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The University of California Transportation Center, founded in 1988, facilitates research, education, and public service for the entire UC system. Activities have centered on the Berkeley, Davis, Irvine, Los Angeles, Riverside, and Santa Barbara campuses.



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Nobel Prize

BACK IN THE EARLY '70s, a group of us at UC Berkeley got together to conduct the BART Impact Studies. BART was soon to begin operations, and we were out to capture baseline data that would allow later appraisal of the system's outcomes. No metropolitan area had built a new subway system since the 1920s. There we were, living in the midst of a huge de facto natural experiment, so we felt obligated to observe it, measure it, and attempt to evaluate its effects.

BART had been planned to help strengthen the central city and to reorganize the suburbs. Its planners expected it to reshape land markets and reduce urban sprawl, to entice commuters from their cars and thus relieve traffic congestion, and to increase accessibility and thus promote economic development. In response to so broad an agenda, our research team was a multidisciplinary mix of city planners, transportation engineers, economists, psychologists, and no doubt others.

Daniel McFadden, a professor of economics, had never worked in transportation, but he saw here an opportunity to test some ideas he'd been pondering about consumer choice. Working with a group of graduate students from several fields, he conducted a series of home-interview surveys and theoretic studies, searching for ways to predict who would ride BART and why. That research led to his Urban Travel Demand Forecasting Project which, in turn, formalized new kinds of models for predicting travel behavior and then, more generally, consumer behavior. His 1973 article on discrete-choice analysis, "Conditional Logit Analysis of Qualitative Choice Behavior," set new directions in econometrics, using models of consumer and firm behavior. He has since adapted his travel-demand models to consumers' use of energy appliances, the economics of aging, incidences of illness and wellness, and the valuation of public goods.

His insights and innovations have by now been acknowledged with awards of the coveted John Bates

Clark Medal from the American Economics Association, the Erwin Plein Nemmers Prize in Economics, the Frisch Medal from the Econometric Society, and, last year, the Nobel Prize in Economic Sciences.

Before BART began carrying passengers, McFadden projected its likely patronage at but half as many riders as BART itself was predicting. Then, when the trains began running and actual numbers of passengers were counted, his forecasts turned out to be right. So far as I know, few of the later patronage forecasts for rail transit systems in other metropolitan areas came even close to the counts of actual riders, even though McFadden's models were fully available in the literature. Those discrepancies continue to raise questions about the methods and rationales behind overly optimistic projections.

BART's own initial forecast of patronage anticipated 258,500 riders in 1975, about double the number who actually rode in that year (131,400). Now, thirty years after BART's opening, I'm pleased to report that patronage is now running at about 313,000 one-way trips per weekday, reflecting a 34 percent increase in the district's population, additional rail routes into the exurbs, ever increasing highway congestion, and maturation of the BART system. As Landis and Cervero reported here in Spring '99, outside downtown San Francisco, BART has yet to generate the land use changes its planners hoped for. But now that people who live nearby are intimately familiar with BART, they're equipped to make informed choices among available modes. And now that patronage is up, perhaps we can remain optimistic about BART's potential role as agent of metropolitan betterment.

In the following excerpt from his acceptance address at the Nobel Award ceremony, McFadden describes the evolution of his research, and development of the discrete-choice models that are now standard in transportation planning and elsewhere.

Melvin M. Webber

The Path to Discrete-Choice Models

BY DANIEL L. MCFADDEN



GRAVITAS

The research I'd like to describe was initiated in response to the travel models that were available in 1970. At that time, the dominant tool for urban transportation planning was the gravity model. I thought it was just too coarse to yield sensitive predictions of travelers' choices among modes. Besides, because it was nonbehavioral, it was a poor fit for those of us brought up on economic theory. Before recounting the exploratory path that led to discrete-choice models, I should first say something about gravity models.

Here's how they work. You divide an urban area up into small zones. You do a massive household survey to determine how often people travel, and the origin and destination zones of their trips. You aggregate these counts to establish a flow of travelers between zones. You then define these flows as proportional to the zone sizes, measured say by the number of people or the number of jobs they contain, and inversely proportional to travel time between zones. This mimics the physicist's equation for the gravitational attraction between two bodies, hence the name "gravity model." In these models, travel time was often replaced by some generalized measure of travel cost, including out-of-pocket cost and the value of time. For transportation policy, one could tweak the generalized travel cost to reflect an initiative such as added freeway capacity and predict the resulting flows through the system.

Gravity models were, and still are, a useful tool for tracking and projecting network flows, but they have two major limitations. First, they do not use all the information contained in the data collected for their calibration. By aggregating data, they lose the detailed associations between individual circumstances and travel choices, like whether a car is available at the time a trip has to be made. If you can include this information, you can do a better job of predicting what individuals will do, and this can improve the accuracy of your forecasts. Second, there are lots of transportation policies one would

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like to consider, but gravity models are unable to predict their effects. What happens if you reroute a bus line, or introduce a new fixed-rail rapid transit system? It's very hard to get a gravity model to give you a relevant answer.

My proposal in 1971 was to forecast travel demand at the level of the individual rather than at the level of the traffic zone. We would collect data on individual travelers and trips and model the choices they made in response to the transportation environment they faced. If we could articulate the environment in sufficient detail, say with information on the number of blocks to a bus stop, or the amount of waiting time a trip would require, and so forth, then we should be able to forecast how individuals would change their behavior in response to policy alternatives like changing bus routes or headways. Data on individual trips would be a lot noisier than aggregated interzonal flows. But they would contain the detailed links from circumstance to behavioral response that one must understand to do a good job of predicting response to fine-grained, innovative transportation policy initiatives. >

CHOICES

One feature of travel-demand behavior at the individual level is especially important for modeling and statistical analysis. Travel choices are discrete. You either go or you don't, you go either by car or by bus, you go either to Safeway or to another grocery. In 1971, economists had no track record for successfully forecasting demand at this level. Worse, they had no theory for such choices and no models or statistical tools for forecasting them. What economists did have was a general proposition that people make decisions to advance their self-interest. This proposition was developed into a theory of how consumers would adjust levels of demand for various goods in response to changes in income and prices.

In the mid-1960s when I started thinking about these problems, I observed that in a population with heterogeneous tastes, self-interest would lead some to one discrete choice and others to a different one. The attributes of the different alternatives, such as their costs, would determine a tipping point in the distribution of tastes where people would switch from one alternative to another. Thus, the same reasoning that led to the indifference curves and substitution effects found in economics textbooks would, in a world with discrete alternatives and a distribution of tastes, lead to probabilities of choice that depend on economic variables and the attributes of each option in a predictable way. Drawing on work in psychology by Thurstone, Marschak, and Luce, I devised a practical way to implement these ideas in empirical models.

Today, this is called discrete-choice analysis or the theory of random utility maximization, and the original models are called multinomial logit models. In 1971, I worked out a way to apply these methods to the study of travel-demand behavior, estimating work and nonwork travel-demand models for Pittsburgh, PA, including trip generation, destination, and mode choice. I then looked for a natural experiment that would give this modeling framework an acid test, to see whether it had the ability to forecast demand for an entirely new transportation mode.

At that time, the Bay Area Rapid Transit electric railsystem was under construction in San Francisco, scheduled to open soon, and I set as my objective forecasting BART demand before it began operation. My team would then revisit the sampled subjects after BART opened to determine how well the forecasts worked. We conducted a survey in 1972, and then obtained an NSF grant with the cooperation of the Metropolitan Transportation Commission that allowed us to set up the Urban Travel Demand Forecasting Project, conduct a larger survey in 1973, and reinterview the same people in 1975 after BART was running. Our motto was "Zones don't travel; people travel."

FIGURE 1
Predicted and actual modal split—journeys to work (pre-BART model and post-BART choices)

	Auto Alone	Carpool	Bus	BART	Total
Predicted Share	55.8%	22.9%	14.9%	6.3%	100%
Actual Share	59.9%	21.7%	12.2%	6.2%	100%



How did we do? The official forecast of BART patronage in 1973 foresaw it carrying about 15 percent of all work trips. This forecast was based very loosely on gravity model calculations, with a dollop of BART boosterism. Based on our survey and models, we forecast that BART would carry 6.3 percent of work trips. In 1975, BART was carrying 6.2 percent of work trips. Thus, we turned out to be spot on.

