip distances (m) and non-work trip speeds (t) for each travel diary respondent.

DATA

The Portland Travel Diary for 1994 is a two day travel diary collected for individuals in the three county area surrounding Portland Oregon. Information was collected on standard socio-demographic data, trip speeds and distances, and nature of related activities. Table 1 provides a list of variables used in the regressions presented here.

(***Insert Table 1 Here***)

The exogenous socio-demographic variables used here are identical to those used in Boarnet and Greenwald (*5*). The land use variables are also the same, with the following exception. Boarnet and Greenwald used a derivative of the Pedestrian Environment Factor (PEF) score to incorporate urban form into the discussion of non-work automobile trip generation. The score is a composite generated on four criteria: ease of street crossing, sidewalk continuity, street connectivity (grid vs. cul-de-sac) and topography. In that work, each category was scored on a scale from one to four (four being the best ranking), so each transportation analysis zone had a maximum possible score of 16 and a minimum of four. The higher the score, the greater the degree to which the zone accommodates non-automobile based travel.

The PEF score used in Boarnet and Greenwald were modifications of the original pedestrian factors developed by the 1,000 Friends of Oregon, created specifically for the purpose of measuring the degree to which specific transportation analysis zones facilitated pedestrian travel (*13*). These changes were made to incorporate the PEF score into Emme2 traffic modeling as part of the Portland Metro regional planning process. However, since this process focused on automobile usage as opposed to pedestrian travel, we chose to use the original PEF scores developed by the 1,000 Friends of Oregon. These scores measure the same attributes, but have a slightly different scoring scale, ranging from a maximum of 12 to a minimum of four.

The PCTGRID variable was created using GIS software by buffering within one quarter mile of the home location of each individual respondent, then summing the land area of all street sections within that buffer that were of a quadrilateral nature. That sum was then divided by the area of the quarter mile radius circle to get a proportion of the buffer area covered by a grid street pattern. This leads to a measure of street patterns that is similar to the one used in Boarnet and Sarmiento (*9*). The incorporation of the PCTGRID and pedestrian based PEF variables are direct attempts to address the points raised by Crepeau (*11*).

RESULTS

The analysis presented here is conducted at two similar levels of geography for the local level. Census block groups and transportation analysis zones were chosen due to their similarity in geographic scale for the region under investigation. Visual comparison of maps for the Portland Metro region suggest that transportation analysis zones are contiguous with individual census block groups or combinations of adjacent block groups. In addition, this finer level of geographic detail allows for more localized observations, making these findings more in line with the scale of geography intended by neo-traditionalist proponents and New Urbanists.

Table 2 shows the results of an ordered probit regression for non-work walking trip frequencies.

(***Insert Table 2 Here***)

The independent variables in the first column of Table 2 are socio-demographic characteristics of the individual traveler or their family; this regression provides a framework against which to measure the effects of land use on influencing individual travel decision making. The results in column 1 confirm behavior patterns one would expect to see with regards to walking trip generation. Age reduces the likelihood of walking trips, as does the number of cars per driver in the household, though both of these results evaporate as land use characteristics are incorporated into the models. Households with more children consistently make more walking trips, while households with greater numbers of employed persons tend to make fewer non-work walking trips. One possible explanation for the latter effect is that some non-work activities are tied to the work commute, which is less likely to be completed exclusively on foot.

Columns 2 and 3 of Table 2 demonstrate what effect land use variables have on local walking behavior. Column 2 indicates that in the presence of land use considerations, the only variable that significantly predicts non-work walking behavior is the number of children per household. This is most likely an artifact of the specific regression, due to the loss of degrees of freedom associated with the PCTGRID variable. When this variable is removed in the Column 3 model, the statistical significance of children in the household is maintained and the importance of the number of employed persons per household returns. Additionally, the importance of traveling on workdays and census block group population density is revealed;

fewer non-work walking trips are expected on weekdays, and population density positively affects the likelihood of non-work travel being completed by walking trips. This last point speaks directly to the New Urbanist contention that density affects walking behavior, a contention bolstered by the fact that as trip cost variables (median walking distance and speeds for individuals) are added in Column 4, block group density becomes an even stronger predictor of walking behavior.

Ideally, one would expect all land use variables to be significantly related to non-work walking behavior. However, correlation between the land use measures is high enough to question whether or not including all urban form variables in the same model will mask the effects each is contributing to the behavioral pattern under examination (correlations for block group population density compared with retail density and PEF scores were r=.4363 and r=.5026, respectively). Table 3 shows a joint significance test for the set of local land use measures, per the strategy used by Boarnet & Sarmiento (*9*).

(Insert Table 3 Here)

The differences in log-likelihood results between the unrestricted model (i.e., including the full set of land use variables, less the PCTGRID variable for reasons already mentioned) and the restricted model (the basic model without any land use characteristics) is sufficiently large to imply that the land use variables as a set are significant in determining probabilities of non-work walking travel. Table 4 further supports this point by running the base model with each land use characteristic included separately. In each case the land use variables are significant and of the expected sign with regards to the New Urbanist paradigms.

(Insert Table 4 Here)

The results from Tables 2 through 4 beg the question of whether or not these observations are indicative of an effect beyond the local scale. Does land use affect walking behavior at the regional level? Tables 5 and 6 speak to this issue by employing the same models for population and retail density that were used in Tables 2 and 3 for the ZIP code level of analysis.

(Insert Tables 5 and 6 Here)

Direct measures of urban form are not employed in these latest tables because there are no methodological equivalents of pedestrian environmental factor or percentage of urban street grid orientation at the regional level known to the authors at this time. The results in Table 5 suggest regional densities are not as important in determining individual walking behavior, as indicated by the insignificance of the population and retail density variables. Additionally, individual trip costs become insignificant when analyzed in the context of regional variables, lending further support to the idea that land use impacts on pedestrian travel have highly localized impacts, and results in Table 6 argue that regional densities are not significantly useful as a set of predictors.

The results in Tables 5 and 6 should not be taken as the final word on regional impacts of New Urbanist practices. Though the standardized scores for population density in ZIP codes are strictly insignificant at the traditional five percent level, they are sufficiently close to the critical values to imply that these results are artifacts of this particular data set; magnitude and sign are still preserved. In addition, without similar urban form measures at the regional level any comparisons between the results in Tables 2 and 5 are unwarranted.

FEEDBACK BETWEEN RESIDENTIAL LOCATION CHOICE AND TRAVEL BEHAVIOR

Up to this point we have made the assumption that travel behavior is the exogenous component of land use/transportation relationships; urban form dictates travel behavior.

However, a plausible alternative explanation does exist. Perhaps individuals who prefer to travel by pedestrian modes select into residential locations where the urban environment facilitates this type of behavior. The observed relationship between land use and transportation would not in this situation be indicative of support for New Urbanist practices as a method for altering travel behavior.

To demonstrate the problem formally, we expand the model represented by Equation 3 in Section III. Assume the number of non-work walking trips is approximately continuous, such that the number of such trips is given by

$$N = a_0 + a_1'\mathbf{L} + a_2 y + a_3 y^2 + a_4'\mathbf{S} + u \qquad (9)$$

where u = the regression error term.

If persons choose residential locations (and thus land use patterns near their residence) based on unobserved preferences which are correlated with attitudes about walking (or any other mode of transportation), the variables in the **L** vector can be correlated with **u**, the error term in Equation 9. Under those circumstances, the least squares parameter estimates for the above equation will be biased and inconsistent. As in other situations where independent variables are correlated with the regression error term, a solution is to use instrumental variables.

Choice of instruments in this situation requires careful consideration. The instrumental variables selected must be highly correlated with urban form yet not significantly correlated with **u.** The residential location of an individual is a function of individual and location characteristics, shown below.

$$ResLoc_i = f(\mathbf{C}_i, \mathbf{A}_i) \qquad (10)$$

where $ResLoc_i$ denotes the residence location for person "i"

$\mathbf{C}_i$ = individual sociodemographic characteristics

A_i = characteristics of residential locations, including location-specific amenities such as school quality, the demographic composition of the surrounding neighborhood, and the age of the housing stock in the surrounding neighborhood.

The variables in Equation 10, because they explain residential location choice, are potential instruments for the **L** variables in Equation 9. Of the variables in Equation 10, the individual characteristics in **C** are likely to be the same as the demographic variables in **S**, leaving only the non-transportation neighborhood amenities in **A** as allowable instruments. We select six non-transportation neighborhood amenities as instruments, listed below.

PCINCBG - Per capita income in the area (Census Block Group only)

PCTCOLLEGE – Percentage of population living in geographic area with at least a college education.

PCTBLK - Percentage of population identified as African American from the 1990 Census living in the geographic area

PCTHSP - Percentage of population identified as Hispanic from the 1990 Census living in the geographic area

PCTNFRM - Percentage of housing units in the geographic area classified as rural and not classified as farms

PCTURB - Percentage of housing units in the geographic area classified as urban dwelling units.

All instruments are taken from the 1990 U.S. Census (*14*). The ethnicity based instruments are reminiscent of Boarnet and Crane, Boarnet and Sarmiento and Boarnet and Greenwald (*8, 9, 5*). The education and income instruments are selected to get at previously unexamined aspects of the **C** matrix that might impinge on location choice. Individuals might choose residential location on aspects of similarity other than ethnicity, and income and educational attainment are strong indicators of socioeconomic class. The housing stock instruments selected for density and urban form variables were chosen because they come closer to measuring the realized physical characteristics of the surrounding environment than the housing stock age instruments used by the Boarnet and Crane, Boarnet and Sarmiento and Boarnet and Greenwald inquiries (*8, 9, 5*).

Tables 7 and 8 show how successful was the use of instrumental variables analysis for location choice.

(Insert Table 7 Here)

For Table 7, the instrument set was valid for all land use variables except retail density, as indicated by the overidentification tests conducted on each IV model (note; the null hypothesis for overidentification tests is that the instrument set is valid). Of the three remaining valid instrumental regressions, two continue to support the conclusion that New Urbanist practices promote walking behavior for non-work travel, when considered individually. Block group population density and PEF score are both significant individually in both the ordinary least squares and the instrumental variable regressions. The PCTGRID variable, though significant in the ordinary least squares model, becomes insignificant when instrumented. The socio-demographic and trip cost variables in each case exhibit the trends seen in Table 2, where only trip distances were a significant predictor for probabilities of non-work walking behavior.

Table 8 continues to support the conclusion that densities play a smaller role in generating non-work walking behavior at the regional level.

(Insert Table 8 Here)

The instrument set employed in the Table 8 regressions is slightly different in that it does not include a per capita income measure. Including this instrument would have made both instrumental regressions at the ZIP code level invalid. Again we find that regional population and retail densities are statistically insignificant in promotion of individual walking behavior for non-work trips.

CONCLUSIONS

In this paper, we have analyzed the impacts of land use on decisions for non-work walking travel. Several lessons are apparent from this investigation. First, to the extent that densities do impact walking decision making, this effect is highly localized. This stands in stark contrast to previous findings regarding non-work automobile travel, where regional land use traits are more important (Boarnet & Sarmiento, Boarnet & Greenwald (*9,5*)).

Second, though the elements of New Urbanist practices appear to have some merit, at least in the generation of walking behavior, the relative contribution of the elements is anything but clear. This is most likely due to correlation between the urban form variables and the density measures employed here, though the joint significance test in Table 3 and the individual contributions demonstrated in Table 4 suggest that each of these factors alone, or together in subsets, has the potential to influence walking behavior for non-work activities.

Third, with regards to trip costs, the most important determinant of walking behavior appears to be trip distances; shorter distances increase the likelihood of individual walking trips for non-work activities. New Urbanist and TOD practitioners are thus quite correct to focus on this aspect of urban design if they wish to promote pedestrian behavior as an alternative to personal vehicle use.

Finally, without the ability to test the importance of regional urban form variables any discussions about the ability of New Urbanist practices to generate benefits beyond the local level are unfounded. The use of direct measurements of urban form are a necessary precursor to testing land use/transportation practices, and the geographic scale of analysis can only legitimately proceed as far as these measurements have or can be developed. We now have reason to believe that neighborhood level urban form can influence walking behavior; this is of course useful to local planners whose job it is to optimize the operation of their specific jurisdictions. Whether or not that influence extends beyond one's immediate surroundings, and thus can be used by regional analysts, remains to be seen.

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TABLE 1 Variable Names and Definitions

Dependent Variable

NWTRIPS	Number of non-work walking trips per person over two day travel diary period

Socio-Demographic Variables

AGE	Age of individual respondent
CARSPRDR	Number of cars per licensed driver in household
GENDER	Gender of individual (1=Female, 0=Male)
INCOME	Household income
INCOMESQ	Household income squared
KIDS	Number of children under the age of 16 per household
NUMEMPLY	Number of employed workers per household
RACE	Ethnicity of individual respondent (1 = white, 0 = non-white)

Neighborhood Level Land Use Variables

PCTGRID	Percentage of area in 1/4 mile buffer zone covered by grid format
PEFSCORE	Pedestrian Environment Factor score for zone of home location
POPDENBG	Population density per square mile in 1990 census block group
RET94DEN	Density of retail employment within 1 mile of home location in 1994

Regional Land Use Variables

ZPPOPDEN	Population density per square mile for ZIP code in 1990
ZIPRETDN	Density of Retail jobs per square mile in ZIP code in 1992

Trip Cost Variables

MDWLKDST	Median trip distance per individual
MDWLKSPD	Median trip speed per individual
WORKDAY	Variable for whether or not diary covered at least one work day (1 = Yes, 0 = No)

Instrumental Variables

PCINCBG	Per capita income in census block group in 1990
PCTBLKBG	Percent of Black persons living in census block group in 1990
PCTBLKZP	Percent of Black persons living in ZIP code in 1990
PCTCLGBG	Percent of persons in census block group with at least an undergraduate degree in 1990
PCTCLGZP	Percent of persons in ZIP code with at least an undergraduate degree in 1990
PCTHSPBG	Percent of Hispanic persons living in census tract in 1990
PCTHSPZP	Percent of Hispanic persons living in ZIP code in 1990
PCTNUHBG	Percent of housing units in block group classified as located in rural environment but not classified as farms in 1990
PCTNUHZP	Percent of housing units in ZIP code classified as located in rural environment but not classified as farms in 1990
PCTUHBG	Percent of housing units in block group classified as located in urbanized environment in 1990
PCTUHZP	Percent of housing units in ZIP code classified as located in urbanized environment in 1990

TABLE 2 Ordered Probit Models for Non-Work Walking Trips - Census Block Group Level

	Socio Demographics		Socio Demographics and Land Use (PctGrid Included)		Socio Demographics and Land Use (PctGrid Excluded)		Socio Demographics, Land Use and Trip Costs	
Variable	Coefficient	Z	Coefficient	Z	Coefficient	Z	Coefficient	Z
gender	-0.064482	-0.976	-0.125703	-1.394	-0.062192	-0.933	-0.062273	-0.932
age	**-0.005159**	**-2.47**	-0.002748	-0.964	-0.003833	-1.815	-0.003851	-1.82
race	-0.03977	-0.271	0.0338668	0.177	-0.082298	-0.554	-0.100161	-0.672
income	-1.28E-05	-1.834	-1.39E-05	-1.408	-1.02E-05	-1.461	-9.38E-06	-1.336
incomesq	8.39E-11	1.392	8.50E-11	1.006	6.47E-11	1.066	5.70E-11	0.937
kids	**0.089725**	**2.631**	**0.1070024**	**2.149**	**0.1443604**	**4.074**	**0.1391419**	**3.917**
workday	-0.221035	-1.656	-0.185839	-0.92	**-0.289129**	**-2.154**	**-0.297134**	**-2.207**
carsprdr	**-0.178713**	**-2.313**	-0.042041	-0.346	-0.096116	-1.22	-0.099895	-1.265
numemply	**-0.174813**	**-2.988**	-0.14181	-1.934	**-0.147597**	**-2.49**	**-0.151022**	**-2.546**
popdenbg			0.0000206	1.409	**0.0000282**	**2.985**	**0.0000291**	**3.061**
ret94den			0.0000304	0.386	0.0001021	1.815	0.0000999	1.773
pctgrid			0.008555	0.399	----------	----------	----------	----------
pefscore			0.4756505	1.562	0.0160342	1.079	0.0168821	1.128
mdwlkdst							**-0.047444**	**-2.229**
mdwlkspd							0.0040484	1.653
N		1091		608		1084		1084
Log (L)		-1545.9175		-822.86836		-1520.4641		-1517.7944

Note: Coefficients in bold are significant at the five percent level or greater.

TABLE 3 Test for Joint Significance of Land Use Explanatory Variables - Census Block Group Level

	Restricted Model		Unrestricted Model	
Variable	Coefficient	Z	Coefficient	Z
gender	-0.063458	-0.958	-0.062192	-0.933
age	**-0.005236**	**-2.503**	-0.003833	-1.815
race	-0.047851	-0.323	-0.082298	-0.554
income	-0.000013	-1.857	-1.02E-05	-1.461
incomesq	8.71E-11	1.441	6.47E-11	1.066
kids	**0.0920167**	**2.693**	**0.1443604**	**4.074**
workday	-0.218985	-1.641	**-0.289129**	**-2.154**
carsprdr	**-0.169044**	**-2.175**	-0.096116	-1.22
numemply	**-0.178345**	**-3.041**	**-0.147597**	**-2.49**
popdenbg			**0.0000282**	**2.985**
ret94den			0.0001021	1.815
pef2			0.0160342	1.079
log(L)		-1539.2985		-1520.4641
N = 1084				
X^2 observed = 2*(log[Unrestricted Model] - log[Restricted Model])				37.6688
X^2 critical (dF=4)				9.49

TABLE 4 Significance of Land Use Variables Run Individually - Census Block Group Level

	Population Density		Retail Densit		Percentage Grid Area		PEF Score	
Variable	Coefficient	Z	Coefficient	Z	Coefficient	Z	Coefficient	Z
gender	-0.07173	-1.082	-0.044909	-0.677	-0.119029	-1.329	-0.073579	-1.109
age	-0.00408	-1.938	**-0.004136**	**-1.967**	-0.003177	-1.121	**-0.004778**	**-2.276**
race	-0.066128	-0.445	-0.06934	-0.472	0.0673819	0.353	-0.069678	-0.47
income	-1.06E-05	-1.515	-1.06E-05	-1.522	-0.000016	-1.649	-0.000012	-1.72
incomesq	6.70E-11	1.108	6.55E-11	1.083	1.05E-10	1.255	7.95E-11	1.314
kids	**0.1303174**	**3.735**	**0.131388**	**3.732**	0.088548	1.829	**0.1099993**	**3.188**
workday	**-0.271757**	**-2.029**	**-0.27039**	**-2.019**	-0.178149	-0.882	-0.256076	-1.911
carsprdr	-0.116371	-1.489	-0.129605	-1.661	-0.05885	-0.489	-0.136628	-1.748
numemply	**-0.157738**	**-2.681**	**-0.140397**	**-2.379**	**-0.155673**	**-2.139**	**-0.173771**	**-2.959**
pop90_sq	**0.0000417**	**5.776**						
ret94den			**0.0002235**	**4.831**				
pctgrid					**0.6452183**	**2.212**		
pef2							**0.0500604**	**3.876**
N		1089		1091		608		1084
Log(L)		-1533.2152		-1534.3041		-825.07784		-1531.7701

TABLE 5 Ordered Probit Models for Non-Work Walking Trips - Zip Code Level

	Socio Demographics		Socio Demographics & Land Use		Socio Demographics, Land Use and Trip Costs	
Variable	Coefficient	Z	Coefficient	Z	Coefficient	Z
gender	-0.064482	-0.976	-0.061138	-0.921	-0.065262	-0.982
age	**-0.005159**	**-2.47**	**-0.005019**	**-2.38**	**-0.005069**	**-2.399**
race	-0.03977	-0.271	-0.015501	-0.105	-0.022851	-0.155
income	-1.28E-05	-1.834	-0.000012	-1.716	-1.17E-05	-1.677
incomesq	8.39E-11	1.392	7.52E-11	1.241	7.29E-11	1.203
kids	**0.089725**	**2.631**	**0.0968196**	**2.785**	**0.0943681**	**2.711**
workday	-0.221035	-1.656	-0.234615	-1.756	-0.246758	-1.843
carsprdr	**-0.178713**	**-2.313**	**-0.154368**	**-1.975**	**-0.154674**	**-1.978**
numemply	**-0.174813**	**-2.988**	**-0.182507**	**-3.031**	**-0.185416**	**-3.077**
zppopden			0.0000258	1.945	0.0000258	1.934
zipretdn			0.000023	0.65	0.0000241	0.683
mdwlkdst					-0.037481	-1.86
mdwlkspd					0.0018124	1.674
N		1091		1083		1083
Log (L)		-1545.9175		-1531.8802		-1529.9204

Note: Coefficients in bold are significant at the five percent level or greater.

TABLE 6 Test for Joint Significance of Land Use Explanatory Variables - Zip Code Level

	Restricted Model		Unrestricted Model	
Variable	Coefficient	Z	Coefficient	Z
gender	-0.062245	-0.939	-0.061138	-0.921
age	**-0.00547**	**-2.605**	**-0.005019**	**-2.38**
race	-0.034471	-0.235	-0.015501	-0.105
income	-1.23E-05	-1.757	-0.000012	-1.716
incomesq	7.81E-11	1.292	7.52E-11	1.241
kids	**0.0842882**	**2.463**	**0.0968196**	**2.785**
workday	-0.221765	-1.661	-0.234615	-1.756
carsprdr	**-0.180696**	**-2.337**	**-0.154368**	**-1.975**
numemply	**-0.184674**	**-3.087**	**-0.182507**	**-3.031**
zppopden			0.0000258	1.945
zipretdn			0.000023	0.65
log(L)		-1534.8546		-1531.8802

N = 1083

X^2 observed = 2*(log[Unrestricted Model] - log[Restricted Model])	5.9488
X^2 critical (dF=4)	9.49

TABLE 7 Comparison of OLS and Instrumental Variable Regressions for Non-Work Walking Trips: Census Block Group Level

	Block Group Density (OLS)		Block Group Density (IV)		PCT Grid (OLS)		PCT Grid (IV)	
nwtrips	Coefficient	T	Coefficient	T	Coefficient	T	Coefficient	T
gender	-0.051274	-0.608	-0.119559	-1.122	-0.111582	-1.016	-0.138369	-1.003
age	-0.003334	-1.254	0.0002769	0.08	-0.004307	-1.253	-0.00309	-0.671
race	-0.084117	-0.446	-0.145282	-0.621	-0.055707	-0.235	-0.008676	-0.028
income	-1.19E-05	-1.329	-1.44E-05	-1.248	-1.66E-05	-1.382	-1.62E-05	-1.044
incomesq	7.41E-11	0.959	9.24E-11	0.936	1.02E-10	0.994	8.61E-11	0.654
kids	**0.1715581**	**3.837**	**0.2699982**	**4.948**	0.0840812	1.418	0.1296092	1.54
workday	**-0.355839**	**-2.049**	**-0.561769**	**-2.776**	-0.238862	-0.951	-0.356252	-1.203
carsprdr	-0.181064	-1.832	**-0.290294**	**-2.072**	-0.083497	-0.567	-0.182351	-1.03
numemply	**-0.207611**	**-2.805**	-0.150316	-1.63	**-0.202986**	**-2.291**	-0.061939	-0.574
mdwlkdst	**-0.05909**	**-2.37**	-0.040686	-1.21	-0.042837	-1.33	-0.049822	-1.355
mdwlkspd	0.0020722	1.477	0.0023985	0.615	0.0005392	0.142	0.0012336	0.24
constant	**3.042184**	**9.344**	**3.098447**	**6.737**	**3.181426**	**7.043**	**3.050788**	**5.243**
popdenbg	**0.0000569**	**6.122**	**0.0000596**	**2.292**				
pctgrid					**0.9931173**	**2.774**	1.436442	1.071
N		1089		618		608		388
F-Test		8.31		5.22		2.66		1.44
Prob > F		0		0.0000		0.0018		0.1433
R^2		0.0848		0.115		0.0509		0.0572
Adj. R^2		0.0746		0.0975		0.0317		0.027
OverIdentification Test								
X^2 Critical				11.100				11.100
X^2 Observed				10.5678				8.0316

Note: Coefficients in bold are significant at the five percent level or greater.

Table 7 (Cont.) Comparison of OLS and Instrumental Variable Regressions for Non-Work Walking Trips: Census Tract Level

	PEF Score (OLS)		PEF Score (IV)		Employment Density (OLS)		Employment Density (IV)	
nwtrips	Coefficient	T	Coefficient	T	Coefficient	T	Coefficient	T
gender	-0.051381	-0.6	-0.102569	-0.972	-0.015627	-0.185	-0.069576	-0.649
age	-0.00433	-1.611	0.0000901	0.026	-0.003405	-1.276	0.0014164	0.393
race	-0.092054	-0.481	-0.169975	-0.727	-0.100313	-0.534	-0.233245	-0.96
income	-1.39E-05	-1.532	-1.26E-05	-1.089	-1.18E-05	-1.314	-1.25E-05	-1.065
incomesq	9.02E-11	1.15	7.70E-11	0.779	7.10E-11	0.914	8.13E-11	0.813
kids	**0.1439387**	**3.197**	**0.2646515**	**4.906**	**0.1762717**	**3.887**	**0.2986162**	**4.975**
workday	-0.329744	-1.872	**-0.572548**	**-2.833**	**-0.353847**	**-2.028**	**-0.581488**	**-2.828**
carsprdr	**-0.222403**	**-2.208**	**-0.307395**	**-2.232**	**-0.195718**	**-1.974**	-0.276852	-1.913
numemply	**-0.232003**	**-3.098**	-0.150554	-1.639	**-0.186387**	**-2.498**	-0.124328	-1.308
mdwlkdst	**-0.052537**	**-1.97**	-0.036642	-1.097	**-0.051407**	**-2.057**	-0.032392	-0.959
mdwlkspd	0.0024324	0.76	0.0023088	0.596	0.0017196	1.223	0.0018906	0.483
constant	**3.054213**	**8.589**	**2.806559**	**5.333**	**3.192477**	**9.887**	**2.971126**	**5.732**
PEF Score	**0.0606048**	**3.649**	**0.0792254**	**2.38**				
ret94den					**0.0003146**	**5.248**	**0.0007719**	**2.013**
N		1084		618		1091		618
F-Test		6.1		5.29		7.43		5.04
Prob > F		0		0		0		0
R^2		0.064		0.1208		0.0764		0.0985
Adj. R^2		0.0535		0.1034		0.0661		0.0806
OverIdentification Test								
X^2 Critical				11.100				11.100
X^2 Observed				10.7532				17.0568

Note: Coefficients shown in bold are significant at the five percent level or greater.

TABLE 8 Comparison of OLS and Instrumental Variable Regressions for Non-Work Walking Trips: ZIP Code Level

	CT Density (OLS)		CT Density (IV)		Employment Density (OLS)		Employment Density (IV)	
nwtrips	Coefficient	T	Coefficient	T	Coefficient	T	Coefficient	T
gender	-0.041276	-0.48	-0.042105	-0.489	-0.036977	-0.429	-0.034602	-0.4
age	-0.004736	-1.746	-0.004309	-1.562	-0.004985	-1.842	-0.004837	-1.762
race	-0.035652	-0.187	-0.021618	-0.113	-0.045089	-0.237	-0.041041	-0.215
income	-1.46E-05	-1.602	-1.42E-05	-1.547	-1.52E-05	-1.667	-1.53E-05	-1.673
incomesq	9.22E-11	1.171	8.81E-11	1.114	9.73E-11	1.235	9.77E-11	1.24
kids	**0.1259343**	**2.788**	**0.1341774**	**2.907**	**0.1258455**	**2.767**	**0.1320344**	**2.686**
workday	-0.298951	-1.693	-0.306106	-1.73	-0.299645	-1.695	-0.305555	-1.72
carsprdr	**-0.243857**	**-2.424**	**-0.222246**	**-2.145**	**-0.256717**	**-2.564**	**-0.249316**	**-2.43**
numemply	**-0.24277**	**-3.163**	**-0.244346**	**-3.179**	**-0.232437**	**-3.014**	**-0.226412**	**-2.857**
mdwlkdst	**-0.051084**	**-2.015**	**-0.050155**	**-1.974**	**-0.052168**	**-2.057**	**-0.052221**	**-2.058**
mdwlkspd	0.0016176	1.133	0.0017231	1.202	0.00154	1.079	0.0015658	1.095
constant	**3.500163**	**10.574**	**3.342037**	**8.887**	**3.611686**	**11.3**	**3.569702**	**10.385**
zppopden	0.0000276	1.718	0.000053	1.617				
zipretdn					0.0000526	1.221	0.0000893	0.753
N		1083		1083		1083		1083
F-Test		5.26		4.71		5.13		4.54
Prob > F		0		0		0		0
R^2		0.0557		0.0535		0.0544		0.0538
Adj. R^2		0.0451		0.0429		0.0438		0.0432
OverIdentification Test								
X^2 Critical				9.49				9.49
X^2 Observed				3.8988				3.4656

Note: Coefficients in bold are significant at the five percent level or greater.

What's The Value of A Sidewalk?

(To view and print pdf files, use Adobe Acrobat Reader available at this link.)

