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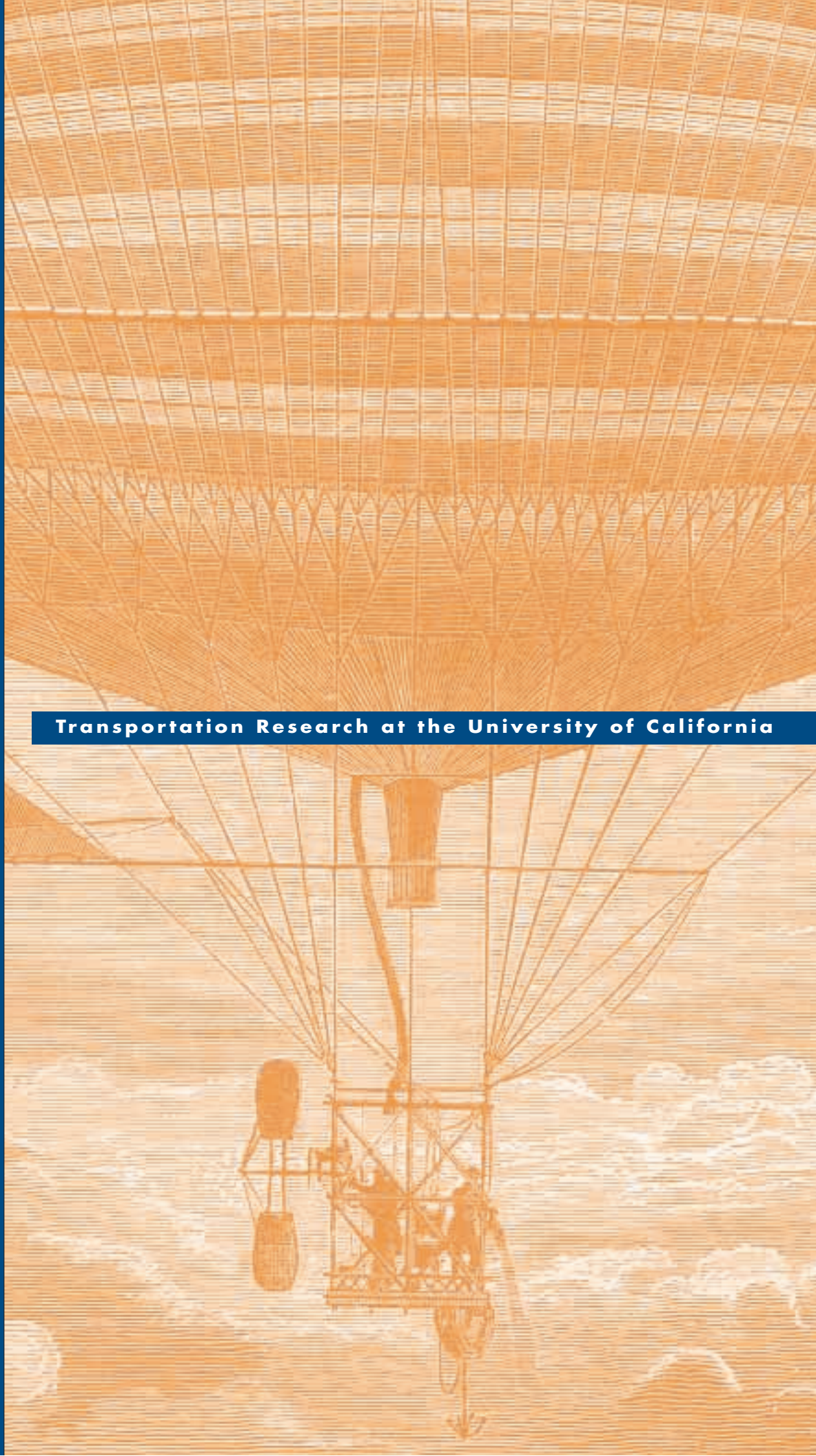
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# ACCESSES



FALL 2002  
NUMBER 21

Transportation Research at the University of California



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## No Lying Game

**D**ECEPTION, CRONYISM, and multimillion-dollar scams are synonymous with corporate America nowadays. But private executives aren't alone in cooking the books.

The same thing happens in the nuts-and-bolts world of public works construction. Last July, the *Journal of the American Planning Association* published a study by Bent Flyvbjerg, professor at Aalborg University in Denmark, on pervasive cost overruns in public works projects worldwide. In 258 projects completed between 1910 and 1998, Flyvbjerg found that actual costs exceeded estimated costs by an average of 28 percent. I've learned that culprits include New York's Holland Tunnel (52 percent), the Channel Tunnel (80 percent), and the Panama Canal (200 percent). Boston's unfinished \$14.6 billion Big Dig may break new ground, and not just literally: the underground highway project is already 500 percent over budget.

Flyvbjerg states that old-standby excuses—technical problems, inadequate data or models, or over-optimism—aren't plausible. After all, cost estimates haven't improved in eighty years. It seems no one is learning from past mistakes, so he concludes that underestimation is best explained by “strategic misrepresentation, that is, lying.”

But it seems something even more insidious is going on. Indeed, to assume everyone is overtly lying is to trivialize the subtle game that determines which public works projects get built. Players include politicians, engineers, city planners, labor union leaders, bankers, lawyers, developers, and the press. The implicit objective is the public interest, yet players are inherently self-serving.

The game has no name. But all successful players know the rules—and how to score. Within an exclusive club of elites, members absorb the culture's norms. They exchange friendship, information, and influence. In turn, they profit from hot tips and later from contracts and exchange of money—all very proper and legal. Building a

multimillion-dollar rail system or ballpark means lucrative contracts for engineering and construction firms. That's no surprise. But less obvious are the windfalls gained by other insiders, from investment bankers to commercial developers to landowners.

Clearly, players who intentionally falsify numbers are corrupt. But more pervasive are those who earnestly believe they are honest professionals as they tout low construction costs, high ridership, high revenues, and arrays of other benefits. It might seem odd that low-cost, high-revenue forecasts miraculously fit clients'—and forecasters'—silent wishes, time and time again. But their wishes may not be questioned or criticized. They'd be genuinely insulted by any inference of chicanery. Rather, their deep-seated conviction holds that the proposed highway or transit line or runway is the correct answer to the problem. Then they subconsciously come up with just the right cost-revenue estimates. Like patriotism, their conviction—and their forecasts—require no further justification and allow no serious doubt. Once politicians, interest groups, and the media accept forecasted costs and benefits as if they were hard facts, projects follow by sheer momentum.

Meanwhile, the general public—the nonplayers—are often mere bystanders. While many public works projects require taxpayer approval for bond financing, the millions or billions involved are mind-boggling. A billion dollars (imagine a stack of \$1,000 bills as high as the Washington Monument) is beyond most citizens' comprehension. Most Americans seem to vote for new public works with their gut. Will the train look speedy? Will it be painted silver or gold? Will it symbolize the future?

Of course urban infrastructure is valuable to all. Of course many do opt to build rather than not to build. But it should be evident that the main beneficiaries include those who promote such projects in the public interest—and find they just happen to serve their private interest as well.

*Luci Yamamoto*  
Former Access Editor

# Are SUVs Really Safer Than Cars?

BY TOM WENZEL AND MARC ROSS

**L**AST SPRING'S Senate hearings on Corporate Average Fuel Economy standards made much about the increased risk Americans would face if forced to give up their SUVs for vehicles that weigh less. To find out whether that risk is real, and whether SUVs really are safer than cars, as some have alleged, we analyzed highway fatality data. Our findings came as a surprise.

We focused on “driver death rates,” a concept of risk developed by the Insurance Institute for Highway Safety. However, our analysis differs from the Institute’s in two important ways. First, we examine risk not only to drivers of vehicles of a particular type, but also to drivers of vehicles that crash with that vehicle type. Second, we limit our study to recent models having sold enough vehicles to permit statistical analysis. By studying risks associated with vehicle models built between 1995 and 1999, we focus on vehicles with up-to-date safety designs and constraint technologies. Seat belts and airbags are improved and more widely used; vehicle design is more sophisticated; and the standardized head-on crash test and regulations have hastened design improvements. Manufacturers continue to make additional improvements to vehicles.



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## TWO TYPES OF RISK

We consider nine categories of cars and light trucks, classed according to size and weight. Figure 1 shows two types of risk. First is the risk to drivers of each vehicle type, shown on the horizontal axis (we're calling these primary drivers); and second is the risk to drivers of other vehicles that crash with that type (the vertical axis). We define "risk" as *driver deaths per year per million vehicles sold*. Both estimates of risk are calculated for vehicles from model years 1995 to 1999 and from the number of deaths in those years. The other vehicle may be of any model year or type (including motorcycles and heavy-duty trucks and buses); we have not broken down the other vehicle numbers according to type or model. The risk to primary drivers includes driver fatalities from all types of collisions, whether with another vehicle, a fixed object, a pedestrian, or a cyclist, as well as noncollisions such as rollovers. To avoid biases associated with varying numbers of passengers per vehicle, we consider driver deaths only.

The small circles in Figure 1 show the two weighted average risks for popular models of each vehicle type. For example, for the average midsize car, the risk to drivers is 72 deaths per year per million cars, while the risk to drivers of vehicles they collide

with is 34 deaths per million cars. The shapes around each circle represent the ranges in each risk for individual models: The horizontal axis shows that the risk to drivers of, for example, midsize cars ranges from 47 deaths per year per million cars for the lowest risk model (Camry) to 97 for the highest risk model (Lumina). The vertical axis shows that the risk to drivers that collide with midsize cars ranges from 24 (Camry) to 47 (Lumina) deaths per million midsize cars.

We define the "combined risk" of each vehicle type and model as the sum of the "risk to primary drivers" plus the "risk to drivers of other vehicles." Diagonal lines in Figure 1 illustrate combined risks of 100, which roughly corresponds to that of the average large car, and 130, which roughly corresponds to that of the average SUV. These lines are diagonal because they combine the risk to driver (x-axis) and risk to driver of the other vehicle (y-axis).