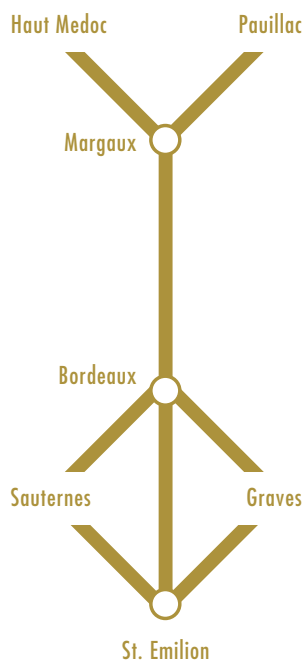
However, to some extent, we were right for the wrong reasons. We overestimated people's willingness to walk to public transport, so we thought that auto or bus access to BART was less important than it has turned out to be. We overestimated bus use in the presence of the BART system. One of the things we have learned since the 1970s is that by asking people a lot more about what they say they would do in well-structured hypothetical-choice settings, we can flesh out our description of how innovative products are perceived, and do a much better job of forecasting their demand. We economists have also learned over the past several decades something that the rest of you knew all along—that people are less single-minded, consistent, and relentless in their pursuit of self-interest than simple economic theories would suggest. There are a number of behavioral reasons for this, but it is convenient to lump most of them under the rubric of mistakes in perception. ➤

PERCEPTION

There is convincing evidence that people's perceptions control their choices and that these perceptions are sensitive to context, and sometimes volatile. That's particularly so when it comes to making choices among unfamiliar alternatives, in situations where probabilistic and statistical thinking is called for, or when some attributes of alternatives are screened from direct attention. For example, people are more sensitive to out-of-pocket costs, such as parking charges, than they are to indirect costs, such as vehicle depreciation. This trait is consistent with behavior in many other arenas where people have to evaluate trade-offs between immediate and delayed gratification.

One of the interesting scientific issues is whether the evidence that people are pulled about by their perceptions means they don't consistently pursue self-interest. A favorite argument of economists is that the market disciplines inconsistent behavior; if people are inconsistent in their perceptions about the choices they make, then some sharp operator will figure out how to turn them into a money pump. In fact, it is clear that while this does happen in some very active markets such as financial markets, it is not universal. Further, people often develop self-protective rules to avoid exploitation.

Here's an example. Consider a simplified road map of the wine-producing regions near Bordeaux.



Bordeaux appears to be closer to St. Emilion than to Margaux. However, you will immediately recognize that this is a version of the classic Muller-Lyer optical illusion in which the distances are actually the same. Could this illusion affect the behavior of wine-lovers? Do travelers arriving in Bordeaux misread their maps, and flock to St. Emilion, even if they prefer the wines of Margaux? In fact, the diagram was inspired by a brochure produced by the commune of St. Emilion, and St. Emilion is more crowded than Margaux, but I doubt this is the result of an optical illusion. We learn to be suspicious of our perceptions, and adopt conservative behavioral strategies, such as adding up distances on maps when we are planning trips, that prevent us from deviating too far from our self-interest. As a consequence, transportation forecasts based on simple models of maximization of self-interest will often be approximately right, not necessarily because that's what people consciously do—or even, given their perceptual limitations, can do—but rather because they learn to adopt rules to avoid behavior that is clearly inconsistent with self-interest.

Over the 25 years that have passed since the Urban Travel Demand Forecasting Project was completed, discrete-choice analysis has become a standard tool not only in transportation planning, but also in marketing, finance, political science, and applied economics. It met a need. Today, if you go to London, Paris, or Hong Kong, you'll find that these tools have been integrated into transportation system facilities planning and operations.

Of course, as they say, no one is a saint in his own country. As far as I know, BART management is unaware that the tools available for transportation policy analysis have changed since 1970. ♦



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REFORMING INFRASTRUCTURE PLANNING

BY DAVID DOWALL

Among the peculiarities of American governments is their tacit belief that infrastructure never dies. A capital project, they assume, needs only its initial investment. Once built, there's no need for anything like a depreciation account or a maintenance budget. Later, if a shortage of capital funds prevents replacement or even long-deferred maintenance, the facilities just wear out or rust away. As a consequence, major infrastructure across America is falling into decay. In regions facing rapid growth, future prospects for sustaining modern standards in transportation, schools, hospitals, water supplies, waste disposal, parks, museums, and the like are mighty dim.

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My observations are based on a recent review of conditions and procedures in California, where things look pretty bad. However, I suspect that California is not exceptional among the states and that the comments in the following pages are pertinent across the nation. In the end, if we're to maintain the standards of living we're capable of, state and local governments are going to have to make some drastic changes in the ways they plan and provide basic infrastructure—indeed, in the ways they govern.

Toward Strategic Planning

Their first step is to recognize that everything really is connected to everything else. Common planning practice is fundamentally flawed, because it treats each public-service sector as though it were an independent domain. For example, we've all learned in recent years that transportation and land use are but sides of the same coin, hence that we must plan transportation facilities as functions of a city's spatial arrangements, and vice-versa. And yet, even though modern traffic-generation models recognize those relations, state DOTs continue to function independently of land use agencies, each going its own way and pursuing its own ends, each following its own preferences and its own profession's interests. It should be obvious to us all that school facilities must be fitted to residential settlement patterns and their demographics; but the school board follows its own compass. Similar relations mark water supply and agriculture; sewerage and housing; airports, rail lines, and freeways; taxes and everything. Above all, the patterns of specialized vested interest and political influence and the established habits of public officials are primary determinants of what gets built and where—not



systematic projections of demand for public services. If we're to become effective planners for public infrastructure and services, we'll have to learn to think strategically. We'll need to conduct our analyses across the various sectors, simultaneously. And we'll need to encompass the political considerations that technically oriented engineers and planners have long thought were outside their realms, even though politics, rather than technics, determine which infrastructure gets built. But first I want to describe some deficiencies in our present governmental systems and suggest some more technical remedies.

The Missing Strategic Mindset

California, like most states, has developed sector plans that seek to specify future supply for various services. Some of those plans were derived with help from sophisticated simulation models and employed the insight and wisdom of professionals and legislators. And yet, few if any reflect the dynamic developmental processes that arise as interdependent sectors constantly interact with each other. As with complex ecologic systems in nature, economic and social systems comprise extremely intricate and interdependent relations, such that events in any one sector are constantly being reshaped by events in others. Thus, for example, developments in California's water systems inevitably affect electric-power production, agriculture, the region's fisheries, the location of urban development, the character of industrial development, and so on, possibly including the climate. In turn, developments in each of these sectors are reflected as changing demand for water and for each of the related sectors. Similar interdependencies affect all other parts of the system. ➤

It's all too true that the sciences are not yet sufficiently developed to permit description of the whole state ecology, much less permit us to simulate its processes. And yet we are not wholly ignorant. We know a lot about the causal chains through which individual sectors affect each other. The trouble is we don't know how to organize ourselves so we can exploit our understandings. We don't know how to get the various departments in state government to work together, much less how to get the various industrial and civic groups to collaborate. We don't even know how to build simulation models to describe these relationships.

Moreover, we've not explored alternative ways of delivering services, such as through public-private collaborations—privately financed research facilities on public university campuses, or jointly owned and operated public facilities—like the new San Jose State University/City of San Jose Library. We have not identified noncapital alternatives for meeting future demand such as year-round education, telecommuting, and advanced forms of water and energy conservation, nor have we experimented adequately with demand-side modes of planning. Traditional supply-side planning made sense when the various sectors were small and still immature, when state growth rates were rapid, and when there was broad consensus in support of growth. But today's environment is changed. Many citizens reject economic and population growth and decry suburban development. Infrastructure planning is politicized, based largely on pork-barrel deal making. Traditional types of capital funds are in short supply, and the various bureaucracies are actively competing to corner what's available.

The Missing Vision for Infrastructure Investment Planning

Several states are actively searching to overcome these difficulties by trying to invent ways of doing long-term, multi-

sectoral strategic planning. Notable among them are Florida, Maryland, and New Jersey—but not yet California. Each has formulated a vision of the state's future economy, its living conditions, and its environment. Each, in turn, is seeking to understand how it might intervene in regional developmental dynamics and thus raise the odds of achieving desirable future conditions.

In place of straight-line extrapolation of the curves tracing past levels of supply, their strategies call for deliberately shaping future demand. The trick is to invent demand-management policies—policies that influence consumers' choice of activities and hence their demand for services. In California the most active demand-management programs are those of the Department of Water Resources, which is seeking to promote water conserva-

tion by differentially pricing water supplies. There are some signs that demand management is slowly moving into agriculture, but there seems to be little interest elsewhere. Until recently neither K-12 nor higher education has embraced demand management as a policy option. But now, the legislature is pressing the University of California to consider year-round operation as a demand-management tool to squeeze more capacity out of its capital infrastructure. So far, however,

there's little interest in using pricing as a means of shortening students' time to receive their degrees and thus getting better use of the infrastructure (the University of North Carolina system is a notable exception).

It seems that the most effective way to affect demand is by pricing the services. And yet, despite considerable research into pricing highways to relieve congestion—and despite the successes of congestion pricing on SR 91 and I-15 in Southern California and bridges and tunnels in New York—state transportation planners seem frightened of the concept. I find the lack



of interest in demand management rather perplexing, given California's tremendous success with demand management in the energy sector. There alone, consumers saved \$7 billion over the past two decades when deliberately designed incentives, including higher prices, encouraged them to reduce their demand for commercialized power.

Some infrastructure is financed through user fees or charges, of course. However, inflation-adjusted fees for education and highways have not kept pace with the costs of services. Fees for California higher education have fallen by nearly twenty percent since 1994, gasoline taxes by fifty percent between 1950 and 1998. Efforts to raise highway user fees have been rebuffed for over seven years by both Republican and Democratic governors.

In response, construction of new highways and maintenance and renewal have severely lagged behind trends in vehicle-miles traveled. Clearly transportation improvements require a more stable and reliable financial base. But, equally important, they require a more effective system of planning and contracting. Caltrans, for example, has been reluctant to partner with the private sector. Unlike other state departments of transportation, it has refused to contract out planning, design, and management work, with the result that its projects take from 7 to 23 years to complete.