Recently, transportation planners and engineers have been concerned with developing metropolitan area communities that integrate bicycling and walking into everyday life. To create these more "livable communities," bicycle lanes and sidewalks, furniture, landscaping, and lighting have been reintroduced to the streetscape in order to encourage bicycling and walking. Considering this recent trend in planning, there exists a real need for reliable performance measures of the pedestrian environment.

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Traditionally, transportation research evaluating roadway performance focused on automobiles and paying little or no attention to the quality of the walking environment. While there has been general agreement among planners and engineers that "pedestrians' sense of safety/comfort" involved a number of complex factors such as "architectural interest" and "personal security," there has been no consensus as to "which features of a roadway environment have statistically reliable significance to pedestrians."

In their article, "Modeling The Roadside Walking Environment: A Pedestrian Level of Service" published by the Transportation Research Board (2001), Bruce W. Landis, Venkat R. Vattikuti, Douglas S. McLeod and Martin Guttenplan sought to identify the factors that "significantly influence a pedestrian's feeling of safety and/or comfort" in order to provide "a measure of the roadway segment's level of service to pedestrians." This measure would allow planners and engineers to design roadway cross sections that meet pedestrians' need to be safe and comfortable, thereby enhancing their enjoyment of the walking experience.

Previous research on the pedestrian environment focused on sidewalk capacity, quality of walking environment and pedestrian's perception of safety/comfort as the main performance measures. The research project described in this article examined "pedestrian's perception of safety/comfort" as a qualitative measure of effectiveness in order to describe traffic operational conditions and perceptions by users.

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For the purpose of this study, researchers created a model using traffic and roadway variables to quantitatively measure the pedestrian's perception of safety/comfort. This model "is objective, transferable, and applicable at the roadway segment, and ultimately when combined with an intersection level of service measure, applicable at the facility corridor and network levels." The model consists of independent variables that were found to be statistically significant.

The research design was a threefold process that involved: 1) placing people on a walking course typical of the metropolitan environment, 2) obtaining real-time responses to roadway stimuli, and 3) creating and testing the relationship of measurable factors that reflect participants' perceptions.

The model developed from the analysis of the statistically significant variables showed several important findings about pedestrians' sense of safety/comfort. The presence of a sidewalk was found to be essential in the pedestrian's sense of safety and comfort. However, the value of the sidewalk depended on its lateral separation, barriers, and buffers from motor vehicle traffic. Pedestrians' sense of safety and comfort was improved when there was an increase in lateral separation and a barrier such as trees and/or parked cars.

An increase in the frequency of passing motor vehicles as well as an increase in motor vehicle speed reduced the pedestrian's sense of safety. Conversely, there was no significant relationship found between the number of driveways and the pedestrian's sense of safety and comfort.

The model created by this study can be used to test roadway segments by "changing the independent variables to find the best combination of factors to achieve a desired LOS (level of service)." The results of this study will provide practitioners with "solid guidance" when designing roadway segments. In addition, the model can inform site-planning decisions relative to pedestrian movement/flow. The study also recommended that further research be conducted to determine the role that intersection conditions have on the "pedestrians' total roadway corridor experience."

The full text of this paper is available here or on the 80th Annual Meeting of the Transportation Research Board CD-Rom. For additional information, contact Bruce W. Landis at Blandis@sprinkleconsulting.com by email. *Adapted with permission*.

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MODELING THE ROADSIDE WALKING ENVIRONMENT:

A PEDESTRIAN LEVEL OF SERVICE

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ABSTRACT

A method is needed to objectively quantify pedestrians' perception of safety and comfort in the roadside environment. This quantification, or mathematical relationship, would provide a measure of how well *roadways* accommodate pedestrian travel. Essentially it would provide a measure of pedestrian level of service within a roadway environment. Such a measure of walking conditions would greatly aid in roadway cross-sectional design and also help evaluate and prioritize the needs of existing roadways for sidewalk retrofit construction. Furthermore, the measure can be used to evaluate traffic calming strategies and streetscape designs for their effectiveness in improving the pedestrian environment. Such a measure would enable pedestrian facility programming to be merged into the mainstream of transportation planning, design and construction.

To meet the need for such a method, as well as to fulfill a state mandate to establish levels of service standards for *all* transportation modes, the Florida Department of Transportation sponsored the development of the *Pedestrian Level of Service (LOS) Model* as described within this paper. The *Model* was developed through a stepwise multi-variable regression analysis of 1250 observations from an event that placed 75 people walking on a roadway course in the Pensacola metropolitan area in Florida. The *Pedestrian LOS Model* incorporates the statistically significant roadway and traffic variables that describe pedestrians' perception of safety or comfort in the roadway environment between intersections. It is similar in approach to the methods used to assess the automobile operators' level of service established in the *Highway Capacity Manual*.

Key Words:

Pedestrian Level of Service, Walking Conditions, Pedestrian Safety, Performance Measure, Sidewalks

INTRODUCTION

In recent years there have been initiatives in metropolitan areas throughout the United States to create more livable communities where walking and bicycling are encouraged and accepted as legitimate forms of transportation. Characteristic of these efforts is the reintroduction of bicycle lanes and sidewalks to the streetscapes, complete with street furniture, landscaping, pedestrian-scaled lighting, and other features making the public right-of-way more inviting for people to travel by bicycle or on foot. The transportation planning and engineering community has recently been attempting to provide analysis and design methods to help create more "livable" streets and roadway environments.

Historically, compared to the level of research that has been done for motorized transportation, there has been relatively little study and analysis of the factors that affect the quality of the walking environment. Evaluating the performance of a roadway section for the walking mode is far more complex in comparison to that of the motor vehicle mode. Whereas operators of motor vehicles are largely insulated in their travel environment and hence are influenced by relatively few factors, the pedestrian is relatively unprotected and is subject to a host of environmental conditions.

In general, planners and engineers have not yet come to consensus on which features of a roadway environment have statistically reliable significance to pedestrians. There have been several recent initiatives by planners to develop "walkability audits"; however, these measures generally include the myriad of features of the entire roadway corridor environment (including conditions at intersections) and they have not yet been statistically tested or widely applied. There is general consensus that pedestrians' sense of safety / comfort within a roadway corridor is based on a complex assortment of factors including:

- personal safety (i.e., the threat of crashes)
- personal security (i.e., the threat of assault)
- architectural interest
- pathway or sidewalk shade
- pedestrian-scale lighting and amenities
- presence of other pedestrians
- conditions at intersections, and etc.

Complexity of the issue, however, should not deter attempts to model pedestrians' response to the roadway environment, even if it is for one aspect or component of a roadway corridor. Elected representatives, public officials, transportation planners and engineers need the capability to determine a roadway's performance with regard to accommodating pedestrian travel. Roadway designers need solid guidance on how to better design pedestrian environments: how far sidewalks should be placed from moving traffic; when, and what type of buffering or protective barriers are needed; how wide the sidewalk should be; and etc.

The purpose of this study, therefore, was to focus on, and identify those factors within the right-of-way that *significantly influence* the pedestrian's feeling of safety and/or comfort. The collection of these factors into a mathematical expression, tested for statistical reliability, provides a measure of the roadway segment's level of service to pedestrians. This measure evaluates the conditions along roadway segments *between* intersections. A key application of this measure is to help planners and roadway engineers make informed decisions when designing or choosing the appropriate cross section for any given roadway – a cross section that meets pedestrians' basic need to feel safe and comfortable while walking. As such, the measure presented in this paper is one piece of the puzzle, albeit an important one – many other factors also influence a pedestrian's (enjoyment of the) walking experience. These factors should be studied further to improve the body of knowledge on this subject.

The researchers of this study acknowledge that intersection conditions also have a significant bearing on the pedestrians' total roadway corridor experience, and must also be studied. Further, they believe that a measure(s) must be developed to be combined with this roadway segment performance measure. In fact the research sponsor, the Florida Department of Transportation, is using this research team to develop intersection performance measure(s) as phase II of this Study. The Federal Highway Administration is beginning a similar study initiative.

MEASURES OF THE PEDESTRIAN ENVIRONMENT

Dan Burden, a leading national advocate for more walkable communities and transportation systems, articulates for many that the pedestrian in the roadside environment is subjected to a multitude of factors significantly affecting his/her feeling of safety, comfort, and convenience. Accordingly, we may classify these factors under three general performance measures describing the roadside pedestrian environment; 1) sidewalk capacity, 2) quality of the walking environment, and 3) the pedestrian's perception of safety (or comfort) with respect to motor vehicle traffic. These three are briefly outlined below.

The first performance measure, *sidewalk capacity*, was developed in the early 1970’s by Fruin *(1)*. His method, as formalized in the *Highway Capacity Manual (2)*, is the only established method of quantifying sidewalk capacity. However, this performance measure is limited in its applicability: it only evaluates conditions for an existing (or a planned) sidewalk and then, only from the perspective of “walking space” or effective sidewalk width available to the pedestrian. Additionally, it cannot be used to evaluate and prioritize roadways for sidewalk retrofit construction, a prevalent need currently in the United States. This is an important limitation. We estimate that typically less than 20% of the collector and arterial network of U.S. metropolitan areas have sidewalks. Furthermore, it is estimated that less than approximately 3% of roadways have pedestrian activity levels that can be effectively measured by Fruin’s capacity method.

Currently, there is no established approach for the second measure, that of the *quality*, or enjoyment aspect of the walking environment. Several researchers and a number of planners have proposed qualitative measures of the *total quality* of the walking experience. Their approaches include numerous qualitative assessments relating to the pedestrian’s *enjoyment* of the walking experience (e.g., convenience of the walking experience and the perception of personal security). Works by Sarkar *(3,4)*, Khisty *(5)*, Dixon *(6)*, Crider *(7),* and others are examples of methods that include a mixed combination of some factors of all three performance measures. However, most of these methods require the presence of a sidewalk to be applicable. And, while the qualitative measure of a pedestrian's enjoyment of the walking experience is important to provide a complete picture of the walking environment and to design an “inviting” sidewalk, it is a separate measure of effectiveness and must be developed and calibrated, if possible, separately from the sidewalk capacity or safety perception measures.

The third measure, the perceived safety or comfort (with respect to the presence of motor vehicle traffic) has not, until now), been quantified as a stand-alone performance measure. The common expression of pedestrians concerning how well a particular street or road accommodates their travel is from a perspective of safety and/or comfort. "It's a dangerous place to walk" or "it's fairly safe and comfortable" is the way they articulate their views of the roadway. This measure is the subject of our research, hence this paper. Considering only the roadway environment (i.e., excluding intersection conditions), the factors thought to *significantly* affect pedestrians' sense of safety or comfort include:

- presence of a sidewalk
- lateral separation from motor vehicle traffic
- barriers and buffers between pedestrians and motor vehicle traffic
- motor vehicle volume and composition
- effects of motor vehicle traffic speed, and
- driveway frequency and access volume, among other factors.

The perception of safety and/or comfort is a qualitative measure of effectiveness recognized by the *1994 Highway Capacity Manual*. The *Manual* states (on pages 1-4 and 1-5), *"The concept of level-of-service uses <u>qualitative</u> (emphasis added) measures that characterize operational conditions within traffic the stream and their perception by (the facility users)…descriptions of individual levels of service characterize these conditions in terms of such factors as speed and travel time, freedom to maneuver,* *traffic interruptions, and comfort and convenience" (emphasis added) for the facility type."* With respect to measures of effectiveness, the *Manual* states, *"For each type of facility, levels of service are defined on the basis of one or more operational parameters that best describe operating quality (emphasis added) for the facility type" (2)*. This is the direction of our (measure of effectiveness) effort to model the roadway walking environment.

Therefore, a calibrated, transferable model is needed to objectively reflect, "the perceived safety or comfort of pedestrians along a roadway segment" using measurable traffic and roadway variables. In response to this need, the *Pedestrian Level of Service Model* outlined herein has been developed. The *Model* is objective, transferable, and applicable at the roadway segment, and ultimately, when combined with an intersection level of service measure, applicable at the facility corridor and network levels. It evaluates roadside walking conditions *regardless* of the presence of a sidewalk. It can also demonstrate the impact of adding or improving sidewalks. It uses common, measurable traffic and roadway variables for economy of data collection, accuracy, and reliable and repetitive application. The Model is designed to evaluate a roadway segment; it does not include intersections and their complex conditions that are the subject of separate research initiatives.

DESIGN OF RESEARCH

This research initiative by the Florida Department of Transportation placed people in actual traffic and roadway conditions to obtain real-time feedback. Although a virtual reality, or simulation approach was briefly considered by the researchers due to its advantage of safety to the participants, it was not pursued because of the approach's inability to include and/or replicate all response stimuli of the roadway environment.

Accordingly, 1) a special event was created to place a significant number of people on a walking course consisting of typical roadways in a typical U.S. metropolitan area, 2) obtain their real-time response to the roadway environment stimuli, and 3) create and test a mathematical relationship of measurable factors to reflect the Study participants' reactions. It should be noted that the research was designed to elicit responses from participants walking individually, not in pairs or groups. The following sections outline this approach.

Participants

Nearly 75 people participated in the first (i.e., the course-walking) portion of the study. The participants represented a broad cross section of age, gender, experience level, and geographic origin. Participants' ages ranged from 13 to 69. Due to the potential hazards of walking in urban-area motor vehicle traffic, children younger than age 13 were not permitted to participate. The gender split of the study group was forty-seven (47) percent female and fifty-three (53) percent male. The researchers and Sponsor sought participant diversity in both geographic origins and walking experience. Accordingly, the study test course was located in Pensacola, Florida - a metropolitan area with significant in-migration. The average participant had lived in areas *other* than the Pensacola Bay region for the majority [approximately seventy-three (73) percent] of their life.

There was a considerable range of walking experience among the participants. There was a significant number who made relatively few walking trips (hence, mileage) and there were some who reported that they walked extensively virtually every day of the week. Average distances walked per week ranged from a low of 1.6 kilometers (one mile) to a high of 79 kilometers (48 miles).

The Walking Course

A walking course was designed to subject the participants to a variety of traffic and roadway conditions. The course included road segments with traffic and roadway conditions typical of U.S. metropolitan areas. Approximately 8 km (5 mi) in length, the looped course consisted of 24 road segments (48 directional segments) with near equal lengths, but with varying traffic and roadway conditions. Although the majority of the segments were collector and arterial roads, some segments were local streets. During the walking event stage of the study, traffic volumes ranged from a low of 200 average daily traffic (ADT) to a high of 18,500 ADT. The percentage of heavy vehicles [as defined in the *Highway Capacity Manual* (2)] ranged from 0 to 3 percent. Traffic running speeds ranged from 25 to 125 km/hr (15 to 75 mi/hr). The roadway cross-sections included two to four lanes in forms of one way, undivided, divided, and continuous left-turn median lane configurations. The walking course included both curb and guttered as well as open shoulder cross-sectioned roadbeds. Some segments also had striped shoulders and some included designated bicycle lanes.

There were a variety of typical metropolitan area roadside conditions within the course. For example, some of the segments were urban in character with mixed combinations of on-street parking, landscaped buffers, street trees, and buildings adjoining the sidewalks with structures and awnings covering the sidewalks. Some segments were more suburban or rural in nature with roadside characteristics ranging from no sidewalks to sidewalks directly adjoining the travel lanes, to sidewalks with intervening buffers of widths ranging from zero to twenty five (25) feet.

The walking course passed through a spectrum of land development forms and street network patterns found in the U.S. metropolitan areas. Retail commercial development forms ranged from large retail shopping centers to small convenience strip centers. Some segments had office buildings or other professional service establishments fronting them. Other land uses included churches, auto dealerships, banks, sit-down and fast-food restaurants with drive-throughs, professional and personal care businesses, car repair shops, and light industrial areas.

In the residential portions there was also an array of development forms directly adjoining the course. Residential dwellings included apartment and condominium units and other forms of attached dwelling units. Some course segments had single-family homes directly fronting them. Portions of the course passed through traditional grid street patterns; other parts ran through curvilinear street-forms. Neighborhoods represented a mix of income levels.

Participant Response

The real-time data collection activity of the study was promoted as an event entitled the *FunWalk for Science*, with prize drawings and gifts as incentives for participation. Volunteer participants were recruited using a broad-based, area-wide, multimedia approach that included newspaper notices and articles, radio announcements, and direct mailings by and to numerous organizations and businesses. Displays with brochure-registration forms were deployed at area retail sports outlets, health clubs, colleges, government office lobbies, major employers, and bicycle shops.

The need for a large number of volunteer walkers mandated a weekend testing period. Accordingly, the *FunWalk for Science* was scheduled for the morning of one of the busier (from a traffic-volume standpoint) Saturdays of the year in Pensacola, March 18th. To ensure that all participants experienced uniform motor vehicle traffic volumes, the event was run during a single time block in the mid-morning. The participants first updated or completed registration forms that included a variety of demographic questions. They were then briefed in groups as to the purpose and rules of walking the course. Following the briefings, walkers were then sent to two starters who released them onto the course individually at one-minute intervals, in opposite directions. Although the participants were briefed on the course configuration and had instructions for completing the response cards, course proctors were also deployed at strategic points throughout the course. The proctors consisted of staff from the West Florida Regional Planning Council, the Florida Department of Transportation, the University of Florida, SCI, Inc., and a number of regional bicycle and pedestrian coordinators from throughout Florida. The proctors ensured that temporal spacing between walkers was maintained and that the participants were independently completing the response cards as they walked each segment. Participants were encouraged to reflect on their accumulating experience and re-grade any previously walked segments as they proceeded through the course.

The study's purpose was to evaluate the quality, or level of service, of the roadway segments, not the intersections. Accordingly, the participants were instructed to disregard the conditions at intersections and their immediate approaches. They were also encouraged to exclude from their consideration the surrounding aesthetics. They were to include only conditions within, or directly adjoining, the right-of-way. The participants evaluated on a 6-point (“A” to “F”) scale how safe / comfortable they felt as they traveled each segment. Level “A” was considered the most safe / comfortable (or least hazardous). Level “F” was considered the least safe / comfortable (or most hazardous).

REDUCTION AND ANALYSIS OF DATA

The study design yielded approximately 1700 initial observations coincident with a myriad of traffic and roadway conditions throughout the walking course. The resulting data was compiled into both spreadsheet and Statistical Analysis Software (SAS) program databases for extensive analyses. Response outliers and trends were identified resulting in 1250 observations and 21 roadway sections (42 directional segments) available for further analysis of the specific effect of traffic and roadway variables.

An interesting response trend was also identified, ultimately determined to be that of response (or scoring) fatigue. A slight diminishing scoring trend was evident. Course length was not a factor (the average total duration of the participant’s course experience was approximately 2 hours) due to the clearly constant slope of the response trend. Presentation order of the segments was not a source of the trend either, since the course presented a variety of traffic, roadway, and urban forms in a random distribution. Since the participants walked the course in two direction groups, the averaging of the responses allowed for removal of the fatigue trend, thus Pearson Correlations among the traffic and roadway variables and stepwise regression of the dependant variable was possible using the non-biased (averaged) responses for correlation.

MODEL DEVELOPMENT

Several Pearson Correlation analyses were run using the SAS program on a variety of traffic and roadway variables. Not surprisingly, several variables exhibited some co-linearity. However, the co-linearity was not enough to preclude the inclusion of some co-linear variables into the *Model* due to notable exceptions. For example, while in some cases the presence and width of sidewalks and buffers correlated with increasing speed, in many cases it did not, reflecting that the current practice of roadside design (and/or provision of sidewalks and buffers) is not consistent with providing a uniform level of pedestrian safety and comfort throughout transportation systems.

A "long list" of potential *primary* independent variables influencing pedestrians' sense of safety or comfort within the roadway was generated, and then tested (along with numerous other potential factors) in the stepwise regression portion of the *Model's* development. The long list was generated based on: 1) the results of the aforementioned Pearson Correlation analyses; 2) the variables (and model terms) identified by group consensus and confirmed during the development of the earlier *Roadside Pedestrian Conditions (RPC) Model* [developed for the Tampa metro area MPO's *Hillsborough County MPO Pedestrian Plan* (*8*)], which is currently the basis for several major metropolitan area pedestrian plans; and 3) extensive iterative testing of segment groupings with common levels of independent variables [wherein additional variables were identified which potentially could further explain the variation of the dependant variable (the pedestrians' ratings of safety / comfort)]. The resulting long list of primary factors included, *but was not limited to*:

1) Lateral separation elements between pedestrians and motor vehicle traffic, including,
   - Presence of sidewalk
   - Width of sidewalk
   - Buffers between sidewalk and motor vehicle travel lanes
   - Presence of barriers within the buffer area
   - Presence of on-street parking
   - Width of outside travel lane
   - Presence and width of shoulder or bike lane
2) Motor vehicle traffic volume
3) Effect of (motor vehicle) speed
4) Motor vehicle mix (i.e., percentage of trucks)
5) Driveway access frequency and volume

The factors listed above were considered the most probable *primary* factors affecting pedestrians' sense of safety. As such, they are the basis for the preliminary structure and testing of the *Pedestrian LOS Model* represented in the following mathematical expression:

$$\text{Pedestrian LOS} = a_1 f(\text{lateral separation factors}) + a_2 f(\text{traffic volume}) + a_3 f(\text{speed, vehicle type}) + a_4 f(\text{driveway access frequency and volume}) + a_n f(x_n) + \ldots + C \quad (1)$$

The researchers conducted step-wise regression analyses using the 1315 real-time observations. Numerous variable transformations and combinations of the factors were tested. Table 1 shows the best model form and it's terms' coefficients and T-statistics. The correlation coefficient (R^2) of the best-fit model is 0.85 based on the averaged observations from the 42 directional segments (see Figure 1 for a plot of predicted *Pedestrian LOS* versus mean observed values). The coefficients are statistically significant at the 95 percent level. Thus, the following *Model* was developed:

$$\text{Ped LOS} = -1.2021 \ln (W_{ol} + W_l + f_p \times \%OSP + f_b \times W_b + f_{sw} \times W_s) + 0.253 \ln (Vol_{15}/L) + 0.0005\ SPD^2 + 5.3876 \quad (2)$$

Where:

W_{ol} = Width of outside lane (feet)

W_l = Width of shoulder or bike lane (feet)

f_p = On-street parking effect coefficient (=0.20)

%OSP = Percent of segment with on-street parking

f_b = Buffer area barrier coefficient (=5.37 for trees spaced 20 feet on center)

W_b = Buffer width (distance between edge of pavement and sidewalk, feet)

f_{sw} = Sidewalk presence coefficient

$$= 6 - 0.3W_s \quad (3)$$

W_s = Width of sidewalk (feet)

Vol_{15} = average traffic during a fifteen (15) minute period

L = total number of (through) lanes (for road or street)

SPD = Average running speed of motor vehicle traffic (mi/hr)

TABLE 1 Model Coefficients and Statistics

Model Terms	Coefficients	T-statistics
Lateral Separation Elements:		
ln(LS)	- 1.2021	- 10.072
Motor Vehicle Volume:		
ln (Vol_{15}/L)	0.253	3.106
Speed and MV type:		
SPD^2	0.0005	2.763
Constant	5.3876	11.094
Model Correlation (R^2)	0.85	

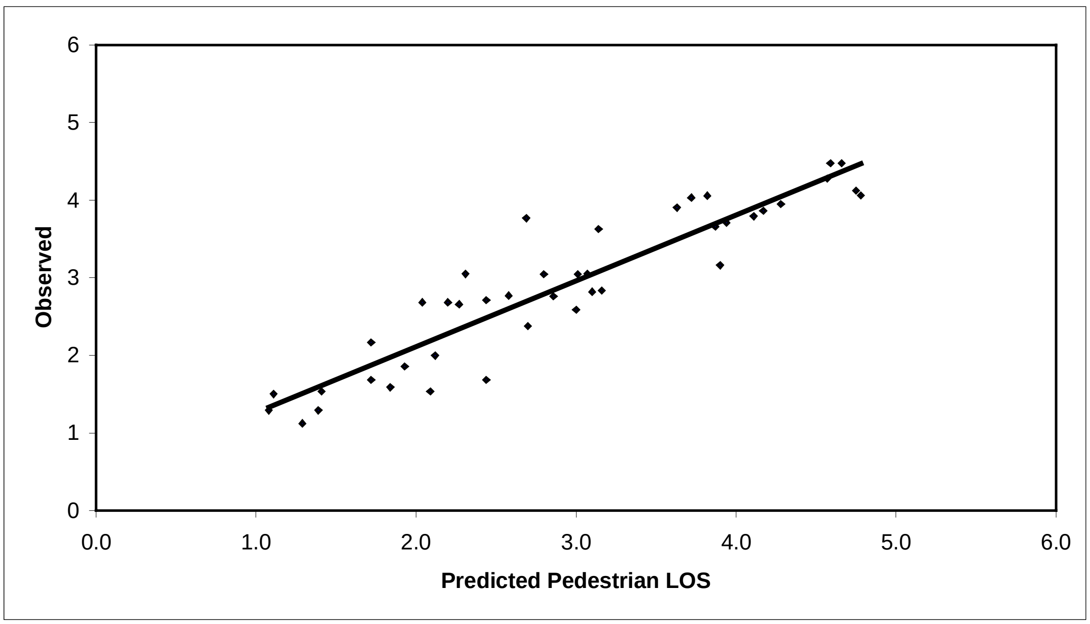

FIGURE 1 Residual plot of predicted and standardized residuals

The *Pedestrian LOS Model* equation was created with a statistical significance at the 95% level. The factor, “driveway access frequency and volume”, while included in the step-wise regression analyses, was not found to be statistically significant at that level.

Table 2 below may be used as a basis for stratifying the *Model's* numerical result into a pedestrian level of service class when it is applied to a particular roadway segment. It should be noted that this stratification was pre-determined as the responses gained in the Study were based on the standard U.S. educational system's letter grade structure (with the exception of Grade "E").

TABLE 2 Level of Service Categories

Level-of-Service	Model Score
A	≤ 1.5
B	> 1.5 and ≤ 2.5
C	> 2.5 and ≤ 3.5
D	> 3.5 and ≤ 4.5
E	> 4.5 and ≤ 5.5
F	> 5.5

Discussion of Model Terms

The terms of the calibrated model were developed and refined through extensive variables transformation testing and regression. The following briefly outlines some of the aspects of the terms and how the dependant variable responds to them.

Presence of a Sidewalk and Lateral Separation

Having a safe, separate place to walk alongside the roadway is fundamental in pedestrians' sense of safety and comfort in the roadway environment. This sense of safety or comfort is strongly influenced by the presence of a sidewalk. Furthermore, as the calibrated *Model* confirms, the value of a sidewalk varies according to its location and buffering (i.e., the lateral separation) relative to the motor vehicle traffic. In general, as the lateral separation increases, the pedestrian's comfort or sense of safety also increases (see Figure 2). Additionally, when a barrier such as on-street parking, a line of trees, or a roadside swale is present in the buffer area between motor vehicle traffic and the pedestrian, the pedestrians' sense of protection, hence safety, is improved (see Figure 3). Finally, the *frequency* of parked cars, trees, or an increase in the depth of the intervening roadside swale would further improve the sense of safety.

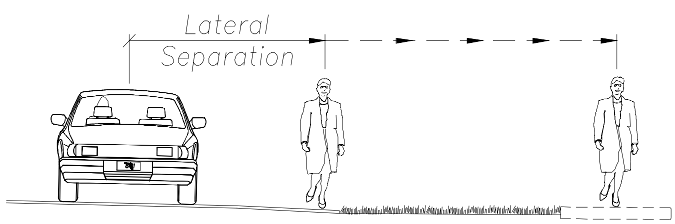

FIGURE 2 Effect of lateral separation.

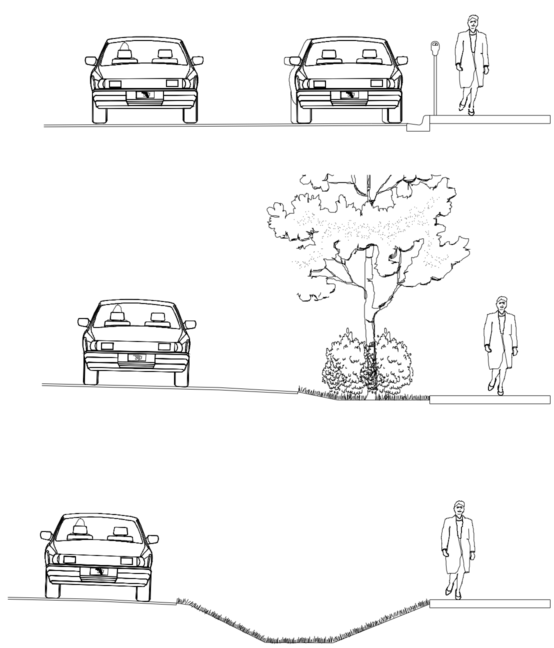

FIGURE 3 Typical barriers within the roadside buffer.

The mathematical expression that reflects these elements of lateral separation, barriers, buffers, and presence of a sidewalk is expressed as follows:

$$LS = W_{ol} + W_l + f_p \times \%OSP + f_b \times W_b + f_{sw} \times W_s \quad (4)$$

Where:

W_{ol} = Width of outside lane (feet)

W_l = Width of shoulder or bike lane (feet)

f_p = On-street parking effect coefficient

%OSP = Percent of segment with on-street parking

f_b = Buffer area barrier coefficients

W_b = Buffer width (distance between edge of pavement and sidewalk, feet)

f_{sw} = Sidewalk presence coefficient

W_s = Width of sidewalk (feet)

Examples of how the lateral separation elements are used to quantify some typical roadway cross-sections are illustrated below.

