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Fighting Traffic Congestion with Information Technology

We now have the technical means to "solve" congestion. But do we have the political will?

Traffic congestion is a vexing problem felt by residents of most urban areas. Despite centuries of effort and billions of dollars worth of public spending to alleviate congestion, the problem appears to be getting worse. Between 1980 and 1999, vehicle-miles of travel on U.S. roadways grew by 76 percent, while lane miles increased by only 3 percent. Average daily vehicular volumes on urban interstates rose by 43 percent between 1985 and 1999, from 10.331 million to 14.757 million. In a study of 68 urban areas published in 2001, the Texas Transportation Institute reported that the percentage of daily travel taking place during congested periods increased from 32 percent in 1982 to 45 percent in 1999; typical motorists faced seven hours per day of congested roadways in 1999 compared with five hours in 1982. According to the Federal Highway Administration, road delays (defined as travel time in excess of that at free flow conditions) increased by 8.5 percent between 1993 and 1997. Congestion also pollutes the air and wastes precious fuel.

Despite the exasperation that traffic congestion causes, most people know surprisingly little about it or what can be done about it, and much of what is stated in the media is oversimplification. We live in a society in which, for political and social reasons, we consistently label congestion a major problem to be solved but find it unacceptable to adopt the most effective solutions. Indeed, the political debate over the issue indicates that we actually prefer the problem to the solutions. If our current path continues, in the coming years we will implement innovations to mitigate worsening traffic and expand the transportation system to accommodate growth in travel to some extent, but we will likely shy away from measures that will literally cure the problem.

There is one factor, however, with the potential to change the course that we are on: information technology. There are a wide variety of applications of information technology that are just beginning to be implemented that could be far more significant in our struggle to defeat traffic congestion than the building of new highways and transit routes or more gov-

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ernment regulation. In fact, we now have the technical means to finally "solve" the congestion problem.

Mixed blessing

Although we always label congestion a problem to be solved, it is surely not all bad. In the United States, worsening traffic congestion is most often associated with prosperity rather than poverty and with growth in population and business rather than decline. Congested city centers are usually the most exciting and high-rent of all urban environments, home to dynamic industries, tourist attractions, and cultural activities. Traffic congestion becomes less pronounced during recessions, and stagnant rust belt cities would willingly trade high unemployment rates and vacant industrial tracts for some troublesome traffic congestion. When and where it reaches very high levels, traffic congestion can become self-correcting; for example, when businesses choose to leave an area because it is too crowded and plagued by delays.

Politicians, not surprisingly, want to have their cake and eat it too. They want the growth and economic vitality that bring congestion, yet they also want to control or reduce that congestion. They worry that congestion will kill the goose that laid the golden egg by slowing growth and driving investment elsewhere, but refuse to implement effective strategies to relieve congestion because stringent solutions might, like congestion itself, redirect growth to other areas. Although technical experts could actually solve the problem of congestion, their solutions are politically unacceptable because they threaten economic growth along with congestion. In theory, automobiles could be banned from sectors of city centers; bridge tolls could be raised to such high levels that they would reduce traffic backups; and taxes on gasoline could be made so high that people would increasingly use mass transit and cycling. But such strategies could not be adopted in the United States and would stifle the economic growth and cultural activity that are considered the greatest successes of our society. Would we really vote for emptier streets if they meant fewer bargains at stores, closed movie houses, and higher rates of unemployment?

The notion that growing traffic has to be accommodated rather than stifled has been the motivation for innovations by private entrepreneurs and public officials over many centuries. The more successful of these have indeed reduced or eliminated congestion in some ways and for some time, but eventually cities have grown and readjusted to create a new equilibrium that includes new and perhaps different patterns of congestion. Then these are again identified as serious problems in need of repair, and new solutions are proposed. That process continues today, and although congestion has never actually been permanently alleviated by any of these innovations, they have surely improved the quality of urban life by supporting the expansion of diverse activity centers.