Figure 2 shows the two risks for individual vehicle models (the most popular ones). The risk to drivers of the most popular subcompact cars varies by more than a factor of two for individual models, e.g. from 60 for Jetta to 148 for Escort. Similarly, the risk to drivers of other vehicles for the most popular pickups ranges by about two times among individual models, from 65 for Chevy S-10 to 136 for Ram. ➤

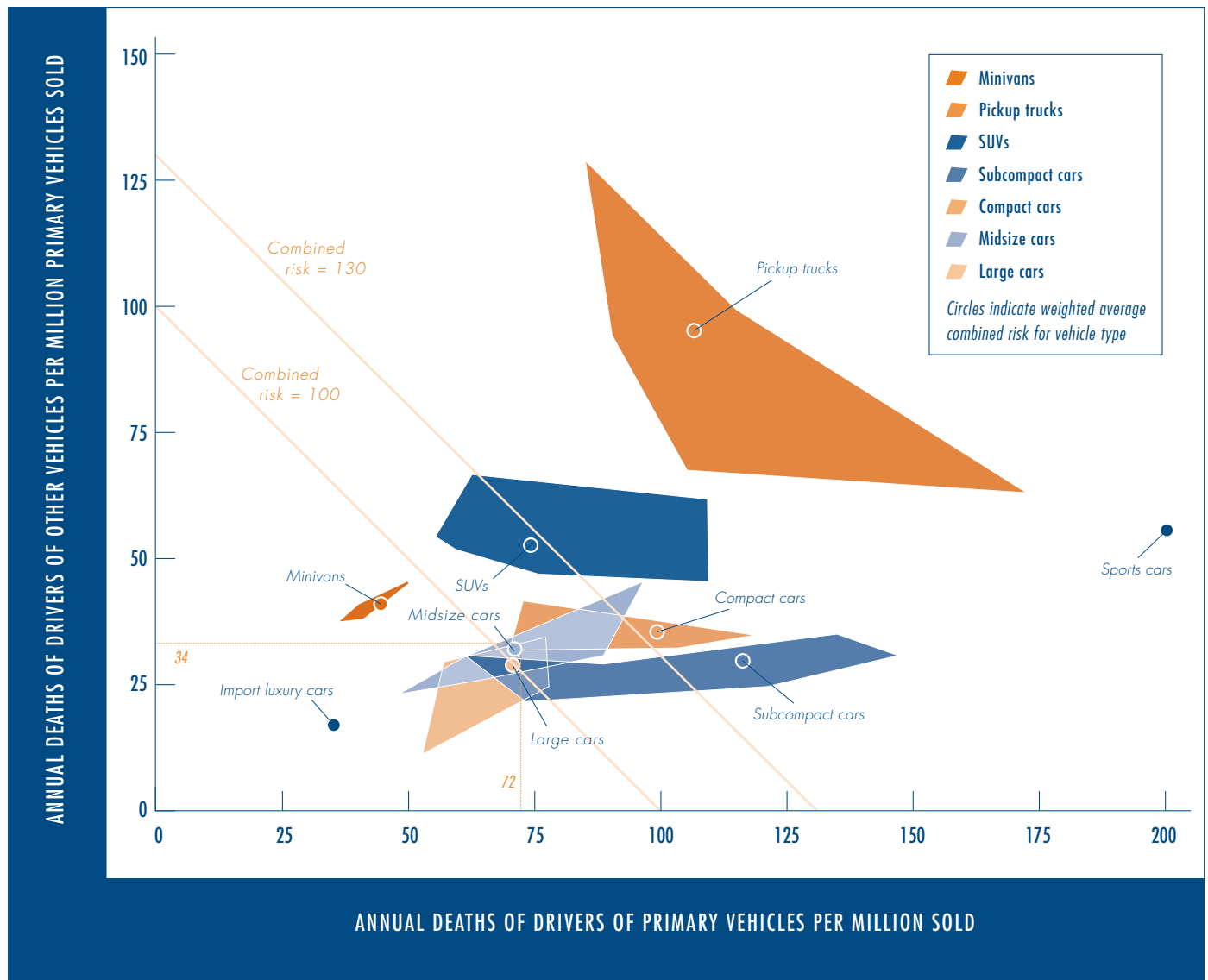


FIGURE 1

Differences in the averages by type that are less than ten percent are not statistically significant.

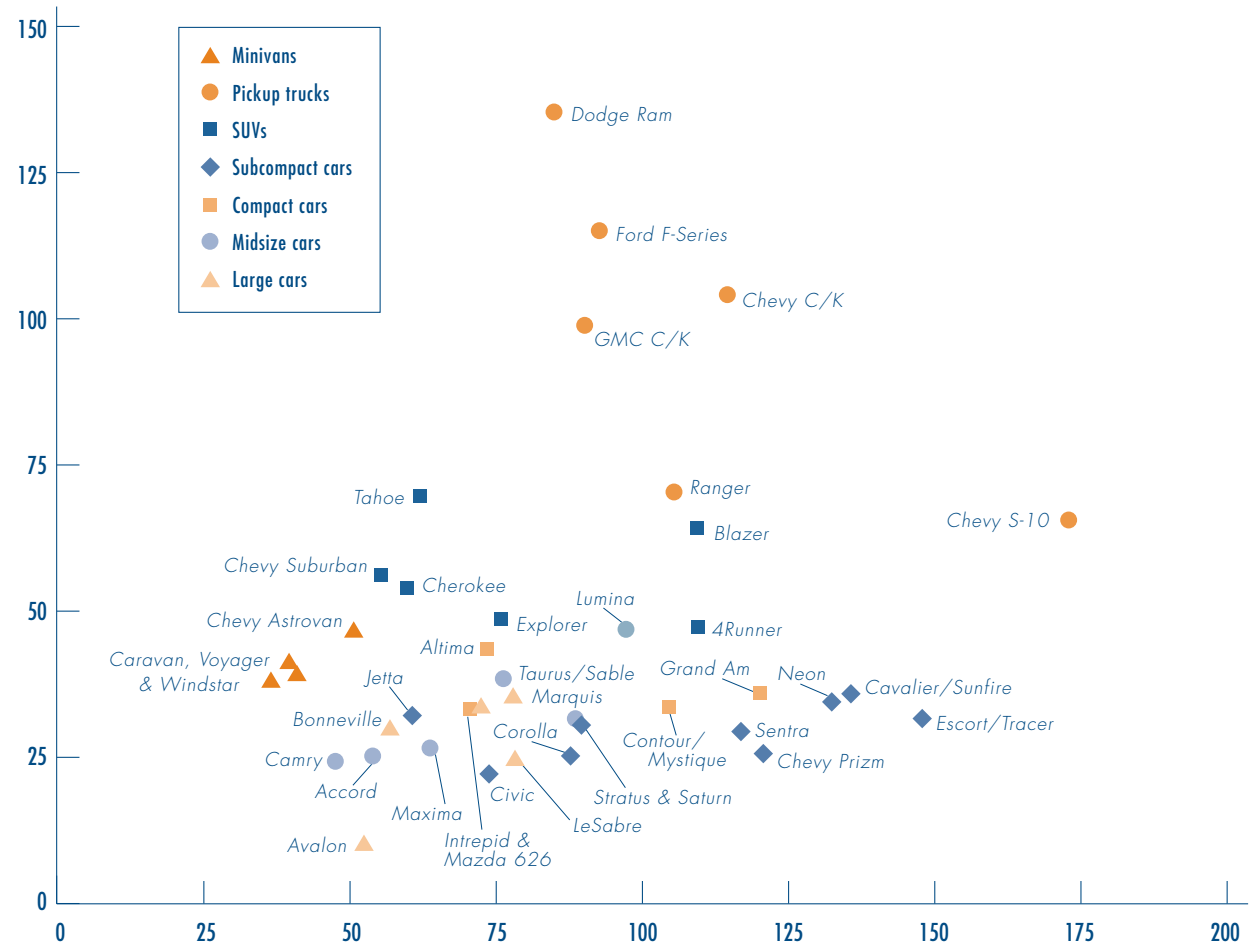
Figures 1 and 2 suggest some important relations between risk and vehicle type. Keep in mind that characteristics of the drivers of certain vehicle types and models and of the environments in which the vehicles are driven may strongly affect their risk. We emphasize that the risks estimated here are not necessarily inherent in the vehicle designs, but include how and where the vehicles have been driven.

*Midsize and Large Cars and SUVs.* The risk to drivers of average midsize and large cars is about the same as for the average SUV. The risks differ in their makeup, with a higher fraction of fatalities in SUVs from rollovers. Similarly, the risk to drivers of the safest midsize and large car models (Avalon, Camry, and Accord) is about the same as for the safest SUVs (Suburban,

Cherokee, and Tahoe). However, the average SUV poses nearly twice the risk to drivers of other vehicles as do the average midsize and large cars. The net result is that the combined risk of the average SUV (129) is about 25 to 30 percent higher than that of the average midsize (105) or large car (100).

*Subcompact and Compact Cars and SUVs.* The combined risk of the average subcompact (141) or compact (136) is only slightly higher than that for the average SUV (129). However, the combined risk of the safest subcompact and compact models (VW Jetta and Honda Civic) is less than that of SUVs.

The risk to drivers of the safest subcompact and compact models (Jetta, Civic, Saturn, and Corolla; Mazda 626 and Altima) is about the same as that of the average SUV (74). A critical



ANNUAL DEATHS OF DRIVERS OF PRIMARY VEHICLES PER MILLION SOLD FROM 1995 TO 1999 FOR MOST MODELS

FIGURE 2

Differences in the models that are less than twenty percent are not statistically significant.

aspect of the dispute regarding the relative danger to occupants of light or small cars is the very wide range in the risk to drivers of subcompacts. At one end are the low-risk Jetta and Civic models, but at roughly twice their risk are the Cavalier, Escort, and Neon models. The latter three inexpensive domestic models are responsible for greatly raising the average risk to drivers of subcompact cars. Does the safety record of those three models prove that light cars in general are unsafe? We have presented evidence that there is no such simple rule. Might it instead suggest that relatively inexpensive cars tend to be unsafe? The recent National Academy majority report on fuel economy argues that the low weight of cars with high fuel economy has resulted in many excess deaths. That inference is unfounded.