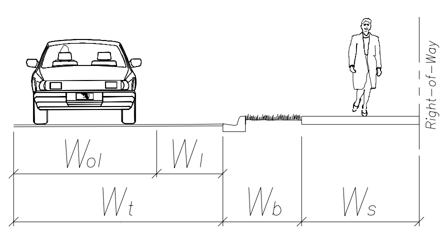

FIGURE 4 Buffers and sidewalk.

Figure 4 above shows a curbed cross-section with no vertical barriers in the horizontal buffer area between the travel lane and sidewalk. Note that there is no on-street parking, therefore the %OSP term equals zero. Thus for this scenario, the lateral separation term is given by:

$$LS = W_{ol} + W_l + f_b \times W_b + f_{sw} \times W_s \qquad (5)$$

In the case where there is on-street parking, as is illustrated in Figure 5, its effect as a barrier is quantified as in Equation (6). Note that there is no striped shoulder or landscape buffer, therefore the W_l and W_b terms equal zero. Thus, the lateral separation term is simplified to:

$$LS = W_{ol} + f_p \times \%OSP + f_{sw} \times W_s \qquad (6)$$

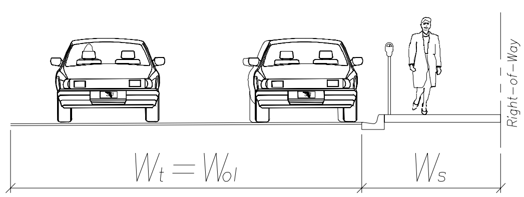

FIGURE 5 Lateral separation with on-street parking.

This section introduced the elements of lateral separation and their mathematical expression. The next sections describe the other two statistically-significant terms of the *Pedestrian LOS Model*.

Motor Vehicle Volume

The frequency of motor vehicles passing pedestrians, represented by the outside lane volume, was also found to be a significant factor. As passing frequency increases, the pedestrians' feeling of safety decreases. The effect of traffic volume is calculated by the following:

$$\text{Traffic Volume} = \frac{Vol_{15}}{L} \quad (7a)$$

where:

Vol_{15} = average traffic during a fifteen (15) minute period

L = total number of (thru) lanes (for road or street)

The equation above assumes a 50/50 directional distribution. In cases where the directional distribution is other than 50/50, equation 7b (below) should be used. The difference between the two is that equation 7b uses a directional factor and instead of using "L" (total number of thru lanes), it uses "L_d" (total number of *directional* thru lanes).

$$\text{Traffic Volume} = \frac{Vol_{15}}{L_d} \times D \quad (7b)$$

where:

Vol_{15} = average traffic during a fifteen (15) minute period

L_d = total number of directional (thru) lanes (for road or street)

D = directional factor

This effect on the walkers in the Study was found to be statistically significant. Transformations of this variable and subsequent stepwise regressions revealed that at lower traffic volumes, changes in the independent variable produced significant changes in the dependant variable. At higher volumes, however, there was less sensitivity; hence the natural log mathematical form of this term.

Effect of Speed

Similarly, the speed of motor vehicle traffic was confirmed as significantly affecting pedestrians' sense of safety. As speed increases, pedestrian discomfort increases. It was determined that the dependant variable had an exponential relationship with the average running speed of the motor vehicle traffic, somewhat similar to that relationship discovered during the development of the *Bicycle Level of Service Model* (*9*), which has been incorporated into Florida's multi-modal level of service analysis guidelines (*10*).

Driveway Access Frequency and Volume

Along a roadway segment, uncontrolled vehicular access to adjoining properties (i.e., driveway cuts) was thought to reduce the pedestrian sense of safety. This transverse feature represents a similar "turbulence" or hazard to the pedestrian as to motor vehicle operators. Accordingly, as the number of driveways increases, a corresponding decrease in the perceived safety to the pedestrian was expected. Affecting this perception of safety is the volume of vehicles accessing the driveways. However, step-wise regression analyses revealed that this effect was not statistically significant at the 95 percent confidence level.

FINDINGS AND APPLICATIONS

The result of this initial research sponsored by the Florida Department of Transportation is the development of a reliable, statistically calibrated pedestrian level of service model suitable for application not only in Florida metropolitan areas, but also throughout North America. The *Pedestrian LOS Model* provides a measure of a roadway segment's performance with respect to pedestrians' primary perception of safety or comfort; as such it serves as the basis for the Florida Department of Transportation's state-wide multimodal (particularly for the pedestrian mode) level of service evaluation techniques. However, it can also be used to greatly influence roadway cross-sectional design and it can also help evaluate and prioritize the needs of existing roadways for sidewalk retrofit construction; applications for which the *Model's* precursor, the *Roadside Pedestrian Conditions Model,* has been successfully used. For example, transportation planners and engineers can now establish a target Pedestrian LOS and use the *Model* to test alternative roadway cross-section designs by iteratively changing the independent variables to find the best combination of factors to achieve the desired LOS. The *Model* thus provides roadway designers with solid guidance on how to better design pedestrian environments: how far sidewalks should be placed from traffic; when, and what type of buffering or protective barriers are needed; how wide the sidewalk should be; and etc. Finally, the *Pedestrian LOS Model*, when coupled with the *capacity* (Fruin) measure and a *quality* performance measure (i.e., a "Walkability Audit" to assess the enjoyment and convenience of the walking experience – in the case of an existing sidewalk) "completes the picture" of the roadside walking environment.

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TABLE TITLES AND FIGURE CAPTIONS

Perspectives on Land Use and Transportation

Trip Generation

Can Buildings Drive US From Our Cars?

(To view and print pdf files, use Adobe Acrobat Reader available at this link.)

Published in the Institute of Transportation Studies (ITS) Review, June 2003, "Can Buildings Drive US From Our Cars?" by Christina Cosgrove is an insightful review of the book, *Travel by Design: The influence of Urban Form on Travel* by Marlon G. Barnett and Randall Crane (Oxford University Press). The original book review is available on the *ITS Review Online* or click here. The book, *Travel by Design: The influence of Urban Form on Travel* can be purchased through a variety of local and online retail bookstores.

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Can Buildings Drive Us From Our Cars?

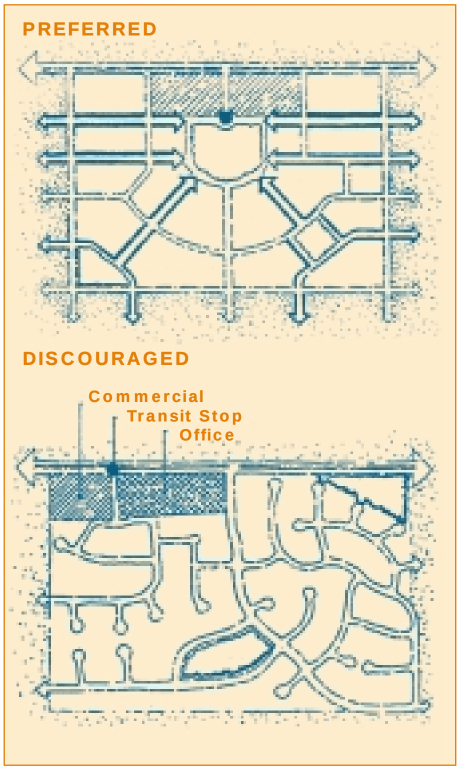
ITS Irvine's Marlon Boarnet and ITS Los Angeles's Randall Crane examine some of the claims made for New Urban designs.

People walk more and drive less in downtown San Francisco than in the suburbs. Is that because of the way San Francisco was built? And, if it is, can people elsewhere be convinced to drive less by changing the built landscape in which they live?

Those are some of the questions that Marlon G. Boarnet, Associate Professor and Chairman of Planning, Policy, and Design at UC Irvine and a participant at the Institute of Transportation Studies Irvine, and Randall Crane, Professor of Urban Planning at UCLA and Associate Director of the Institute of Transportation Studies Los Angeles, address in their book, *Travel by Design: The Influence of Urban Form on Travel* (Oxford University Press). They are central to the arguments made by proponents of New Urbanism, or Neo-Traditional design: that denser, more "traditionally" laid out communities are of value for more than just their aesthetic appeal to those whose taste inclines in that direction, that they can result in measurable reductions in auto use and accompanying reductions in pollution and energy consumption.

"The idea that neighborhoods and cities can be designed to change travel behavior holds much currency these days," they write. "In a manner of speaking, it promises to kill two birds with one very attractive stone: reduce car use and increase the quality of neighborhood life generally by improving the pedestrian and transit environments, all in the form of pretty houses and friendlier, often nostalgic, streetscapes."

For more than a decade, proponents of New Urbanism have argued that higher density, mixed land use and grid-like circulation patterns will encourage walking and transit use, and those ideas have found wide acceptance among architects and planners. The Institute of Transportation Engineers, for example, developed guidelines in 1997 to help cities modify their traffic codes to allow narrower roads, which are widely believed to be more pleasing to pedestrians and to encourage more pedestrian travel. But when the authors set out to review the evidence of whether such practices had the desired results, they were surprised to find that "very little is known regarding how the built environment influences travel, and there is little agreement on how to reliably learn more," they write.



A comparison of "preferred" and "discouraged" street and circulation patterns in the "transit-oriented" development guidelines prepared for the city of San Diego by Calthorpe Associates (City of San Diego 1992) — from *Travel by Design*

Faced with this challenge, they began the research that led to *Travel by Design*, which sets out to determine three things: "Can the built environment solve traffic problems, will such plans be put into practice, and is this approach a good idea?"

Boarnet and Crane point out that master planning has emphasized social goals for decades. Levittown and similar suburbs that grew up in the 40s and 50s were designed so people could escape from crowded, noisy, and polluted cities where they worked. Transportation planners were charged with building the street and highway networks that allowed workers to go home at night to quiet, clean suburbs. Zoning and land-use policies reflected the same goals of segregating commercial, office, and industrial land uses from residential areas.

Fast forward a few decades, however, and the social goals have changed. Commutes are too long, congestion too great, pollution is worsening and the suburbs are sterile places where nobody knows their neighbors, or so goes the widely held impression. The solution? According to the more zealous interpretation of New Urbanist principles, urban forms need to be re-directed to discourage driving.

Intuitively, it seems entirely plausible that building communities where walking is easier and more pleasant will reduce the amount that people drive. But as the authors pored through the literature on urban form and travel behavior, the theory didn't hold up. One study of neighborhoods in southern California's Orange and San Diego Counties appeared to show that traditional neighborhoods featuring many of the qualities found in New Urbanism designs generated fewer car trips per household than neighborhoods lacking those qualities. But on closer examination it appeared that income—not neighborhood features—more accurately predicted differences in trip generation.

"Given the enormous support for using land use and urban design to address traffic problems, it was somewhat surprising ... to find the empirical support for these transportation benefits to be inconclusive and their behavioral foundations obscure," the authors write.

Changes in urban design "can influence automobile travel in ways that are hard to anticipate," they warn. Shorter distances to schools or shopping may promote walking, but may also increase the number of trips taken by car. For example, people who drive five miles to the shopping center may load up and make one trip a week because the drive is unpleasant and congested. But if shopping is only a mile away, instead of walking, they may opt to drive on an errand several times a week.

Furthermore, even if the New Urbanism promises to reduce driving, implementing it depends on land-use regulation—a point the authors say has been "almost completely overlooked in the context of the transportation goals of urban designs." Many of the earlier New Urbanist proposals developed guidelines for land use regulations, but often gave little attention to the tricky political question of whether or how those guidelines would be implemented. Boarnet and Crane note that cities often have incentives that run counter to New Urbanist design proposals. For example, local governments might not wish to build housing around transit centers because commercial development provides more tax revenue. Zoning regulations and traffic codes, which reflect older ideals of lower densities and segregated land uses, are also frequently at odds with the New Urbanist designs. Boarnet and Crane do not argue that local governments will avoid New Urbanist designs—instead they argue that the difficult task of understanding the political economy of local government incentives with respect to land use regulation has until recently been overlooked by New Urbanist proposals that were long on design detail but short on political and planning savvy.

Finally, they ask, how does altering the form of the built environment stack up against other options for reducing traffic congestion and improving air quality? "If the goal is simply to reduce traffic congestion or improve air quality, urban design should not be the first place that policy-makers look," they write, noting that land use and urban design strategies are less flexible than many other regulatory options. Technology can more easily solve problems of pollution, if it is used, for example, to change the price of travel by charging fees to drive on the most congested roads. By comparison, the cost of building new communities or rebuilding old ones is expensive and slow. And, they point out, "The built environment is long lived and difficult to change."

A modern American streetscape, designed primarily for automobile travel, long on cul-de-sacs and short on pedestrians.

"Overall, our analysis ... suggests that the link between the built environment and travel is intimately tied to how urban form influences the cost of travel, and that the effect of design is complex in ways not adequately appreciated in most policy discussions," they write.

Although New Urbanism's proponents may not find much to be enthusiastic about in *Travel by Design*, Boarnet and Crane insist that they do not mean to denigrate New Urbanist intentions. "Possibly the greatest benefits of many of the New Urban designs are the more ephemeral goals of livability, public interaction and community spirit," they write. "While those are admittedly difficult to measure, we suggest that too much emphasis on the transportation benefits may sell some designs short."

The authors suggest that planners should focus on how urban designs influence the speeds and distances of non-work car trips and trip chaining—when people combine trips. "A largely unanswered but important question is how different urban designs do or do not influence trip-chaining patterns, and in turn how that informs transportation policy." If people drop their children at day care before going to work, will particular arrangements of child care and work locations change travel?

One promising area is how urban form could be changed to encourage greater physical activity. Boarnet and his graduate students are researching the links between walking and New Urbanist design, and possible effects on the health of the community.

Along those lines, Crane, together with ITS-Davis' Patricia Mokhtarian, Professor of Civil and Environmental Engineering at UC Davis, and ITS Berkeley's Robert Cervero, Professor of City and Regional Planning at UC Berkeley, and others, is serving on a joint committee of the Transportation Research Board and the Institute of Medicine on "Physical Activity, Health, Transportation, and Land Use." The group will spend the next two years reviewing the influence of the built environment on physical activity, such as walking and biking. The Robert Wood Johnson Foundation has funded the Active Living Research Program at San Diego State University, and Cervero chairs its National Advisory Committee. The foundation is entertaining research proposals to study ways in which urban landscapes can be reshaped to encourage more healthful practices such as increased physical activity, while protecting participants from the risks of the road. ■ ■ ■

—Christine Cosgrove

The Convenience Stores They Are A-Changin'

(To view and print pdf files, use Adobe Acrobat Reader available at this link.)

Over the last three decades, the convenience store industry has undergone substantive transformation. Traditional convenience stores built from the late 1970's until the 1990's were freestanding operations with a range in size from 2,500 square feet to 3,500 square feet and offered convenience type items such as tobacco, snacks, beverages, and pre-made foods. They also typically offered customers four or fewer vehicle fueling positions.

In contrast, the new-style convenience stores being built today are much larger (between 4,500 square feet and 7,500 square feet). They offer a wider variety of convenience items and more services to customers such as made-to-order sandwiches, no-fee ATM machines, expanded produce and dairy sections, and American with Disabilities Act (ADA) compliant public restrooms. Additionally, these modern convenience stores are large enough to accommodate a dedicated manager's office, an employee break room, internal trash storage, and enlarged dry and refrigerated storage facilities.

Trip Generation, 6th Edition published by the Institute of Transportation Engineers (ITE) contains trip generation data for Land Use Code 853 (Convenience Market with Gasoline Pumps). However, trip generation rates expressed in Land Use Code 853 may not reflect the traffic impact of new-style convenience stores because most of the data came from sites characterized by small traditional convenience stores.

In an August 2001 ITE Journal article entitled, “Trip Generation Characteristics for Convenience Stores,” Kevin L. Johnson and Matthew I. Hammond investigated trip generation characteristics of new-style convenience stores to determine if they are different from traditional convenience stores. Also, the research attempted to determine if the pass-by trip characteristics of smaller convenience stores, as reported in *Trip Generation, 6th Edition,* were applicable to the new, larger convenience stores.

The research included a total of 28 sites from Virginia, Delaware, New Jersey, and Maryland. Every store was located at the intersection of a major highway, had no less than 4,690 square feet, and provided between 12 and 20 fueling positions. The trip generation rates and standard deviations for the data collected from this research were then compared with the data published in *Trip Generation, 6th Edition* for Land Use Code 853.

Analysis of the two data sets demonstrated that the new-style convenience store sites have higher trip rates in the a.m. peak hour than the old-style convenience stores, but significantly lower trip rates in the p.m. peak hour. This was true using both building area and fueling positions as independent variables. The pass-by rates for the new-style convenience stores were found to be much higher in both the a.m. and p.m. peak hours than the pass-by trip rates reported in *Trip Generation, 6th Edition*. This results in a non-pass-by rate for new-style convenience stores that is at least 24 percent lower than for convenience stores in Land Use Code 853 in *Trip Generation, 6th Edition*.

Finally, while the research showed “low standard deviations for the two independent variables (building area and number of fueling positions), it was not statistically significant from the standard deviation rate for the average trip rate per site.” This finding casts doubt on whether the trip generation rate for a new-style convenience store is directly related to building size or the number of fueling positions. This is important since it is often assumed that reducing building size and/or the number of pumps will result in a lower trip generation rate.

In addition, the article recommended that further research on this subject is needed. Until such a time the multiple-regression equations provided in *Trip Generation, 6th Edition*, average rates, and graphic plots will remain the best available source of trip generation data. Given the findings described above, the overall conclusion of this research report is that a new land use category should be developed for the next edition of *Trip Generation* that reflects trip generation characteristics of new-style convenience stores.

To view this article in full, see the August 2001 edition of the ITE Journal or online here. For further information, contact Matthew Hammond at 610-326-3100 by phone or at mhammond@trafficpd.com by e-mail. (*© Institute of Transportation Engineers Adapted with permission*.)

Trip-Generation Characteristics for Convenience Stores

THIS STUDY FOUND TRIP-GENERATION RATES SIGNIFICANTLY DIFFERENT THAN ITE'S *TRIP GENERATION, SIXTH EDITION* RATES FOR THE CONVENIENCE STORE WITH GASOLINE PUMPS CATEGORY DURING THE PEAK HOURS, PLUS SIGNIFICANTLY HIGHER PASS-BY-TRIP PERCENTAGES. AS A RESULT, THE AUTHORS SUGGEST CONSIDERATION OF A NEW LAND USE CODE.

BY KEVIN L. JOHNSON AND MATTHEW I. HAMMOND

TODAY'S NEW CONVENIENCE stores have raised issues regarding trip generation and site usage compared to the characteristics of traditional convenience stores constructed between the late 1970s and the early 1990s. Some of the issues related to these new convenience stores often expressed by developers, local municipalities and state departments of transportation are:

- How many vehicle trips will be generated in the a.m. and p.m. peak hours based on gross floor area (GFA) or fueling positions?
- What percentage of the convenience store's vehicle trips is defined as "new trips" to the area during the a.m. and p.m. peak hours?
- What percentage of customers will utilize the different services provided in each convenience store?

This study addresses these questions to accurately portray the trip-generation and site-usage characteristics of these new developments.

HISTORY OF THE CONVENIENCE STORE

The convenience store industry has changed in many ways throughout the years. In the past, the typical convenience store was a stand-alone facility ranging in size from 2,500 square feet (sq. ft.) to 3,500 sq. ft., offering convenience type items (i.e., tobacco, snack foods, beverages and pre-made foods). Some of these smaller facilities also contained four or fewer gasoline dispensers. Today's convenience stores maintain these same convenience products, but the stores are substantially larger, offering customers additional services and meeting requirements of the Americans with Disabilities Act (ADA). Thus the birth of the modern convenience stores. Unlike the existing convenience stores, these modern convenience stores are typically two to three times larger (between 4,500 sq. ft. and 7,500 sq. ft. of GFA). In addition, these convenience stores average twice as many fueling positions (ranging from 12 to 20). Unlike most of the Co-Branded and 7-Eleven type convenience stores, these modern convenience stores offer made-to-order sandwiches, a deli counter and no-fee ATM machines. In addition to expanded produce and dairy sections, the new stores also offer ADA-compliant public restrooms, a dedicated manager's office, an employee break room, internal trash storage, and enlarged dry and refrigerated storage facilities. These convenience stores often create concerns regarding the prospective traffic impact they could create.

HISTORICAL STUDIES OF CONVENIENCE-STORE TRIP-GENERATION CHARACTERISTICS

A traffic impact study (TIS) evaluates the number of trips generated by a site and the impact of the resulting traffic increase on the local roadway network. The characteristics of any development are important to engineers, transportation planners, local agencies, state departments of transportation and the public when estimating the affect these developments will have in a certain study area. Traditionally, the latest edition of the Institute of Transportation Engineers' (ITE) *Trip Generation*[1] is utilized to determine how many trips a particular development will generate. While Land Use Code 853 is contained in *Trip Generation* for a Convenience Store with Gasoline Pumps, the sites studied to develop the rates and equations contained in *Trip Generation* are significantly different from the larger convenience stores being built today. Land Use Code 845 (Gasoline/Service Station with Convenience Market) was not considered in this study because the primary business of the convenience stores studied is the sale of convenience products, not the fueling of motor vehicles.

Table 1. Summary of driveway data collected.									
Site		Number of fueling	Total	Tripends		Rate (1,000 GFA)		Rate (fueling position)	
Number	Location	positions	GFA	a.m. peak	p.m. peak	a.m.	p.m.	a.m.	p.m.
1	East Lampeter Township, PA	12	5,500	189	214	34.36	38.91	15.75	17.83
2	Ephrata Borough, PA	12	5,060	366	264	72.33	52.17	30.50	22.00
3	East Vincent Township, PA	16	5,543	240	213	43.30	38.43	15.00	13.31
4	Upper Macungie Township, PA	16	5,565	270	160	48.52	28.75	16.88	10.00
5	West Sadsbury Township, PA	16	5,500	226	212	41.09	38.55	14.13	13.25
6	Muhlenberg Township, PA	16	4,993	221	192	44.26	38.45	13.81	12.00
7	Millsboro, DE	12	5,488	284	266	51.75	48.47	23.67	22.17
8	Bristol, PA	16	5,565	316	332	56.78	59.66	19.75	20.75
9	Bel Air, MD	12	4,694	214	218	45.59	46.44	17.83	18.17
10	Frederick, MD	16	4,694	382	264	81.38	56.24	23.88	16.50
11	Salisbury, MD (#1)	12	4,694	244	216	51.98	46.02	20.33	18.00
12	Salisbury, MD (#2)	12	4,694	182	162	38.77	34.51	15.17	13.50
13	Fredericksburg, VA (#1)	12	4,848	220	232	45.38	47.85	18.33	19.33
14	Woodbridge, VA (#1)	16	4,848	298	254	61.47	52.39	18.63	15.88
15	Woodbridge, VA (#2)	12	5,242	268	222	51.13	42.35	22.33	18.50
16	Spotsylvania, VA (#1)	16	4,848	336	314	69.31	64.77	21.00	19.63
17	Spotsylvania, VA (#2)	16	4,848	268	274	55.28	56.52	16.75	17.13
18	Stafford, VA (#1)	16	4,848	188	146	38.78	30.12	11.75	9.13
19	Fredericksburg, VA (#2)	12	5,242	170	186	32.43	35.48	14.17	15.50
20	New Castle, DE (#1)	20	4,694	204	210	43.46	44.74	10.20	10.50
21	New Castle, DE (#2)	16	4,694	316	328	67.32	69.88	19.75	20.50
22	Middletown, DE	16	4,694	180	188	38.35	40.05	11.25	11.75
23	Newark, DE	16	4,694	186	222	39.63	47.29	11.63	13.88
24	Lanoka, NJ	16	5,094	284	200	55.75	39.26	17.75	12.50
25	Cream Ridge, NJ	16	5,565	386	362	69.36	65.05	24.13	22.63
26	Medford, NJ	16	5,565	364	428	65.41	76.91	22.75	26.75
27	Egg Harbor, NJ	16	4,694	454	308	96.72	65.62	28.38	19.25
28	Florence, NJ	16	5,565	256	222	46.00	39.89	16.00	13.88
	Average	15	5,070	268	243	53.07	48.03	18.27	16.58

The average site studied in *Trip Generation* contained 3,000 sq. ft. and eight fueling positions. Only 2 of the 53 sites studied contained more than 4,500 sq. ft. of space with a maximum of 16 fueling positions. Both are substantially different from the convenience-store sites being constructed today.

The objective of this research was to determine if the trip-generation characteristics of convenience stores are different than those for the older convenience stores with gasoline contained in Land Use Code 853 of *Trip Generation*. If determined to be different, a second objective of this research was to develop a database of trip-generation characteristics and prepare such rates or equations that can be used for forecasting future trip-generation characteristics for similar convenience stores.

An additional publication, the *Trip Generation Handbook*,[2] also contains information on pass-by-trip characteristics. "Pass-by trips are trips that are attracted from traffic passing the site on an adjacent road that offers direct access to the generator."[2] Most of the a.m. and p.m. peak-hour pass-by data in the *Trip Generation Handbook* were collected from sites in Florida, Indiana and Kentucky in 1993. An objective of the research study was to determine if the pass-by-trip characteristics of the smaller convenience stores with gasoline were also applicable to the new, larger convenience stores.

STUDY SITES

The study sites were selected to help identify trip-generation characteristics of prototypical new-style convenience stores. The sites included seven stores in Pennsylvania, seven stores in Virginia, five stores in Delaware, five stores in New Jersey and four stores in Maryland. All 28 sites used for the development of the trip-generation characteristics are located at intersections along major highway routes. Traffic counts at the driveways and customer surveys were conducted during the peak periods (7 a.m. to 10 a.m. and 3 p.m. to 6 p.m.) when the adjacent roadways had their highest traffic

Table 2. Pass-by-trip and non-pass-by-trip percentages.						
Site	Non-pass-by trips*		Pass-by trips		Peak-hour volumes of adjacent intersection	
number	a.m. peak	p.m. peak	a.m. peak	p.m. peak	a.m. peak	p.m. peak
1	15%	16%	85%	84%	2,975	4,025
2	16%	9%	84%	91%	3,219	4,181
3	16%	13%	84%	87%	1,933	2,363
4	23%	19%	77%	81%	2,262	2,770
5	18%	10%	82%	90%	1,570	2,616
6	25%	28%	75%	72%	1,991	2,917
7	20%	27%	80%	73%	N/A	N/A
8	32%	24%	68%	76%	2,854	3,362
9	28%	22%	72%	78%	2,440	3,549
10	10%	11%	90%	89%	2,278	2,755
11	22%	33%	78%	67%	1,561	2,272
12	21%	34%	79%	66%	2,764	3,514
13	45%	29%	55%	71%	1,398	2,350
14	32%	33%	68%	67%	2,106	2,954
15	26%	30%	74%	70%	1,160	2,445
16	15%	22%	85%	78%	2,676	3,086
17	25%	17%	75%	83%	3,244	4,143
18	29%	27%	71%	73%	1,663	2,534
19	29%	44%	71%	56%	548	950
20	16%	24%	84%	76%	3,864	1,616
21	26%	27%	74%	73%	2,185	1,858
22	42%	41%	58%	59%	962	1,344
23	16%	28%	84%	72%	2,956	3,434
24	14%	14%	86%	86%	1,260	1,730
25	42%	39%	58%	61%	1,253	1,713
26	21%	14%	79%	86%	1,928	1,721
27	21%	19%	79%	81%	1,859	1,734
28	16%	19%	84%	81%	1,953	2,227
Average	24%	24%	76%	76%		

Primary trips and diverted-linked trips are included.

volumes. Every site studied had a convenience store in excess of 4,690 sq. ft. with 12 to 20 fueling positions.

DATA COLLECTION

The following were assumed in the collection of the data from each study site:

- Traffic data during the a.m. and p.m. peak hours are the most important for TIS; and
- The trip-generation characteristics during the peak hours on the adjacent roadways will produce the worst-case scenario for traffic impact on the roadways.

Trip-generation data were collected at the driveways for entering and exiting movements. All traffic counts were taken on one day between Tuesday and Thursday during a typical workweek throughout the year. Approximately 25 percent of the sites studied were located in rural areas, while approximately 75 percent of the sites studied were located in urban areas. Site-usage observations were recorded for the different customer activities (i.e., food-only purchase, gasoline-only purchase, food and gasoline purchase) present at each of the study sites during the peak hours. Pass-by-trip and new-trip data were collected via customer interviews that were conducted inside the stores as well as at the gasoline pumps at each store to obtain a balanced result due to pay-at-the-pump options. Table 1 is a summary of the data collected pertaining to the driveway counts.

Table 3. Site usage of convenience stores studied.			
Time period	Food only	Gas only	Food and gas
a.m. peak hour	52%	39%	9%
p.m. peak hour	39%	49%	12%

DATA ANALYSIS

Analysis of the data collected included trip-generation rates per 1,000 feet of GFA and trip rates per fueling position. Based on these 28 sets of counts, composite trip-generation rates and standard deviations were calculated. These composite rates are shown in Table 1.