Policymakers usually base their recommendations on statements about congestion that consistently and dramatically oversimplify reality. In some cases, the beliefs that motivate policymaking may actually be dead wrong. Do we really know the extent to which citizens worry about traffic congestion or see it as a serious public policy problem? The evidence is confusing at best. Residents of the San Francisco Bay area recently rated urban traffic congestion as the single most important problem affecting their quality of life, even more important than public education or crime. This is consistent with research findings indicating that driving in heavy traffic is stressful, as measured by elevated blood pressure, eye pupil dilation, and the occurrence of incidents of road rage. On the other hand, there is also recent research showing that many people find driving to be a relaxing interlude between their many other stressful activities. Survey research recently has shown that a substantial proportion of drivers would actually prefer to spend more time traveling each day than they presently do. Presumably, a diversity of personality types and differences in our attitudes based on the time of day at which we travel and the purposes of our trips mean that it is difficult to generalize.

Press releases from transportation agencies and political leaders frequently speak of tens of millions of dollars in annual "costs" associated with congestion in metropolitan areas. Where do such numbers come from, and what do they mean? These estimates come quite simply from multiplying aggregate hours of delay by some dollar figure such as a "typical" hourly wage rate: A million hours of delay per year times $10 per hour yields a cost of congestion of $10 million, a dramatic figure quickly reported by the news media. But it is not at all clear that this number has any meaning. Some drivers, like those behind the wheels of commercial vehicles, are indeed paid wages for time they spend on the road, but most are not. And if we could produce a miracle that would enable us tomorrow to spend much less time in congested traffic than we did today, would we actually convert the saved time into labor that would produce added income? For most of us the answer would be no, so the wage rate may be a meaningless way to value congestion. If we used the saved time to mow the lawn or go for a jog, the time saving would certainly have value, but is that value appropriately expressed by a wage rate?

Although "smart growth" does reduce overall auto use, it does so by creating congestion rather than relieving it.

It is similarly not clear that if one citizen loses 10 minutes a day whereas another loses 100 minutes to congestion, that the second person's loss is worth 10 times that of the first person. We may not be willing to pay anything to save 10 minutes per day but willingly pay to save 100 minutes, so the value of time may be quite nonlinear, complicating the situation greatly.

As we learn more about travel behavior, we have begun to understand that travelers are more interested in the predictability of the time that a trip takes than they are in the average length of trip time. In other words, people are not likely to complain as much if a trip takes them on average 45 minutes instead of 30 minutes, but they are likely to be quite concerned if it takes 15 minutes one day and 45 minutes the next. To avoid being late to work or to an important appointment, we must plan a trip to allow for the longest travel time that can reasonably be expected rather than for an average travel time. Aggregate hours of delay may very poorly measure what is most important to people about traffic congestion, and attaching dollar values may obfuscate rather than clarify the issue. Census data show us that the median journey from home to work in the United States is increasing by only a few minutes per decade, even though cities are spreading out considerably. People in the suburbs travel longer distances between home and work than do those in the inner city, but generally they make those trips at higher speeds, so travel times are growing very slowly. In the face of this evidence that typical travel time is hardly growing, it is probably our concern with the variance or reliability of travel time that explains our growing concern about traffic congestion. Interestingly, although variance is more important than median travel time, we collect data on the median and report nothing to the public about the variation.

Policymakers also have a poor understanding of the mechanics of traffic congestion, which is highly localized in time and space. Well over 90 percent of our roads are uncongested for well over 90 percent of the time. Some congestion—indeed, up to a third of all traffic delay—is caused by incidents that are difficult to predict, such as accidents, spilled loads, or construction equipment. Recurrent congestion, caused by demand outstripping capacity, occurs mostly at busy activity centers and important bottlenecks such as bridges, tunnels, and critical intersections. When overall congestion becomes worse, however, it generally does not become more intense at locations that are already heavily congested; rather, it spreads over longer periods each day and to additional locations. Drivers can often avoid congestion by choosing alternate routes or times at which to travel, but as many people leave earlier or later for work or choose an uncongested boulevard in preference to a crowded expressway, they gradually cause congestion to build at those times and on those alternative routes.

Traffic congestion is also nonlinear, meaning that when volume doubles or triples on a lightly traveled street the effect on travel times is minimal, whereas adding just a few cars and trucks to a crowded roadway causes large increases in delay. This explains why traffic seems to be much worse on the day that school reopens in the fall and to be surprisingly light in New York or Boston on Jewish holidays. Adding or removing only a small fraction of all travelers can make an enormous difference in traffic flow, which makes traffic eminently subject to management strategies. Although congestion is nonlinear, people think in linear ways; congestion on a major bridge leads to calls for another bridge, even though small adjustments could quite dramatically reduce delay.