It is also essential to deal more emphatically with maintenance. A recent report ranked California's road condition at 48th in the nation. I find that most surprising in light of the state's reputation as a world leader in highway developments. But that study found fifty percent of the roads in poor or mediocre condition. It estimates that potholes, ruts, and rough pavements are costing the average driver some \$350 per year in added maintenance and operating expenses. This totals to \$7.4 billion per year for the state as a whole. And yet, despite rising VMT and

increased maintenance, maintenance expenditure per 100 vehicle miles traveled declined from eleven cents in 1987 to seven cents in 1996 in constant dollars.

What should the state do?

A series of mutually reinforcing steps seems appropriate and necessary.

1. *Formulate a coherent vision for the future* of the state's economy, demography, life styles and life qualities, urbanization patterns, social and physical environments, patterns of governance, and civic life. Then create a capacity inside state government for thinking and acting strategically, i.e., for exploring long-term future options and alternative means of acting in pursuit of those options. A vision should guide the many policies

and programs for creating future infrastructure and public services.

2. *Install demand-management methods* that will sensitize infrastructure plans to consumers' preferences and create incentives that can help shape consumer wants. This innovation will create quasi-market arrangements in public sectors comparable to those in private sectors. Prices will surely be among the more powerful instruments for managing demand, matching newly supplied infra-

structure to users' preferences and potential benefits, and fitting fees to actual costs. Exceptional care must of course be taken to ensure that fees reflect ability to pay and that adjustments do not limit access of low- and moderate-income households to services. This calls for a range of offsets—lifeline rates, financial aids, tax rebates.

3. *Make capital funding more predictable* by developing demand-based long-term investment plans linking annual tariffs and appropriations to future capital costs. Governments must move beyond the current pork-barrel method of allocating >



funds for capital investment; that habit causes erratic financial flows and makes for nonrational decisions that divert monies from good civic projects to self-serving ones.

4. *Introduce accountability measures* to expose winners and losers in the investment game, to permit appraisal of each agency's performance, and to improve project delivery. But accountability alone will not assure improved service. In addition, strong incentives are needed to reward high-level performance, promote competition among public agencies and between public and private agencies, and thus, in turn, help to improve performance of the public service systems. Infrastructure planning, development, and management need to be depolitized by shifting financial responsibility for services to the user and beneficiary, and at the same time developing ability-to-pay offsets for low- and moderate-income households. If users and beneficiaries start to finance infrastructure directly, they will demand more accountability and transparency in infrastructure service delivery. Taking the pork out of infrastructure financing requires that users and beneficiaries exert more control over infrastructure planning, investment, and management decisions.

No citizens will tolerate pork-barrel planning if they clearly recognize that they are paying for someone else's pork.

Wishful thinking? Perhaps, but consider the success of the Santa Clara County Traffic Authority. Frustrated with traffic congestion and Caltrans inaction, citizens of the county approved a sales taxes increase to finance the formation of the Authority. The SCCTA was able to build needed highway improvements in one-third of the time proposed by Caltrans and in the process

saved over \$100 million. The key to success was active local control of the project and partnership with a private engineering firm to implement the project aggressively.

5. *Introduce lifecycle costing and management* to go beyond procurement costs and encumber future maintenance expenses in the project's initial budget. Governments need to hold their agencies accountable for maintaining capital facilities. At a minimum this requires much better reporting of facility

conditions. Agencies should be required to report deferred maintenance backlogs and develop five-year plans for eliminating deferred maintenance. Recent changes in government accounting standards require state and local governments to estimate the condition and value of their capital assets annually. This should provide the impetus for governments to consider lifecycle costs.

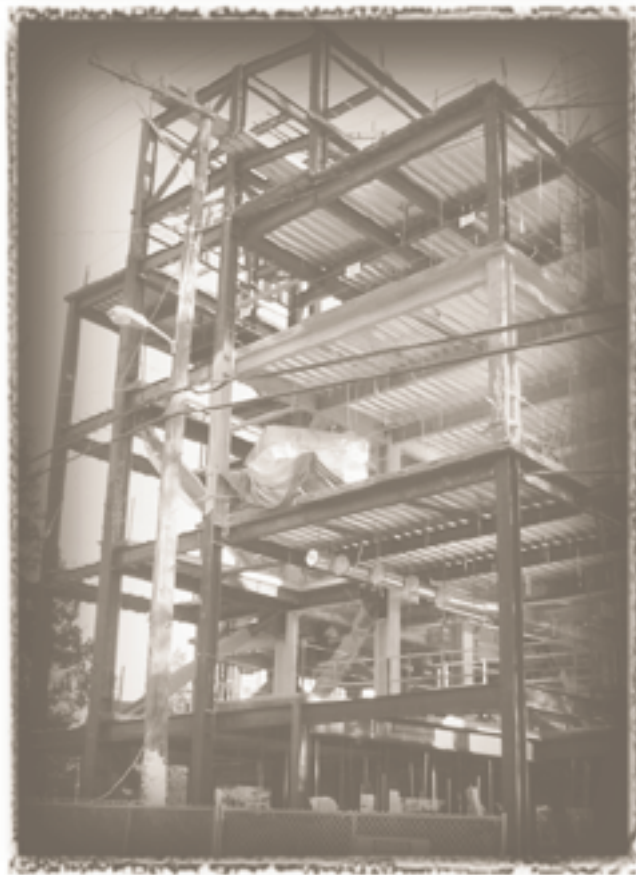
Where to Start?

The California Legislature has already taken the first step, requiring the Governor to submit a five-year capital plan that will chart a future course of action. I suggest the plan be divided into three phases: (a) immediate steps to relieve the most severe congestion and infrastructure shortfalls; (b) near-term efforts to alleviate the next

series of poor conditions; and (c) long-term overhaul to remove structural and institutional impediments to improving infrastructure. What might these look like?

Immediate actions—demand management and pricing.

These will have the quickest effects, creating new capacity within weeks or months without capital outlays. Where traffic congestion is most costly, congestion-pricing pilot projects



can help. In the Bay Area, for example, experiments with higher peak-hour tolls should be tried on the bridges for a one-year trial, preferably with discounted commuter fares on the transit systems. The state's gasoline taxes should be raised, perhaps by as much as twenty percent per year over the next five years. Local government could help by levying parking excise taxes on municipal and private parking services. Similar responses should simultaneously be mandated for schools, water supplies, waste treatment, recreational facilities, and so on across the full array of governmentally supplied services.

Hopelessly optimistic? Consider that thirty years ago, water rates were based on decreasing block charges (the more you consumed, the less you paid per unit). Now, to promote conservation and demand management, residential and industrial rates are almost universally based on *increasing* block tariffs.

*Medium-term actions—
institutional and financial
restructuring.*

Over the next five years the state should restructure its infrastructure institutions and establish closer links between strategic and capital planning. Funding-allocation systems for education, transportation, and other sectors need to be made more equitable and more efficient.

Toward those ends, they might experiment with dedicated full funding for maintenance, with programming capital outlay grants to sectors based on projected demand, and with balancing pay-as-you-go and debt financing to improve the predictability of infrastructure financing. With the adoption of AB 1473, the state is already moving in this direction.

Long-term actions—creating a vision and integrating policies for multisectoral infrastructure.

The state should formulate a vision for future economic and environmental developments over the next ten to twenty years. A broadly focused vision might sensitize the state's various departments to likely effects of their own projects on the domains of other departments. Mutual concern for others' domains should help to promote interdepartmental cooperation and intersectoral planning.

Were the technical agencies of government equipped to collaborate, especially to collaborate with financial agencies, the odds of achieving elements of the long-term vision would surely be enhanced. Perhaps then the processes of governance would be nudged away from pork-barrel modes of deciding and investing.

Although what I am proposing may sound Pollyannaish, these changes could be successfully implemented over the next five to ten years if we begin gradually to devolve responsibility for infrastructure to users, beneficiaries, and local governments, and to place more of the financing burden on users and local governments. The key to reform is to introduce more accountability into the infrastructure delivery system. ♦



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In the Dark: Seeing Bikes at Night

BY KAREN DE VALOIS, TATSUTO TAKEUCHI, AND MICHAEL DISCH

IT'S MIDNIGHT. You're driving home after an evening out, when you notice a small bright object—or perhaps two—moving across your field of view in an odd scalloped pattern. Because you have seen one before, you may recognize it as the reflector on the wheel of a bicycle approaching on an intersecting street. You must quickly decide whether to stop, slow down, speed up, or continue at the same speed. To make that decision correctly, you must know not only how fast you are moving, but also when the bicycle will enter and leave the intersection. This is considerably more difficult than you may think.

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Reflecting An Illusion

If the bicycle frame is dark and the rider is wearing dark clothing, the bicycle may be visible only because light from your car strikes a reflector on a wheel. You must judge the bicycle's position, speed, and direction from the motion of the reflector, yet the reflector is not traveling in a straight line.