PASS-BY-TRIP AND PRIMARY-TRIP OBSERVATIONS

Convenience stores attract a large portion of their customers from traffic passing the facility on an adjacent roadway, which contains direct access to the site. In other words, these types of facilities attract a high percentage of pass-by trips. Approximately 9,500 customers were interviewed at the facilities studied to determine percentages of pass-by trips, diverted-linked trips and primary trips. Customers were interviewed to determine the origin of their trip before arriving at the store, the destination of their trip after leaving the store and whether they were passing by the site or traveling out of their way to patronize the facility. The results of the customer interviews are shown in Table 2.

SITE-USAGE DISTRIBUTIONS

Convenience stores also attract multipurpose trips. It is often important to recognize the specific destinations of each customer on the site for purposes of analyzing the impact of adding gasoline service at an existing food-only facility or when municipal ordinances governing two uses on one site permit the second use only if it is an auxiliary use. Table 3 shows the relationship between the three possible on-site uses at the 28 sites studied.

As indicated in Table 3, there are roughly one-third more food-only customers than gasoline-only customers in the a.m. peak hour, with roughly 25 percent more gasoline-only customers in the p.m. peak hour than food-only customers. The most frequently cited reason for this difference is that customers typically purchase only a food product (e.g., coffee, doughnuts, lunch, etc.) on their way to work in the a.m. peak hour to avoid being late to work and purchase gasoline on their way home from work in the p.m. peak hour. Interaction on-site involving purchases of both food and gasoline account for 9 percent of the trips in the a.m. peak hour and 12 percent in the p.m. peak hour.

CONVENIENCE-STORE DATA VS. *TRIP GENERATION* DATA

Table 4 presents a comparison between the trip-generation rates and standard deviations for the data collected vs. those published in *Trip Generation* for Land Use Code 853. As indicated in Table 4, the data collected at the new-style convenience store sites result in higher trip rates in the a.m. peak hour but significantly lower trip rates in the p.m. peak hour.

Comparison of the standard deviations for the new convenience-store data vs. *Trip Generation* data for Land Use Code 853 indicates that the new convenience-store data is less variable than the Land Use Code 853 data. The data collected at the new convenience stores also result in significantly higher pass-by rates in the a.m. and p.m. peak periods than the rates published in the *Trip Generation Handbook*. The percentage of non-pass-by trips in each peak hour for each independent variable will be significantly less (24 percent to 44 percent) for the convenience stores than for Land Use Code 853 as indicated in Table 5.

Table 4. Trip-generation comparison.

Time period	Data collected for convenience store	*Trip Generation* Land Use Code 853
a.m. peak hour		
Pass-by percentage	76%	63%
1,000 sq. ft. GFA		
Trip generation rate	53.07	45.58
Standard deviation	15.20	18.50
Fueling positions		
Trip generation rate	18.27	17.17
Standard deviation	5.06	11.32
Trips per site		
Trip generation rate	268.29	N/A
Standard deviation	74.51	N/A
p.m. peak hour		
Pass-by percentage	76%	66%
1,000 sq. ft. GFA		
Trip generation rate	48.03	60.61
Standard deviation	12.40	35.37
Fueling positions		
Trip generation rate	16.58	19.22
Standard deviation	4.35	12.02
Trips per site		
Trip generation rate	243.18	N/A
Standard deviation	65.39	N/A

Note: N/A = Rates are not provided in Trip Generation *or the* Trip Generation Handbook.

Table 5. Non-pass-by trip-generation-rate comparison.

	Time period	Independent variable	Total trip-generation rate	Non-pass-by rate	Non-pass-by trip-generation rate
Convenience store	a.m. peak	1,000 sq. ft. GFA	53.07	0.24	12.74
Land Use Code 853	a.m. peak	1,000 sq. ft. GFA	45.58	0.37	16.86
Convenience store	a.m. peak	Fueling positions	18.27	0.24	4.38
Land Use Code 853	a.m. peak	Fueling positions	17.17	0.37	6.35
Convenience store	p.m. peak	1,000 sq. ft. GFA	48.03	0.24	11.53
Land Use Code 853	p.m. peak	1,000 sq. ft. GFA	60.61	0.34	20.61
Convenience store	p.m. peak	Fueling positions	16.58	0.24	3.98
Land Use Code 853	p.m. peak	Fueling positions	19.22	0.34	6.53

NEED FOR FURTHER RESEARCH ON OTHER INDEPENDENT VARIABLES

Unlike the convenience industry, the gasoline industry has developed multiple-regression models to project future sales. These models include areawide population, average incomes, location of competitors, average daily traffic volumes, separation distance between curb cuts and the nearest signalized intersection, etc., as independent variables. While the data collected for this report shows low standard deviations for the two independent variables (number of fueling positions and building area), it is not statistically different from the standard-deviation rate for the average trip rate per site. This result gives credence to what the gasoline industry and the convenience industry have been stating for years—trip generation is not directly related to the size of the building or number of fueling positions. This fact is important since many government officials believe that reducing the building area or the number of fueling positions at a proposed site can reduce the number of trips. However, until additional research is completed or multiple-regression equations are provided in *Trip Generation,* average rates and graphic plots will be the best available source of trip-generation data.

CONCLUSIONS

Based on the research conducted at the new convenience stores, it can be concluded that these sites have different trip-generation characteristics from the smaller convenience stores with gas, which are the basis for developing the trip-generation rates for Land Use Code 853 (Convenience Store with Gasoline Pumps). The trip-generation rates for new-style convenience stores are greater in the a.m. peak hour than the existing *Trip Generation* rates (for Land Use Code 853) using both building area and number of fueling positions as the independent variable. However, the trip-generation rates for the new-style convenience store in the p.m. peak hour are significantly less than the rates in *Trip Generation* for Land Use Code 853. The pass-by rates for the new-style convenience store are significantly higher than the rates in the *Trip Generation Handbook* for both the a.m. and p.m. peak periods. As a result, the non-pass-by trip-generation rate for new-style convenience stores is at least 24 percent less than for convenience stores in Land Use Code 853.

Furthermore, a review of the standard deviations for the new-style convenience-store data vs. the Land Use Code 853 data indicates that the former is significantly less variable.

Based on these results, consideration should be given to the creation of a new land use category in the next edition of *Trip Generation* to more accurately project the trip-generation characteristics of these new-style convenience-store sites. ■

References

1. ITE. *Trip Generation, Sixth Edition.* Washington, DC, USA, 1997.

2. ITE. *Trip Generation Handbook: An ITE Recommended Practice.* Washington, DC, USA, 2001.

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Do Sailors Drive Less than the Rest?

(To view and print pdf files, use Adobe Acrobat Reader available at this link.)

Increasingly, military personnel and their families live in off-base housing complexes. Accordingly, local jurisdictions are finding that they have to consider the infrastructure demands being placed on them by the increasing presence of off-base military housing accommodations. In considering the potential traffic impacts of off-base military housing, local jurisdictions typically turn to *Trip Generation, 6th Edition*, published by the Institute of Transportation Engineers (ITE), for guidance on the number of trips that might be expected from this land use type. Unfortunately, off-base military housing is not a land use type listed in *Trip Generation, 6th Edition*.

In 1998, Mark E. Peterson, AICP and Frank Owsiany, P.E. conducted a study that looked at trip generation rates of off-base military housing. Their findings are detailed in an article entitled "Military Housing Trip Generation Study" published in the February 1998 edition of ITE Journal on the Web. The study focused on three off-base military housing developments in the San Diego, California region. All three developments were located within 15 miles of the 32nd Street Navel Station and were comprised of townhouse style units, apartment units, or a mixture of the two styles.The developments ranged in size between 120 and 245 dwelling units per development and were at least 90 percent occupied.

Trip generation rates were derived for all three developments, as was a weighted average trip generation rate. The weighted average trip rate for all three sites was calculated as being 6.2 trips per dwelling unit, significantly less than the comparable trip generation rate of 8 trips per dwelling unit for condominium developments in the region (as determined by the San Diego Association of Governments).

Another significant study finding was that "all three off-base military housing sites were found to exhibit peak hour trip generation earlier than the generally accepted conventional peak travel periods on regional roadways." Off-base military housing peak trip travel periods were found to be from 5 a.m. to 7 a.m. and from 3 p.m. to 5 p.m., as opposed to the region's typical peak travel periods from 7 a.m. to 9 a.m. and from 4 p.m. to 6 p.m.

Taken together, the primary findings of the study imply that the traffic impacts of off-base military housing are substantially lower than similar civilian styles of development. As such, these results should help transportation planners and engineers to accurately estimate the potential transportation impacts of off-base military housing and to develop appropriate measures for addressing those potential impacts.

To view this article, click here or see the November 1998 edition of the ITE Journal On The Web. For additional information, contact Frank E. Owsiany, P.E. at fowsiany@mtdb.sdmts.com by e-mail or at the Metropolitan Transit Development Board in San Diego, CA. (.) *Adapted with permission.*

Military Housing Trip Generation Study

STUDY RESULTS FOUND THAT MILITARY HOUSEHOLD TRIP GENERATION RATES WERE LOWER THAN CONVENTIONAL HOUSEHOLDS. SUPPORTING EVIDENCE WILL BE PRESENTED.

BY MARK E. PETERSON AND FRANK E. OWSIANY

THIS ARTICLE DOCUMENTS THE results of a trip generation study of off-base military housing facilities in the San Diego Region (Calif., USA). The study was undertaken to provide data and information on the number of daily and peak hour vehicular trips attracted to or produced by military housing units. These data will be used to assist military planners in locating future housing facilities in the San Diego Region. Information was developed based on studies of vehicle counts entering and exiting military housing sites and derivation of trip rates related to specific military housing site characteristics and residential trip making parameters.

Three military housing sites in the San Diego Region provided the basis for the study, including the following:

- *Howard Gilmore Terrace*, located in La Mesa, approximately 15 miles east of the 32nd Street Naval Station, which is a major work center for naval personnel. The quarters are townhouse style, situated on 38.5 acres, consisting of 244 junior enlisted units (154 two-bedroom units and 90 three-bedroom units). At the time of the study, 229 of the 244 units (93.9 percent) were occupied.
- *Terrace View Villas*, located in east San Diego, approximately six miles northeast of the 32nd Street Naval Station. The quarters are apartment style dwellings situated on 17.2 acres, consisting of 236 junior enlisted units (64 one-bedroom units and 172 two-bedroom units). At the time of the study, 216 of the 236 units (91.5 percent) were occupied.
- *Pomerado Terrace*, located in north central San Diego County, approximately 15 miles from the 32nd Street Naval Station and two miles from the Miramar Naval Air Station. The quarters are both townhouse and apartment style dwellings situated on 51.9 acres, consisting of 120 senior enlisted units (72 two-bedroom units and 48 three-bedroom units). At the time of the study, 109 of the 120 units (90.8 percent) were occupied.

Each of the military housing sites was chosen based upon representativeness of housing facilities, regional location and clarity of access, including location of entrance/exit driveways.

OVERVIEW OF METHODOLOGY

To insure validity and acceptability of results, the study was undertaken using data collection and analysis guidelines established by the San Diego Association of Governments (SANDAG), the local Metropolitan Planning Organization (MPO).[1] Key steps in the study process included the following:

1. Completion of seven-day traffic counts at entry/exit roadways serving the study sites. The results of these counts were compiled to determine the number of vehicles entering and exiting the military housing sites by 15-minute intervals. Average daily (weekday and weekend) and peak hour (a.m. and p.m.) traffic summaries were developed for each site. Vehicle occupancy counts also were conducted at each facility.
2. Collection of site characteristics and residential parameters that have been shown to affect trip generation, including the following:
   - Number of housing units;
   - Number of occupied housing units;
   - Average number of residents per unit;
   - Number of residents deployed; and
   - Average number of drivers per unit.
3. Deriv ation of trip generation rates, including the number of daily and peak hour trips per dwelling unit.

Traffic counts were conducted at each of the military housing sites during June and July 1996. Site characteristics and residential parameters were provided by personnel from Commander, Naval Base San Diego and the Public Works Center, San Diego.

TRIP GENERATION STUDY RESULTS

Site Characteristics and Residential Parameters

Site characteristics and residential parameters for each military housing facility were obtained from the Naval Facilities Engineering Command, Southwest Division, and included the total number of dwelling units (DUs), number of occupied units and residents per unit. A list of resident military personnel by duty station was used to identify personnel on extended deployment to the Western Pacific (WESTPAC) during the time frame of the study. The number of residents per occupied dwelling units were adjusted to accurately reflect those present during the time frame of the study.

The number of residents of driving age were identified by assuming all military persons and their spouses were of driving age and identification of dependent drivers via review of birth date data. Table 1 summarizes the site characteristics and residential parameter data for each military housing facility.

Traffic Data

Traffic data for each military housing facility were collected for a period of one week with automatic counters, for the purpose of quantifying the vehicular traffic entering and exiting each site by 15-minute intervals. Average daily and a.m./p.m. peak hour traffic summaries were developed for each site, with sepa-

Table 1. Site characteristics and residential parameters.

	Howard Gilmore Terrace (City of La Mesa)	Terrace View Villas (City of S.D.)	Pomerado Terrace (City of S.D.)	Average	Range
Dwelling Units (DU)	244	236	120	200.0	120 – 244
Acres (Gross)	38.5	17.2	51.9	35.9	17.9 – 51.9
Dwelling Units per Acre	6.3	13.7	2.3	7.5	2.3 – 13.7
Dwelling Units Occupied	229	216	109	184.7	109 – 229
% Dwelling Units Occupied	93.9%	91.5%	90.8%	92.3%	90.8% – 93.9%
Residents	771	597	371	580	371 – 771
Residents Deployed When Traffic Counts Taken	10	14	4	9	4 – 14
Residents per Occupied DU	3.3	2.7	3.4	3.1	2.7 – 3.4
Residents of Driving Age	468	435	235	379	235 – 468
% Residents of Driving Age	60.7%	72.9%	63.3%	65.4%	60.7% – 72.9%
Driving Age Residents per Occupied DU	2.0	2.0	2.2	2.1	2.0 – 2.2

Source: BRW Inc.; Aug. 5, 1996

Table 2. Traffic data.

	Howard Gilmore Terrace (City of La Mesa)	Terrace View Villas (City of S.D.)	Pomerado Terrace (City of S.D.)	Average	Range
Average Weekday Traffic (AWDT)	1405	1104	906	1138	906 – 1405
Saturday Traffic	1249	990	783	1007	783 – 1249
Sunday Traffic	1072	987	688	916	688 – 1072
Average Weekday a.m. Peak Hour	5:00 – 6:00	6:00 – 7:00	5:00 – 6:00	—	—
Average Weekday a.m. Peak Hour Volume	102	80	56	79	56 – 102
(% in/out)	(30.3%/69.7%)	(31.4%/68.6%)	(16.0%/84.0%)	(25.9%/74.1%)	
a.m. Peak Hour % of AWDT	7.3%	7.2%	6.2%	7.0%	6.2% – 7.3%
Average Weekday p.m. Peak Hour	3:00 – 4:00	4:00 – 5:00	2:00 – 3:00	—	—
Average Weekday p.m. Peak Hour Volume	116	93	75	95	75 – 116
(% in/out)	(58.5%/41.5%)	(64.0%/36.0%)	(60.8%/39.2%)	(61.6%/38.9%)	
p.m. Peak Hour % of AWDT	8.3%	8.4%	8.3%	8.3%	8.3% – 8.4%
Average Vehicle Occupancy	1.5	1.4	1.5	1.5	1.4 – 1.5
Trolley Trips (6:00 a.m.–8:00 p.m.)	26	N/A	N/A	N/A	N/A
(% in/out)	(61.5%/38.5%)				

Source: BRW Inc.; Aug. 5, 1996

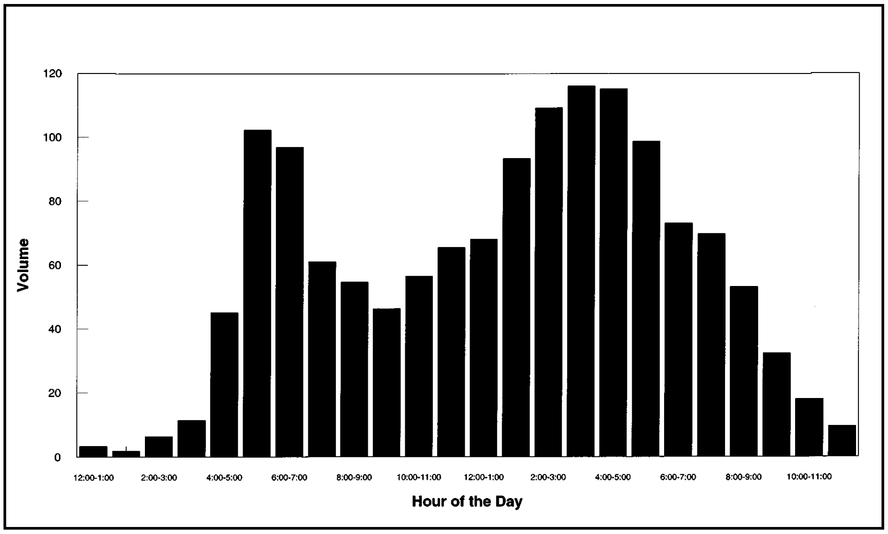


Figure 1. Average (exiting/entering) weekday volume by hour (Howard Gilmore Terrace).

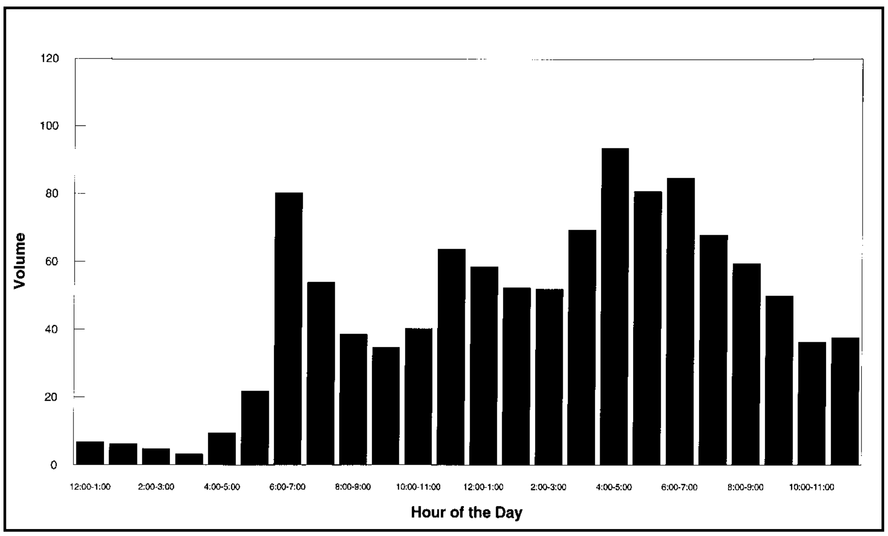


Figure 2. Average (exiting/entering) weekday volume by hour (Terrace View Villas).

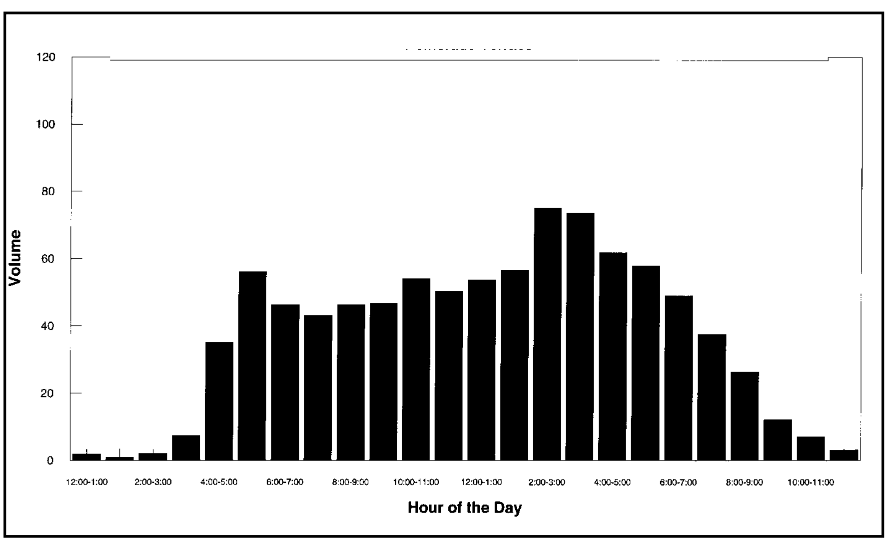


Figure 3. Average (exiting/entering) weekday volume by hour (Pomerado Terrace).

rate weekday and weekend totals also developed.

Because of the close proximity of one of the military housing facilities (Howard Gilmore Terrace) to a San Diego Trolley light rail transit station, there was concern that the site may be atypical due to a higher proportion of transit utilization compared with other military housing sites in the San Diego Region. For the purpose of verifying transit usage at this site, a manual count of transit trips was obtained through personal interviews of pedestrians accessing the trolley platform.

Table 2 summarizes the traffic data for each facility. Figures 1, 2 and 3 graphically display the average hourly distribution of trips entering and exiting each of the military housing sites.

Trip Generation Rates

Military housing trip generation rates were calculated using the site characteristics, residential parameters and traffic data. Weekday and weekend trip rates for each facility were calculated by dividing the average weekday or weekend traffic volumes entering and exiting the sites by the number of occupied dwelling units. Trip rates (a.m./p.m.) were calculated for each facility by dividing the highest, one-hour, peak hour volume by the number of occupied dwelling units. A weighted average trip rate also was calculated reflecting an average for all the facilities.

Table 3 summarizes the trip generation rates for the individual military housing sites, as well as a representative average rate for all the sites surveyed.

SUMMARY OF KEY OBSERVATIONS

Based upon review of the resulting military housing trip generation rates, a number of key observations are presented to summarize the study results.

- Trip generation rates were found to vary by dwelling unit density, as well as by suburban or urban location.
- Dwelling units per acre for the surveyed military housing sites ranged from 2.3 to 13.7, and resulting trip rates ranged from 5.1 to 8.3 trips per dwelling unit, with an average trip rate of 6.2 for all three sites. The compara-

ble residential trip generation rate from SANDAG is eight trips per dwelling unit for condominiums (or any multi-family less than 20 units/acre).

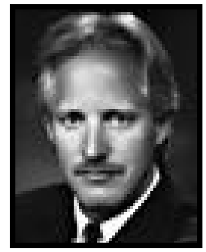
- Of the three sites surveyed, Pomerado Terrace resulted in the highest trip generation rate. Pomerado Terrace also has the highest number of both residents and drivers per occupied dwelling unit. The lower density and more suburban location of Pomerado Terrace, compared with the other surveyed military housing sites, also were determined to have a causal relationship with the higher trip rates as well.
- Peak hour trip rates are 0.5 trips per dwelling unit for the a.m. peak hour and 0.6 trips per dwelling unit for the p.m. peak hour.
- All three military housing sites were found to exhibit peak hour trip generation earlier than the generally accepted conventional peak travel periods on regional roadways. In the San Diego Region the typical peak hour traffic hours are from 7 a.m. to 9 a.m. and 4 p.m. to 6 p.m. Military housing traffic peaks were found to be earlier, from 5 a.m. to 7 a.m. and 3 p.m. to 5 p.m. Military housing peak hour trip generation is consistent with the shifts normally worked by naval personnel, which begin and end earlier than the typical civilian workday.
- The number of San Diego Trolley trips at Howard Gilmore Terrace was found to be rather low, in spite of its close proximity to a trolley station. Trolley trips at the site (26) translated to an approximate 1.2 percent transit mode split for the site, similar to the San Diego regional average.

CONCLUSIONS

Given the unique characteristics of military work schedules coupled with their extended deployment rates and relocation practices, military household trip generation rates were found to be lower than conventional households. Study results will assist planners and transportation engineers in determining potential traffic impacts associated with military housing facilities. Data within this study ultimately will be used to appropriately address these impacts to support military housing needs in the future. ■

Reference

1. San Diego Association of Governments and CALTRANS, District 11. *San Diego Traffic Generators.* San Diego, Calif., USA. Published by San Diego Association of Governments, January 1990 (with updates).



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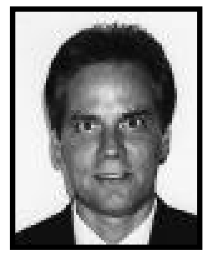

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Table 3. Trip generation rates.

	Howard Gilmore Terrace (City of La Mesa)	Terrace View Villas (City of S.D.)	Pomerado Terrace (City of S.D.)	Weighted Average	Range
Weekday Trips per Occupied DU	6.1	5.1	8.3	6.2	5.1 – 8.3
Weekend Trips per Occupied DU (Saturday/Sunday)	5.5/4.7	4.6/4.6	7.2/6.3	5.5	4.6 – 7.2
a.m. Peak Hour per Occupied DU	0.5	0.4	0.5	0.5	0.4 – 0.5
(% in/out)	(25.4%/74.6%)	(31.8%/68.2%)	(16.1%/83.9%)		
p.m. Peak Hour per Occupied DU	0.6	0.5	0.8	0.6	0.5 – 0.8
(% in/out)	(55.5%/44.5%)	(51.3%/48.7%)	(64.4%/35.6%)		

Source: BRW Inc.; Aug. 5, 1996

Gas, Grub, Groceries & Go!

(To view and print pdf files, use Adobe Acrobat Reader available at this link.)

Most interchanges are dotted with numerous businesses that cater to the needs of motorists, like gas stations, convenience stores, and restaurants. At one time, these uses stood separate from one another. If customers needed an item from each of these uses, they would have to travel from shop to shop, usually along the adjacent arterial. Soon, gasoline companies discovered the advantages of expanding their stations to include convenience markets that carried a wider selection of goods than was previously common. Gas patrons could conveniently pick-up a snack or a newspaper and purchase gasoline in a single trip, while the business would simultaneously experience greater revenue by selling a product that yielded a high profit margin.

Recently, a new trend has emerged. These service stations, which already housed two uses under one roof, have started teaming up with fast-food restaurants to provide full fast-food meals. Throughout the United States, restaurants like McDonald's, Burger King, Dunkin' Donuts and others are being incorporated into service station operations where both an eating area and, in many cases, a drive-thru window is provided. In one stop, motorists can now gas up, buy a newspaper and eat a complete meal.

Trip Generation, 6th Edition, published by the Institute of Transportation Engineers (ITE), includes trip generation data for "service stations with a convenience market and car wash." However, with fast-food restaurants now encompassing a substantial area of these stations, there is a growing belief that the existing ITE category fails to accurately describe these new uses. To address these concerns, researchers from Wayne State University in Michigan were charged with collecting data regarding the trip generation characteristics of these businesses and developing a model to predict the expected trip generation rates of future stations. Their findings are detailed in an article entitled "Trip-Generation Models for Multiuse Highway Commercial Developments" published in the February 1998 edition of the ITE Journal.

The researchers focused on 11 service stations in Michigan that sold gasoline, included a convenience store and contained a fast-food restaurant, like McDonald's, Taco Bell, or Dunkin' Donuts. All five service stations that housed a McDonald's also had a drive-thru window. Each site abutted an arterial street that carried a "significant" amount of through traffic and provided access to the nearby highway. Nine out of the 11 study sites were within one-half mile of a freeway interchange, while the other two sites were along major highway routes. Two additional stations abutting arterial roadways were also selected to serve as testing sites to validate the study's findings.

The researchers assumed the station's greatest impact to the adjacent arterial would occur during the roadway's peak hour, which was recorded on weekdays, as opposed to the peak hour of the service station, which was recorded on weekends. Data was collected for three non-consecutive days during a typical workweek and in-coming and out-going traffic was counted for the morning, midday, and afternoon peak hour. The researchers were also responsible for recording how many customers purchased gasoline, bought items from the convenience store, and/or ate at the fast-food restaurant. Through these observations, researchers discovered that customers did indeed frequent both the convenience store and fast food restaurant in a single trip (see Table 1).

Table 1
Averages of Trip Destinations Observed

	A.M. Peak	Midday Peak	P.M. Peak
Fast-food only	24%	36%	25%
Gasoline/convenience store	58%	51%	62%
Fast-food, Gasoline/ Convenience store	8%	13%	13%

Two approaches were taken to analyze the field data. The first approach used the traditional ITE approach with one single independent variable, gross floor area (GFA). This approach yielded a high standard deviation for all three time periods. As the researchers expected, the trip rates estimated using the traditional ITE single variable approach were substantially higher than the observed data when the "single variable approach" was applied at the two test sites.

The second approach was based on the following four variables: the number of fueling positions, the area and number of seats associated with the fast-food restaurant, and the gross floor area of the building. Based on this multiple variable approach, multiple regression models were developed to predict the expected number of trips per hour for all three periods of time (this model is described in detail in the ITE Journal article). For example, the following multivariate regression model was developed for the A.M. peak period:

Number of trips/hour = 5.289 x the number of fueling positions + 0.0105 x the area of fast food development + 2.9776 x the number of seats + 0.0111 x the gross floor area – 55.3892.