Figure 1 shows that the risk associated with lightweight cars has a very wide range. In other words, weight does not determine the risk. New vehicle designs that pay close attention to safety considerations have helped make many cars in the subcompact-to-midsize range as safe as large cars and SUVs.

**Minivans.** Of all major vehicle types, minivans have the lowest primary risk and the lowest combined risk (excluding luxury imports). This happy outcome may reflect their drivers' special care, for they are often used to transport children. But it also reflects minivan design, for most are built on car platforms, rather than on pickup-truck chassis. That basic design feature probably reduces the risk to their drivers, and certainly reduces the risk to other drivers. For example, the car-like body of ➤





the Grand Cherokee, an SUV, presents about twenty percent lower risk to its drivers than does the truck-based Cherokee (a suggestive result, although not statistically significant).

*Pickup Trucks.* Pickup trucks are riskier than any other type of vehicle, excluding sports cars. Their average combined risk is more than twice that for large or midsize cars. Light trucks, especially pickups and to a lesser extent SUVs, are responsible for the deaths of many people in other vehicles, as shown by the vertical axis in Figure 1. This result mirrors earlier findings by Hans Joksch, who examined the outcomes of two-vehicle crashes as reported to the police. He found that there are twice as many driver deaths in pickup-car crashes as in car-car crashes and 1.8 as many deaths in SUV-car crashes as in car-car crashes. To a substantial degree, the risks that light trucks impose on other drivers are associated with their basic design. The chassis of pickups and most SUVs are more rigid than those of cars, and the bumpers are higher. Moreover, these deaths to others occur largely in urban and suburban settings, where pickups are rarely used to carry cargo.

The *risk to drivers* of pickups is a distinct issue. That risk is not significantly different from that of average compact and subcompact cars. The pickup risk is partly due to trucks driven in rural areas, where conditions are relatively less safe owing to high speeds on poorly designed and policed roads, as well as the tendency of some of these vehicles to roll over.

*Import Luxury and Sports Cars.* Import luxury cars have the lowest combined risk, while sports cars have the highest combined risk of all vehicle types we studied. It is likely that much of the high risk of sports cars is associated with aggressive driving.

#### EFFECT OF DRIVER AND ENVIRONMENT ON RISK

It is extremely difficult to determine the inherent safety of a vehicle type or model, because driver characteristics and behavior (speed, use of seat belts, aggressive lane-changing, etc.) and environmental factors (such as road conditions) cannot be adequately accounted for. Some car models, such as most sports cars, attract relatively aggressive drivers, and their aggression increases fatalities associated with those models,

independent of their design. The Chevy Corvette illustrates that both vehicle design and driver variables are important. Like drivers of other sports cars, Corvette drivers face a higher risk (275) than drivers of other types of cars (way off scale to the right of Figure 2). But, although Corvettes are driven dangerously, the risk to drivers of vehicles that collide with Corvettes (25) is lower than that of the average midsize car (34, in Figure 1). The low-slung design and plastic body of the Corvette probably account for its low risk to other drivers.

To explore some of the effects of driver behavior, we also looked at driver age and gender in fatal crashes. We found no evidence that either factor accounts for the differences in risk discussed here. In the future, we plan to explore the effects of other driver characteristics and environmental variables in an attempt to refine our analysis.

### CONCLUSIONS

Opponents of strengthened fuel-economy standards claim higher standards will result in more traffic fatalities. If the new fleet were to be like the recent average light vehicle, traffic deaths probably would increase, as shown by the increase in risks to drivers as one goes from the average midsize and large cars to the average compact and subcompact cars, as shown in Figure 1. That simple conclusion mirrors the statistical analyses emphasized in the National Academy fuel-economy study. But that simple conclusion is probably wrong.

Many existing small-car models, built primarily by foreign manufacturers, are as safe as their larger and heavier (and less efficient) counterparts, as shown in Figure 2. There is reason to expect that manufacturers can further improve the safety of vehicles by making them lighter without making them smaller, given such technological advances as smaller high-tech engines and transmissions, unibody or space-frame structures replacing the body-on-frame of most SUVs and pickup trucks, and increased use of lightweight materials. While it is reasonable to expect that increased fuel economy standards would make for lighter vehicles, we have shown that reduced vehicle weight does not imply reduced safety. ♦

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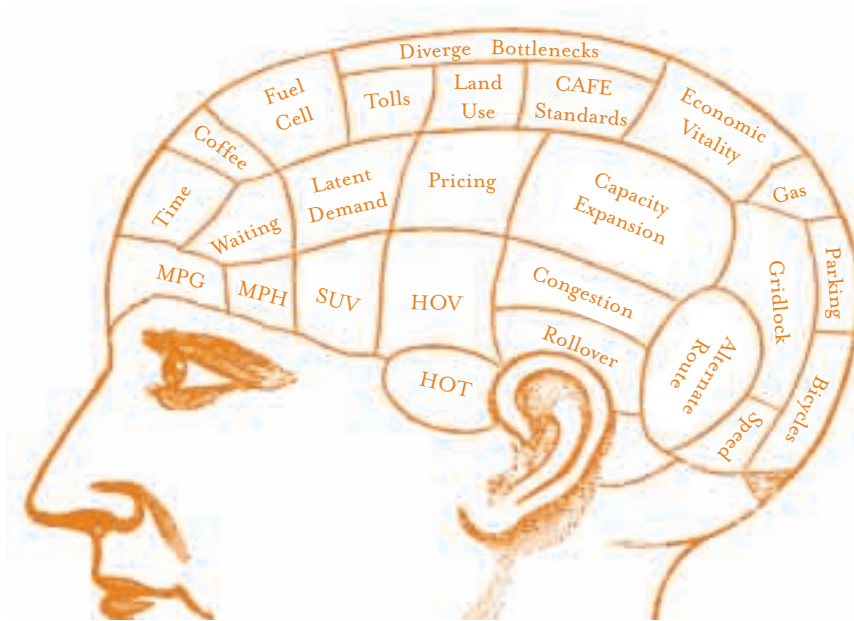
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# Rethinking Traffic Congestion

BY BRIAN D. TAYLOR

Traffic congestion and cities, it seems, go hand in hand. Everyone complains about being stuck in traffic; but, like the weather, no one seems to do anything about it. In particular, traffic engineers, transportation planners, and public officials responsible for metropolitan transportation systems are frequently criticized for failing to make a dent in congestion.

But is traffic congestion a sign of failure? Long queues at restaurants or theater box offices are seen as signs of success. Should transportation systems be viewed any differently? I think we should recognize that traffic congestion is an inevitable by-product of vibrant, successful cities, and view the “congestion problem” in a different light.

Conventional wisdom holds that traffic congestion exacts a terrible social and economic toll on society; expanding transportation capacity only makes things worse; and redesigning cities and expanding alternative transportation modes offer the best long-term means for reducing traffic congestion. I want to offer ten propositions that challenge these ideas and suggest how we might begin to think differently about traffic congestion. >

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**PROPOSITION ONE: Traffic congestion is evidence of social and economic vitality; empty streets and roads are signs of failure.**

We frequently read staggering estimates of the costs traffic congestion imposes on society. The Texas Transportation Institute, for example, placed the cost of metropolitan traffic congestion in 75 of the over 300 US metropolitan areas at \$68 billion in the year 2000. Given such estimates, we can't help but conclude that the economic health of metropolitan areas is threatened by congestion. While nobody likes being stuck in traffic, I think we overestimate its costs.

Cities exist because they promote social interactions and economic transactions. Traffic congestion occurs where lots of people pursue these ends simultaneously in limited spaces. Culturally and economically vibrant cities have the worst congestion problems, while declining and depressed cities don't have much traffic. By some estimates, New York and Los Angeles are America's most congested cities. But if you want access to major brokerage houses or live theater, you will find them easier to reach in congested New York than in any other metropolitan area. And if your firm needs access to post-production film editors or satellite-guidance engineers, you will reach them more quickly via the crowded freeways of LA than via less crowded roads elsewhere.

Despite congestion, a larger number and wider variety of social interactions and economic transactions can be consummated in large, crowded cities than elsewhere. Seen in this light, congestion is an unfortunate consequence of prosperity and a drag on otherwise high levels of accessibility, not a *cause* of economic decline and urban decay. So while we can view congestion as imposing costs on metropolitan areas, the costs of inaccessibility in uncongested places are almost certainly greater.

The terrible economic and environmental tolls that congestion exacts in places like Bangkok, Jakarta, and Lagos are undeniable. But mobility is far higher and congestion levels are far lower here in the US, even in our most crowded cities. That's why, for now, we don't see people and capital streaming out of San Francisco and Chicago, heading for cities like Alturas, California, and Peoria, Illinois.

**PROPOSITION TWO: Our current focus on transportation networks is misplaced and ignores the effects of congestion on individuals and firms.**

Freeways form the backbone of nearly every metropolitan transportation network in the US. While they comprise only a small fraction of metropolitan street and highway mileage, freeways carry more than a third of all vehicular travel. When people speak of congestion in cities, they typically mean freeway congestion, and most studies of metropolitan congestion focus mostly, if not exclusively, on freeway delay. But freeway delay may not be a meaningful way to measure how congestion affects people.

Consider the following example. A commuter walks from her front door to her car, parked in her driveway. She drives a quarter mile on local streets to a larger collector

street, and then a half mile to a large arterial street. She then travels on the arterial for a couple miles to a freeway on-ramp. Once on the freeway, she drives in congested conditions for six miles, exits onto another arterial, and drives another mile and a half before entering a parking structure at her worksite. She makes three loops up to the third level of the structure, where she parks. Then she walks fifty yards, waits for an elevator which takes her to the first floor, enters another building, and waits for another elevator to take her to her fifth-floor office.