A long history

Congestion is not a new phenomenon, and every civilization has developed innovative solutions to control or accommodate it. In ancient Rome, the Caesars noted that the passage of goods carts on narrow city streets so congested them that they became impassable and unsafe for pedestrians. A government edict required goods vehicles to make deliveries at night, but this policy was soon overturned because citizens complained that their sleep was interrupted by the sounds of vehicles traversing the pavement and of animals straining under their loads. Charles II of England issued a famous edict in 1660 to ban standing carriages, wagons, and horses from the streets of Westminster and London because they were excessive and were creating a public nuisance. He ordered that they be required to wait for their passengers off the main thoroughfares to enable the traffic to flow more freely on the boulevards.

Industrialization brought urbanization, and 19th-century cities were incredibly crowded places. Most people walked to work or lived above or behind their businesses, and rudimentary horse-drawn public transit was too expensive for most citizens. Population densities in industrial cities were many times what they are today, and urban congestion was then widely understood to mean the crowding of people in limited space. By the late 19th century, the high density of dwelling units, high occupancy of residential quarters, proximity of living areas to working areas, environmental hazards of factories, and transportation systems based on animal power were together defined as congestion. The innovation that addressed this problem was improved public transportation, first on the surface and powered by horses; later elevated or underground and powered by cables, steam, and eventually electricity. Affordable and reliable public transportation meant that people could live farther from where they worked and travel much more. At first, only the rich could move away from the center, but gradually fares fell in relation to incomes, and more and more people could commute to work. At the first national Conference on Planning and the Problems of Congestion nearly 100 years ago, speakers urged lower densities and the deliberate suburbanization of the population. In New York, zoning was introduced in part to lower the land use intensity so as to ease overcrowding. The flat subway fare (meaning that the fare was the same for a 20-mile journey as for a 1-mile trip) was adopted to encourage lower-income people to move out of the city center and new immigrants to locate in outlying neighborhoods, which were considered safer and more healthful than the crowded downtown areas.

As more people moved out of the centers of large cities and relied on public transportation, the perception of congestion changed from crowded neighborhoods to crowded streetcars on tracks so filled with trolley cars that movement was extremely slow. Innovations that helped ease this new form of crowding included the construction of the first urban elevated routes and, just before 1900, the development of underground transit routes, along with the development of signaling systems to control complex flows in the transit networks. Grade separation of vehicles with passengers from pedestrians and horse-drawn goods vehicles provided the capacity for more movement within cities, permitting both growth and decentralization.

Rapid declines over just a few decades in the cost of auto ownership in relationship to worker wages meant that many more people became mobile. Automobiles provided an order of magnitude increase in movement capacity and meant that cities could continue to grow and spread. The most rapid growth rates in automobile ownership and drivers' license holding occurred between 1910 and the Great Depression, and city streets became very crowded with motor vehicles during that time. Innovations devised during this period by engineers, politicians, and bureaucrats included the widening of roads and the rationalization of street networks by, for example, straightening streets and making them more continuous with one another. Busy intersections gradually came to be managed by signs and mechanical signals that were eventually replaced by electric signals that later were coordinated with one another into systems that accommodated higher traffic volumes. Proposals for access-controlled and grade-separated roadways also originated in this period, but years of depression and war slowed their adoption as automobile ownership and use continued to grow. After World War II, prosperity returned and growth picked up in employment, the economy, and travel. In response to dramatic increases in congestion, the federal government in the 1950s planned, and over 40 years built, a national system of "interstate and defense highways," encouraging state governments to build more than 40,000 miles of freeways by providing them with more than 90 percent of the money. Roadway capacity for a short while grew faster than motor vehicle travel, so this growth in new capacity seemed to solve the problem of congestion, but population and economic activity also expanded; land use became more dispersed; and, as the statistics in the opening paragraph indicate, over time goods movement and passenger travel have grown to utilize and surpass the capacity of the road network.

Extensive integration of IT with the transportation network is key to managing congestion growth.