The Code of Federal Regulations (Ch. II, Section 1512.16, 1-1-00 Edition) specifies that street bicycles have a reflector on each wheel, and that "the center of spoke-mounted reflectors shall be within 76 mm (3.0 in) of the inside of the rim. Side reflective devices shall be visible on each side of the wheel." (The law allows for reflective sidewalls or rims instead, but these are not common.) Since the reflector must be near the inside of the rim rather than on the axle, its motion will be a combination of the linear forward (or *translational*) motion of the bicycle and the *rotation* of the wheel. The curve produced by combining a translation and a rotation is called a *cycloid*. Figure 1A illustrates a cycloid, showing the path that would be followed by a reflector if it were mounted directly on the rim of a bicycle wheel. However, a reflector can't actually be mounted on the rim without interfering with the brakes, so it's placed on a spoke inside the perimeter of the wheel. There its trajectory takes the shape of a *prolate cycloid*, as shown in Figure 1B.

There are several interesting things about the cycloid path. First, it is significantly longer than the path followed by the bicycle itself. Since the reflector must traverse its longer path in the same time that the bike travels a shorter distance, the average speed of the reflector must be greater than the speed of the bicycle itself. How much greater it is depends on the distance between the reflector and the axle.

Second, notice that the forward-moving (or translational) speed of the reflector is not constant. It progresses alternately rapidly and slowly. When the reflector is moving across the top of the wheel, its forward motion is rapid. When it is nearer the bottom of the wheel, it moves primarily up and down, exhibiting relatively little forward motion.

Finally, note that the reflector never moves backwards. Its forward motion is not at a constant speed, but it never loops back on itself. If you have ever watched the reflector on a moving bicycle wheel, you may find this surprising. Most observers describe the apparent trajectory of the reflector as looking like the *curtate cycloid* drawn in Figure 2. But the only way the reflector could actually loop back on its path would be if the distance from the axle to the reflector were greater than the distance from the axle to the rim, which is, of course, not possible. So not only does the reflector traverse a longer path than the bicycle, but in our perception it travels even farther. Psychologist Dennis Proffitt and his colleagues have found that even high school physics teachers and experienced bicyclists are subject to the same perceptual error: they think that the reflector's path loops back on itself.

These comments are pertinent because we do not fully understand how people judge the speed, direction, and position of moving objects. It seems intuitively obvious that to determine the speed of a moving object, you would note its position at time 1, its position at time 2, and the amount of time that elapses between the two. However, this is probably not the way we normally do it. Unrelated factors such as contrast within a pattern or certain spatial features can affect our perception of speed. >

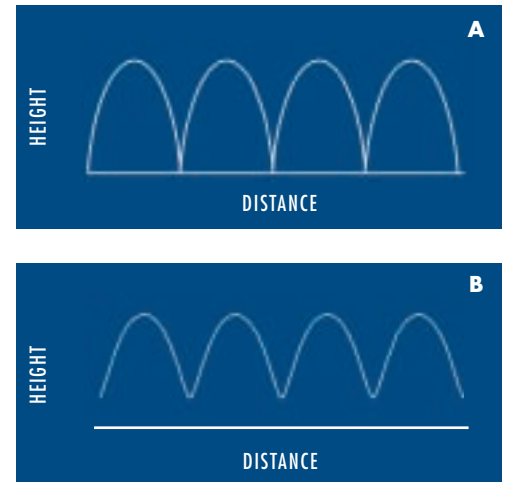


FIGURE 1

The cycloid in Fig. 1A shows the path that would be followed by a reflector mounted on the rim of a bicycle wheel. The prolate cycloid in Fig. 1B is the path that would be followed by a reflector mounted on a spoke part way between the axle and the rim.

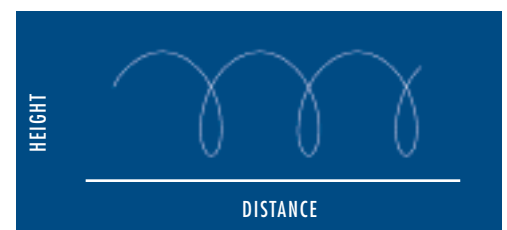


FIGURE 2

This curtate cycloid illustrates the apparent path of a reflector on the spoke of a moving bicycle wheel. Observers perceive the reflector's path as looping back on itself, though it does not actually do so.

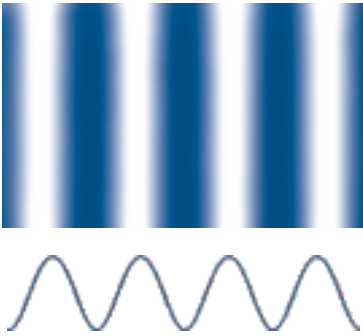


FIGURE 3

In this grating pattern, the luminance varies sinusoidally across space, as shown by the line below.



FIGURE 4A

Here the frequency and orientation of the grating are identical to those in Figure 3, but the contrast has been reduced. If this pattern and that in Figure 3 were moving at the same velocity, this one would appear to be moving more slowly.



FIGURE 4B

Here the contrast is high but the lines are narrower, which makes the grating appear to move more slowly.

Consider a simple striped pattern like that illustrated in Figure 3. If we were to see that pattern through a window and set it in motion (left to right, say), it would appear to move smoothly, and its apparent speed would be closely related to its actual speed. However, if we either reduce the contrast within the pattern (as in Figure 4A) or make the stripes narrower (as in Figure 4B), the apparent speed would decrease even though the actual physical speed doesn't change. In fact, if we change the stripes from black and white to a carefully balanced red and green, the motion of the pattern might appear to stop entirely even though it continues to move with the same speed. We do not fully understand why we experience such strange and anomalous percepts. In all these cases, we are quite capable of seeing the individual stripes and telling their positions, so it's unlikely that we use this information to judge speed.

The problem of judging the speed of a bicycle from the perceived motion of reflectors on its wheels is complex. In essence, we need to extract the lateral translation and ignore the rotational component of the reflector's motion. Since our understanding of how the brain interprets speed is incomplete, we'd been unable to predict how well observers would perform if we asked them to judge the speed of an object moving along a cycloidal trajectory.

We devised a simple task that could be carried out using a computer display, rather than going immediately to field tests. We put observers in a darkened room and asked them to look at a computer monitor. Two white circles appeared against a dark background, one on each side of the screen, one on the upper half and one on the lower half. The two circles began to move towards the midline of the monitor. One moved at a constant speed along a straight path; the other moved along a cycloid path or some variation. We asked the observers to tell us which appeared to be moving faster across the screen. By randomly varying the starting points and the total distance each dot traveled, we ensured that extraneous cues such as time to cross the midline or time of disappearance could not be used.

The results were startling. Virtually every observer thought that the circle moving along a cycloid path was crossing the screen faster than the one moving along a straight path when their actual forward-moving speeds were the same. The error in speed judgment was sometimes quite substantial, as great as 25 percent overestimation for some observers. The consequences of such a large error in estimation can be quite serious. If a driver believes that a bicycle is moving much faster than it really is, for example, he may judge that it will clear an intersection before the car reaches it and accordingly fail to brake at the appropriate time.

Fixing The Problem

We were quite surprised by this result and wondered whether there might be a simple way to reduce or eliminate the perceptual error. Since the illusion seems to be a consequence of the trajectory of the reflector, we thought that the addition of a second reflector at the center of rotation—as though on the axle of a bicycle wheel—might help. We considered removing the reflector from the spoke, but there are compelling arguments against doing so.

A reflector on the axle moves in a straight line at the same speed as the bicycle itself, unlike a reflector on a wheel spoke. However, a single bright dot moving along a straight

line does not draw one's attention as readily as a fluctuating one; nor does it give very useful information about the identity of the object. So we measured the apparent speed of a two-dot configuration, placed as though one were on a spoke and one on the axle. We thought that the "bouncing" dot would draw attention and help identify the object, while the center dot would give correct information about trajectory and speed. We were startled to find, however, that observers still made errors in estimating speed—but the errors were in the opposite direction. Our subjects now significantly *underestimated* the forward speed of the moving dots.

This result led us to examine several two- and three-dot configurations that might be fitted to bicycles, hoping to find one or more that would not produce such perceptual errors. We found that when two dots (or reflectors) were placed exactly opposite one another, observers judged the speed without bias or significant error. Three dots evenly spaced around the axle also produced accurate estimates. In general, however, any configuration that included a significant asymmetry in the placement of dots led to perceptual error. Configurations with a dot at the center of rotation produced an underestimation of speed, and those that included an asymmetric arrangement of dots on the spokes or rim led to overestimation.

The apparent slowing in the former case may be related to the characteristics of neurons in cortical area MT, a region of the brain believed to be integrally involved in the analysis of visual motion. Many MT cells respond selectively to objects moving in a particular direction, but their responses are reduced when other objects move in the same direction nearby. These neurons would produce a smaller response to a dot moving at the center of rotation when one or more other dots move nearby as though on the spokes of a wheel.

The perceived increase in speed of a single cycloid or an asymmetric arrangement of dots on a cycloid path suggests a different kind of explanation. The observer's task is to distinguish the linear speed even though no single visible feature is moving at that speed. Since each of the individual features (dots) is moving along a longer trajectory, the average speed of each must be greater than the linear speed the observer is trying to estimate. Perhaps the observer's judgment is influenced by the higher average speed of the visible features.