In this example, the drive on the congested freeway accounts for well over half the travel distance, but much less than half the travel time. So even a dramatic fifty percent increase in travel speed on the congested freeway link of this trip would reduce the time of this sample commute by only five minutes—less than fifteen percent.

Travel behavior research has consistently found that transfer and waiting times—such as walking from the car to the office, or waiting for a bus or an elevator—comprise a large share of total trip times *and* are viewed by travelers as far more onerous than in-vehicle travel time. Most travelers would much rather reduce transfer and waiting times by five minutes than in-vehicle travel on a congested roadway by five minutes.

So we cannot estimate congestion costs by simply measuring network delay. We must instead examine congestion’s influence on the choices firms and households make about location and travel. If delay on a congested freeway comprises only a small portion of someone’s commute, that person’s congestion costs are low even if congestion on the freeway network is high. And if a firm chooses to locate in a congested area that offers easy access to suppliers or customers, it is a mistake to consider congestion costs without balancing them against access benefits. >

A sample drive-alone commute trip

TRIP SEGMENT	DISTANCE	TIME	SPEED	DISTANCE SHARE	TIME SHARE
Walk to car	0.01 miles	0.2 min	3 mph	0.1 %	0.6 %
Drive to collector	0.25 miles	1.3 min	12 mph	2.4 %	3.5 %
Drive to arterial	0.50 miles	1.9 min	16 mph	4.7 %	5.2 %
Drive to freeway	2.00 miles	6.0 min	20 mph	18.9 %	16.6 %
Drive on congested freeway	6.00 miles	14.4 min	25 mph	56.6 %	39.9 %
Drive on arterial	1.50 miles	4.5 min	20 mph	14.1 %	12.5 %
Drive in parking structure	0.25 miles	1.9 min	8 mph	2.4 %	5.2 %
Walk to office	0.10 miles	6.0 min	1 mph	0.9 %	16.6 %
Total/Average	10.61 miles	36.1 min	18 mph	100.0 %	100.0 %

**PROPOSITION THREE:** Automobiles are central to metropolitan life, and efforts to manage congestion must accept this fact.

The so-called American love affair with automobiles is not an irrational addiction, as some assert. Instead it is a rational response both to the utility of private vehicles and to public policies supporting their use. Widespread auto use unquestionably imposes significant costs on society, but it also brings enormous private benefit. It's so easy to see the many costs of auto use—like chronic traffic congestion—that we can forget how fast and flexible automobiles benefit travelers.

Most research confirms that motorists do not pay the full costs they impose on society. While there is much debate over how much automobile travel is underpriced, there is general agreement that proper pricing of automobile use would both reduce congestion and increase the attractiveness of other modes such as public transit, bicycling, and walking.

But even if so-called marginal cost pricing of automobile use were implemented, private vehicles would not soon forfeit their dominant role. Most (though not all) experts agree that automobiles will remain central to urban life for the foreseeable future, and even the most ambitious efforts to increase the attractiveness of public transit, bicycling, and walking are unlikely to change this fact. Even in European cities where policies and planning explicitly favor alternative modes over automobiles, private vehicle use is increasing. Most transportation researchers also agree that some form of pricing would be the best way to reduce metropolitan traffic congestion. But many public officials see toll roads and parking charges as politically risky and unpopular, and insist that traffic congestion be mitigated by other, less effective means. The traveling public's frosty reception of such serious proposals to reduce congestion suggests to me that people see it as less of a problem than they let on.



**PROPOSITION FOUR:** Short-lived congestion relief through capacity expansion is not proof that adding capacity is a bad idea.

When capacity is expanded on heavily used roads, reduced delay can prove fleeting. This leads some observers to conclude that widening roads is a waste of time and money. Others go further, claiming that it makes things worse, since more people are delayed and more emissions are produced after the expanded facility fills up again with traffic. Some have likened it to buying a bigger belt to address the problem of weight gain.

But this analogy is misleading because it treats travel as simply a bad habit, and ignores the role of mobility in facilitating social interactions and economic transactions. While capacity expansion in areas of dense activity may fail to eliminate congestion, it may still bring significant social and economic benefit by accommodating more activity.

**PROPOSITION FIVE:** The effects of latent/induced demand are not confined to capacity expansion.

Given that latent/induced demand may help to reconstitute roadways following capacity expansion, some argue that we should instead emphasize operational improvements (such as coordinated signal timing and ramp metering) and transit-capacity expansions (like added rail transit and express bus service). Such improvements may be wise investments, but they are no less vulnerable to the reconstituting effects of latent/induced demand than road widenings.

When capacity is expanded on a congested facility, delay is reduced in the short term, and traffic speeds increase. Increased speeds reduce the time costs of trips, making travel more attractive. Travelers who were previously dissuaded by congestion from making car trips begin to do so, and the facility gradually becomes congested again. This, in a nutshell, is the latent-demand effect.

But the effects of latent/induced demand are not limited to road widenings. If a new ramp-metering program smoothes traffic flow and reduces delay in the short-term, it has the same effect as increased capacity on the time-cost of travel; so does a new rail line that lures a substantial number of travelers off a parallel roadway. This is why congestion on the San Francisco-Oakland Bay Bridge was only temporarily reduced when BART opened in the 1970s. Absent some corresponding increase in the monetary price of a trip, *any* change that reduces delay and travel times is subject to these effects.

To get around this conundrum, some argue that we need to focus, not on transportation systems, but on the land uses that generate and attract trips. Specifically, they call for mixing land uses and increasing development densities into more compact, transit-oriented development. But compact development is unlikely to reduce congestion, as the remaining propositions testify. ➤





**PROPOSITION SIX:** Changing land use patterns in an attempt to change travel behavior is a very long-term endeavor.

**M**etropolitan land use patterns change very slowly, slower than changes in employment, trade, demographics, and especially technology. Even in rapidly growing areas, new urban developments and new land uses comprise only a fraction of the overall urban fabric. Thus, even dramatic changes to new development patterns would have to be maintained for decades before they could significantly reshape metropolitan land uses and, in turn, overall travel origins and destinations.



**PROPOSITION SEVEN:** Compact development is correlated with more walking and transit use, but the nature of this relationship is not completely understood.

**T**he extensive research on land use/transportation relationships is fraught with methodological problems that scholars are only now beginning to untangle. We know that older, central cities host far more walking and transit use than do newer cities, but what is it about older, central cities that causes this? Higher population and employment densities? Proportionally lower levels of street and road capacity? Limited and expensive parking? Frequent transit service operating in dense networks? Commercial destinations located within walking distances of households? Higher proportions of lower-income households with less access to automobiles? Higher proportions of immigrants, elderly residents, and young, single residents who are more willing to walk and use transit?

Almost certainly, all these factors (and more) synergistically combine to increase walking and transit trips. But we still don't know for certain which of these factors is most important in influencing mode choice. And it remains unclear whether exporting a design-oriented subset of these factors—such as higher population densities and mixed land uses—to new developments in outlying areas will have much influence on travel behavior at all.

**PROPOSITION EIGHT:** The best way to get more people to walk and ride transit is by making driving slow, uncertain, and expensive.

Some argue that compact development increases the attractiveness of alternative modes like walking, biking, and transit riding. This is probably true. But the research in this area suggests to me that older, densely developed areas encourage walking and transit use more by decreasing the utility of driving—through scarce and expensive parking and slow speeds on congested streets—than by increasing the utility of other modes. But most proposals for compact development in outlying areas emphasize design treatments to increase the ease of walking and transit use far more than they seek to increase the cost, time, or uncertainty of auto use.

**PROPOSITION NINE:** Compact development—whether in older, central city areas, or in newer, outlying areas—increases congestion.

The most densely developed cities tend to be most congested. Traffic congestion decreases the attractiveness of automobile travel, thereby increasing the relative attractiveness of some other modes (though travelers may not be better off as a result). So although land use planning may raise densities and possibly lead to increased walking and transit use and to decreased car travel, it does so in part by increasing congestion.

Here's an example from the San Francisco Bay Area: In Healdsburg, at the northerly reaches of Sonoma County, population density is low at five people per acre, and vehicle travel is high at thirty miles per person per day. In Berkeley, population density is six times higher at thirty people per acre, while vehicle travel is two-thirds lower at ten miles per person per day. And in downtown San Francisco, population density is fifty times higher than in Healdsburg, at 250 people per acre, while vehicle travel is 7.5 times lower at just four miles per person per day. Does this mean that congestion levels are 7.5 times higher in Healdsburg than in San Francisco? Of course not.

If we compare the *density* of vehicle travel in Healdsburg and San Francisco, we can see why. In Healdsburg, residents generate 150 daily vehicle miles of travel per residential acre. In Berkeley, residents generate 300 daily vehicle miles of travel per residential acre. But in San Francisco, residents generate 1,000 daily vehicle miles of travel per residential acre. Put simply, vehicle travel decreases more slowly than population density increases, and congestion is the result. ➤

#### Population density versus travel density

LOCATION	POPULATION DENSITY (people per acre)	PERSON TRAVEL (vehicle travel per person per day)	TRAVEL DENSITY (vehicle travel per acre per day)
Healdsburg	5 people/acre	30 miles/person	150 miles/acre
Berkeley	30 people/acre	10 miles/person	300 miles/acre
Downtown San Francisco	250 people/acre	4 miles/person	1,000 miles/acre



**PROPOSITION TEN:** Absent some form of congestion/parking pricing, development patterns congruent with private vehicle use offer the best chance for land use planning to reduce congestion.

Automobiles offer both temporal and point-to-point flexibility that travelers clearly find attractive. The problem arises, of course, when too many automobiles are headed in the same direction at the same time.