Multiple *R* = 0.97, *R-Squared* = 0.94, Standard error = 40.73

The accuracy of the multiple variable approach was verified by the actual observed trip generation characteristics of the two test sites. As shown in Table 2, the results proved that the trip generation predictions formed using the "multiple variable approach" were more accurate, for each time period, than those made using the average trip generation models provided in *Trip Generation, 6th Edition*.

Table 2
Comparison of Estimated Results

	Test Site 12				**Test Site 13**			
	A.M. Peak		**P.M. Peak**		**A.M. Peak**		**P.M. Peak**	
Observed Trip Ends	206		215		185		216	
Multiple variable model projections	248	+20%	266	+24%	152	-17%	194	-10%
Single variable model projections using average trip rates produced by ITE's *Trip Generation, 6th Edition*	301	+46%	269	+25%	269	+45%	247	+14%

With the greater accuracy of the multiple variable approach, the researchers point out that the model can be applied to future traffic impact studies for similar service stations. The data needed for this approach can readily be obtained from the developer's site plan at no additional cost to the analyst. The researchers also believe that use of the model will reduce the need for individual field observations, thereby reducing expenses for both the developer and agency responsible for reviewing the site plan. Furthermore, the model can also "increase the credibility of forecasts to city and township officials."

To view this article in full, see the February 1998 edition of the ITE Journal, or click here. For additional information, contact Dr. Tappan K. Datta at Wayne State University in Detroit, MI at 313/577-3803 or at tdatta@ce.eng.wayne.edu by e-mail.

Trip-Generation Models for Multiuse Highway Commercial Developments

TRIP-GENERATION CHARACTERISTICS FOR HIGHWAY COMMERCIAL DEVELOPMENTS THAT COMBINE GASOLINE STATION/CONVENIENCE STORE/FAST-FOOD RESTAURANT ARE IMPORTANT IN DETERMINING THE POTENTIAL TRAFFIC IMPACT ON ADJACENT ROADWAYS.

BY TAPAN K. DATTA, SUE DATTA AND PRASAD NANNAPANENI

THE ESTABLISHMENT OF A commercial development near a freeway or along an arterial street requires careful investigation of its traffic impact on the existing highway network. Some critical issues related to such a development often faced by developers and local road agencies are as follows:

- How many vehicles will be added to the existing traffic due to such a commercial development?
- How many vehicle trips are attracted to such a development during the a.m., midday and p.m. peak periods when the adjoining roadways often experience the worst traffic congestion?
- What percentage of trips are captured from the existing traffic to make an intermediate stop at such a highway commercial development, and what percentage of trips are newly generated at various times of the day?
- Do multipurpose trips reduce vehicle-miles traveled since they often satisfy several travel needs under one roof?

While all of these questions are important, this study addresses only the second question.

In the past, most gasoline stations included auto repair facilities. The next generation of gasoline stations eliminated the repair facilities and included convenience stores. Later, car wash services were combined with the convenience stores. Such multiuse developments often created concerns regarding the potential traffic impact it would create. Finally, the multiuse highway commercial developments added the fast-food/Quick Service Restaurant (QSR) to the gasoline station and convenience store. These multiuse developments initially created even more of a concern because their trip- and parking-generation characteristics were unknown. Traffic engineers and planners have struggled to estimate future traffic scenarios and to predict potential traffic impacts produced by these new multipurpose land uses.

Traffic impact assessment studies are based on the number of trips generated by a proposed development. Trip-generation characteristics of multipurpose commercial land uses are important to the planners, engineers and other interested parties in estimating the number of vehicle trips likely to be generated by this particular development. Gasoline stations, convenience stores and QSRs in one building are being developed all over the United States. However, the Institute of Transportation Engineers' (ITE) *Trip Generation* informational report[1] does not address this type of multipurpose land use. The nearest related land use category included in the ITE report is "Service Station with Convenience Market and Car Wash" (land use #846). Trip-generating characteristics for the multiuse developments described in this paper may be substantially different from service stations with convenience markets and car wash (#846) and fast-food restaurants without a drive-through window (#833) and those with a drive-through window (#834) taken alone or in combination with each other. This type of multiuse development is generally located at the corners of intersections of major arterial roads and near freeway interchanges to capture the pass-by traffic.

The objective of this research was to develop a database on trip-generating characteristics of multiuse highway commercial developments, and models that can be used for forecasting future trip-generation characteristics for a proposed multiuse development which includes gasoline stations with convenience stores and QSRs.

WHAT IS AVAILABLE TODAY?

In the early 1970s, ITE initiated a program of collecting trip-generation characteristics for various land uses from published literature, unpublished study reports and traffic impact analyses. The profession participated in providing information and shared its experiences with ITE. The accumulation of this database over the years has produced the ITE publication, *Trip Generation*. Over the past few decades, this publication has been updated several times, most recently in October 1997, to include more land uses and improved analysis results.

Most of the analysis has included linear and/or polynomial regression analysis with single independent variables such as gross floor area or the number of seats or the number of fueling positions. Dependent variables such as daily or hourly tripends have been used for highway commercial land uses. The publication also provides average tripend rates; ranges for a.m. and p.m. peak periods of the adjacent roadways; and a.m. and p.m. peak periods of the generator and weekend peak periods.

The use of single independent variable models inherently assumes that the planning and design of such commercial developments are performed using only the required amount of space for the building and gasoline fueling positions, in response to objectively predicted potential customer demand at a particular location. However, the design of such a development often is based on practical considerations of issues, such as land availability, local agency requirements and standardized building plans commonly used by various companies. Therefore, it is very unusual to expect that tripend rates will vary predictably with any one independent variable such as Gross Floor Area (GFA), number of seats in the QSR or the number of fueling positions.

MULTIUSE DEVELOPMENTS— A NEW PHENOMENON

The recent advent of multiuse developments with gasoline service stations, convenience stores and QSRs with drive-through facilities built all at the same site, under one roof, often creates a situation where customers can satisfy several of their trip purposes in one single trip. Most of these developments in Michigan, USA, in fact, have been built within the past year or two.

From the developer's point of view, providing several goods and services at one location is a reasonable approach when considering the various economic and market factors. Such factors include the following:

- The high cost of highway commercial land in urbanized areas is difficult for a single- purpose development to sustain.
- The cost of development per individual sales opportunity reduces dramatically for multiuse developments.
- Single-purpose trips often result in multipurpose uses by the customers, thus increasing the sales potential for more than one business.
- The cost of developing such an establishment is lower than individual free-standing units. Therefore, the profit potential of individual units increases dramatically.
- The multiuse developments generally include smaller QSRs that require less operating staff and as such, results in reduced operating costs.

These and other factors make the development of these types an attractive proposition. It is expected that these developments will continue to find their way into our urban fabric. Traffic engineers and planners are faced with this new phenomenon in land development. The estimate of trips to evaluate the impact of such a development has become more subjective than other established land uses due to the lack of data for existing multiuse developments. Individual perceptions and intuitions often play major roles in various local governmental agency zoning and site-plan related decisions across the country.

This study was initiated to develop a database upon which trip-generation estimates could be based in the future.

STUDY SITES

The study sites were selected to help identify trip-generation characteristics of multiuse developments of gasoline stations, convenience stores and fast-food developments. Eleven such sites were selected in Michigan. The sites included a variety of QSRs, including McDonald's, Subway, Taco Bell, Arby's, Dunkin' Donuts and Dawn Donuts. These sites included a combination of various gasoline companies and QSRs and, therefore, represent a good cross section of the multiuse development industry. However, five out of the 11 study sites included a McDonald's restaurant. The variations among the types of QSRs, such as a McDonald's restaurant and a donut shop, are expected to bring variability in the model. However, a trip-generation model for each brand of a QSR is unrealistic and becomes proprietary data.

A multiuse commercial facility

Nine out of the 11 study sites used for the development of the multiple regression model are located within one-half mile of a freeway interchange. The other two sites are located on major highway routes. The two sites used for model testing and validation were built later and also are located in close proximity to freeway interchanges. However, all 13 sites were on arterial streets that carry a significant amount of through traffic in addition to providing access to the freeways. Traffic counts at all the study sites were conducted at the driveways for the peak periods (7:00 a.m. to 9:00 a.m., noon to 1:00 p.m. and 4:00 p.m. to 6:00 p.m.) when the adjacent roadways had high traffic volumes.

The sites studied in Michigan all contained a gasoline station, convenience store and a QSR. Many of the sites included a drive-through window, with the exception of a Taco Bell, a Subway and an Arby's restaurant. The drive-through window is an added convenience for the patrons and also cuts down on the number of parking stalls required on site. Two recently opened multiuse developments consisting of a gasoline station, a convenience store and a McDonald's restaurant in southeastern Michigan were used for model validation purposes. These two sites were not used for model building purposes and, as such, can provide a good test for validation. It is important to note that sites used for empirical model building can never be used for model validation purposes.

TRAFFIC SURVEY AND DATA COLLECTION

Recognizing the vastness of variables and issues that encompasses the trip-generation characteristics of such multiuse developments, the following were assumed in this study:

- Traffic-generation data during a.m., midday and p.m. peak periods of the adjacent roadways would be of most interest for traffic impact studies.
- The trip-generation characteristics during the peak of the adjacent roadways will produce the worst-case scenario for the traffic impact on the adjacent roadways and for the community as a whole.
- Peak trip-generation characteristics of the generator, which often occur on weekends and/or during non-critical periods of adjacent roads, were not of concern to this study.

Trip-generation data were collected at the driveways to note incoming and outgoing traffic. All driveway traffic counts were made between Tuesday, Wednesday and Thursday of a typical work week. Traffic destinations, single-purpose or multipurpose counts were recorded for each of the driveways within a site for a typical hour during a.m., midday and p.m. peak hours of the adjacent roadways.

It is important to note that some of the developments in the 11 study sites did not have a QSR with a.m. peak operations; and, as such, traffic-generation data for the a.m. peak hours for these sites were not included in the development of the model for a.m. peak hours. Traffic surveys were performed during good weather conditions to capture the high end of typical weekday traffic.

Table 1 is a summary of all the data collected. Location information for the study sites are not presented in this paper to protect their confidentiality. The site numbers used in the table are maintained throughout this article. A cursory observation of the data indicates that the gross floor area and the number of fueling positions do not necessarily reflect increased or decreased customer patronage.

DISTRIBUTION OF CUSTOMER DESTINATIONS

Multiuse developments are generally expected to attract multipurpose trips. A

Table 1. Summary of data collected.

Site No.	Site Location	No. of fueling positions	Approximate area of fast food in square feet	No. of seats	Total gross floor area (GFA)	Tripends a.m. peak	Tripends midday peak	Tripends p.m. peak	Remarks
1.	Amoco/Subway/ Dawn Donuts	6	1,700	20 DD=38	2,150	167	182	207	11 sites used for model building
2.	Pilot Gas/Arby's	24	2,400	84	6,780	430	363	401	
3.	Shell/Taco Bell	8	1,250	44	2,500	N/A	143	138	
4.	Total/Taco Bell	6	500	No seating	2,500	N/A	105	101	
5.	Amoco/Subway/ Dunkin Donuts	8-G 4-D	1,700 Dun D = 1,300	25 Dun D = No seats	6,000	194	236	247	
6.	Mobil/Subway	8-G, 1-NG, 10-D	475	12	2,170	N/A	150	196	
7.	Amoco/McDonald's	28	475	18	3,300	177	144	187	
8.	Marathon/McDonald's	8	1,231	22	8,900	184	242	221	
9.	Amoco/McDonald's	12	650	16	2,800	98	151	209	
10.	Mobil/McDonald's	10	749	18	3,100	131	178	171	
11.	Citgo/McDonald's	10	1,419	12	7,300	82	133	161	
12.	Amoco/McDonald's	8	2,970	60	4,587	206	276	215	Two sites used for validation
13.	Mobil/McDonald's	8	2,383	32	4,003	182	187	216	

Note: DD = Dawn Donuts, Dun D = Dunkin Donuts, G = gasoline, D = diesel gasoline and NG = natural gasoline.

Table 2. Averages of trip destinations observed.

	A.M. Peak	Midday Peak	P.M. Peak
Fast-food only	34%	36%	25%
Gasoline/convenience store	58%	51%	62%
Multipurpose	8%	13%	13%

Table 3. Summary of regression analysis results.

A.M. Peak Results

No. of variables	R	R^2	Standard error
4 (NFP, AFF, NS, GFA)	0.969	0.939	40.735
3 (AFF, NS, GFA)	0.899	0.809	62.478
3 (NFP, NS, GFA)	0.967	0.935	36.390
3 (NFP, AFF, GFA)	0.802	0.644	85.195
3 (NFP, AFF, NS)	0.942	0.887	48.064
1 (NFP)	0.548	0.301	97.497
1 (AFF)	0.539	0.290	98.202
1 (NS)	0.856	0.732	60.306
1 (GFA)	0.297	0.088	111.314

Midday Peak Results

No. of variables	R	R^2	Standard error
4 (NFP, AFF, NS, GFA)	0.911	0.829	38.683
3 (AFF, NS, GFA)	0.889	0.792	39.518
3 (NFP, NS, GFA)	0.904	0.816	37.112
3 (NFP, AFF, GFA)	0.821	0.674	49.431
3 (NFP, AFF, NS)	0.847	0.717	46.085
1 (NFP)	0.335	0.112	71.981
1 (AFF)	0.702	0.493	54.368
1 (NS)	0.747	0.558	50.798
1 (GFA)	0.586	0.343	61.917

P.M. Peak Results

No. of variables	R	R^2	Standard error
4 (NFP, AFF, NS, GFA)	0.913	0.833	40.637
3 (AFF, NS, GFA)	0.826	0.682	51.876
3 (NFP, NS, GFA)	0.902	0.814	39.64
3 (NFP, AFF, GFA)	0.840	0.706	49.899
3 (NFP, AFF, NS)	0.886	0.784	42.728
1 (NFP)	0.524	0.274	69.114
1 (AFF)	0.631	0.397	62.965
1 (NS)	0.743	0.552	54.321
1 (GFA)	0.466	0.217	71.785

Note: NFP = number of fueling positions, AFF = area of fast food, NS = number of seats and GFA = gross floor area.

quantitative assessment of single-purpose and multipurpose trips can provide very important data for assessing future traffic impacts of proposed highway commercial developments. The interview of customers was not performed since more than half of the site operators did not cooperate in this study.

Specific destinations of each customer on the study sites were observed and noted. It is important to point out that in many instances, it was quite difficult to identify if customers simply were paying a gasoline bill or also were buying merchandise from the convenience store. See Table 2 for the averages of trip destinations observed. Further studies using customer interviews can provide more refined data regarding customer destinations.

DATA ANALYSIS

The analysis of the field data included the development of the mean and the standard deviation of the tripend rates based on gross floor area of the buildings and a regression analysis based on one to four independent variables and all various combinations.

The mean and standard deviation of the tripend rates during the three time periods are as follows:

A.M. Peak Hour
Mean tripends = 43 per 1,000 Gross Floor Area (GFA)
Standard deviation = 24.99

Midday Peak Hour
Mean tripends = 49.75 per 1,000 GFA
Standard deviation = 23.37

P.M. Peak Hour
Mean tripends = 56.2 per 1,000 GFA
Standard deviation = 26.9

The above analysis indicates that the standard deviations are quite high in all three time periods; therefore, the use of gross floor area as a single independent variable for predicting future trip characteristics for a multiuse development may be inaccurate.

Tripend rates based on one independent variable are based on the assumption that the single independent variable can explain most of the variability of the dependent variable. As a part of this study a multiple regression analysis was performed. In multiple regression analysis, it is desirable to predict one variable by using several other variables as a team of predictors. The following are the variables used in the multiple regression analysis:

Dependent Variables

- Number of trips (tripends) per hour during a.m. peak
- Number of trips (tripends) per hour during midday peak
- Number of trips (tripends) per hour during p.m. peak

Independent Variables

- Number of gasoline fueling positions in the development
- Area of QSR development
- Number of available seats at the QSR development
- Gross floor area of the building

The regression analysis was performed using a single independent variable and all different combinations of two, three and four variables. The summary of the correlation coefficients and standard errors of the various regression models tested in this study are shown in Table 3.

The following are the best results of the multiple regression analysis using all four independent variables:

For A.M. Peak Periods—Regression Model

Number (no.) of trips/hour = 5.289 x no. of fueling positions + 0.0105 x area of fast-food development + 2.9776 x no. of seats + 0.0111 x gross floor area – 55.3892

Multiple $R = 0.97$, $R^2 = 0.94$, Standard error = 40.73

For Midday Peak Periods—Regression Model

No. of trips/hour = 1.9945 x no. of fueling positions + 0.015 x area of fast-food development + 1.5901 x no. of seats + 0.0121 x gross floor area + 42.5564

Multiple $R = 0.91$, $R^2 = 0.83$, Standard error = 38.68

For P.M. Peak Periods—Regression Model

No. of trips/hour = 4.2642 x no. of fueling positions + 0.0193 x area of fast-food development + 1.53 x no. of seats + 0.0084 x gross floor area + 44.4254

Multiple $R = 0.91$, $R^2 = 0.83$, Standard error = 40.63

The above analysis indicates a reasonably good relationship between the independent variables and the dependent variable "number of trips per hour" for the various time periods.

The statistical test provides enough of an indication that the multiple variables most probably influence the trip-generation characteristics of these multiuse developments. There are probably other locational and market variables that may further improve the quality of the multiple regression models, especially to help reduce the standard-error term.

Trip-generation analysis for highway multiuse commercial developments always starts after a site plan is developed based on the developer's market analysis. Such a site plan contains the gross floor areas for the QSR as well as for the total building. It also clearly indicates the number of fueling positions and the number of seats for the QSR; therefore, input data used in this multiple regression model are readily available to predict future trip-generation characteristics.

MODEL VALIDATION

Two recently opened multiuse developments in southeastern Michigan were used to test the predictability of the four variable multiple regression models developed as a part of this study. One such multiuse development is served by eight gasoline fueling positions with an area for QSR of 2,383 square feet (sq ft), 32 seats in the common area and a gross floor area of 4,003 sq ft. The other site is served by eight gasoline fueling positions with an area for QSR of 2,970 sq ft, 60 seats for QSR customers and a gross floor area of 4,587 sq ft.

The expected number of trips for a.m., midday and p.m. peak hours was calculated using the models developed from *Trip Generation*'s average rates. See Table 4 for the trips compared with actual field observations.

This comparison shows that the multiple regression model produced much closer results as compared to the traditional approach of using average rates of single independent variables from *Trip Generation.* In every case, the trip rates from the ITE report predicted a substantially higher amount of traffic than the observed data.

POTENTIAL USE OF MODELS

This study of multiuse highway commercial developments has resulted in multiple regression models which can be used in Michigan for future traffic-impact studies. In the past, such studies were performed using field observations of similar sites. This required identifying one or more similar sites, collecting physical characteristics of the similar site(s), preparing diagrams of the site(s) and performing peak period traffic counts. These activities and others would generally consume the time of two to three professionals, for two to three days. Use of the multiple regression models developed as a part of this study will eliminate these activities related to similar sites.

Table 4. Summary of model validation.

	Site No. 12		Site No. 13	
	a.m.	p.m.	a.m.	p.m.
Observed tripends	206	215	182	216
Projection by multiple regression model	248	266	152	194
Projection by average trip rates from ITE's *Trip Generation*	301	269	269	247

The future peak-period trip predictions can be done using the models economically, yet it also will increase the credibility of forecasts to city and township officials.

This study did not attempt to collect customer interview data to ascertain percentages of "pass-by" or "diverted" traffic. Such data is available in ITE's *Trip Generation* and can be used in conjunction with the models developed as a part of this study.

CONCLUSIONS AND RECOMMENDATIONS

Multiuse highway commercial developments are a fairly new phenomenon in Michigan. These developments include gasoline stations, convenience stores and fast-food restaurants all on the same piece of property. Oftentimes, a car wash is included in such a development. Of the 11 study sites used in the model development, some included such diverse developments as a laundromat and an insurance agent's office.

The evolution of these developments are desirable when one considers that a customer can satisfy two or more travel needs, such as filling his or her gasoline tank, buying breakfast/lunch/dinner, buying a carton of milk, getting a car wash and other conveniences, by making only one trip. A few years ago, a customer with such travel needs would have made two or more trips, to two or more destinations. Thus, he or she would have incurred increased travel distance, travel time and the travel cost would have been more than what one can do today by stopping at a multiuse development. Such an increased number of trips also would have added to the increased number of vehicle counts on the roads and highways.

This study has utilized 11 existing multiuse highway commercial developments in Michigan for model building and two newly built sites for validation. All traffic-related data were collected on typical weekdays. It is expected that such a development may experience higher trips on a weekend day such as a Saturday. However, the adjacent roadway traffic on a typical Saturday generally is much lower than typical weekday traffic.

The multiple regression models developed as a part of this study indicate a reasonable correlation and provide superior predictions in comparison to the single variable models. ■

Reference

1. *Trip Generation,* Update to the 5th Edition. Washington, D.C., USA: Institute of Transportation Engineers, 1995.

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Land Use With A Kick!

(To view and print pdf files, use Adobe Acrobat Reader available at this link.)

As many parents can attest, soccer has become a very popular sport among school-aged children. In the past, outdoor soccer games were played on fields typically designed for football or track and field activities. In light of recent trends, many more recreational facilities are being built solely to accommodate soccer activities. These newer facilities are found in both residential areas and adjacent to other active land uses, with the number of fields ranging from a few to more than a dozen.

In a recent ITE Journal article (February 1999) entitled "Trip Generation at Youth Soccer Complexes: Some Unforeseen Issues," Dr. Jon D. Fricker addressed the potential traffic impact these soccer complexes could have on adjacent roadways. The article emphasized that these facilities generate a large amount of traffic, most often during weekday evenings and on Saturday mornings. These complexes "can cause significant congestion during the relatively few times at which they are active." To determine the potential impact, the study focused on developing a "procedure to predict the traffic volumes (of youth soccer complexes) to assist the developers of a soccer complex and the local transportation officials."

Traffic volume data was collected at two of the busiest youth soccer complexes in the Lafayette, Indiana area. At these locations, volumes were counted at 10-minute intervals to account for the expected fluctuations in entering and exiting traffic. The first site was close to downtown

Lafayette at McAllister Park and used primarily by local teams. The second site was located in a rural setting west of the West Lafayette city limit on Lindberg Road. With only small (although growing) subdivisions located nearby, these fields were targeted for traveling-team matches.

Initially, data gathered for the study focused on two variables, size of the facility in acres and the number of parking spaces. However, problems were encountered during the data collection phase of the study. First, the specific acreage of each site was difficult to enumerate because each facility was not clearly defined by an "effective boundary." Secondly, counting the number of parking spaces became somewhat complex. The Lindberg Road facility had approximately 165 spaces, all of which had not been used at any one time. On the other hand, parking at the McAllister Park fields was "almost impossible to estimate… because any place that is not a playing field in use can become a parking spot." These problems prompted the search for new independent variables that could be 1) clearly defined, 2) measured with little effort or confusion, and 3) easily estimated for proposed complexes.

After looking at several alternatives, the following two variables best fit the selection criteria: the number of playing fields and the number of players present both on the fields and on the sidelines. Information regarding the number of playing fields was readily available for each facility, 13 at McAllister and 3 at Lindberg. The other variable required data collectors to observe how many players were on each field and on along each sideline, which varied from 7 to 11 players per team.

After the variables were selected, manual traffic counts were taken for both soccer complexes. As seen in Tables 1 and 2, the peak hour traffic volumes varied considerably between the two complexes. To fully understand why such a difference occurred, the 10-minute intervals were also studied. It was discovered that while the number of vehicles entering the complexes remained steady and fairly consistent, the number of vehicles exiting the facilities showed a sharp peak for approximately 10 minutes every half hour. This peak was typically in conjunction with the end of a match. This characteristic would have been overlooked had traffic counts been performed solely on an hourly basis, rather than every ten minutes.

Trip generation rates were first related to the number of playing fields. While both complexes yielded a similar trip per field rate based on the peak 10-minute interval, the peak hour trip rate at McAllister Park was over double that of the Lindberg rate (see Table 1). This could partially be explained by the fact that the fields on Lindberg Road are nestled in a rural setting where most matches are between traveling teams. As noticed during the study, out-of-town teams rideshare more often than players living closer to the complex. As such, "vehicle trip generation rates for visiting teams at travel matches may be only half as high as for local teams."

Table 1
Trip Generation Rates
Based on the Number of Playing Fields

	Number of Trip Ends*	Playing Fields in Use*	Number of Trip Ends per Field*
McAllister	110	10	10

Lindberg	36	3	12
	Number of Trip Ends**	**Playing Fields in Use****	**Number of Trip Ends per Field****
McAllister	542	11	49.25
Lindberg	65	3	21.52

* During peak 10-minute interval

** During peak hour

Table 2 lists the trip generation rate based on the number of players present at each soccer complex at the time the counts were conducted. The results are similar to those calculated for trip rates by the number of fields. While the peak 10-minute trip rates were similar for both complexes, the peak hour rates at the Lindberg fields were considerably less than the rates at McAllister Park.

Table 2
Trip Generation Rates
Based on the Number of Players

	Number of Trip Ends*	Number of Players*	Number of Trip Ends per Player*
McAllister	110	242	.45
Lindberg	36	90	.40
	Number of Trip Ends**	**Number of Players****	**Number of Trip Ends per Player****
McAllister	542	242	2.24
Lindberg	65	90	.72

* During peak 10-minute interval

** During peak hour

While the article notes that because the study only focused on two complexes, “solid conclusions” should not be made solely upon this data, the research does suggest that if soccer complexes are ever included in ITE's *Trip Generation*, they may need to be treated as a special case. The special case would be that data, "may have to be collected in time intervals much shorter than one hour and (data) variables may have to defined carefully by both ITE and the data contributors."

Editor's Note: Caution should be used in applying the conclusions of this study due to data collection limitations. Instead, the information conveyed in this study should be used to inform future efforts to collect data and derive trip generation rates for youth soccer facilities.

To view this article in full, see the February 1999 issue of the ITE Journal or online here. For additional information contact: Jon D. Fricker at Purdue University, West Lafayette, Indiana at (765) 494-2205 or at fricker@ecn.purdue.edu.

Trip Generation at Youth Soccer Complexes: Some Unforeseen Issues

THE PURDUE STUDENT CHAPTER OF ITE HELPED THE AUTHOR COLLECT TRIP GENERATION DATA AT THE TWO BUSIEST YOUTH SOCCER COMPLEXES IN INDIANA. THE RESULTS ARE EXAMINED, AND SUGGESTIONS FOR FUTURE DATA COLLECTION ARE OFFERED.

BY JON D. FRICKER

AS THE POPULARITY OF YOUTH soccer continues to grow, more special-purpose facilities are being built to supplement and/or replace the recreational areas that soccer shared with other sports in its early years in many locales. As the parent of a child who plays on a traveling team, the author has seen youth soccer complexes of various sizes and of varying quality. Some are adjacent to residential developments; others are still separated from other active land uses. Some have dozens of fields at one location.

As new soccer complexes continue to be built, it would be helpful to be able to estimate the traffic generated by such a land-use type. In built-up areas, soccer-generated vehicle traffic could have a major impact on nearby intersections. Recreational soccer matches are often scheduled for early evenings (during the evening peak period) or Saturday mornings (in conflict with traffic for shopping and errands). Access drives to youth soccer complexes usually do not meet warrants for traffic signals, but the complexes can cause significant congestion during the relatively few times at which they are active. In less-developed areas, a soccer complex could become the major generator when it is in use. If the road network and traffic-control measures cannot accommodate the traffic generated by a soccer complex, a procedure to predict the traffic volumes would assist the developers of a soccer complex and the local transportation officials.

The Purdue Student Chapter of the Institute of Transportation Engineers (ITE) undertook data collection for trip generation at the two busiest youth soccer complexes in the Lafayette, Ind., USA, area. Because "Youth Soccer Complex" is not a land-use category in the sixth edition of ITE's *Trip Generation*,[1] several issues had to be addressed before the data were collected. This feature summarizes the issues involved and offers some suggestions to anyone interested in collecting data at youth soccer complexes.

THE SITES

The first site was McAllister Park, located on the east bank of the Wabash River, about 1.5 miles north of downtown Lafayette. Immediately to the north of McAllister is a municipal golf course, which shares the main vehicle entrance to the soccer fields from North Ninth Street. A second means of access to McAllister is via a one-lane unpaved road that runs down a short steep hill, which is used by only a few vehicles. Most of the other land use in the area is industrial. Most of the games played at McAllister are by recreational teams on Saturdays and Sundays, although two fields have been used for traveling-team matches in recent years.

The second site is on Lindberg Road, west of the West Lafayette city limits. Some small, but growing, subdivisions are located further west on Lindberg Road, but the overall setting is, for the time being, still rural. These fields, which were used for the first time in the fall of 1997, were developed for traveling-team matches.

STANDARD INDEPENDENT VARIABLES

At the time the Purdue Student Chapter was preparing its data-collection project, ITE's *Trip Generation, 5th Edition Update,*[2] was the most up-to-date reference. Of the 13 suggested independent variables in the update, only two seemed applicable—(9) Acres and (10) Parking Spaces. The value of using these two variables is discussed below.

Acres. McAllister Park is about 60 acres, but most of it is not used for soc-

Table 1. Vehicle entries and exits at McAllister Park Soccer Complex on Saturday, Oct. 11, 1997.