Although these are plausible explanations of the errors in estimating speed, they do not explain the lack of perceptual bias when two (or three) symmetrically placed reflectors are used. In practical terms, of course, it is critical only that we identify which configurations work. Nonetheless, we hope to learn why these particular patterns sidestep perceptual biases.

Our current hypotheses relate to observers' clear sense of the rotational component of each dot's motion in several of the configurations we studied. Only when the dots are symmetrically placed does the observer perceive equal forward and backward >

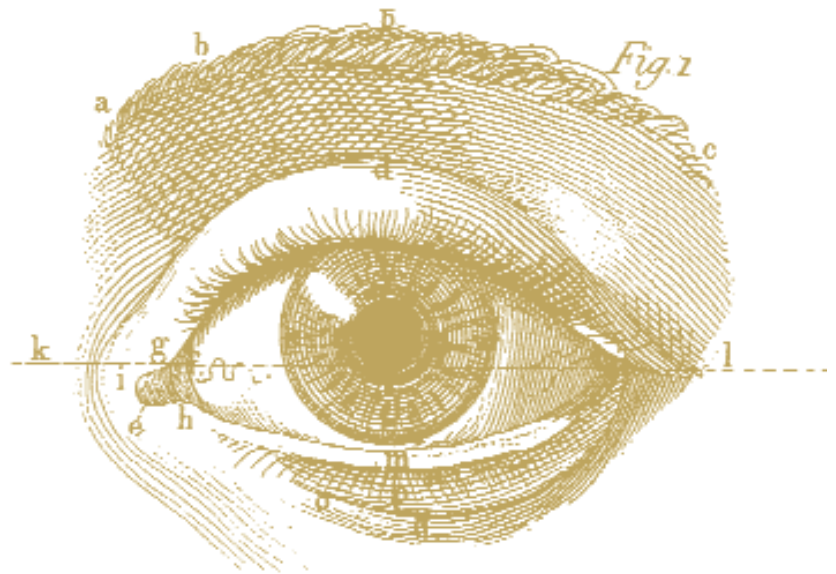




FIGURE 5

Speed estimation task:

- Beginning
- Ball about to enter RE field
- Goal line flashing

rotational motion at every moment. There is, of course, no actual backward motion, but the perception is powerful. We wonder whether, in a symmetrical arrangement, the extra speed attributed to the rotation is effectively canceled out, leaving nothing but forward movement to shape observers' judgments. We hope to come to a more complete understanding with additional research.

There is a further question of interest and relevance. Recall that we always asked the observers to compare the apparent speeds of two targets, one of them moving in a straight line. When the observer matches the two accurately, there is no selective perceptual bias. However, an accurate match on this task does not imply that the apparent speed is identical to the real speed; it merely shows that any error in judging the speed of a single moving dot is repeated in the judgment of the test pattern. We wondered whether our subjects were actually making accurate speed judgments, or whether they were simply consistent in their errors. To find out, we devised a new psychophysical task that does not involve a speed comparison.

We divided a video monitor screen into halves. On one side was an unpatterned gray field. On the other we drew a pattern of random black and white rectangles, with the same average luminance as the gray field (Figure 5). Near the far edge of this random element (RE) field, we drew a black line extending from top to bottom. We told the observer that the black line was a target and that, when the target was hit, it would immediately flash brightly. As the observer watched, a fuzzy white ball appeared at some randomly determined point in the gray field and began to move at a constant speed toward the RE field. When it reached the edge of the RE field, the ball appeared to move behind it, as though it disappeared behind a wall. The observer was told that the ball continued to move towards the target, but it could either speed up or slow down when it moved behind the wall. Once it reached the target line, the line would flash. The observer's task was to judge whether the ball moved faster when it was visible against the gray field or when it was not visible behind the RE field. By keeping the width of the RE field constant and varying the speed at which the ball moved when it was visible, we could determine what the observer estimated the actual speed to be.

The results were quite surprising. The relationship between real speed and apparent speed on this task was highly inaccurate and disproportionate. We found that at slow speeds, observers consistently overestimated the speed of the moving spot, but at high speeds, they consistently (and in some cases dramatically) underestimated its speed.

In fact, above a certain intermediate point, increasing the actual speed had little effect on the judged speed over the range we used, and only for a very small set of actual speeds were estimations approximately accurate. Even when we made all the moving spots equal in effective contrast—something that does not generally occur in nature—our observers still made significant errors in judging the speeds, particularly when they were rapid.

We have found only one set of conditions under which our observers consistently judge the speed of a moving spot accurately. When we increase the contrast between the spot and its background, thus increasing the visibility of the spot, judgments are better. Only if we make the contrast as high as possible with our display can observers determine the speed of the moving spot accurately at all speeds.





What To Do

Our studies of apparent speed are not complete, but they suggest two measures that might increase auto drivers' ability to judge a bicycle's motion more accurately at night. The first is simple—use two reflectors, not one, on each side of the wheel and place them directly opposite each other. This could be easily and inexpensively accomplished. It would not reduce either the visibility of the bicycle or its ability to attract attention and be properly identified.

The second measure is to increase the effective contrast, and therefore the visibility, of the reflectors. This is a more complex task. Actual contrast depends on two factors: the brightness of the background behind the bicycle, and the amount of light reaching the driver's eye from the reflector. Backgrounds cannot be controlled, and reflectors can return only a portion of the light shining on them. The amount of light reaching them largely depends on the characteristics of the car's headlights and its position relative to that of the bicycle. These are not readily predictable or controllable. Furthermore, since it must be visible over a wide angle, the reflected light must be dispersed and will thus be less intense in any given direction than the light that reaches the reflector.

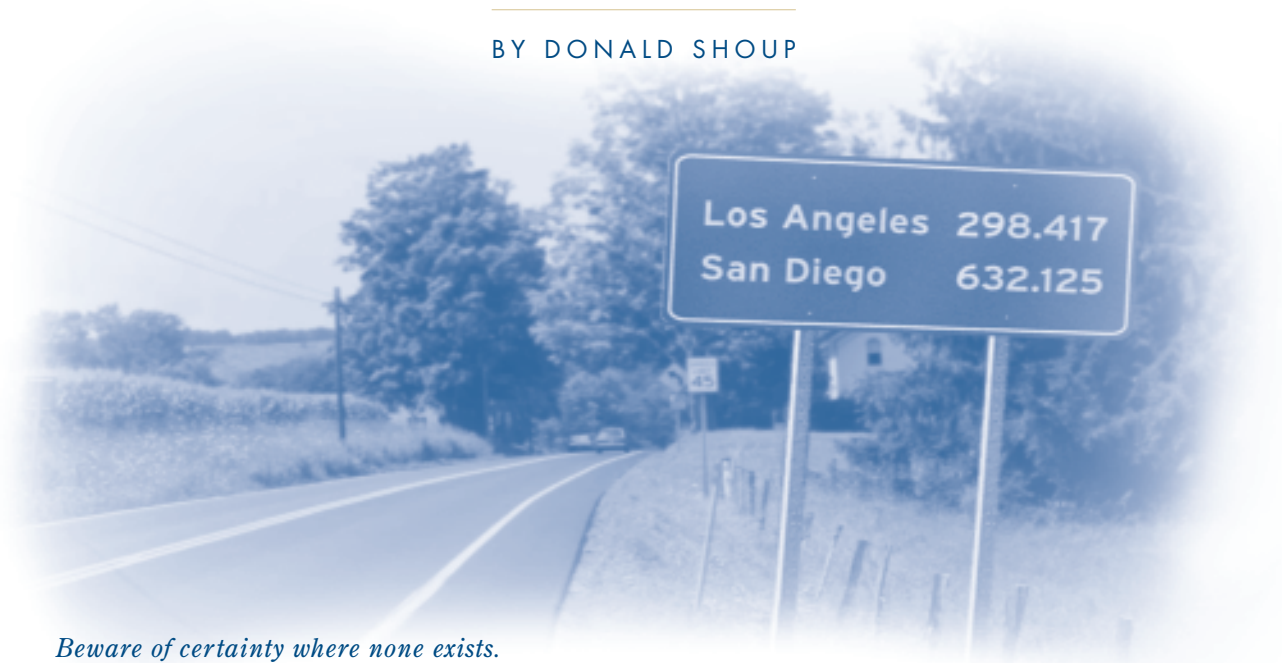
Our data suggest that any increase in contrast will increase the accuracy of the driver's judgment, so it might be worthwhile to replace reflectors with small, bright light sources. Whether this could be done efficiently and without adding significant weight is a question for lighting engineers. Our studies suggest, however, that the potential payoff could be substantial. Not only would bicycles be more visible, but more importantly, drivers would be able to judge their speed more accurately. We might thus increase the safety of bike riders who need to cycle at night. ♦

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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.