Land uses, like large commercial centers, and transportation facilities, like high-capacity freeways, concentrate traffic. Low-density, dispersed land uses, on the other hand, spread traffic widely; they facilitate increased per capita vehicle use, but also decrease the overall density of vehicle travel and, hence, reduce congestion. One might term such development “Smart Sprawl.”

What most people describe as urban sprawl is indeed low-density development. But it is characterized by concentrated commercial and employment centers near freeways that congregate traffic into congested corridors. With respect to congestion, this sort of “Dumb Sprawl” is perhaps the worst of all possible worlds.

I am not necessarily advocating “Smart Sprawl.” Propositions Six and Seven state that planning land uses to influence travel behavior is an uncertain and very long-term proposition. Short-term traffic management objectives should influence, but not drive, the design of new cities and suburbs. The application of new technologies and adroit capacity expansions may present the best opportunities for managing congestion in the short-term, and some forms of road and parking pricing probably offer the best opportunities for reducing congestion over the longer term.

With respect to land use, we may choose to promulgate smart-growth policies to achieve a wide variety of otherwise worthy goals. But, for the reasons I have outlined here, we need to be clear that congestion reduction simply cannot be one of those goals. ♦

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# On the Back of the Bus

BY THEODORE E. COHN

**Y**OU'LL NO DOUBT be surprised to read that transit buses get rear-ended more often than passenger cars do. You're surprised, I suspect, because buses are so large and obvious. Who could fail to see that bulky bus? Who could fail to know it moves slowly and stops often?

These collisions are a tremendous waste of resources. Crashes injure both bus patrons and passengers in other vehicles, damage expensive equipment, cause delays and service disruptions, worsen traffic congestion, lessen acceptance of transit as a travel choice, and they're expensive. A 1997 estimate found that each crash cost \$54,000. Plus, we find, these crashes are largely preventable. >

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## INVISIBLE BUSES

There are presently about 45,000 transit buses operating in this country. Each suffers a crash of some sort about once per year. Veridian, a consulting firm working on a wide-ranging study with the Ann Arbor Transit Authority, reviewed over 300,000 bus crashes during the five years ending in 1998. That review uncovered glaring indications that those bulky vehicles must have been largely invisible to oncoming drivers when they ran into the buses' rear ends. Here's what they found:



**Rear-end collisions are the most common bus crashes (37 percent)**

**The second most common occur when a vehicle turns into the bus's path (22 percent)**

**Two-thirds occur on straight roads when buses are stopped (66 percent)**

**An additional fourth occur when buses are moving or slowing (25 percent)**

**More occur in urban settings than elsewhere (81 percent)**

**Over half occur on undivided roads (54 percent), nearly half on two-lane roads (42 percent)**

**A rather large majority occur between (not at or in) intersections (62 percent)**

**Over half occur on level roads (60 percent); most on straight roads (89 percent)**

**Over half occur where the speed limit is 30 mph or higher (71 percent)**

**Most striking vehicles were going straight, neither turning nor changing lanes (82 percent)**

**Most of those vehicles exhibited no mechanical defect (e.g., brake failure) (92 percent)**

**Most rear-end collisions occur during daylight hours (86 percent)**

**Three-fourths occur under benign weather conditions (neither fog, rain, snow, nor dust) (77 percent)**

**Bus drivers took no corrective action in most cases (86 percent)**

These facts—especially that the bus was usually stopped—strongly suggest it's the oncoming drivers who need help, not the bus drivers. We recently joined the Ann Arbor study to help find a way of alerting drivers when they are either too close to a bus or approaching too rapidly. Because we're unable to intervene in the bus driver's activity, the project focused instead on the bus itself. Suppose the *bus* could perceive the vehicle behind it; and, once perceived, suppose the *bus* could deliver a message to the oncoming driver in a form that might be quickly and clearly received and acted on.

Our task in this project was to devise such a signal to be attached to the back of the bus. We were told there would be a radar system, fitted to the rear of the bus. It surveys traffic behind the bus and reports its location and the rate at which the gap between the bus and any approaching vehicles is shrinking. When the combination of these variables is in a critical zone, a computer programmed to interpret the radar message generates a warning signal. This system requires no intervention by the bus driver.

Our question then: What should this warning be?

## THE SPEED OF LIGHT

We began with a signal provided by our sponsor. It was a rather simple device, rectangular in shape (150 cm by 8 cm) and designed to be fixed to the rear end of the bus at about the eye level of an oncoming driver. When lit, all eight identical units, each containing a pair of automotive halogen bulbs and an amber lens, would be seen as a single bright amber bar (hence we called it a “light bar”). The choice of shape was dictated by convention as well as the availability of components. The choice of color was constrained by the prohibition against using green (wrong message), red (for brake lights only), white (for backing and headlights, not for signaling), and blue (restricted to emergency vehicles). Our task was to work with the given design of this device to produce a signal that would be seen quickly.

Our first step was to replace the sluggish incandescent lamps with fast-igniting light-emitting diodes (LEDs). Incandescents turn on quite slowly:  $\frac{1}{25}$  of a second elapses before these bulbs even begin to glow, then nearly  $\frac{1}{4}$  of a second passes before they are fully lit. We made some simple measurements of how long it takes humans to see this sluggish turn-on compared to instantaneous turn-on of LEDs and found the delay is about 75 milliseconds. The slow turn-on of the incandescent lamp is thus quite a serious problem, since it requires about 75 thousandths of a second more than an LED for observers to actually see that the lamp is lit. This may not seem like much, but it is significant; we’ll come back to this number again below.

The only other degree of freedom we had in our design was the ignition pattern of the light bar’s eight elements. For this we relied on our understanding of the human visual nervous system, mentioned in these pages in the past (ACCESS No. 14, Spring 1999). The visual nervous system comprises two separate, parallel pathways. One of these is relatively insensitive to small changes in light level, but sensitive to fine detail and color. The other is highly sensitive to light change, time change, and motion. We judged it more advantageous—and easier—to excite the latter than the former. >





### THE TORTOISE AND THE HARE

We conducted two experiments in the laboratory. For the “hare” test we operated the light bar in its native mode, in which all eight elements turned on together and immediately. For the “tortoise” test we lit the elements in a unique sequential pattern. We started with the innermost pair of elements, then ignited the next most central pair  $\frac{1}{20}$  of a second later. We continued this sequence, waiting  $\frac{1}{20}$  of a second between pairs, until the entire light bar was ablaze.

Human observers—our willing students and some cooperative staff members—judged the race. The task of each was to indicate, by pushing a button, the moment he or she saw the light bar turn on. We started a digital timer capable of millisecond accuracy when the first element came on, then stopped it when the observer pushed the button.

The light bar was placed in a position just above the bumper of a nearly life-size photo of a bus’s rear end. We tried a number of different situations, simulating daytime and night viewing. The light bar was seen up close (4.6m distant) and farther way (45.7m). It was operated at full intensity and at five percent intensity to simulate poor viewing conditions, such as dirt-covered lenses. We encouraged observers to look just above it and to be ready for it, or to look at random anywhere on the picture of the bus to simulate what real drivers might be doing behind a real bus. To detect how quickly such signals can be seen, we made repeated measurements, usually 25 repetitions for a given observer and a given condition.

Here’s what we found. When we turned on the light bar’s individual units sequentially, the bar was seen *more quickly* than when we lit up the whole bar instantaneously. Under daytime conditions, the average reaction time for the instantaneous lighting, the “hare” test, was 0.269 second. That’s fairly fast. But the improved, sequentially activated light bar, “the tortoise,” which turned on 0.15 second *more slowly*, was seen about ten percent *more quickly*, in an average of 0.237 second.

We looked more closely at our data, and discovered something interesting: averages fail to convey the whole story. Consider the data cited above as an example. In that test, we recorded 150 reaction times for our six observers. The average, as I noted, was about ten percent better for the sequential light bar. But of the 150 tests, more than half of the reaction times were under  $\frac{1}{4}$  second for the sequential light bar, but less than half were that short for the instantaneous one. In contrast, about six percent took longer than



$\frac{2}{5}$  second for the standard, but under one percent took that long for the optimized bar. In sum, the sequential light bar “converts” some very long reaction times into very short ones.

The time saved seems small but is highly consequential, given the speeds at which cars hit buses. Every  $\frac{1}{10}$  second saved is 4.4 feet additional stopping room for a car traveling at 30 mph. That is about what our design can do. Adding the 75 thousandths of a second saved by converting to LEDs to the 32 thousandths saved by turning on the light bar sequentially gives just over  $\frac{1}{10}$  of a second average improvement—a blink of time that could be enough to prevent a crash. ♦

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# Location Matters

BY MARKUS HESSE

## THE DEATH OF DISTANCE?

The merger of modern communications technologies and physical distribution systems is transforming many aspects of the shipping industries, including their locations and the way they use space. But these changes are not evidence of the promised dissolution of distance that was expected with the advent of global telecommunications. Instead, electronically sophisticated freight handlers are finding that locational considerations are as compelling as ever.

In recent years freight services have been expanding via all modes—trucks, airplanes, railroads, oceangoing ships, inland waterway vessels, and pipelines. As Amelia Regan recently reported in these pages (ACCESS No. 20, Spring 2001), this expansion has been accompanied by the incorporation of new technologies aimed at integrating producers, wholesalers, freight forwarders, retailers, and consumers.

As better communications bring faster, more reliable, and more efficient handling and movement of goods, competition requires freight companies to be fast, flexible, precise, and cost-sensitive. New practices like just-in-time production and, more recently, demand-side inventory management and customer orders placed on the web are contributing to a new business model in which storage plays a lesser role and mobile inventories are the norm.

Yet the industry does not float out there somewhere in cyberspace. As in the old days, it remains rooted in local and regional geographies, but in new ways. One of the reasons the online retailer Webvan failed was that it did not pay enough attention to the fact that even virtual commerce is accompanied by—and depends on—physical distribution in material time and space. The integrated management of materials supply, manufacturing, distribution, and consumption—known as “supply-chain management”—also has important spatial implications, including enlarged geographic range and concentration of logistics functions at strategic locations.