During the past 20 years, the costs of new highway capacity have become political liabilities that exceed its benefits. Community disruption, land taking, decentralization of population, production of air pollution, and dependence of the automobile and highway system on petroleum energy sources all limit the likelihood that government policy will emphasize continued expansion of roadway networks. It is now common to say that we cannot build our way out of congestion, because new roads induce new traffic. Whereas decentralization of the city was to another generation the solution for congestion, many today urge that we slow the pace of suburbanization by promoting "smart growth" that includes dense commercial and residential nodes of development at transit stations. Whereas road construction was to another generation the solution to traffic congestion, today it is just as often seen to be the cause of the problem.

The limitations of smart growth

Environmentalists and urban planners have adopted smart growth as the ultimate solution to congestion. They urge that we cluster development near transit stations, increase urban densities, and mix land use, including putting stores and housing together, so that people can live without relying so much on their cars. By redirecting growth back into the city center, they believe that more people will be able to walk and use public transit and that automobile use will decline. This approach appeals to intellectuals, who are often fond of the kinds of environments found in downtown New York, Boston, and San Francisco, and their proposals are exciting for many reasons. Those reasons, however, do not include potential reductions in congestion. In fact, this strategy seems to confuse the solution with the problem. Should we emulate Hong Kong, Tokyo, or Manhattan as the strategy for alleviating congestion?

It is true that low-density environments create more vehicle miles of driving per capita or per household than high-density environments. Without doubt, people are more likely to walk and use public transit in dense, mixed-use urban neighborhoods, but they are likely to do so in part because those neighborhoods are seriously congested. Can congestion be seen as the cure for congestion? Yes, but only in part. A strategy that creates more dense, mixed-use, transit-oriented communities and fewer low-density suburban neighborhoods can reduce vehicular travel in the aggregate, but at the expense of greater congestion in our city cores. A suburban neighborhood that contains five dwelling units per acre might produce 10 person-trips per day per household, which by simple arithmetic means 50 trips per acre per day, few or none of which would be made by walking or public transit. An urban neighborhood with 20 dwelling units per acre might, by contrast, produce only seven person-trips per household, but the same arithmetic shows that this neighborhood would produce 140 trips per acre per day. If 10 or 20 percent of these trips were made by walking or public transportation, the urban neighborhood would still produce more automobile traffic per acre than the suburban neighborhood. In other words, smart growth does reduce overall automobile travel, but it does so by creating congestion rather than relieving it. This is not necessarily bad, but it implies that many planners and environmentalists are disingenuous when they urge us to fight congestion through smart growth. Like the politicians, they really want more congested environments but presumably want that congestion to be somehow managed and accommodated. If it is not accommodated, people will start to move to the suburbs specifically to avoid congestion, and that will create more reliance on automobiles.

Applying information technology

What we choose to do about worsening congestion in the next few decades will be a product of the long and complex history of multiple innovations outlined above and also of the types of innovations and technology that characterize the current era. If history teaches us any lessons, it is that the effectiveness of available technical innovations will be tempered and directed by political priorities and interpretations of what is possible and desirable. Today there is little political will to dramatically expand existing highway networks and little support for extreme measures, such as vehicle restrictions that could control congestion but stifle economic growth. A large proportion of available transportation resources will be needed to maintain, replace, and repair our existing aging highway and transit networks, leaving little money to spend on new roads or expanded transit systems.

We now have the technical capacity to integrate into one system the mechanisms for financing roads and controlling congestion.

At the same time, the major force influencing the world economy in recent years has been information technology (IT). Rapid and extensive integration of IT with the transportation network is already underway and is the key to the management of congestion growth. Thus far, however, the accomplishments are quite modest in comparison with the possibilities.

Travelers today can receive directions to their destinations in their vehicles on handheld computers or by using devices incorporated into their dashboards. Most currently available information is similar to a traditional road atlas in that route information is not yet modified by data on current traffic conditions. For 30 years, traffic and transportation authorities have been gradually incorporating instruments into roadways and vehicles to provide increasingly useful information for managing traffic flows. "Loop detectors" buried under arterial streets and freeways report on traffic density, and the data they collect are being used to estimate speeds and travel times with increasing accuracy. In some cities, these data are being used to optimize the timing of traffic signals in order to maximize flows on segments of street networks. Cameras located on bridges and over busy intersections complement the data collected from the detectors to feed visual images of incidents to traffic control centers from which tow trucks and emergency vehicles can be dispatched when needed.