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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

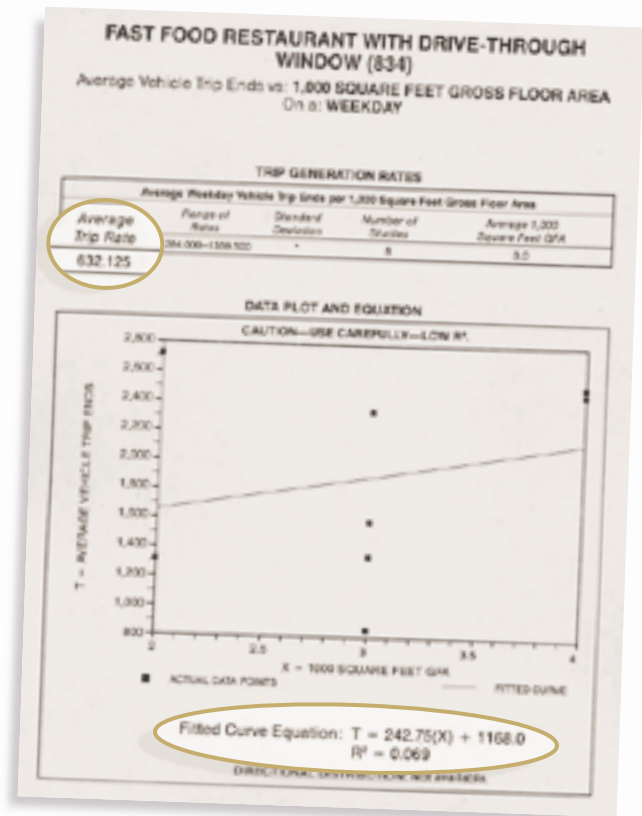


FIGURE 1

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 R²,” 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.

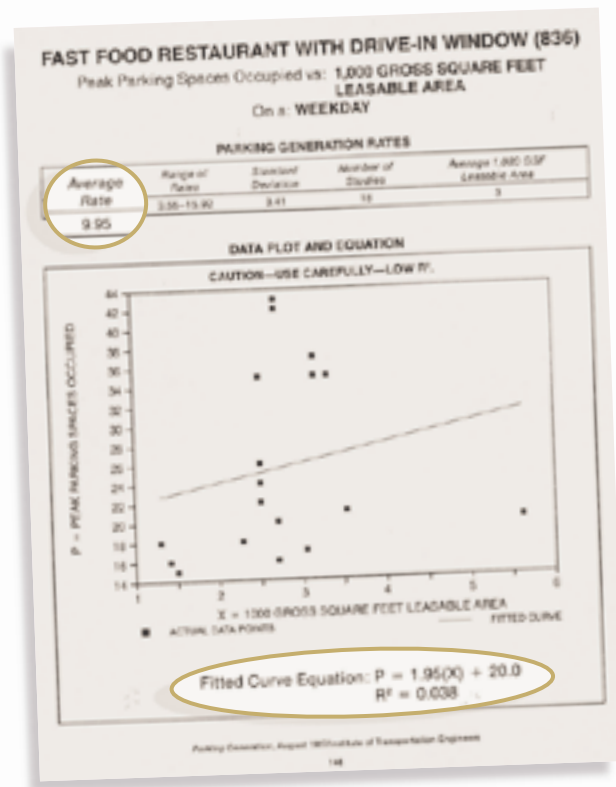


FIGURE 2

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 >

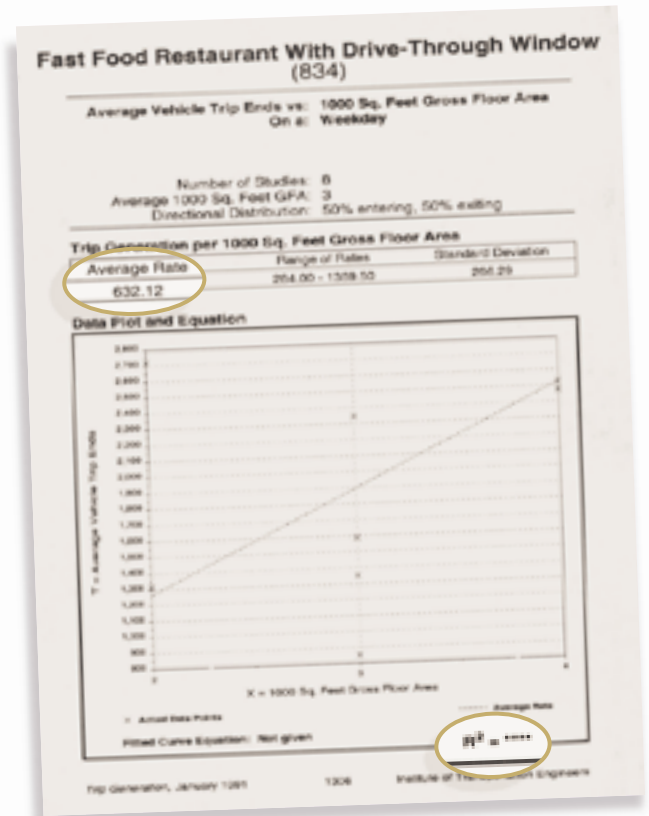


FIGURE 3

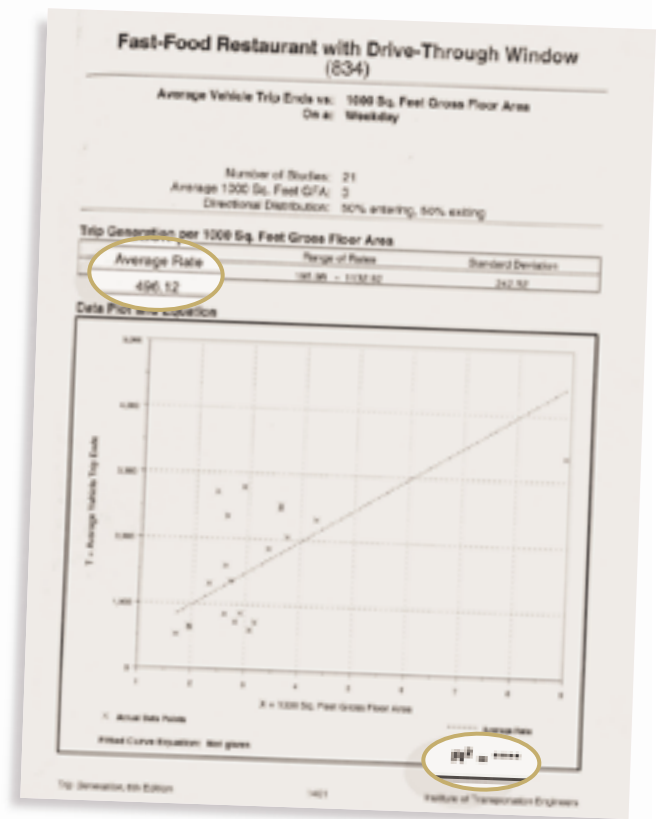


FIGURE 4

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. ♦

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Transforming the Freight Industry

*From Regulation to
Competition to
Decentralization in
the Information Age*

BY AMELIA REGAN

INTRODUCTION

Thirty-five years ago, the common-carrier freight industry was backward and inefficient—the result of strict federal regulation that suppressed competition and innovation. Regulators determined rates, routes, entry of new firms, and even the kinds of goods firms could carry. In one famous instance, a trucking firm was licensed to carry frozen hush-puppies, nothing more, between two given cities in Louisiana, and was not permitted to carry anything on its return journeys.