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## LARGE-SCALE DISTRIBUTION CENTERS

All these factors have given rise to new types of transshipment points—distribution centers (DCs)—that manage the logistics of automated and customized freight flows. Unlike traditional warehouses, which are primarily storage facilities, these centers consolidate and process materials flowing through them. The typical large-scale DC consists of loading bays for in-bound and out-bound trucks, fast-moving automated conveyors, sophisticated information systems that sort parcels and control movement from receiving docks to shipping docks, and management systems that simultaneously control transactions. These recently evolved facilities are in buildings that are larger than traditional warehouses and may be built on extensive suburban and exurban sites. Their high volume and precise inventory management require more frequent movements of smaller loads via increasing truck, parcel van, and airplane traffic. (Amazon.com distributed the last *Harry Potter* title by using 100 air-freight planes and 9,000 trucks to deliver the book to thousands of customers on its publication day.)

Large-scale distribution centers mark a trend toward concentration of short-term storage and inventory in a few high-throughput locations for national or continental distribution. They provide economies of scale in land, buildings, and operations; and they reflect the comparatively low costs of transportation that followed deregulation.

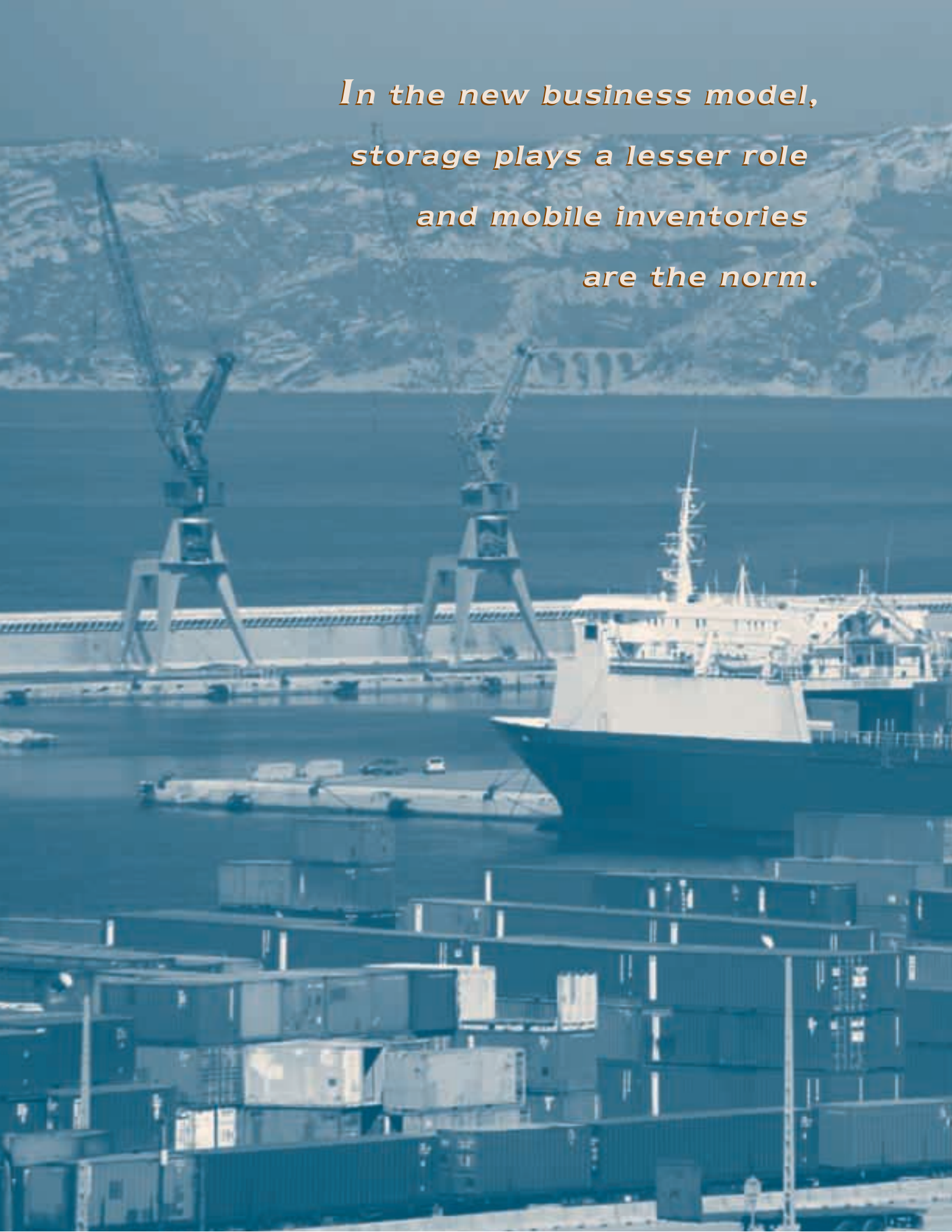
As a consequence, a new locational pattern is emerging. Manufacturing plants were once concentrated inside urban core areas, reflecting the advantages of access to labor, markets, and transport. Traditionally, freight-distribution facilities were located adjacent to production plants, and they delivered goods directly to wholesalers and retailers. Today, goods flow through few gateways, mainly large seaports and airports, on their way to customers. Economic growth, changing consumer habits, and the accompanying growth of trade and transport are provoking competition among these gateways and compelling them to expand their infrastructure. But, of course, land and infrastructure for expansion are scarce; and expansion plans evoke opposition from neighbors. So distribution centers are increasingly moving to hinterland sites where large blocks of land can be had and where freeways, railways, and airways still provide high accessibility.

These processes can be observed in traditional gateway regions, such as Los Angeles/Long Beach and New York/New Jersey, but increasingly also in the Midwest, where so-called “inland ports” are emerging in places like the Ohio River Valley. The West coast is favored as a hub location to serve consumers west of the Rockies. One of the new large DCs opened recently in California’s Central Valley, occupying 1.7 million square feet and providing distribution for IKEA stores from San Diego to the Canadian West. Even seemingly isolated Nevada is coming to be favored as a site for large-scale distribution hubs because of low land costs, low taxes, and excellent accessibility. ➤





*In the new business model,  
storage plays a lesser role  
and mobile inventories  
are the norm.*



## URBAN DISTRIBUTION CENTERS

Consumer destinations and thus metropolitan regions have always been important places for distribution, reflecting the sheer volume of urban markets and the advantages of fast and flexible response to goods purchase at the point of sale. But local delivery inside urbanized areas is much more costly than long-distance shipment, in part because it must operate on congested streets, in part because it must use small vehicles with their low productivity. As a result, transshipment points remain advantageous within urbanized areas as well. We can find such urban DCs both inside and outside metropolitan centers. Nevertheless, economies of scale, newfound flexibilities afforded by contemporary communication technologies, cheap land, cheap labor, and access to both urban and nonurban transportation networks are enticing many new urban DCs out into exurban locations.

## THE SAN FRANCISCO BAY AREA

The east side of San Francisco Bay is following what may be the prototypical pattern. The classic early-industrial configuration had been firmly established there, with factories arrayed north to south, paralleling the East Bay shoreline, alongside railroad tracks and the freeway, and near the Port of Oakland's docks and airport. But plans for expansion ran up against rising costs, including expensive land and heavy traffic—not to mention preferences of municipalities for non-freight-related land uses and NIMBY opposition.

So, despite the advantages of their established locations, most recent warehousing and distribution centers have been locating far eastward, across the Coast Range and into the Central Valley. Here, at towns like Stockton and Tracy, distribution firms comprise about eighty percent of all firms in new industrial districts, and ninety percent of these firms are reported to have moved from the Bay

Area. This large-scale relocation seems rational, owing to their requirements for large buildings with complex networks of conveyors and the ability to expedite in-and-out cargo flows. But the externalities may prove costly.

Relocation is having major consequences for the regional distribution of economic activities. First, there's increasing land consumption in districts that until recently were agricultural. Second, there's significant growth of feeder and delivery trips by trucks, because many customer destinations remain located within the Bay Area's urban core. It's not surprising that massive truck traffic clogs the regional freeway system. ➤







### THE RESULTING DILEMMA

Improved freight distribution must surely be counted as a positive contribution to the efficiency of each region's and the nation's economy. It's no coincidence that some cities and regions are proclaiming themselves to be desirable distribution hubs. But modern distribution systems also carry immense costs. There are internal costs of land and transport infrastructure, and then there are further external costs associated with truck noise, air pollution, traffic accidents, and exacerbated traffic congestion. Trucks operate around the clock, so these problems are not confined to certain times of day.

It is evident that the merger of electronic communication and goods-handling technologies have freed manufacturing and freight firms from traditional locational strictures. They now enjoy expanded locational freedom, able to locate almost anywhere there are roads and airports and preferably anywhere that suits their logistical requirements for efficient cargo management. But, contrary to popular belief, they are not wholly freed from the constraints of geography. Location, location, and location still matter. The shipping industry is still rooted in physical space and social contexts. The costs associated with site arrangement, cargo movement, market access, labor relations, and labor supply remain real. In these respects, little has changed.

So policy makers face another of those classic dilemmas: how to exploit the advantages of new high-tech logistics and freight-moving systems while avoiding the disadvantages of new high-tech logistics and freight-moving systems. As long as economic activity remains fixed in place and as long as geography still matters, the DCs must conform to their internal operating requirements, and urban areas must bear the costs. ♦

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# COMPLICATIONS AT OFF-RAMPS

BY MICHAEL CASSIDY



YOU'RE DRIVING ALONG the freeway when suddenly everything slows down. A crash? A sudden overload of cars joining the freeway from on-ramps up ahead? Maybe. Sometimes the cause never reveals itself to you—inexplicably, everything just starts moving again. If this happens every day in the same spot, you may develop a theory or two as to why it happens. Would it occur to you that the congestion might be caused not by too many cars getting on the freeway but by too many cars trying to get off?