Time period beginning	Entries at each driveway		Exits at each driveway	
	North	South	North	South
8:16 a.m.	31	*a*	0	*a*
8:21 a.m.	23	*a*	1	*a*
8:26 a.m.	17	*a*	1	*a*
No data collected from 8:31 a.m. to 8:54 a.m.				
8:54 a.m.	24	3	11	5
8:59 a.m.	22	3	21	8
9:04 a.m.	21	1	29	5
9:09 a.m.	31	0	6	2
9:14 a.m.	32	3	3	2
9:19 a.m.	29	2	4	0
9:24 a.m.	26	3	20	0

Notes:
[a]South driveway was not observed from 8:16 a.m. to 8:31 a.m.
On average, 11 of 14 fields were in use for recreational league games.
Each team had seven players on the field and approximately three reserve players. Approximately 220 players were present.
No public transportation service was available.

cer fields. A lot of space is used by vehicles parked on the grass next to each of the perimeter soccer fields; other space is left open at McAllister for such activities as flying remote-controlled model airplanes. The effective boundary of the soccer complex is not easy to define, and the 60-acres value is the result of the author's best estimate. At the Lindberg Complex, the area seeded for playing fields, warm-up and spectators, plus the area covered with crushed stone for parking, totals 15 acres. However, as is the case for most land-use types, "acres" should be used as an independent variable only if no other variable is available.

Parking Spaces. At Lindberg, the crushed-stone lot can hold about 165 vehicles. So far, all of these spaces have not been used at one time, but not all fields have been put into operation. Once this happens, more spaces may be needed. Obviously, this is not a good independent variable to use to develop a trip generation rate. At McAllister, the number of parking spaces is almost impossible to estimate. Any place that is not a playing field in use can become a parking spot. Based on the discussion regarding Lindberg's finite-capacity lot, estimating McAllister's parking capacity would not be worth the effort.

Clearly, new independent variables that help define a usable trip generation rate relationship for youth soccer complexes needed to be devised.

NEW INDEPENDENT VARIABLES

The criteria used by the student-chapter members in proposing any new independent variable were:

- It could be defined clearly;
- It could be measured with little effort or confusion; and
- Its numerical value for a *proposed* youth soccer complex could be meaningfully estimated.

The independent variables considered are discussed below.

Number of Playing Fields. Just as "Number of Drive-In Windows" for Land Use 912 Drive-In Banks in *Trip Generation*[1] needs to be clarified in terms of "number available" vs. "number in use," this value can be easily misunderstood and misused. At McAllister, 14 fields are laid out, but not more than 11 are usually used at one time. At Lindberg, immediate plans for five fields exist; four are laid out, but only three fields were scheduled for use last fall when data were collected. This variable is easy to count, but its use in predicting what traffic a future soccer complex would generate depends on how "number of fields" is defined. If the *eventual* number of fields available for use at a proposed site is treated as the "build-out" condition and previous data were collected with X = number of fields *in use*, then this variable could help establish a reasonable upper bound on T.

Number of Players. A recent trend in youth soccer is to play "small-sided" matches, in which each team has seven players on the field, instead of the traditional 11. Fewer players means fewer vehicles to drop off and pick up players, unless the number of teams (and matches and fields) is increased to accommodate the player demand. This variable would require the data collector to observe how many players were playing on each field. Seven-player matches use smaller fields, so there is room at a site for more such fields. This is another reason to be careful when simply counting the number of fields for use as an X variable. At McAllister, the recreational matches had seven players on the field, with about 11 players present. At Lindberg, the traveling teams had rosters of 15, with 11 players on the field.

ISSUES REGARDING DEPENDENT VARIABLES

Peaking. In the *Trip Generation Update*,[2] land uses have weekend data for Saturday, Sunday, and Saturday or Sunday "Peak Hour of Generator." Peaking at a youth soccer complex is unlike that at almost any other land use. It may even vary from complex to complex. Depending on how tightly the matches are scheduled, players and parents for one match may arrive before the

Table 2. Vehicle entries and exits at Lindberg Soccer Complex on Saturday, Oct. 11, 1997.

Time period beginning	Vehicle entries	Vehicle exits
2:35 p.m.	3	2
2:40 p.m.	5	6
2:50 p.m.	9	27
3:00 p.m.	7	5
3:10 p.m.	2	2
3:20 p.m.	10	6
3:30 p.m.	4	3
3:40 p.m.	5	0
3:50 p.m.	9	4
4:00 p.m.	2	2
4:10 p.m.	2	1
4:20 p.m.	3	11
4:30 p.m.	0	34
4:40 p.m.	2	14
4:50 p.m.	1	3
5:00 p.m.	1	1
5:10 p.m.	0	5
5:20 p.m.	2	0
5:30 p.m.	1	1
5:40 p.m.	1	2
5:50 p.m.	0	5
6:00 p.m.	0	23

Notes:
Only two of four fields were in use for these traveling-team games.
U14 girls match ended about 4:15 p.m.; U12 boys match ended about 4:30 p.m.
Each team had 11 players on the field and approximately three reserve players. Approximately 56 players were present.
165 parking spaces were available. No public transportation service was available.

players and parents for the previous match have departed. At some complexes, start times for matches are staggered; at other sites, all matches may be scheduled to start at the same time. The impact on the adjacent street system may depend on how pronounced the peak is within any given hour. The severity of this peak will not be captured by reporting and publishing a value for an hour. The data in Table 1 for 5-minute intervals at McAllister indicate a fairly steady entry flow over the time observed but show a sharp peak in the exiting traffic for 10 minutes. At Lindberg, sharp peaks were observed shortly after a match ended (Table 2). It may be a good idea to record driveway counts at youth soccer complexes in intervals of at most 10 minutes.

Recreational match or traveling? Most of the author's child's traveling-team matches are more than one hour's drive from Lafayette. Many of the team parents own vans. As a result, much ridesharing is done to out-of-town matches. For home matches, very little ridesharing takes place. It is possible that the *vehicle* trip generation rate for visiting teams at travel matches may be only half as high as for the local teams. If this proves to be a significant phenomenon, a separate land-use category could be established. At this point, however, a simple note as to the number of fields in use by travel teams should be part of the data report.

SAMPLE CALCULATIONS

Tables 1 and 2 illustrate the erratic temporal distribution of trip ends at youth soccer complexes. Because of this, the daily (or even hourly) trip rates found in *Trip Generation* may not be the best representation of the site's impact on the adjacent street system. It is essential to have a clear concept of why the rate is being calculated. For example, if the driveway(s) or road(s) to/from a proposed soccer complex may require traffic signals, the trip generation rates must be calculated in a way that is compatible with the method used to conduct a signal-warrant analysis.

In Table 3, some trip rates are calculated from the data in Tables 1 and 2. In Table 1, the peak 10 minutes of the generator occurred between 8:59 and 9:09 a.m. Between 8:54 and 9:29 a.m. (a period 35/60-hour long), 316 entries and exits were observed. At Lindberg (Table 2), 226 entries and exits took place between 2:35 and 6:05 p.m. (3.5 hours). The generator's peak 10-minute period was from 2:50 to 3 p.m. The value of the "Players Present" variable was calculated for McAllister as follows: 11 fields × 11 roster players/team × 2 teams/field = 242 players. For Lindberg, the corresponding calculation is 3 × 15 × 2 = 90 players.

The rates in Table 3 do not follow the typical calculations in *Trip Generation* because of the unusual traffic patterns associated with this land use. With a more substantial database, it may be possible to calculate 10-minute and one-hour rates that can be applied to traffic-signal-warrant analysis and other uses.

SUMMARY

Based on observations made at only two complexes, it is not wise to draw solid conclusions. In collecting data at the two sites, the counting of vehicles was the easiest part of the project. There are typically few entrances to a youth soccer complex, even if the parking is as unstructured as at the McAllister site. The difficulty in devising a useful relationship between vehicle trips and independent variables at a soccer complex is deciding upon appropriate independent variables. If this land use is ever included in a future edition of *Trip Generation*, it may need to be treated as a special case. Data for the T variable may have to be collected in time intervals much shorter than one hour, and the X variables may have to be defined carefully by both ITE and the data contributors.

Clearly, more data collection at youth soccer complexes must take place before some of these issues can be resolved. In the meantime, the author would appreciate the comments and suggestions of anyone who has thoughts on the subject.

ACKNOWLEDGMENTS

The data for this project were collected by the author and Ben Good, Darren Jorgenson and Gary Shoup, members of the Purdue Student Chapter

Table 3. Sample rate calculations for two youth soccer complexes.			
Independent Variable	**Time Period**	**McAllister**	**Lindberg**
Acres	Peak 10 minutes	110/60 = 1.83	36/15 = 2.40
Acres	Observed data converted to average hourly rate	[316/(35/60)]/60 = 9.03	(226/3.5)/15 = 4.30
Parking Spaces	Peak 10 minutes	Number of parking spaces hard to determine	36/165 = 0.22
Parking Spaces	Observed data converted to average hourly rate		(226/3.5)/165 = 0.39
Playing Fields in Use	Peak 10 minutes	110/11 = 10.0	36/3 = 12.0
Playing Fields in Use	Observed data converted to average hourly rate	[316/(35/60)]/11 = 49.25	(226/3.5)/3 = 21.52
Players Present	Peak 10 minutes	110/242 = 0.45	36/90 = 0.40
Players Present	Observed data converted to average hourly rate	[316/(35/60)]/242 = 2.24	(226/3.5)/90 = 0.72

of ITE, who, along with other student-chapter members, took part in "brainstorming" about some of the issues discussed in this feature. The suggestions made by the reviewers of the manuscript also were very helpful. ■

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Mixed Feelings About Mixed-Land Use

(To view and print pdf files, use Adobe Acrobat Reader available at this link.)

Since the 1960's, the typical urban development pattern has been to locate residential neighborhoods at a substantial distance from employment and service centers. This trend has led to measurable increases in traffic congestion, pollution, and a general unhappiness with suburban life. Recently developers and planners have turned to neo-traditional mixed land use communities that incorporate residential and commercial uses to help reduce automoblie dependency and its associated problems.

The residents of neo-traditional developments can incorporate alternate forms of transportation such as short driving distances, biking and walking into their daily lives. Yet, despite the interest and claims of the advocates of these neo-traditional mixed land use communities, there has been no substantive data analysis to show a relationship between non-work travel behavior and mixed land use patterns.

In the study, "The Travel Impacts of Mixed Land Use Neighborhoods in Seattle," published by the Transportation Research Board (2001), Edward McCormack, G. Scott Rutherford and Martina G. Wilkinson collected empirical data about neo-traditional land use travel behaviors to determine if "the travel behavior of residents of mixed-use neighborhoods differed significantly from the travel behavior of residents in areas with more homogenous land use patterns." The authors investigated transportation characteristics of residents of mixed-use land use neighborhoods in Seattle (King County), Washington, and compared them to the travel behaviors of people who live in traditional suburban areas in the same county.

The first dataset, collected for this study in 1992, was comprised of travel data from three mixed neighborhoods in greater Seattle. The neighborhoods had characteristics that proponents of the neo-traditional movement consider important for decreasing automobile usage. These characteristics include "more than one distinct land use (residential as well as other uses such as commercial and recreational), a gridded street pattern, a pedestrian friendly environment and frequent transit service."

The second dataset, travel characteristics of King County residents, was gathered by the Puget Sound Regional Council's (PSRC) Transportation Panel Survey in 1989. This dataset allowed the researchers' to compare the findings of the first dataset (mixed land use neighborhood data) with county-level travel characteristics. Because this PSRC survey was conducted first, the researchers modeled their mixed-use survey (used to collect data for the first dataset) on the PSRC survey instrument and had the same contractor randomly contact all households and administer the travel diaries.

The analysis of the datasets suggested that neo-traditional design may have an impact on reducing travel distances. Residents of neo-traditional communities travelled considerably fewer miles per day than residents of suburban developments, especially the outer suburbs. The residents of mixed-use communities recorded more walking and neighborhood trips. In addition, the data showed that travel time is a more appropriate measure than travel distance for mixed-used communities because transit and walking are slower means of travel. As a result, the reduction of travel distance for work and chores may simply allow time for other forms of automobile intensive activities, thereby undermining the benefits of mixed-use neighborhoods.

The article suggests that to determine the effectiveness of neo-traditional design, the travel characteristics of mixed-use residents should be examined in a regional context because although they made more stops in their neighborhood than other groups studied, these stops comprised only 20 percent of their total trips. Most of the mixed-use residents' trips were taken outside of their neighborhoods so residential travel patterns appeared to be more influenced by regional employment and access issues than neighborhood design alone.

Nevertheless, neo-traditional design does appear to be associated with a reduction in travel distances. The neo-traditional movement must conduct further research to determine if this relationship is a direct result of land use and if this travel difference can provide a solution to the problem of increasing urban congestion.

The full text of this paper is available here or on the 80th Annual Meeting of the Transportation Research Board CD-Rom. For additional information, contact Dr. Edward McCormack at the Washington State Transportation Center, University of Washington, Seattle, WA 98155 or edm@u.washington.edu by email. *Adapted with permission*.

A Recommended Practice For Estimating Vehicle Trips Generated by Multi-Use Development

(To view and print pdf files, use Adobe Acrobat Reader available at this link.)

Traditionally, the Institute of Transportation Engineers (ITE) has based trip generation rates on single use, free-standing sites. However, with the growing popularity of multi-use developments, ITE has developed a new methodology for determining trip generation rates for these widely emerging land uses. Often, transportation planners calculate trip generation for these multi-use sites by totaling the trip generation rate for each single use. However, as ITE points out in Chapter 7 of the 1998 publication, *Trip Generation Handbook: An ITE Proposed Recommended Practice*, “there is potential for interaction among those uses within the multi-use site, particularly where the trip can be made by walking.” These “internal trips” can significantly reduce the total number of trips generated at the project site.

Specifically, these developments are defined by ITE for trip generation purposes as a single real estate project with two or more ITE land use classifications between which trips can be made without using the off-site road system. Many other forms of development, which can also be described as multi-use, are excluded from this definition because they are already included in *Trip Generation, 6th Edition* as a distinct land uses. For example, these include downtowns, shopping centers, and office parks or office buildings with retail or support services. The newly emerging multi-use developments addressed here include projects that typically range in size from 100,000 square feet to 2 million square feet. Trips made between uses can be completed on internal roadways or paths by walking or by car without using the external street system.

The handbook provides a step-by-step approach for estimating trip generation for multi-use developments. As pointed out in the handbook, existing procedures exclude important factors like the proximity of on-site land uses to one another, the type of pedestrian connection between uses, and if the site is in an urban or suburban environment. This procedure is described in Table 1.

Table 1
Methodology to Calculate Trip Generation of a Multi-Use Development

Step	Action	Sample
Step 1: Document Characteristics of Multi-Use Development	· List each land use · Find appropriate variable needed to calculate trip generation	Retail: 200,000 sq. ft. (LUC 820) Office: 120,000 sq. ft. (LUC 710) Residential: 200 DU (LUC 221)
Step 2 : Select Time Period	· Select time of day and day of week	Time: Peak hour of adjacent street traffic Day: Weekday

Step 3: Compute Trip Generation	· Look up trip generation rate in ITE's *Trip Generation*, 6^{th} *Ed*. · Determine number of trips by direction	Retail: Enter=476 Exit=516 Office: Enter=36 Exit=178 Residential: Enter=81 Exit=41
Step 4: Estimate Internal Capture Rates	· Identify internal capture rates between each pair of land uses as computed by ITE.[1]	From retail to office (outbound): 3% To office from retail (inbound): 31%
Step 5: Estimate Volumes	· Apply internal capture rates to trip generation volumes.	From retail to office (outbound): 516 X 3%=15 trips To office from retail (inbound): 36 X 31%=11 trips
Step 6: Select Controlling Value	· Select the lesser trip generation value between each pair of land uses.	Retail generates 15 internal trips to the office, but office only receives a maximum of 11 trips, thus only 11 trips are recorded.
Step 7: Estimate Total Internal Trips	· Calculate total number of internal trips made to and from each land use.	Internal trips entering retail: 10 (from office) + 22 (from residential) = 32 trips Internal trips exiting retail: 11 (to office) + 25 (to residential) = 36
Step 8: Estimate # of External Trips	· Subtract internal trips from total trips for each individual land use.	Retail: 476 total entering trips – 32 internal trips = 444 entering trips

Step 9: Calculate Total External Trip Generation	· Total external volumes for all land uses	Retail: 444 entering trips Office: 25 entering trips Residential: 54 entering trips Total: 523 peak hour trips (entering volume)[2]

[1]If a land use fails to match an ITE land use category, ITE encourages users to collect local data or assume no internal capture.

[2]See ITE's *Trip Generation Handbook* for additional details on the calculations shown here.

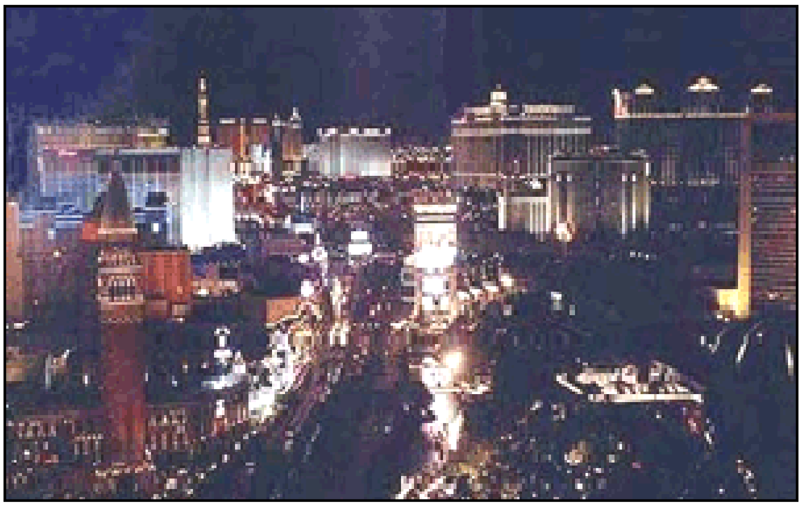
Other factors may affect the total trip generation of the site. If the multi-use development is within an urban environment with similar land uses surrounding the area, the number of internal trips could be dramatically reduced. In suburban areas, where other competing uses are a considerable distance away, residents, employees, and customers within the multi-use development would tend to stay within the site strictly due to location and convenience. Finally, internal trips may exceed those estimated by ITE if the developer chose to install bicycle or footpaths, place complementary uses near one another, and/or provide pedestrian refuge areas. However, no site trip generation data are currently available on which to base adjustment factors of this type.

For more information including a detailed description of ITE's methodology and data collection procedures for multi-use development sites, refer to the *Trip Generation Handbook, 6th edition* produced in 1998 by the Institute of Transportation Engineers.

Revisiting Hotel/Casino Trip Generation Rates

(To view and print pdf files, use Adobe Acrobat Reader available at this link.)

For people around the world, the hotel/casinos of Las Vegas, Nevada are an attractive travel destination. In fact, many of the world's largest hotels are located in Las Vegas with some facilities providing more than 3,000 rooms. The planners of Las Vegas are faced with the unique challenge of determining the traffic impacts of these expansive resorts with thousands of hotel rooms and gaming positions.



The current estimates of the number of trips generated by Las Vegas' hotel/casinos are based on the results of a study entitled, "Trip Generation Rates for Las Vegas Area Hotel-Casinos" written by Kenneth W. Ackeret and Robert C. Hosea III (ITE Journal, May 1992). The data analyzed in this study were collected in 1990 for 21 hotel/casinos and included the casino floor area, the number of rooms and the number of employees.

Since this study was conducted, the number of hotel/casinos in Las Vegas has more than doubled to 46. In addition, similar studies in other regions of the United States have shown that the number of gaming positions should be used as an independent variable when estimating trip generation rates for hotel/casinos.

In the article, "Recalibration of Trip Generation Model for Las Vegas Hotel/Casinos" (ITE Journal, May 2002), Curtis D. Rowe, Mohamed S. Kaseko, and Kenneth W. Ackert investigated the number of trips generated by the hotel/casinos using the casino floor area, number of rooms and employees as well as the number of gaming positions as independent variables. Data were collected from vehicle generation counts at 15 minute intervals during weekday morning (7 a.m. to 9 a.m.) and evening (4 p.m. to 6 p.m.) peak hours from existing hotel/casinos. These data were supplemented with the older data used in the Ackeret and Hosea study (1992) and the "Trip Generation Analysis Report: Hotels-Casinos Within the Las Vegas Urbanization Area," published by the Transportation Research Center at the University of Nevada-Las Vegas in May 1991. The data on number of hotel rooms and employees, and casino square footage were obtained from various Las Vegas publications and telephone surveys with hotel/casinos management. The data on the gaming positions were acquired from the State of Nevada, Gaming Control Board.

To evaluate these data, the hotel/casinos were assigned to two groups based on their locations. The hotel/casinos located in the resort corridor of Las Vegas were considered resort corridor facilities, while hotel/casinos outside the resort corridor were categorized as local facilities. Resort corridor hotel/casino facilities had more pedestrian walking trips than local hotel/casino facilities.

Regression analysis was conducted on the data to determine which independent variable was statistically significant as the "best" estimate of trip generation for both resort corridor hotel/casinos and local hotel/casinos. The results of the regression analysis for resort corridor hotel/casino facilities showed that the four independent variables (casino floor area, number of rooms, number of employees and the number of gaming positions) were statistically significant for estimating the trip generation for both peak hour periods. However, the best indicator of trip generation for hotel/casinos in both the morning and evening peak hours was the number of gaming positions. In cases where all of the four variables were not available, the best equation to forecast the trip generation for the facility includes the two variables - the number of employees and the number of gaming positions. However, prior to the construction of a local hotel/casino, the number of employees and gaming positions may not be available. In that case, the casino floor area would be a valid means of estimating trip generation.

The research concluded that using the number of gaming positions as an independent variable improved previous equations to estimate trip generation for hotel/casinos in Las Vegas. The equations developed from the data in this study were based on the specific characteristics of facility size and proximity found in Las Vegas so the equations should be cautiously applied to hotel/casinos outside the area. However, the equations may be useful in studying trip generation at gaming facilities in other regions in the United States.

The full text of this paper is available in the May 2002 issue of the ITE Journal On The Web or online here. For additional information, contact F. Curtis Rowe by email at curtis.rowe@kimley-horn.com (*© Institute of Transportation Engineers.) Adapted with permission.*

Recalibration of Trip Generation Model for Las Vegas Hotel/Casinos

AN UPDATED TRIP GENERATION STUDY FOR LAS VEGAS HOTEL / CASINOS IS PRESENTED IN THIS FEATURE USING THE NUMBER OF GAMING POSITIONS AS AN INDEPENDENT VARIABLE. REGRESSION ANALYSIS USING GAMING POSITIONS AND PREVIOUS INDEPENDENT VARIABLES (EMPLOYEES, CASINO FLOOR AREA AND HOTEL ROOMS) WAS PERFORMED TO DETERMINE THE "BEST" SINGLE OR MULTIVARIABLE EQUATIONS.

BY CURTIS D. ROWE, MOHAMED S. KASEKO AND KENNETH W. ACKERET

INTRODUCTION

The hotel/casinos of Las Vegas, NV, USA, provide an attraction destination for visitors from locations worldwide. Many of the world's largest hotels providing more than 3,000 rooms at a single facility are located in Las Vegas. The number and proximity of these resorts provide Las Vegas with thousands of hotel rooms and gaming positions unlike anywhere else in the world. Understanding the trip generation characteristics of these facilities is key to determining associated traffic impacts and roadway mitigation measures.

This trip generation study was motivated by the work conducted by Kenneth W. Ackeret and Robert C. Hosea III as presented in the May 1992 issue of *ITE Journal* in "Trip Generation Rates for Las Vegas Area Hotel-Casinos."[1] Ackeret and Hosea calibrated the number of vehicle trips generated by a hotel/casino as a function of casino floor area, number of hotel rooms and employees. The results of their study are the basis for the current method of estimating the number of vehicle trips generated by Las Vegas hotel/casinos. However, this method is based on a relatively limited data set. The data used were collected in and prior to 1990 for 21 hotel/casino counts. Since then, numerous hotel/casinos were constructed that conducted facility driveway trip counts within the Las Vegas metropolitan area. This increased data consisting of 46 hotel/casino vehicle generation counts is expected to provide more statistically significant results in trip-making characteristics. Likewise, it is believed that the independent variable of the number of gaming positions would be a good variable for estimation of trip generation. In other areas of the country, gaming positions have been used as an estimator of hotel/casino trips. However, the number of gaming positions as compared with expected trip generation has not been studied within the Las Vegas area. Therefore, one hypothesis tested in this feature is that the number of gaming positions is a good estimator of trips generated by hotel/casinos.

METHODOLOGY

The vehicle trip generation of a hotel/casino is dependent on various factors. Certain factors, such as size, location and type of hotel/casino all contribute to the trip generation of a facility. Facility size characteristics can be identified as the number of hotel rooms or the amount of casino floor area. Likewise, the number of gaming positions within a casino and/or the total number of employees can be factors affecting the number of vehicle trips generated by hotel/casinos.

The conducted study developed a set of regression equations for estimating the number of vehicle trips generated by a typical Las Vegas hotel/casino property, existing or proposed. The regression analysis was conducted using data obtained from various existing hotel/casinos that had vehicle generation counts conducted during the a.m. and p.m. peak hours to determine the number of vehicles entering and exiting individual casino properties. The following independent variables were used in the analysis:

- Number of gaming positions;
- Number of employees;
- Number of hotel rooms; and
- Casino floor area.

Data Collection

To determine equations that accurately estimate the number of peak-hour vehicle trips generated by a hotel/casino, an extensive amount of data was required. The data needed included the typical a.m. and p.m. adjacent-street peak-hour facility driveway count volumes, number of gaming positions,

Table 1. Resort corridor hotel/casino single-variable equations.

Independent variable	Time period	Directional distribution	Equation	R^2	F-statistic	F-critical @ 95% level	Average rate	Range of rates	Standard deviation
Gaming positions	a.m. peak	59% enter 41% exit	T = 0.377 (X) – 109.344 T = a.m. peak-hour trips X = number of gaming positions	0.84	134.21	4.25	0.332	0.047–0.516	0.115
	p.m. peak	48% enter 52% exit	T = 0.000137 (X^2) + 289.769 T = p.m. peak-hour trips X = number of gaming positions	0.91	301.31	4.16	0.463	0.151–0.778	0.171
Employees	a.m. peak	59% enter 41% exit	T = 0.232 (X) + 117.461 T = a.m. peak-hour trips X = number of employees	0.79	94.86	4.25	0.292	0.044–0.534	0.113
	p.m. peak	48% enter 52% exit	T = 0.432 (X) + 89.67 T = p.m. peak-hour trips X = number of employees	0.76	96.88	4.16	0.487	0.144–1.300	0.218
Hotel rooms	a.m. peak	59% enter 41% exit	T = 0.333 (X) + 117.239 T = a.m. peak-hour trips X = number of hotel rooms	0.73	67.39	4.25	0.482	0.096–2.188	0.383
	p.m. peak	48% enter 52% exit	T = 0.638 (X) T = p.m. peak-hour trips X = number of hotel rooms	0.78	109.99	4.16	0.702	0.210–2.801	0.468
Casino floor area	a.m. peak	59% enter 41% exit	T = 8.046 (X) + 174.380 T = a.m. peak-hour trips X = casino floor area (1,000 sf)	0.74	72.57	4.25	12.344	1.968–35.351	6.874
	p.m. peak	48% enter 52% exit	T = 16.991 (X) T = p.m. peak-hour trips X = casino floor area (1,000 sf)	0.81	134.49	4.16	18.374	6.238–52.541	9.708

number of hotel rooms, number of employees and casino floor area of each hotel/casino. The data used by Ackeret and Hosea[1] and the "Trip Generation Analysis Report,"[2] conducted by the University of Nevada–Las Vegas, were supplemented with data collected more recently and used for this study.

Existing Count Data

The first step of the additional data-collection effort involved obtaining count data conducted at facility access driveway locations for existing hotel/casinos. The count data obtained were from counts conducted at all facility driveways during 15-minute intervals on a weekday during the typical a.m. and p.m. peak-hour periods. Therefore, the count volumes collected reflect the highest one-hour period between 7 a.m. to 9 a.m. and 4 p.m. to 6 p.m. on a weekday. It is recognized that the facilities' trip generation may be greater during other hours of the day or week. The typical weekday peak-hour time periods were studied based upon availability of data that was collected in accordance with local requirements for analysis during these time periods. Limited proprietary data exists, which indicates the peak hour of the casino generator generally occurs around 7 p.m. At this time, the trip generation of the hotel/casinos is generally 15 percent greater than during the typical commuter peak hours. This increase should be recognized when analyzing specific traffic demands at intersections comprising primarily hotel/casino traffic. The count data may be obtained by requesting it from the authors.