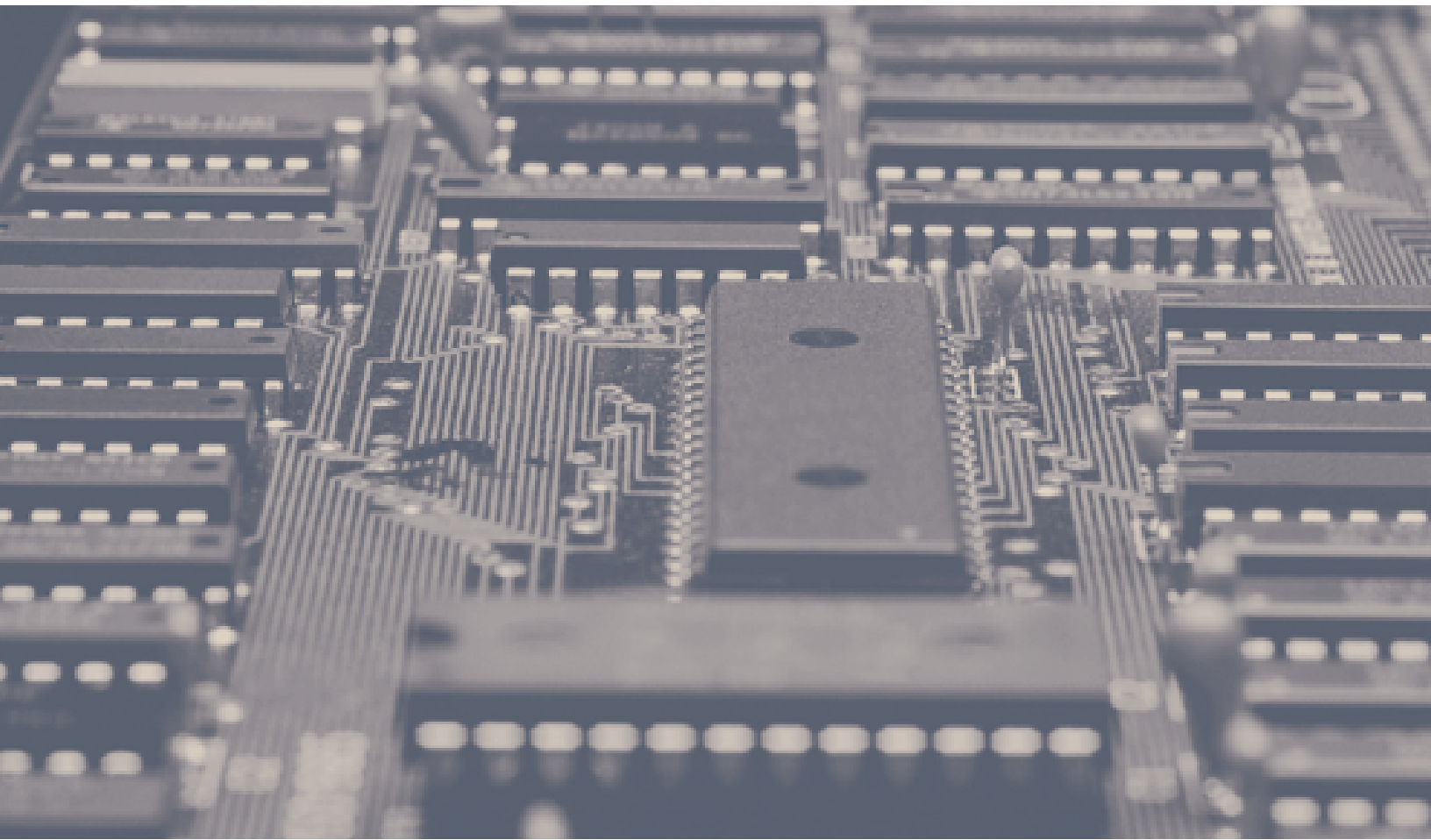
When the freight industry was deregulated, it was at last free to change and evolve. New firms formed, routes opened up, and competition lowered rates. Eventually, innovators began to change the very structure of the industry: new kinds of firms arose to act as intermediaries between shippers and carriers, performing a variety of services that increase efficiency. As manufacturers and retailers came to rely on just-in-time delivery, and shipments could more easily be coordinated between planes, ships, rail, and trucks, that efficiency became ever more crucial. Today, the revolution in information technology is spurring new innovations, and new “infomediary” firms are coming into being that can perform functions undreamed of three decades ago. ➤



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The revolution in information technology is spurring innovation, making possible services undreamed of three decades ago.





THE RISE OF THE INTERMEDIARY FIRMS

Deregulation of the freight industry in 1978 resulted in a far more complex world. Shippers now faced an enormous number of alternatives for booking and moving their cargo. Specialized knowledge became important, and a new type of business emerged: freight transportation intermediaries that provided a bridge between shippers and carriers, facilitating the flow of information and goods. These third-party logistics providers (or 3PLs, as they are commonly called) deal with multiple trucking, ocean, rail, and air-cargo providers to manage shipping and receiving for firms that now found their goods movements too complex to handle themselves.

Some 3PLs evolved from the pre-deregulation freight brokers that had acted as marketing agents and load matchers for smaller trucking companies. And some evolved from the pre-deregulation shipping agents who bought capacity from railroads and sold it to shippers. When they began, most 3PLs were affiliated with a parent transportation or warehousing company, but many are now integrating themselves more deeply into manufacturers' operations. Some provide product configuration and packaging—in effect shifting the final stages of production from the manufacturer to the warehousing and distribution portion of the supply chain.

THE EVOLUTION OF THE “INFOMEDIARIES”

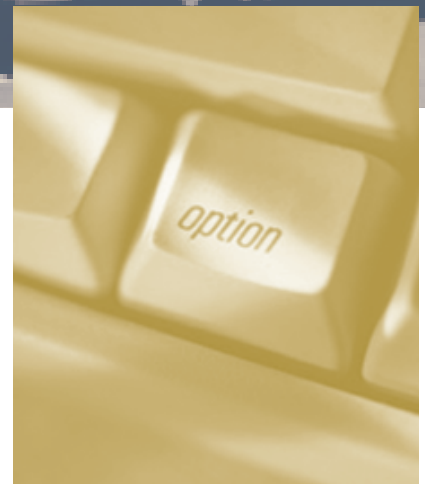
New types of intermediaries and new business models have emerged recently. Online logistics providers are attempting to use the power of the Internet and new software tools to interact efficiently and simply with shippers, carriers, and traditional 3PLs. Some firms provide online marketplaces, enabling the purchase and sale of transportation capacity. These range from simple load-posting bulletin boards to sophisticated online exchanges. Some firms develop software tools to optimize freight operations or to simplify complex shipping problems. Others supply information on container ports or other intermodal facilities, or organize and aggregate buying power for various companies.

These new intermediaries offer opportunities for third-party logistics providers to operate more effectively and provide better services, but they also threaten to supplant them by providing many of the services previously handled by traditional 3PLs.

During the last few years, infomediary firms experimented with many different business models. The first models used passive spot-market exchanges that allowed shippers and carriers to post available loads or capacity on a web-based bulletin board. While a few of these firms are still up and running, most went out of business quickly or were replaced by those offering more services such as tracking, automated payment, and freight matching.

Internet-based exchanges can leverage economies of scale and scope by managing freight for many smaller trucking firms and shippers. Their websites typically also offer discount rates for equipment and supplies, made possible by consolidating smaller purchases. Other exchanges allow load “pooling” among collaborative freight transportation communities, thus creating more efficient freight networks. The current leaders in that market claim to be reducing logistics costs for their clients by five to fifteen percent.

Another promising web-based service is pure information. Online “infomediaries” facilitate operations, such as at ports, provide real-time traffic information, or simply act as clearing houses for information and news. The Internet potentially can put up-to-the-minute information at the fingertips of anyone who needs it.



POTENTIAL BENEFITS

Potential benefits of online freight transportation intermediaries are enormous. For small carriers, access to spot markets could significantly improve profitability—so long as the cost of accessing these markets is reasonable. More than seventy percent of trucking companies operating in the US in 1998 had six or fewer trucks. Access to inexpensive tracking, reinforced by automated billing and payment systems, would allow small carriers to operate with little administrative overhead. Many small carriers are already acting as subcontractors to large carriers; moving these relationships online should make them more efficient.

Medium-sized carriers may also benefit from participating in exchanges that encourage collaboration between groups of shippers and carriers. If issues related to proprietary information and competition can be resolved, truckload carriers in particular would be better able to schedule loads for multiple shippers simultaneously. Less-than-truckload operations could benefit too, from increased access to compatible partial loads and better information about congestion at terminals. Large carriers will benefit most from participation in private exchanges that facilitate communication and allow them to subcontract suboptimal loads to spot markets.

Shippers may benefit from opportunities to transform significant portions of their small shipments to less costly full loads. Small and medium-sized shippers should enjoy significantly reduced search costs, and they may also benefit from creative >



contracting arrangements with web companies, and from new software developed to streamline transportation management, bidding, and contract management.

Finally, traditional 3PLs should benefit from access to technological improvements without having to make heavy investments. Large 3PLs that have already established relationships with many carriers should be able to leverage significant economies of scale. Once security issues have been resolved, customs-clearance services provided by online communities should simplify and automate cross-border movement of goods.

POTENTIAL DRAWBACKS

Online exchanges may encourage a trend to view goods movement as a commodity rather than a complex service. Such an approach could underestimate the human factor in successful freight transportation systems management. The industry, heavily dependent on personal contacts, already appears reluctant to accept change.

Carriers worry that the online business model will further curtail their already thin profit margins by forcing them to price more loads on the margin, rather than relying on long-term contracts in which profitable loads compensate for unprofitable ones.

Shippers will want to maintain long-term carrier relationships that have been nurtured and developed over many years. Indeed, reliable transportation service and

accountable partners, not just low prices, have probably been the guarantors of successful shipper operations.

In addition, traditional 3PLs risk losing business to Internet firms. They have benefited for years from possessing and guarding information that has been difficult to obtain. In today's information-rich Internet environment, they may be forced to transform themselves into something new.

Finally, carriers, shippers, and 3PLs are concerned about security—of proprietary information and online transactions—and reliability, particularly in supply chains that add yet another intermediary. Online companies are finding creative solutions to all of these concerns. Nonetheless, carriers and shippers have been slow to join the online exchanges. This has forced many of the early developers, some with seasoned professional management teams and \$50 to \$100 million in startup funds, into insolvency as soon as their startup funding ran out.

This creates one more serious concern. Everyone is mindful of the dot-com bust, and carriers, shippers, and 3PLs will be reluctant to sign on with companies that have a tenuous future. They will try to work with the clear market leaders, though so far these have been difficult to identify.