For decades, traffic engineers have been managing freeway congestion by using meters to restrict the rates that vehicles enter the freeway from on-ramps. A metering scheme can often keep cars moving faster on the freeway, and sometimes can even reduce traveler delay systemwide. Realizing these benefits requires metering that is suitably designed, but traffic engineers disagree about what constitutes a suitably designed plan. >

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### THE MERGE BOTTLENECK

We all know what a bottleneck is on a freeway. We suspect traffic slows down because too many cars are trying to merge, or a lane disappears, or there's some similar shortage of space. A similar thing can happen when people leave a sports stadium. If a lot of fans stay until the end of the game (say it's the World Series and the score is tied until the bottom of the ninth), then when they leave there will be pedestrian bottlenecks at the exit gates. Say people coming from the bleachers and people coming from the reserve seats all go out through the same gate. Figure 1A illustrates what happens: more pedestrians arrive from the bleachers and the reserved seats than the gate can handle. The two paths meet, and the short stretch of the common stream before the gate soon piles up in a queue. Fans slow down as they pass through the gate, and queues propagate backwards on both paths. This is a merge bottleneck.

The resulting delay can be displayed on a standard queuing diagram like the one in Figure 2. The top curve, labeled "V" (for virtual departures), depicts the cumulative number of fans from both the bleachers and reserved seats that would like to have left the stadium by any time "T". It shows the number of people that would have gone through the gate by any particular time if there were nothing to slow them down.

One could construct this curve by measuring, for each path, all individual arrival times at some specified location before the queue—say, at the hot dog stand—adding the amount of time it would take each individual to reach the gate from the hot dog stand if there were no one in the way, then plotting these virtual times cumulatively. The number of people who actually leave the stadium by any time "T" is represented by the lower curve "D" (for actual departures), and the shaded area between the two curves is the total delay collectively incurred by all pedestrians in the system.

This queuing diagram is a means of displaying real, measurable data. The only conjecture here is in the slope of the lower curve, which assumes that, if not impeded by some additional queue further downstream, people pass through the gate at its capacity

whenever a bottleneck forms. This maximum rate is independent of both the number queued and the proportion of pedestrians coming from each section of the stands.

Now suppose a stadium employee acts as a kind of ramp meter by restricting the rate at which people from the bleachers merge into the common stream. Speed and flow would increase for those coming from the reserve seats; and, since they'd leave the stadium at a higher rate, they'd suffer less delay. Nonetheless, the metering hasn't changed the total amount of delay. It has merely redistributed it, reducing some delay for the reserved seats but creating more delay for the bleachers. Figure 2 shows that total delay is unchanged as long as the two curves are unaltered; that is, as long as the same number of people are trying to get out and the gate's capacity remains the same.

But suppose people coming from the bleachers are restricted so much that fewer people than the gate's capacity come through. In this case, people from the reserved seats won't have to queue up. The flow of people on this path will be higher than it was without the metering. Yet total delay in the system, as well as the duration of the rush, would both increase, since people leave the stadium at a lower rate than the maximum possible. This would show up on Figure 2 as a drop in the slope of "D" and an increase in the size of the shaded area.

The key to holding down delay is keeping the outflows from the whole system as high as possible. Maximizing outflows should be a primary objective when setting up metering plans. It holds true for the simple system in Figure 1 as well as for complex freeway systems. ➤

FIGURE 1A

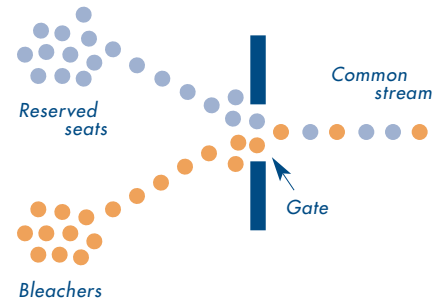


FIGURE 1B

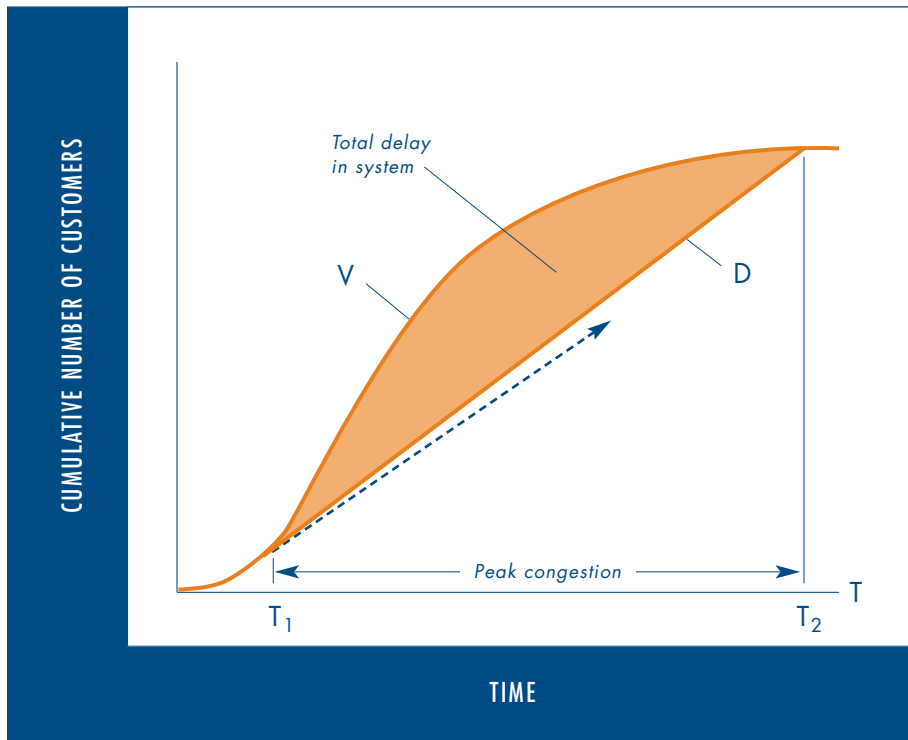
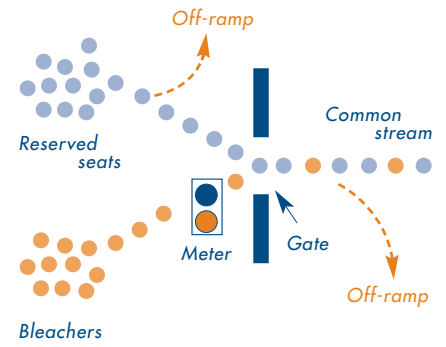


FIGURE 2





### A CONGESTED OFF-RAMP AND WHAT A METER CAN DO

Now go back and complicate the original scenario with some off-ramps. Queues have formed on both paths. Next put in another exit, an “off-ramp” before the common stream, on the path from the reserved seats (Figure 1B). If we metered the bleachers just enough to increase the rate of people coming from the reserved seats, we could increase outflow, since people from the reserved seats could now get to that first exit sooner. Thus we could reduce delay in the entire system, though people coming from the bleachers may not know it.

But suppose there’s also an off-ramp just beyond the gate, and that this second off-ramp’s capacity is less than the gate’s. Some proportion of those entering the common stream from both the bleachers and the reserved seats are bound for this off-ramp. Even with the current metering scheme in place, problems can arise if the number of people headed for the second off-ramp exceeds that ramp’s capacity. The off-ramp would be unable to absorb the extra people, and a queue would form in the common stream that could eventually block the gate. In this case, the flow approaching this downstream off-ramp diminishes as traffic is blocked by the queue for the off-ramp. The extent to which the flow diminishes depends upon the proportion of people in the common stream who are bound for that off-ramp; a higher proportion of these people means a greater reduction in flow, and an increase in delay.

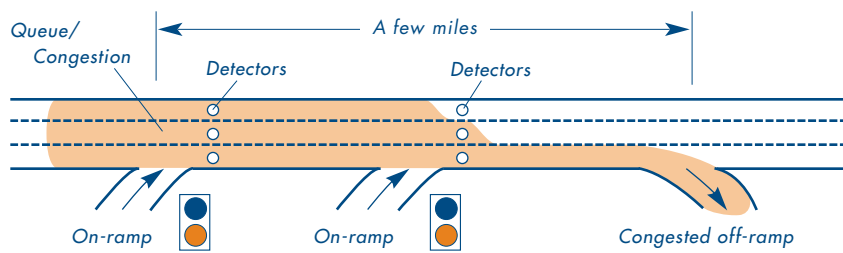
Obviously, metering can’t increase the off-ramp’s capacity. But it can affect who’s in the queue upstream, and this can have either positive or negative effects on the system. If, for example, most of the people bound for the problematic off-ramp happen to come from the reserved seats, the metering scheme in place would have exacerbated the problem by allowing a higher proportion of people headed for this ramp to enter the common stream. What’s needed instead is a scheme to reduce that proportion.

### METERING FOR OFF-RAMPS

Empirical evidence shows that people driving vehicles on a freeway behave much the same as our pedestrians in the stadium. Some traffic engineers have conjectured that by eliminating queues, on-ramp meters can increase capacities at merge bottlenecks. But, to date, conclusive evidence of this is scarce, and further empirical study on the subject is needed.

Also, many engineers erroneously see higher vehicle speeds and flows on sections within a freeway system as evidence that a metering scheme has diminished delay. The potential flaw in this reasoning was evident in the stadium analogy. Before introducing off-ramps to the simple system, our metering method promoted higher speed and flow for one path but could not lessen overall delay. An overly restrictive scheme even resulted in greater delay.

In the real world, metering schemes often function with what is called a “demand-capacity” logic. According to this logic, on-ramp metering rates are established to keep flows on each freeway section from exceeding that section’s estimated capacity. But this is not appropriate for a freeway with a congested off-ramp. For example, some metering algorithms adjust an on-ramp’s metering rate according to roadway occupancies measured downstream. At regular intervals the metering is made more—or less—restrictive if the measured occupancy is above—or below—some specified target, typically the highest number of vehicles that flow freely on that freeway section.