Independent Variables

The independent variables associated with each of the hotel/casinos were collected for the time period corresponding to the date of the reported field traffic counts. The specific traffic studies reports and *ITE Journal* feature used for the count data were also reviewed to extract information on the number of employees, hotel rooms and casino square footage. Data, other than the number of gaming positions, were also obtained from the *Las Vegas Perspective*,[3] the *Top Rank Nevada 1999, Statewide Book of Lists*[4] and the *Book of Lists*.[5] Data that were still not available from these sources were obtained from telephone surveys with the hotel/casinos management. The gaming position data were obtained from the State of Nevada, Gaming Control Board for the current and historic count periods at each of the hotel/casino sites. The independent-variable data may be obtained by requesting it from the authors. The following are definitions of the key independent variables studied:

- Number of employees: The total number of people employed at a hotel/casino for all shifts;
- Casino floor area: The square footage that contained the gaming positions;
- Number of gaming positions: The number of gaming positions was defined to be the total number of slot machines within a casino plus the number of table games multiplied by seven positions per table. The average of seven gaming positions per table is consistent with the

Table 2. Resort corridor hotel/casino summary of results.								
	a.m. peak hour 59% entering, 41% exiting Appropriate equations				p.m. peak hour 48% entering, 52% exiting Appropriate equations			
Known variables	Average rate	Equation variables used	Regression equation	R^2	Average rate	Equation variables used	Regression equation	R^2
At least positions and employees	N/A	Positions and employees*	$T = 0.241 (X_1) + 0.100(X_2) - 68.429$ T = a.m. peak-hour trips X_1 = number of gaming positions X_2 = number of employees	0.88	N/A	Positions and employees*	$T = 0.000108 (X_1^2) + 0.120 (X_2) + 184.063$ T = p.m. peak-hour trips X_1 = number of gaming positions X_2 = number of employees	0.93
Positions without employees	0.312	Positions	$T = 0.377 (X) - 109.344$ T = a.m. peak-hour trips X = number of gaming positions	0.84	0.463	Positions	$T = 0.000137 (X^2) + 289.769$ T = p.m. peak-hour trips X = number of gaming positions	0.91
Employees, rooms and casino area without positions	–	–	–	–	N/A	Employees, rooms and casino area	$T = 0.169 (X_1) + 0.174 (X_2) + 7.790 (X_3) - 84.407$ T = p.m. peak-hour trips X_1 = number of employees X_2 = number of hotel rooms X_3 = 1,000 sf of casino floor area	0.87
Employees and casino area without positions	N/A	Employees and casino area	$T = 0.145 (X_1) + 4.003 (X_2) + 78.003$ T = a.m. peak-hour trips X_1 = number of employees X_2 = 1,000 sf of casino floor area	0.86	N/A	Employees and casino area	$T = 0.214 (X_1) + 10.203 (X_2) - 43.014$ T = p.m. peak-hour trips X_1 = number of employees X_2 = 1,000 sf of casino floor area	0.89
Employees and rooms without positions or casino area	N/A	Employees and rooms	$T = 0.150 (X_1) + 0.154 (X_2) + 57.307$ T = a.m. peak-hour trips X_1 = number of employees X_2 = number of hotel rooms	0.85	N/A	Employees and rooms	$T = 0.228 (X_1) + 0.367 (X_2) - 63.760$ T = p.m. peak-hour trips X_1 = number of employees X_2 = number of hotel rooms	0.85
Rooms and casino area only	N/A	Rooms and casino area	$T = 0.168 (X_1) + 4.583 (X_2) + 107.789$ T = a.m. peak-hour trips X_1 = number of hotel rooms X_2 = 1,000 sf of casino floor area	0.79	N/A	Rooms and casino area	$T = 0.290 (X_1) + 9.780 (X_2)$ T = p.m. peak-hour trips X_1 = number of hotel rooms X_2 = 1,000 sf of casino floor area	0.86
Employees only	0.297	Employees	$T = 0.232 (X) + 117.461$ T = a.m. peak-hour trips X = number of employees	0.79	0.486	Employees	$T = 0.432 (X) + 89.67$ T = p.m. peak-hour trips X = number of employees	0.76
Casino area only (1,000 sf)	12.344	Casino area (1,000 sf)	$T = 8.046 (X) + 174.380$ T = a.m. peak-hour trips X = 1,000 sf of casino floor area	0.74	18.374	Casino area (1,000 sf)	$T = 16.991 (X)$ T = a.m. peak-hour trips X = 1,000 sf of casino floor area	0.81
Rooms only	0.482	Rooms	$T = 0.333 (X) + 117.239$ T = a.m. peak-hour trips X = number of hotel rooms	0.73	0.700	Rooms	$T = 0.638 (X)$ T = p.m. peak-hour trips X = number of hotel rooms	0.78

*Please note: * = best equation; N/A = not applicable; and – = equation not statistically significant.*

definition suggested by Finigan[6] for typical gaming operations throughout the United States; and
- Number of hotel rooms: The total number of hotel rooms at the facility.

Location Classification

The hotel/casinos evaluated were divided into two groups based on their locations. A hotel/casino was considered to be a resort corridor facility if it was located within the Clark County Regional Transportation Commission's defined area bound by Valley View Boulevard on the west, Maryland Parkway on the east, Washington Avenue on the north and McCarran International Airport on the south (Robindale Road). These boundaries, which include the famous Las Vegas "Strip," provide the limits of the accepted resort corridor of Las Vegas. A hotel/casino not located within the resort corridor was classified as a local facility. This classification was necessary to accurately distinguish the trip generation characteristics of these two distinct groups of hotel/casinos. Resort-corridor facilities experience significant nonvehicle trip sharing due to pedestrian walking trips as a result of the synergy created by the close proximity of the hotel/casinos. Local facilities primarily have vehicle trips and minimal pedestrian trips associated with them. This is due to the location of these resorts being outside of the resort corridor and away from other hotel/casinos.

Table 3. Local hotel/casino single-variable equations.

Independent variable	Time period	Directional distribution	Equation	R^2	F-statistic	F-critical @ 95% level	Average rate	Range of rates	Standard deviation
Gaming positions	a.m. peak	57% enter 43% exit	Ln(T) = 0.604 Ln(X) + 2.147 T = a.m. peak-hour trips X = number of gaming positions	0.72	26.00	4.96	0.470	0.267–0.884	0.191
	p.m. peak	52% enter 48% exit	Ln(T) = 0.794 Ln(X) + 1.278 T = p.m. peak-hour trips X = number of gaming positions	0.83	59.77	4.75	0.788	0.505–1.540	0.246
Employees	a.m. peak	57% enter 43% exit	Ln(T) = 0.710 Ln(X) + 1.506 T = a.m. peak-hour trips X = number of employees	0.77	32.70	4.96	0.566	0.311–0.840	0.160
	p.m. peak	52% enter 48% exit	Ln(T) = 0.847 Ln(X) + 1.086 T = p.m. peak-hour trips X = number of employees	0.72	30.16	4.75	1.021	0.639–1.466	0.313
Hotel rooms	a.m. peak	57% enter 43% exit	Not statistically significant	0.24	3.11	4.96	2.538	0.668–9.300	2.445
	p.m. peak	52% enter 48% exit	Not statistically significant	0.01	0.01	4.75	5.067	0.869–16.200	4.246
Casino floor area	a.m. peak	57% enter 43% exit	Ln(T) = 0.433 Ln(X) + 4.848 T = a.m. peak-hour trips X = casino floor area (1,000 sf)	0.71	24.13	4.96	14.078	4.794–48.091	11.502
	p.m. peak	52% enter 48% exit	Ln(T) = 0.527 Ln(X) + 4.999 T = p.m. peak-hour trips X = casino floor area (1,000 sf)	0.72	30.19	4.75	22.342	6.792–62.591	13.372

Directional Distribution

A directional distribution of entering and exiting trips during the peak hours was calculated based upon the observed data. The average directional distributions were calculated separately for resort corridor and local hotel/casinos, as well as the a.m. and p.m. peak hours.

Average Trip Rates

Based upon the data collected, average trip rates were calculated for both groups of hotel/casinos to determine the average number of vehicle trips expected per independent variable. The average trip rates and standard deviation were calculated for each independent variable. An average trip rate was determined to be acceptable if the standard deviation was less than 110 percent of the average rate as described in the Institute of Transportation Engineers' (ITE) *Trip Generation Handbook, An ITE Proposed Recommended Practice*.[7]

Regression Analysis

Regression analysis was conducted to develop regression equations for estimating the number of trips generated by the casinos as a function of several combinations of independent variables. The stepwise regression procedure was used as outlined in *Basic Econometrics* by Damodar Gujarati.[8]

In this study, regression analysis of the data was used to determine the "best fit" equation of a line that most accurately estimates the number of peak-hour trips for both resort corridor and local hotel/casinos. Both linear and nonlinear equations were evaluated as provided in ITE's *Trip Generation*.[9] For the nonlinear equations, the natural logarithmic and squared polynomials were used to determine which type of equation would best estimate the trip generation of a hotel/casino.

After equations were obtained for the single-variable equations, the t-statistics were first evaluated to determine statistical significance of the coefficients of the variables. A confidence level of 95 percent was used. However, since regression equations that provide intercepts are viewed favorably by practitioners to differentiate between average rates and regression equations, a lower confidence level of 75 percent was utilized for the intercept. If the intercept did not prove to be significant by the t-test, the equation was recalculated with the y-intercept being forced through zero. The resulting equations were compared to determine which type of equation was the "best" model for estimation of the peak-hour trips. An analysis of variance was conducted for each model as provided by Gujarati.[8] To compare the models, the R-squared and F statistics were evaluated. The R-squared value demonstrated how closely the equation fit the data points. In general, R-squared values closest to 1.0 are desirable. Also larger values of the F statistic are desirable. After determination of the best equation for each independent variable, the data, average rate and "best" regression equation were plotted. To determine which independent variable estimated the number of peak-hour trips best, the F statistic was again compared for each equation.

Development of the "best" regression equation was done using the stepwise regression analysis procedure. In this procedure, the effect of adding a variable to an existing equation is evaluated using the

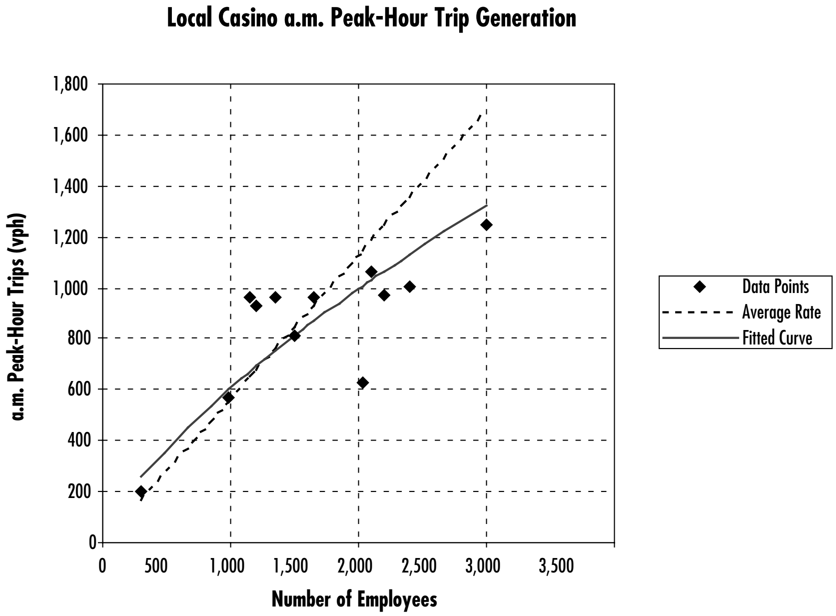
Average Vehicle Trip Ends vs: Number of Employees
On a: Weekday a.m. peak hour

Number of Studies: 12
Average Number of Employees: 1,655
Directional Distribution: 57% entering, 43% exiting

Trip Generation per Number of Employees

Average Rate	Range of Rates	Standard Deviation
0.5657	0.3108–0.8400	0.1597

Data Plot and Equation



Fitted Curve Equation: $Ln(T) = 0.710\ Ln(X) + 1.506$ F = 32.70 $R^2 = 0.77$
where: T = number of a.m. peak-hour trips
$F_{crit} = 4.96$ at 95% confidence level
X = number of employees

Figure 1. Local a.m. peak trips vs. employees.

partial F statistic. This statistic evaluates whether the contribution of the additional variable to the accuracy of the model is statistically significant. If different variables are added to the same equation, then the variable with the highest partial F that is statistically significant is selected.

RESORT CORRIDOR HOTEL / CASINOS RESULTS

Directional Distribution

The existing trips generated by the resort corridor hotel/casinos had an average distribution of 59 percent entering and 41 percent exiting during the a.m. peak hour. Likewise, during the p.m. peak hour, the directional distribution was found to be 49 percent entering and 51 percent exiting.

Single-Variable Equations

Table 1 provides the results for average trip rate and regression equations for the a.m. and p.m. peak-hour trips generated by a resort corridor hotel/casino. As these single-variable equations illustrate, all four independent-variable equations are statistically significant during both peak hours based on the critical F value. The equation with the highest F value was considered to be the "best" statistically significant equation to estimate trip generation. For both a.m. and p.m. peak hours, the number of gaming positions is the best estimator of the trip generation for a resort corridor hotel/casino. For the a.m. peak hour, the number of employees is the next best trip generation estimator, followed by casino floor area and, lastly, the number of hotel rooms. For the p.m. peak hour, the casino floor area is the second-best estimator followed by number of hotel rooms and then employees.

Average Trip Rates

The average trip rates were found to be acceptable for estimation of the number of trips generated by a hotel/casino for all studied independent variables, because the standard deviation was less than the established limit of 110 percent of the average rate.

"Best" Multivariable Regression Equations

As discussed earlier, the forward stepwise regression analysis approach was adopted to determine appropriate multivariable equations. Starting with the "best" single-variable equation, containing the variable for the number of gaming positions, partial F statistic analysis was conducted to determine an additional variable that would statistically best improve the accuracy of estimation. The best two variable equations for both the a.m. and p.m. peak hours was found to be combining the variables for the number of gaming positions and number of employees. Therefore, the "best" equations to estimate the number of vehicle trips during the peak hours were found to be as follows:

a.m. peak hour

$T = 0.241\ (X_1) + 0.100\ (X_2) – 68.429$

$R^2 = 0.88$

where

T = number of a.m. peak-hour trips;

X_1 = number of gaming positions; and

X_2 = number of employees.

p.m. peak hour

$T = 0.000108\ (X_1^2) + 0.120\ (X_2) + 184.063$

$R^2 = 0.93$

where

T = number of p.m. peak-hour trips;

X_1 = number of gaming positions; and

X_2 = number of employees.

Determining the Most Appropriate Equation for Practical Use

In practice, there are occasions when certain independent variables are not available for forecasting of trip generation of a facility. Typically, prior to the construction of a hotel/casino, the number of employees and gaming positions is not known. Or if the number of employees is known, it may be an estimate. It is important that the practitioner use caution when using equations with the number of employees prior to the construction of a hotel/casino to ensure the number of employees are estimated most accurately. In such a case, other variables may have to be used for forecasting. Normally in such cases, the number of rooms and casino floor area would be known. Table 2 is provided as a guideline to determine which equations to use depending on which independent-variable data is available. The equations in each row are provided in descending order of their statistical significance. The equation shown in the top row was found to be the most statistically significant equation. Therefore, if these independent variables are known, this equation should be used to make the best trip generation estimation for the facility.

LOCAL HOTEL / CASINOS RESULTS

Directional Distribution

The existing trips from count data at local hotel/casinos had an average distribution of 57 percent entering and 43 percent exiting during the a.m. peak hour. During the p.m. peak hour, the directional distribution was found to be 52 percent entering and 48 percent exiting.

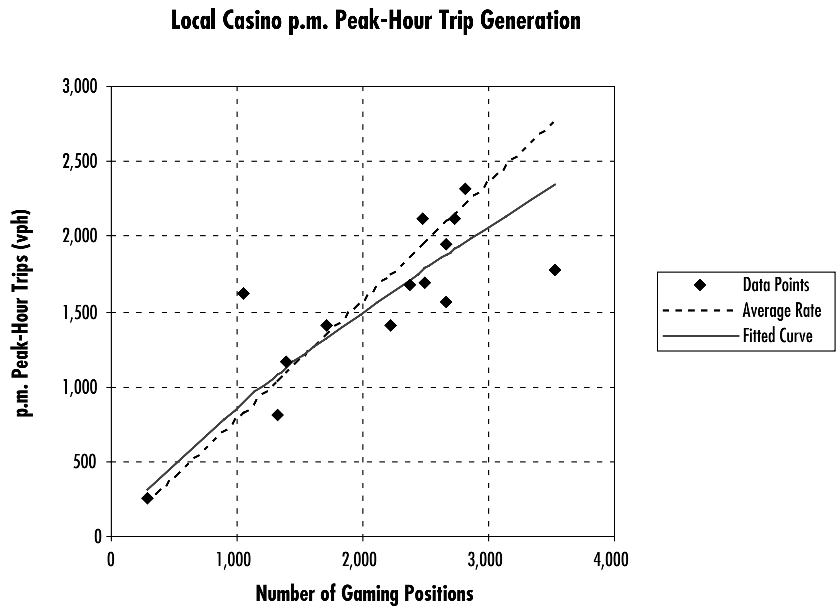
Average Vehicle Trip Ends vs: Number of Gaming Positions
On a: Weekday p.m. peak hour

Number of Studies: 14
Average Number of Gaming Positions: 2,122
Directional Distribution: 52% entering, 48% exiting

Trip Generation per Number of Gaming Positions

Average Rate	Range of Rates	Standard Deviation
0.7877	0.5047–1.5399	0.2462

Data Plot and Equation



Fitted Curve Equation: $Ln(T) = 0.794 \, Ln(X) + 1.278$ $F = 59.77$ $R^2 = 0.83$

where: T = Number of p.m. peak-hour trips

$F_{crit} = 4.75$ at 95% confidence level

X = Number of gaming positions

Figure 2. Local p.m. peak trips vs. gaming positions.

Single-Variable Equations

Table 3 presents the results for single-variable regression analysis for the a.m. and p.m. peak-hour trips generated by a local hotel/casino. From the single independent-variable regression analysis, three of the four variables provide statistically significant models for estimating the expected number of trips generated by a local hotel/casino during the peak hours. The number of hotel rooms was determined not to be a good independent variable for trip estimation. This is likely due to the relatively small number of hotel rooms provided at a local hotel/casino. Likewise, the patrons of a local hotel/casino primarily live in the Las Vegas area, and the patrons of the hotel rooms are not a major proportion of the trips generated.

Average Trip Rates

The average trip rates were found to be acceptable for estimating the number of trips for all independent variables, because the standard deviation was less than the established limit of 110 percent of the average rate.

"Best" Multivariable Regression Equations

Similar to the resort corridor hotel/casino analysis, the forward stepwise regression analysis approach was adopted to determine appropriate multivariable equations. For both the a.m. and p.m. peak hours, it was determined that no multivariable equations are more significant than the single-variable equations. Therefore, the "best" equations to estimate the number of vehicle trips during the peak hours are as follows:

a.m. peak hour

$Ln(T) = 0.710 \, Ln(X) + 1.506$

$R^2 = 0.77$

where

T = number of a.m. peak-hour trips; and

X = number of employees.

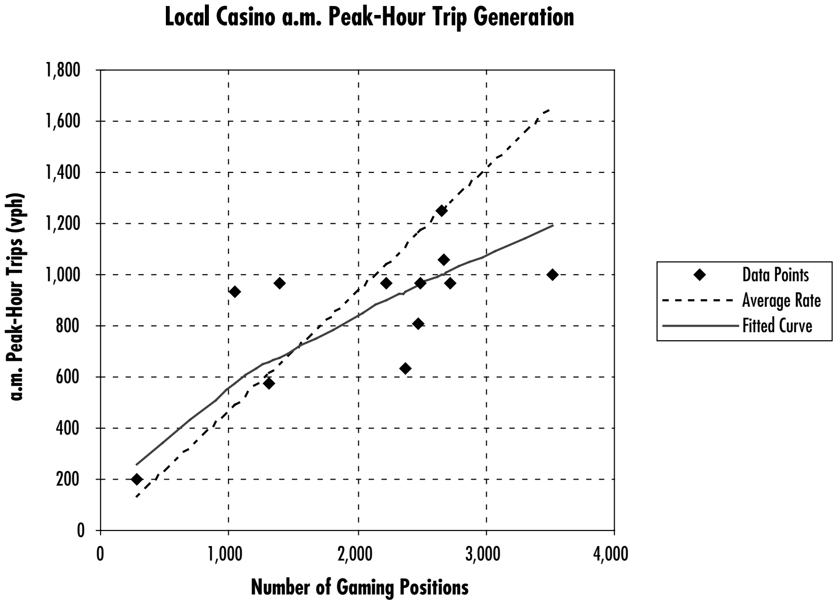
Average Vehicle Trip Ends vs: Number of Gaming Positions
On a: Weekday a.m. peak hour

Number of Studies: 12
Average Number of Gaming Positions: 2,098
Directional Distribution: 57% entering, 43% exiting

Trip Generation per Number of Gaming Positions

Average Rate	Range of Rates	Standard Deviation
0.4701	0.2667–0.8840	0.1913

Data Plot and Equation



Fitted Curve Equation: $Ln(T) = 0.604\ Ln(X) + 2.147$ F = 26.00 $R^2 = 0.72$

where: T = Number of a.m. peak-hour trips

$F_{crit} = 4.96$ at 95% confidence level

X = Number of gaming positions

Figure 3. Local a.m. peak trips vs. gaming positions.

p.m. peak hour

$Ln(T) = 0.794\ Ln(X) + 1.278$

$R^2 = 0.83$

where

T = number of p.m. peak-hour trips; and

X = number of gaming positions.

Figures 1 and 2 illustrate these regression equations as well as the average trip rates, for the a.m. and p.m. peak-hour "best" equations, respectively. Likewise, Figure 3 is shown to provide estimation of trip generation for gaming positions during the a.m. peak hour. Other figures may be obtained by requesting them from the authors.

Determining Most Appropriate Equation

Similar to the resort casinos, for practical use, there are occasions where certain independent variables are not available for estimating the trip generation of a hotel/casino facility. Typically prior to the construction of a hotel/casino, the number of employees and gaming positions is not known. Likewise, the number of employees may be an estimate that may not be accurate to the actual number of employees after completion of the project. Therefore, the equation relating the casino floor area to peak-hour trips is believed to be acceptable for estimating trip generation. However, if certain variables are known, the following list provides the order to use the independent-variable regression equations to determine the best trip generation estimation for a local hotel/casino during each peak hour:

a.m. peak hour (T = peak-hour trips)
– 57% entering and 43% exiting

1 Employees (X)
$Ln(T) = 0.710\ Ln(X) + 1.506$
$R^2 = 0.77$
$T = 4.509\ X^{0.710}$

2 Gaming Positions (X)
$Ln(T) = 0.604\ Ln(X) + 2.147$
$R^2 = 0.72$
$T = 8.559\ X^{0.604}$

3 Casino Floor Area (X)
$Ln(T) = 0.433\ Ln(X) + 4.848$
$R^2 = 0.71$
$T = 127.485\ X^{0.433}$

p.m. peak hour (T = peak-hour trips)
– 52% entering and 48% exiting

1 Gaming Positions (X)
$Ln(T) = 0.794\ Ln(X) + 1.278$
$R^2 = 0.83$
$T = 3.589\ X^{0.794}$

2 Casino Floor Area (X)
$Ln(T) = 0.527\ Ln(X) + 4.999$
$R^2 = 0.72$
$T = 148.265\ X^{0.527}$

3 Employees (X)
$Ln(T) = 0.847\ Ln(X) + 1.086$
$R^2 = 0.72$
$T = 2.962\ X^{0.847}$

Instead of using regression equations, average trip rates may also be used. These rates are as follows:

a.m. peak hour

Trips per gaming position:	0.470
Trips per employee:	0.566
Trips per hotel room:	2.538
Trips per 1,000 square feet (sf) of casino floor area:	14.076

p.m. peak hour

Trips per gaming position:	0.788
Trips per employee:	1.021

Trips per hotel room:	5.067
Trips per 1,000 sf of casino floor area:	22.342

CONCLUSIONS

From this analysis, it was found that the addition of gaming positions as an independent variable was a significant improvement over previous developed equations. It is important to recognize that these trip generation equations were developed using data from Las Vegas hotel/casinos. As previously described, the trip-making characteristics of the resort corridor Las Vegas hotel/casinos are unique based on facility size and proximity to each other. Caution should be used when applying these equations to hotel/casinos outside of Las Vegas. However, the local hotel/casino equations developed may have applications to other gaming establishments throughout the United States. It is recommended that further study be conducted comparing these equations to other regional gaming facilities for the various independent variables. ■

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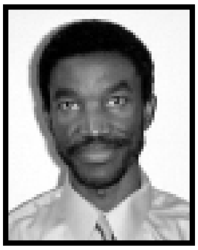

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Trip Generation For Entertainment Land Uses

(To view and print pdf files, use Adobe Acrobat Reader available at this link.)

A paper entitled "Trip Generation for Entertainment Land Uses" was written and presented by Julie M. Doyle, P.E. with the Duluth, GA consulting firm Street Smarts at the 69th Annual Meeting of the Institute of Transportation Engineers (ITE) held in August 1999. This paper presented trip generation data and analysis for several new and emerging land uses not currently included in *Trip Generation, 6th Edition* published by the Institute of Transportation Engineers (ITE). The land uses reviewed include:

- movie theater complexes with 16 or more screens,
- multiuse entertainment facilities offering video games and other indoor sporting activities
- coffee shops,
- microbreweries, and
- laser tag facilities.

Movie Theaters

For years the majority of movie theaters in suburban areas typically contained fewer than ten screens. As such, the trip generation rates given in *Trip Generation, 6th Edition* for this land use category are for movie theaters with an average of between six and nine screens. However, recent development trends have seen the number of screens in an individual complex increase dramatically, with some housing 24 screens and more.

Street Smarts performed trip generation studies of two existing theater complexes in the Atlanta area, one with 16 screens and the other with 24 screens. In each case, the complexes were standalone structures with distinct parking areas that serviced only theater patrons.

Table 1. Trip Generation Rates per screen

Facility	Daily trips/screen			Peak hour of generator per screen		
6-9 screen theater[1]	Weekday[2]		Saturday	Weekday[2]		Saturday
	15.33		529.47	89.48		89.81
16 & 24 screen theater (avg/screen)	Thurs	Fri	Sat	Thurs	Fri	Sat
	97.4	292.5	506.85	12.88	48.95	67.78

[1] *Trip Generation, 6th Edition*

[2] *Includes Fridays*

Daily traffic counts at all complex driveways were collected on a Thursday, Friday and a Saturday. The results of the traffic studies indicate that larger movie theater complexes generate fewer trips per screen than the smaller movie theater complexes used to derive the trip generation rates presented in *Trip Generation, 6th Edition* (see Table 1). Excluding Fridays as part of the weekday counts, the number of daily trips per screen made to the 16 and 24 screen theaters was approximately 36 percent less than ITE documented for a theater with fewer screens. It was discovered, however, that the number of trips made on a Friday for the larger theater was more than 50 percent higher than estimated by ITE. On Saturday, the busiest day at each of these cinemas, a 5 percent difference in the number of daily trips was seen between the larger and smaller facilities on a per screen basis. In contrast to the number of daily trips, the per screen trip rate during Friday's peak hour at the larger complexes was nearly 44 percent less than an average weekday at the smaller facilities, while the Thursday peak hour per screen trip rate was only 15 per cent of that for an average weekday rate as reported in *Trip Generation, 6th Edition*. On Saturdays, the smaller theaters generated 89 trips per screen during the peak hour while the larger theaters generated only 67 trips per screen, 25 percent fewer trips per screen.

Entertainment/Sports Activity Complexes

A separate trip generation study focused on a proposed multiuse entertainment complex that would provide patrons with dining, video games, and other indoor sporting activities. Although *Trip Generation, 6th Edition* contains data for multipurpose recreational complexes, this category characterizes facilities that offer mostly outdoor rather than indoor activities. Therefore, the trip generation characteristics of an existing 48,600 sq. ft. entertainment/ sports complex in Cobb County, Georgia were studied. Similar to the proposed development, the complex offered patrons restaurants, bar, videos, pool tables, and a bowling alley. Weekday trip generation rates per 1,000 square feet were developed. The observed rates are listed in Table 2.

Table 2. Weekday trip generation rates
Entertainment Sports Activity Complex (trips/1000 sq. ft.)

AM peak hour of adjacent street			PM peak hour of adjacent street		
Total	In	Out	Total	In	Out
0.14	100%	0%	2.28	62%	38%

Table 3. Weekday trip generation rates
Other new types of developments (trips/1000 sq. ft.)

Facility	AM peak hour of adjacent street			PM peak hour of adjacent street		
	Total	In	Out	Total	In	Out
Coffee Shop	119.41	51%	49%	49.8%	57%	43%
Microbrewery	0	-	-	4.8	92%	8%
Laser Tag Facility	0	-	-	1.96	79%	21%

Other Developments
Other types of land uses studied included microbreweries, coffee shops, and laser tag facilities. In each case, the land uses did not fit precisely into any of the land use categories listed in *Trip Generation*, *6th Edition*. The businesses studied to determine appropriate trip generation rates were all located in shopping centers and shared parking with adjacent tenants. Data were collected for the weekday peak hours of the adjacent streets. Only vehicles coming to/from the specific businesses were counted. Weekday trip generation rates per 1,000 square feet were developed. The observed rates from this are listed in Table 3.