CONCLUSION

These new online freight transportation intermediaries and infomediaries are transforming the freight industry by enabling companies to “move beyond traditional business paradigms, profiting from the synergies of information.” Intuitively, an industry made up of many small firms, with many existing levels of intermediation, is an ideal potential beneficiary of the Internet. For example, better information about congestion, queues at intermodal facilities, and border crossings, and attractive purchasing agreements should increase equipment utilization and network efficiencies and thus reduce operating costs. However, the optimal application of the Internet is not yet clear. This uncertainty, combined with insufficient resources, has slowed adoption of new technologies, but there is no question that the radical transformations seen in the post-deregulation era will continue. ♦

FURTHER READING

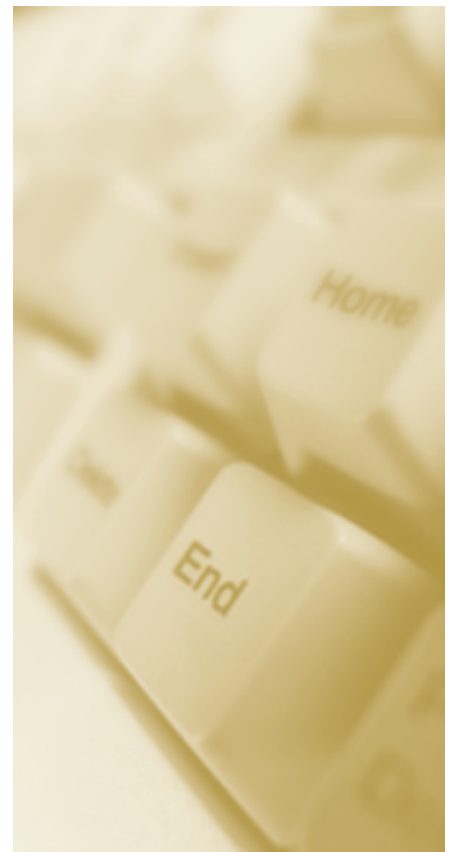
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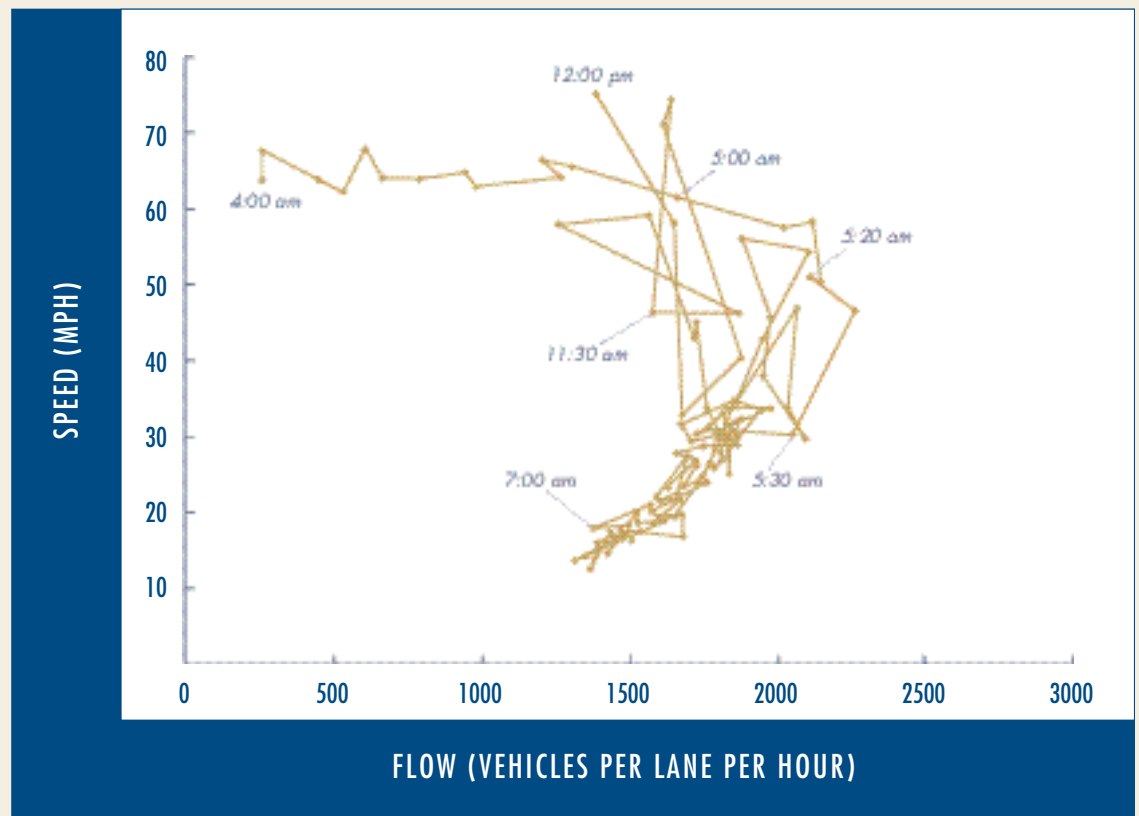
The Freeway-Congestion Paradox

BY CHAO CHEN AND PRAVIN VARAIYA

TRAFFIC CONGESTION on a freeway sets in once the density of vehicles exceeds a certain critical number. Above that, both vehicle speed and vehicle flow drop precipitously. Well-designed ramp meters can limit the number of vehicles entering a freeway, so that critical density is not reached, congestion is avoided and, paradoxically, both speed and flow increase. This double gain of reduced travel time and increased flow far exceeds any improvements that can be achieved by constructing more freeway lanes.

FIGURE 1

Congestion begins at 5:20 am. By 7:00 am, both speed and flow drop dramatically



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FIGURE 2

LA freeways, September 1, 2000.
Average speed detected in each
lane during 25-minute period
surrounding maximum flow.

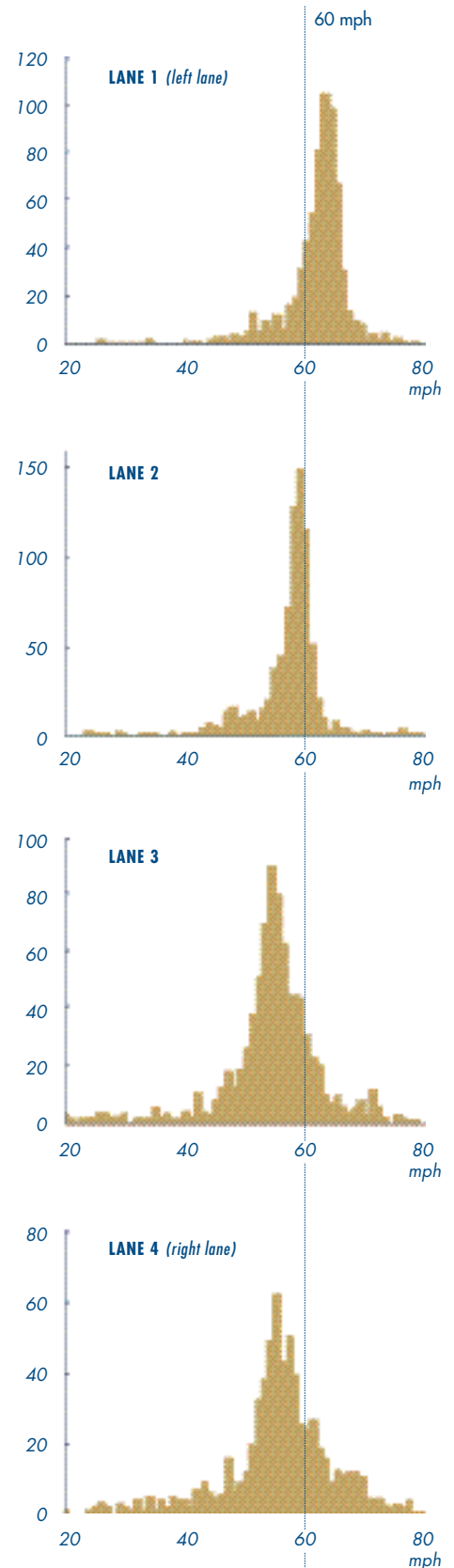
Figure 1 shows the cause and consequence of congestion. It plots speed vs. flow on the fast lane on one section of west-bound I-10 in Los Angeles from 4:00 a.m. to noon. Until 5:10 a.m. there is no congestion—a flow of 2,100 vehicles per hour (vph) moves at 58 mph. By 5:30 a.m., the density doubles, causing congestion, and speed drops to 30 mph. At 7:00 a.m., speed is a stop-and-go 15 mph, and the flow decreases to 1,300 vph. Only at 11:30 a.m. has demand and the resulting density decreased sufficiently to restore the free-flow speed of 60 mph. In the depth of congestion at 7:00 a.m., efficiency of this section is 15 percent, down from 100 percent at 5:00 a.m.

Figure 2 gives the macroscopic picture for all of Los Angeles. We examine data from all 3,363 functioning detectors at 1,324 freeway sections in LA for the 12-hour period beginning at midnight on September 1, 2000.

For each detector we find the 5-minute interval during which the detector records maximum flow. We then find the average speed at each detector during the 12.5 minutes before 12.5 after this maximum-flow interval. The figure plots the distribution of this “speed at maximum flow” for each lane. Clearly, maximum flow occurs at free-flow speeds ranging from 65 mph in lane 1 to 55 mph in lane 4. These data show that:

- The most efficient freeway operation occurs when traffic is moving freely at 60 mph and not at 35 to 45 mph as is commonly assumed.
- Ramp metering, which controls vehicle entry so that traffic moves freely, will reduce travel time and increase flow, permitting optimum efficiency of the freeway. ♦

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