**FIGURE 3**

But suppose we used this metering plan on the freeway stretch shown in Figure 3. The off-ramp near the downstream end of this section becomes congested during the rush. Its queue, shaded in the figure, backs up from the off-ramp onto the freeway and propagates backward past two neighboring on-ramps upstream. Each of these on-ramps' detectors then measures an occupancy above the target and adjusts to a more restrictive metering rate.

However, relatively few, if any, of the vehicles from these nearby on-ramps are likely to be bound for the congested off-ramp, because most trip lengths on a freeway are more than a few miles. So, by restricting inflows from these nearby on-ramps, the meters have inadvertently created a mix of freeway traffic having a higher percentage of vehicles headed for the problem off-ramp. As in our stadium analogy, this reduces outflow and makes the queue upstream even denser. The on-ramps' detectors then measure occupancies farther above the targets. A downward spiral may thus occur, whereby at regular intervals metering at nearby on-ramps becomes more restrictive, in turn intensifying queuing and increasing delay.

Even if not subjected to perverse outcomes like the one above, congested off-ramps can create huge delays. Fortunately, there are effective traffic management strategies for this type of bottleneck. For example, one might coordinate the metering rates at multiple on-ramps in selective ways. Those on-ramps serving higher numbers of vehicles headed for the congested off-ramp can be metered more restrictively than others.

Moreover, traffic management strategies suitable for this kind of congestion are not limited to on-ramp metering. In many cases the simplest solution is to increase the rate at which vehicles can discharge from off-ramps. This would commonly entail treating bottlenecks on nearby surface streets, since off-ramp queues often reverberate from them.

### SOME FINAL THOUGHTS

No single metering scheme can address all freeway conditions. So a metering plan, or any traffic management strategy, should be designed only after the particular freeway system has been carefully examined and all its sources of delay identified. Unfortunately the literature has surprisingly little to say on this subject. Most reports promoting or criticizing demand-capacity schemes make no mention of their limitations in addressing congestion from off-ramps.

To the contrary, the literature gives the impression that some of the best-known metering algorithms follow from the assumption that all freeway bottlenecks are merge bottlenecks. But freeway bottlenecks come in many flavors, including those created by congested off-ramps. ♦



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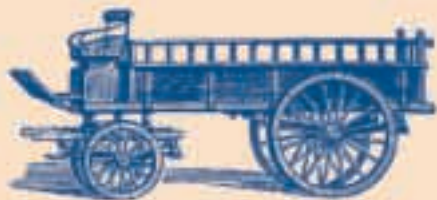
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# Travel Patterns Among Welfare Recipients

BY PAUL ONG AND DOUGLAS HOUSTON

**W**ELFARE REFORM ENDED America's public assistance program as we knew it, transforming it from an income-entitlement program to an employment-assistance program. Following its enactment, welfare rolls dropped by more than half, from about 12 million in 1994 to just over 5 million in late 2001. Fortunately, the majority of those who left public assistance found work. Nevertheless, welfare reform still faces a large, and largely unrecognized, problem.

Inadequate transportation is keeping many from finding and holding jobs. Perhaps just as important for the job search as skills, education, attitudes, and childcare, job-seekers must be able to get to job sites.

Welfare recipients' transportation needs depend on whether they're still actively seeking employment or are already employed. Job searchers must travel to potential employers for interviews and applications, so they make almost twice as many trips as those not in the labor force, and their trips are often to dispersed locations. Many don't own cars, so they're reliant on public transit, but the bus is less flexible and sometimes less reliable than a private car.

Transportation needs go beyond work-related travel; in fact employment-related trips constitute only a small share of total trips (only eleven percent). A typical former recipient also makes multiple daily trips for shopping and social activities, and to fulfill childcare and household obligations.

While most transportation programs emphasize the needs of transit-dependent persons, most people nevertheless rely on

automobiles for daily travel. Only 55 percent of welfare recipients own a car, but they make 64 percent of their trips in cars. Households with cars make 83 percent of their trips in private vehicles; but even those who don't own cars travel by private car 35 percent of the time.

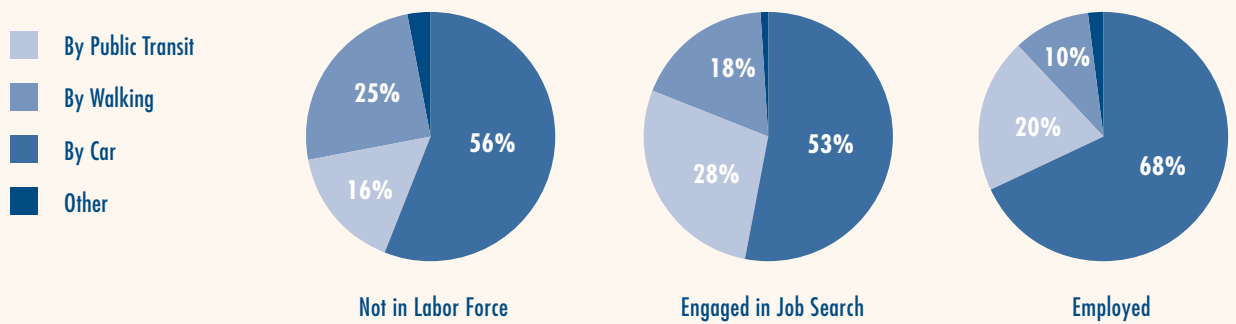
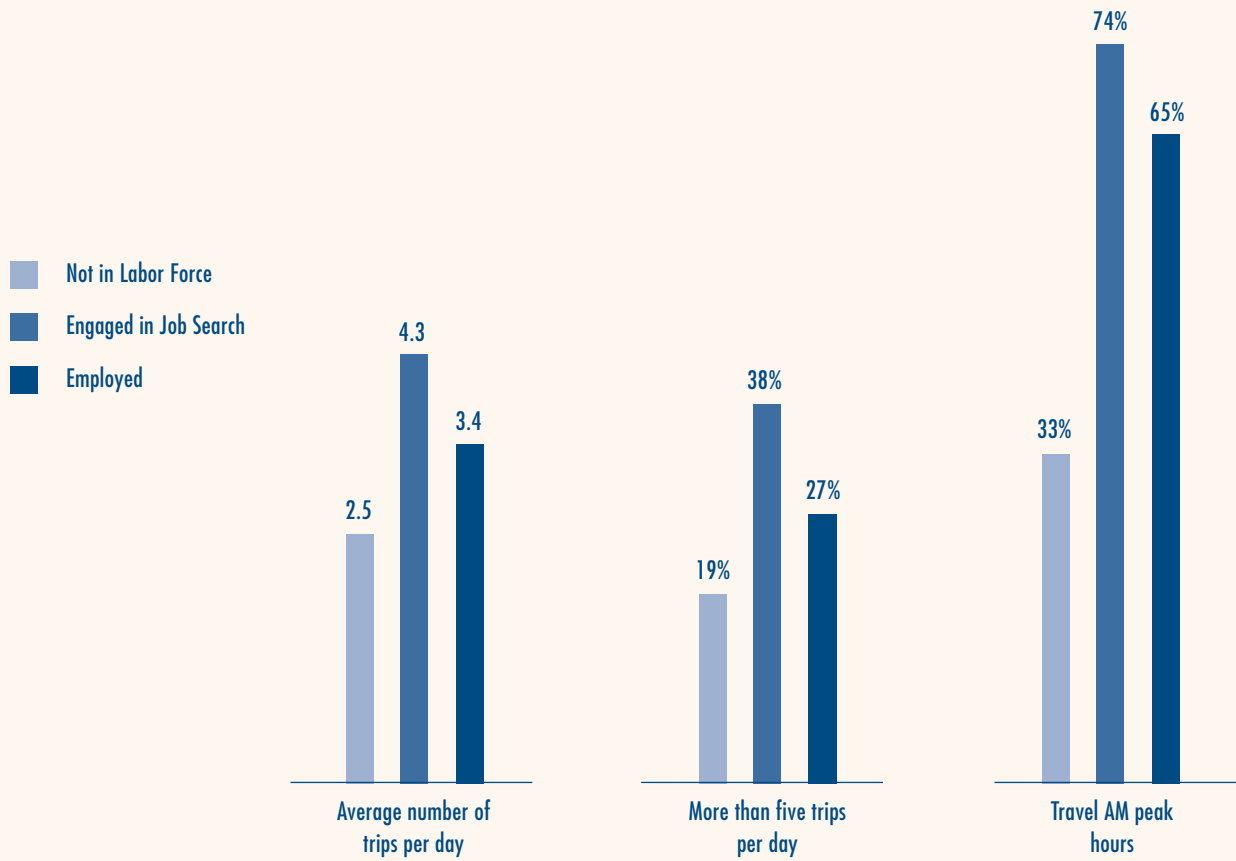
Travel patterns of welfare recipients are converging with those of other low-income people. Average trips per day among welfare recipients were only slightly fewer than among low-income single parents in the 1995 Nationwide Personal Transportation Survey. For both populations, work trips comprise only a tenth of all trips, while shopping and other trips dominate. For both groups, less than a fifth use public transit. Moreover, the average commute distance for employment is about seven miles among former recipients and about nine miles among low-income single parents. This convergence is not surprising since welfare reform is transforming the welfare population into a working-poor population.

These travel patterns have profound implications for the next stage of welfare reform. Transportation policies must now heed the complex and diverse travel needs of both current and former welfare recipients who use both private and public transportation. Moreover, as travel patterns of welfare recipients and working poor converge, policy makers must confront the difficulties that job-seekers and carless job-holders face, by facilitating car ownership and by promoting new transit modes that are affordable, auto-like, and likely to help families that are struggling toward self-sufficiency. ♦

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## Trip characteristics of people moving from welfare to employment







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