The full text of this paper is available on the 69th Annual Meeting of the ITE CD-Rom or online here. For additional information, contact Julie M. Doyle, P.E. at 770-813-0882 or at julied@streetsmartsga.com by email. *Adapted with permission*.

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Trip Generation for Entertainment Land Uses

Julie M. Doyle, P.E.

This paper presents trip generation data collected by Street Smarts in the Atlanta, Georgia metropolitan area in early 1998 for some new and emerging land uses: a movie theater with a large number of screens, a coffee shop, a microbrewery, a laser tag facility, and a multi-use entertainment/sports activity complex.

The movie theater data were collected as part of a traffic impact study for a proposed 22-screen movie theater. The coffee shop, microbrewery, laser tag, and multi-use entertainment/sports activity complex data were collected as part of a traffic impact study for a proposed multi-use entertainment facility to include a bowling alley, health club and spa, restaurants, movie theater, coffee shop, microbrewery, and laser tag.

Movie Theaters

The trip generation rates given in the Institute of Transportation Engineers (ITE) *Trip Generation, 6th Edition* for movie theaters are for theaters with an average of six to nine screens. It was felt that the movie theaters which are being built today with at least twice as many screens would generate less traffic on a per screen basis. Therefore, trip generation studies were conducted at two movie theaters in suburban Atlanta to develop rates more appropriate for theaters with a large number of screens.

The theaters studied were selected based on the number of screens and the parking lot layouts. Many theaters that are part of shopping centers do not have distinct parking areas separate from the shopping centers; therefore, it would be difficult to separate the theater traffic from the shopping center traffic. These types of theaters were not selected. The theaters which were selected had their own parking areas with little opportunity for theater patrons to park elsewhere or for non-theater patrons to park in the theater lot and then walk to another facility.

One of the theaters studied had sixteen screens, and the other had 24 screens. 72-hour directional counts were taken on a Thursday, Friday, and Saturday for all the driveways at the two theaters using automatic traffic recorders. The trip generation rates developed using the data collected are shown in Table 1, as well as the rates given in the ITE *Trip Generation*.

Table 1. Trip Generation Rates per Screen for Movie Theaters

Facility	Day of Week	Daily	A.M. Peak Hour of Adjacent Street			P.M. Peak Hour of Adjacent Street			P.M. Peak Hour of Generator		
			Total	In	Out	Total	In	Out	Total	In	Out
16-Screen Theater	Thurs	95.06	1.88	60%	40%	9.44	60%	40%	14.63	40%	60%
	Fri	289.94	0.38	67%	33%	25.88	58%	42%	46.63	45%	55%
	Sat	524.88	-	-	-	-	-	-	74.63	52%	48%
24-Screen Theater	Thurs	98.96	0.96	57%	43%	9.38	55%	45%	13.33	51%	49%
	Fri	294.21	1.29	52%	48%	16.96	56%	44%	60.21	47%	53%
	Sat	494.83	-	-	-	-	-	-	75.13	51%	49%
16- & 24-Screen Theaters	Thurs	97.4	1.33	58%	42%	9.4	57%	43%	12.88	50%	50%
	Fri	292.5	0.88	51%	49%	20.18	57%	43%	48.95	46%	54%
	Sat	506.85	-	-	-	-	-	-	67.78	52%	48%
ITE *Trip Generation* (average of 6 to 9 screens)	Wkdy	153.33	9.50[1]	n/a	n/a	44.53	52%	48%	89.48	57%	43%
	Sat	529.47	-	-	-	-	-	-	89.81	58%	42%

[1] A.M. Peak Hour of Generator

The daily rate developed by Street Smarts for a Thursday, which is a typical weekday, is over 35% lower than the daily rate given in the ITE *Trip Generation* for a weekday. The daily rate developed by Street Smarts for a Friday is almost twice as high as the ITE weekday rate. The Saturday daily rate developed by Street Smarts is approximately 5% lower than the ITE rate for a Saturday.

The ITE *Trip Generation* does not give a rate for the weekday A.M. peak hour of the adjacent street; however, it does contain a rate for the A.M. peak hour of the generator. It is not surprising that the ITE rate for the A.M. peak hour of the generator is much higher than the rate developed by Street Smarts for the weekday A.M. peak hour of the adjacent street. Therefore, when determining the traffic impact of a movie theater during the A.M. peak hour, if the ITE rate for A.M. peak hour of the generator were used to be conservative because of a lack of other information, the number of trips estimated would be much higher than the Street Smarts data would indicate.

For the weekday P.M. peak hour of the adjacent street, the rate developed by Street Smarts for a Thursday is approximately 1/5 of the rate given in the ITE *Trip Generation*. The rate given in the ITE *Trip Generation* for the weekday P.M. peak hour of the adjacent street included counts taken on Fridays. The data collected by Street Smarts indicates that on Fridays, movie theaters generate over twice as many trips during the P.M. peak hour as on Thursdays. The Street Smarts rate for the P.M. peak hour of the adjacent street for Fridays is still over 50% lower than the ITE rate.

For the weekday P.M. peak hour of the generator, the ITE rate is much higher than the rates developed by Street Smarts for either a Thursday or a Friday.

For the Saturday P.M. peak hour of the generator, the rate developed by Street Smarts is approximately 25% lower than the rate given in the ITE *Trip Generation*. When estimating the trips expected from a 22-screen theater, this difference is substantial.

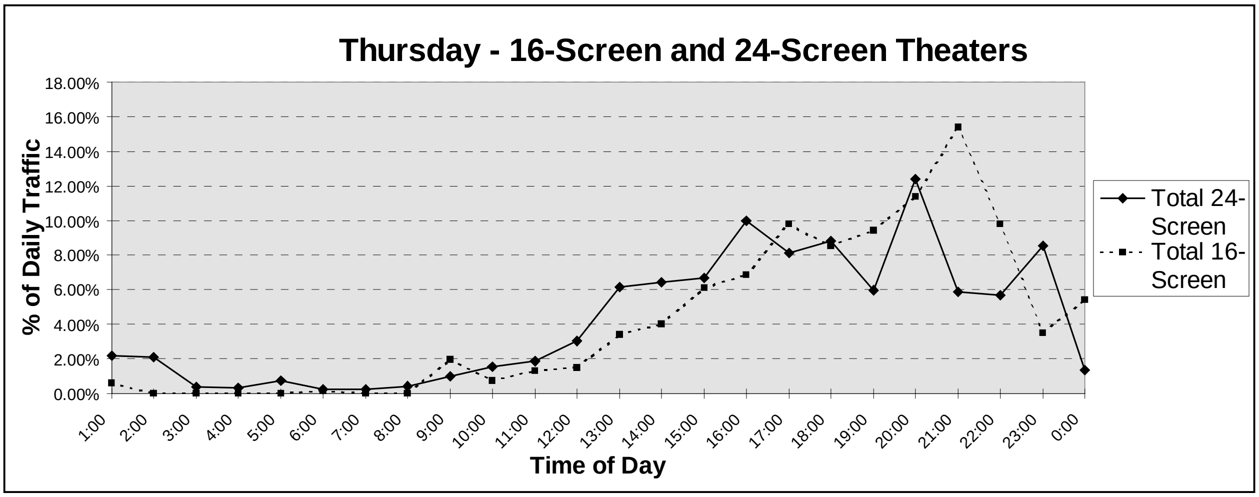
While the two facilities studied generated approximately the same number of trips per screen for their individual Thursday and Saturday P.M. peak hours of the generator, these peak hours occurred at different times. When the trips at the two theaters were combined, the resulting peak hour trip generation was lower than for the individual theaters.

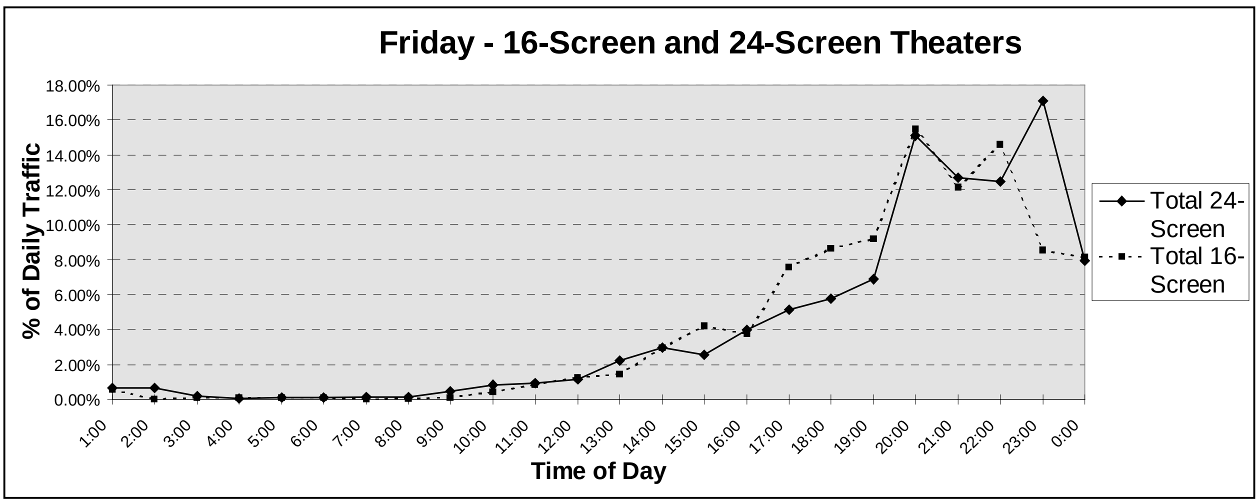
The time of day distribution for the combined trips from the two theaters is listed in Table 2. The time of day distribution for the individual theaters is shown in Figure 1. The time of day distribution shows that on Thursday, the theaters had a higher percentage of their daily trips during the afternoon hours than on Friday. Friday and Saturday had higher percentages of their daily trips during the late night hours than Thursday.

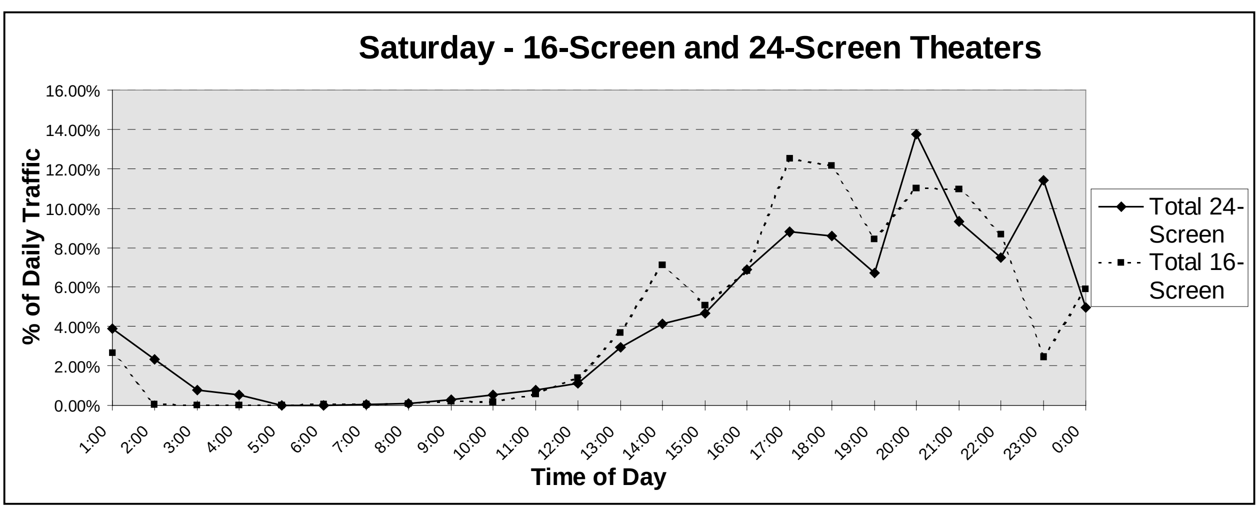
Table 2. Time of Day Distribution for Movie Theater Trips (Combined Theaters)

End Time	Thursday % of Daily			Friday % of Daily			Saturday % of Daily		
	Total	In	Out	Total	In	Out	Total	In	Out
1:00	1.6%	1.5%	1.6%	0.6%	0.5%	0.7%	3.4%	2.7%	4.1%
2:00	1.3%	1.1%	1.5%	0.4%	0.3%	0.5%	1.4%	1.0%	1.8%
3:00	0.2%	0.3%	0.2%	0.1%	0.1%	0.2%	0.4%	0.3%	0.6%
4:00	0.2%	0.2%	0.2%	0.1%	0.1%	0.0%	0.3%	0.2%	0.4%
5:00	0.2%	0.3%	0.2%	0.1%	0.1%	0.2%	0.4%	0.3%	0.6%
6:00	0.2%	0.2%	0.2%	0.1%	0.1%	0.1%	0.0%	0.0%	0.0%
7:00	0.1%	0.2%	0.1%	0.1%	0.1%	0.1%	0.1%	0.1%	0.0%
8:00	0.3%	0.3%	0.3%	0.1%	0.1%	0.1%	0.1%	0.1%	0.1%
9:00	1.4%	1.6%	1.1%	0.3%	0.3%	0.3%	0.2%	0.2%	0.3%
10:00	1.2%	1.3%	1.1%	0.7%	0.7%	0.6%	0.4%	0.4%	0.4%
11:00	1.6%	1.9%	1.3%	0.9%	0.8%	0.9%	0.7%	0.7%	0.7%
12:00	2.4%	2.8%	2.0%	1.2%	1.2%	1.2%	1.2%	1.3%	1.1%
13:00	5.1%	5.3%	4.9%	1.9%	2.0%	1.8%	3.3%	3.5%	3.0%
14:00	5.5%	6.4%	4.5%	3.0%	3.3%	2.7%	5.4%	6.3%	4.4%
15:00	6.4%	6.6%	6.3%	3.2%	3.3%	3.1%	4.8%	5.1%	4.6%
16:00	8.8%	8.3%	9.2%	3.9%	3.7%	4.1%	6.9%	7.0%	6.7%
17:00	8.8%	8.3%	9.3%	6.1%	6.7%	5.4%	10.3%	10.9%	9.8%
18:00	8.7%	10.4%	7.0%	6.9%	7.7%	6.1%	10.1%	10.5%	9.6%
19:00	7.3%	7.6%	7.1%	7.8%	7.7%	7.9%	7.4%	7.1%	7.8%
20:00	12.0%	12.2%	11.8%	15.2%	15.8%	14.7%	12.6%	12.9%	12.3%
21:00	9.6%	8.4%	10.8%	12.5%	13.0%	12.0%	10.0%	10.2%	9.8%
22:00	7.3%	6.6%	8.0%	13.3%	12.6%	14.0%	8.0%	7.5%	8.5%
23:00	6.6%	5.7%	7.4%	13.7%	12.7%	14.7%	7.7%	7.3%	8.1%
24:00	2.9%	2.5%	3.4%	8.0%	7.2%	8.8%	5.3%	4.7%	6.0%

Figure 1. Time of Day Distribution for Movie Theater Trips (Individual Theaters)







Entertainment/Sports Activity Complex

Street Smarts conducted a study for a proposed multi-use entertainment facility that would combine dining places with opportunities for playing video games and other indoor sporting activities. This is a relatively new type of development.

It was not felt that the land uses in the ITE *Trip Generation* were appropriate for this type of recreational facility. The ITE *Trip Generation* has a Multipurpose Recreational Facility land use which is described as having mostly outdoor sports-type uses. Since the multi-use entertainment facility for which the study was conducted would have more indoor entertainment-type uses, it was felt that the Multipurpose Recreational Facility land use was inappropriate.

Therefore, data were collected at an entertainment/sports activity facility recently opened in Cobb County, Georgia, that was felt to be similar the development proposed. The facility studied contains restaurants, a bar, video games, games of skill, pool tables, and a bowling alley. The data were collected for the weekday A.M. and P.M. peak hours of the adjacent streets. Trip generation rates per 1,000 square feet were developed.

The number of vehicles arriving and departing between 7 and 9 a.m. and 4 and 6 p.m. on a typical weekday were manually counted. The facility studied is a stand-alone facility. The trip generation rates developed using the data collected are shown in Table 3.

Table 3. Weekday Trip Generation Rates, Entertainment/Sports Activity Complex (Trips per 1,000 Square Feet)

A.M. Peak Hour			P.M. Peak Hour		
Total	**In**	**Out**	**Total**	**In**	**Out**
0.14	100%	0%	2.28	62%	38%

Other New Types of Development

As with the Sports Complex, other elements of the proposed multi-use entertainment facility did not fit precisely into any of the categories in the ITE *Trip Generation* publication. Therefore, trip generation studies were also performed the following land uses:

- microbrewery
- coffee shop
- laser tag facility

The establishments that were studied are located in the Sandy Springs area of Atlanta. The microbrewery includes the brewing facilities and a bar and restaurant. The laser tag facility also includes some video games and games of skill.

Data were collected for the weekday A.M. and P.M. peak hours of the adjacent streets. All of the facilities are located in shopping centers and share parking with the other tenants. Manual counts were performed so that the counter could observe where the people getting in and out of the cars came from or went to in the shopping center. Only the vehicles coming to/from the facilities being studied were then counted. Trip generation rates per 1,000 square feet were developed. The results of the trip generation studies for these developments are provided in Table 4.

Table 4. Weekday Trip Generation Rates, Other New Types of Developments (Trips per 1,000 Square Feet)

	A.M. Peak Hour			P.M. Peak Hour		
Facility	**Total**	**In**	**Out**	**Total**	**In**	**Out**
Coffee Shop	119.41	51%	49%	49.8	57%	43%
Microbrewery	0	-	-	4.8	92%	8%
Laser Tag Facility	0	-	-	1.96	79%	21%

Conclusions

It was felt that the data collected for movie theaters by Street Smarts supported the hypothesis that the movie theaters being built today with at least twice as many screens as the movie theaters included in the ITE *Trip Generation* generate fewer trips per screen on a daily basis as well as during the weekday P.M. peak hour of the adjacent street and the weekday and Saturday P.M. peak hours of the generator.

For the other land uses, the limited locations studied suggest rates that could be applied elsewhere. It is clear that more trip generation studies should be performed at multi-use entertainment facilities as well as emerging restaurant land uses.

Author's Information

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Trip Generation At Traditional Shopping Centers

(To view and print pdf files, use Adobe Acrobat Reader available at this link.)

Transportation planners continually strive to reduce traffic congestion and improve roadway efficiency. The most popular ways to achieve these goals have traditionally focused on improving existing roads, constructing new facilities, or encouraging transportation demand management practices. Neotraditional town planners also strive to reduce congestion by designing compact pedestrian-friendly "villages" where goods and services are easily accessible by walking, bicycling, or transit. These villages cluster development where retail shops and services are a short distance from nearby neighborhoods.

In a recent article in the University of California Transportation Center's journal *Access* entitled "Traditional Shopping Centers," Ruth L. Steiner investigated if a traditional neighborhood or New Urbanist design approach actually reduces automobile usage by promoting both walking and transit usage. The studies were based on six shopping districts that reflected principles of the New Urbanist approach. Located in the San Francisco Bay Area, each district offered employment opportunities and was surrounded by medium-density residential neighborhoods. All but one of the six shopping districts, an old suburban shopping mall, had a continuous sidewalk that abutted retail shops. Four of the six centers were within a half mile of a Bay Area Rapid Transit (BART) station. Studies found that two of these districts selling resident's daily needs were mostly frequented by locals. In other four shopping districts, two attracted almost the same percentages from the locality as from outside, while two that had adjacent BART stations, attracted most of its customers living outside the nearby neighborhood.

Outside visitors were attracted to the area by the charm of the traditional design and the quality of merchandise being offered. As pointed out in the article, “shopping in (these) areas have become popular largely in response to the quality of their goods...crowded streets and frenetic purchasing contribute to a carnival atmosphere that, in itself, serves to attract even more customers.” Although the traditional design encouraged walking from nearby neighborhoods, it simultaneously attracted visitors from the outside who predominantly arrived by automobile. In five of the six districts, it was found that 85 percent of the non-local shoppers drove.

Consistent with the principles of the New Urbanist movement, Steiner found that a considerable percentage of shoppers from the nearby neighborhoods walked to each shopping district, especially when only a short distance was involved. In five of the six districts, the article reported that between 25 and 50 percent of customers walked from the nearby neighborhoods. In three of those districts, almost 66 percent of the residents living within a mile of the shopping area walked. In the remaining district, which was home to the older suburban mall, only 10 percent of all customers walked. As expected, the closer a resident lived to the shopping district, the more willing they were to travel by foot. It was observed that customers who lived less than one mile from the shopping district were the most willing to walk, with the average distance of all walkers being a third of a mile. However, when the shopping trip involved the purchase and transport of groceries or other cumbersome goods, local residents often chose to drive.

Although each district was located near a BART transit center, only a small percentage arrived by BART or bus. Overall, only 5 percent of customers frequenting the retail shops arrived by any form of transit. Customers were more apt to use transit in the shopping districts where there was only a short walk between the BART station and the shops. In the case of one district, 15 percent of customers arrived by BART. In another district where a half-mile walk was involved, only 3 percent arrived by BART. Of those leaving the districts using BART, over a third walked to the BART station. To study whether walking and transit ridership reduced traffic congestion and parking demand, Steiner looked to Institute of Transportation Engineers (ITE) trip generation rates and parking requirements. ITE generation rates provided the number of car trips that each use in each district could be expected to generate. She compared the actual number of customers frequenting the shopping district to the number suggested should be there by the ITE trip generation rate. By counting the number of shoppers in each retail area, it was found that the totals exceeded those predicted by ITE in four of the six districts. In the remaining two districts, activity was less than predicted. Steiner attributed this to the fact that these areas “mostly serve adjacent residents during a short commute period each day.” After subtracting the number of shoppers who did not drive to the district, the remaining amount nearly equaled the ITE trip generation rate or in some cases doubled the rate, most notably on Saturdays. In other words, the traditional shopping districts generated the same or more vehicle trips than conventional shopping developments, even after taking into account shoppers who walked from nearby residential areas.

Parking continued to be in high demand in three of the shopping districts. Areas that attracted a number of residents from outside the neighborhood experienced a high demand for parking. Only one district, where a high percentage of visitors were from the nearby neighborhood, had sufficient parking.

Conclusion

As discovered during this study, many people living in the surrounding area of these traditional districts did indeed walk to the nearby shops. However, these districts also attracted numerous customers from outside the neighborhood who drove. As Steiner stated, “counts and surveys taken during average (not major) shopping days reveal levels of traffic and parking demand in excess of comparable standards for peak demand.” Thus, the number of expected automobile trips generated by the retail uses did not decline as New Urbanist theory would suggest. Instead, automobile usage from outside visitors made up for the trips that locals would have completed had they chosen to drive instead of walk. Steiner suggests that placing more high density residences near the district would inevitably increase the number of customers who could walk to the shops. However, retailers in the district, whose business relies significantly on visitors who drive from out-side the immediate area, would still want to attract these types of customers. To do so, they must provide sufficient parking. As concluded in the article, “the New Urbanist’s challenge is to incorporate enough parking into the site plan to attract customers without making the physical design unattractive. To design a shopping center only for walkers, or even primarily for walkers, might doom the investment from the start.”

To read the original article please see Transportation Research Record 1617 (1998) by Transportation Research Board, or to view the Access article in full, see the Spring 1998 edition of Access, published by the University of California Transportation Center in Berkely, CA, or online *here*.

For additional information, contact Dr. Ruth L. Steiner at the University of Florida in Gainesville, FL at 352-392-0997, ext. 431 or at *rsteiner@ufl.edu* by e-mail. *Adapted with permission.*

Trip and Parking Generation Rates: Truth or Fiction?

(To view and print pdf files, use Adobe Acrobat Reader available at this link.)

Trip Generation, 6th Edition (and the previous five editions), published by the Institute of Transportation Engineers, contains expected trip generation rates for a variety of land uses. *Parking Generation, 2nd Edition* (and the previous edition), also published by the Institute of Transportation Engineers, contains parking generation rates for a variety of land uses. Planners and engineers rely on information provided in *Trip Generation, 6th Edition* and *Parking Generation, 2nd Edition* for a variety of transportation purposes ranging from estimating potential traffic impacts of a proposed project to establishing minimum parking requirements in local land development codes. Both of these documents are among the most widely used transportation resources in the country and around the world.

In the paper entitled "Truth in Transportation Planning," Dr. Donald Shoup of the University of California Los Angeles contends that the estimates of trip and parking generation rates, though stated as precise numbers in *Trip Generation, 6th Edition* (1997) and *Parking Generation, 2nd Edition* (1987), are in fact, highly uncertain. ITE's trip generation rates are based on surveys conducted by transportation engineers, planners, and consultants. However, these surveys often produce a wide range of results. For example, in *Trip Generation, 4th Edition* (1987), eight studies were used to determine the trip generation rate of a fast food restaurant. Results ranged from 284 trips to 1360 trips per 1000 square feet of floor area. The R2 (a statistical measure of the ability of the independent variable to predict the dependent variable) showed that floor area explained less than 4 percent of the variation in vehicle trips. Further analysis of the data revealed that no statistically significant relationship existed between floor area and vehicle trips. Yet ITE reported the average trip generation rate as "precisely" 632.125 trips per day per 1000 square feet of floor area with a caution about the low R2. Similarly, trip generation rates for other types of land uses were given in an equally precise manner.

In *Trip Generation, 5th Edition* (1991), ITE revised its policy regarding statistical significance. ITE decided to show best fit curves only when each of the following three conditions were met:

- The R2 is greater than or equal to .25

- The sample size is greater than or equal to 4
- The number of trips increases as the size of the independent variable increases

In *Trip Generation, 6th Edition*, ITE again revised its policy regarding statistical significance. The regression equations would be reported only if the R2 was greater than or equal to .5. The rest of their policy remained the same. In the 6th edition, the trip generation rate for a fast food restaurant calculated using 21 studies showed that the rate declined to 496.12 vehicle trips per 1000 square feet. The R2 was not reported. There is a significant difference between the previously reported 632.12 vehicle trips per 1000 square feet in *Trip Generation, 5th Edition* and the rate of 496.12 vehicle trips per 1000 square feet reported in *Trip Generation, 6th Edition*.

Under this policy, *Trip Generation, 5th Edition* reported the trip generation rate of fast food restaurants (using the same 8 studies discussed above) as precisely 632.12 vehicle trips per 1000 square feet, but omitted the regression equation and the low R2. While the policy was well intentioned, the paper contends that omission of the R2 actually encourages misuse of the data because the low R2 would warn planners to use the rate cautiously.

The rates for a fast food restaurant reported in *Trip Generation, 5th Edition* and *Trip Generation, 6th Edition* were generated from data that showed no statistically significant relationship between floor area and vehicle trips. The paper argues that it is, therefore, difficult to believe that the number of vehicular trips for a fast food restaurant could have declined so substantially between the two editions of ITE informational reports.

In *Parking Generation, 2nd Edition*, the paper suggests that parking generation rates “suffer the same uncertainty” as trip generation rates. Again using a fast-food restaurant as an example, 18

studies were used to determine the parking generation rate reported in *Parking Generation, 2nd Edition* . The range of results from the base data ranged from 3.55 to 15.92 parking spaces per 1000 square feet. Here again, the low R2 showed that floor area explained less than 4 percent of the variation, but ITE reported the average parking generation rate as precisely 9.95 parking spaces per 1000 square feet. While logic suggests that there is a relationship between the restaurant's floor area and parking demand or vehicle trips, there is no statistically significant relationship that has been proven by the data analyzed thus far.

Despite these admitted flaws in parking and trip generation rates, the paper notes that planners and engineers continue to consult the ITE resources because it relieves them of the obligation of conducting their own research. Most land use regulations are based on these precisely stated, but uncertain trip and parking generation rates. The rates are "deeply embedded" in municipal codes and case law so planners are reluctant to admit the "flimsy basis" of ITE's trip and parking generation rates because this could eventually lead to legal challenges.

Additionally, the parking and trip generation rates are calculated from land uses that offer free parking. To satisfy the community demand for free parking, planners establish minimum parking requirements that ensure enough parking spaces are available to meet the peak demand for free parking. The author's arguments regarding free parking are further explored in his article, "Instead of Free Parking," Access, November, 1999. A summary of that article entitled, "There is No Such Thing as Free Parking" is available on this web site.

The paper concludes by making five specific recommendations, including the following two:

- ITE should report parking and trip generation rates as ranges rather than point estimates, and
- ITE should show the regression equation and R2 for each land use in the parking and trip generation reports. In addition, ITE should state whether the coefficient of floor area (or other independent variable) in the equation is significantly different from zero.

The paper suggests that the precision of parking and trip generation rates as reported in the ITE informational reports causes transportation professionals to place misguided confidence in uncertain data that in turn results in poor policy decisions. This argument suggests that less precision would, in fact, introduce more truth into transportation planning.

The full text of this paper is available on the 80th Annual Meeting of the Transportation Research Board CD-ROM or online here. Also available on this site is Dr. Shoup's article, "Roughly Right or

Precisely Wrong" published in Access, no. 20, Spring 2002. For additional information, contact Dr. Donald Shoup at the University of California Los Angeles, CA 90095-165 or by email shoup@ucla.edu *Adapted with permission*.