Thus far, most applications of this technology have enabled us to improve the management of parts of the transportation system in real time on the basis of information on current flows. Because traffic patterns repeat themselves day after day, techniques are emerging that will soon enable us to merge historical data with information taken from the monitoring of current flows to predict traffic patterns with increasing accuracy over the coming minutes and hours. This information will in the near future be made available to potential travelers over the Internet and through cell phones, car radios, or dashboard display screens to those already on the road.

The extent to which the application of IT will allow us to better manage traffic flows to save travelers time and money is in the longer term more likely to be limited by political and social considerations than it is by the technology itself. For example, it is technologically feasible to track vehicle locations and to provide drivers with specific information on the current and projected traffic levels and travel times on several alternate routes. However, concerns about intrusion into personal privacy could limit the use of this innovation.

Because they present fewer challenges to privacy and produce greater gains in efficiency, these technologies will more quickly be applied to trucks and public transit vehicles. Operators of truck fleets and transit operators already use Automatic Vehicle Location (AVL) technology that employs Global Positioning Satellite Systems (GPSS) to keep track of the location of vehicles on city streets. Trucks can be programmed while in service for additional pickups and deliveries based on their current locations, and this type of information is increasingly used to tell bus drivers to bypass certain stops in order to fill gaps in service. Through display terminals at bus stops or through cell phone access, this type of information is also beginning to be used to provide bus users with information on the expected arrival time of the vehicle they hope to board. Such innovations will help us manage traffic congestion, and many believe that applications of "intelligent transportation systems" can accommodate up to half of the growth in congestion that will occur over the coming decades. That's impressive, but is it enough?

Congestion pricing

In the past, the vast majority of the costs of building and operating transportation systems have been paid through a system of user fees. Tolls are the most direct user fees, with fuel taxes really functioning as surrogate tolls, because they collect money roughly in proportion to how much we drive. When fuel taxes were adopted more than 80 years ago, they were seen as inferior to tolls because they didn't levy charges at the location and time of travel. But fuel taxes had lower costs of administration; just a few percent of the fuel tax is spent to cover the costs of collecting the money, whereas the cost to operate tollbooths often amounted to a quarter of the tolls collected.

Americans are by and large not even aware that as much as one-third of the cost of gasoline at the pump is a charge (technically a fee rather than a tax) used to cover the costs of building, maintaining, and managing roads and transit systems. Over time, however, improved vehicle fuel economy and political reluctance to raise the price of gas have reduced the fiscal productivity of these fees. In the near future, hybrids, electric cars, and fuel cell-powered vehicles may make fuel taxes obsolete as a source of funds with which to finance the transportation system. This apparent problem could actually be the key to finally solving the problem of highway congestion.

Economists have long argued that the only way to completely solve the congestion problem is through congestion pricing. Economic theory says that the price of traveling should be higher at the places and times of day when demand for (and benefit from) using them is greatest. If it were to cost, for example, three times as much to pay a bridge toll at the period of highest congestion as it does in the middle of the night, some travelers would surely be more likely to use public transit, form carpools, use less crowded alternate routes, or reschedule less essential trips at off-peak hours. It is theoretically possible to eliminate congestion through pricing, because in principle the price can ultimately be raised to a level that is high enough to clear the traffic jam. There are now a dozen or more travel corridors throughout the world where variable pricing for travel is in use, including a small handful in the United States. Congestion pricing has been successfully used in Singapore for more than 25 years, and London is planning to implement such a system early in 2003.

Although transportation experts have written about congestion pricing for decades, one of the major obstacles to its implementation has long been the technical difficulty of collecting tolls: Building toll plazas and varying the charges with time of day and class of vehicle are complex, expensive, and politically problematic tasks. But the recent advances in IT now make congestion pricing much more technically feasible. Small inexpensive transponders, already in use in millions of vehicles to pay tolls, enable each motorist to be charged a different fee to use each segment of road at a particular time of day. The charges can appear on monthly credit card bills. I can envision a future in which the familiar "gasoline tax" is eliminated, especially because gasoline itself may have a limited future as a source of power in transportation. Instead, motorists would be charged more directly for the use of roadways through simple applications of IT.

We now have the technical capacity to integrate into one system the mechanisms for financing our highway system and controlling congestion. Charging more than we now do for the use of the busiest roads at the busiest times of day, and quite a bit less than we now do at other times, would be the fairest and most efficient way to raise the funds needed for operating and expanding the capacity of the transportation system. At the same time, we would use the charges to meter the use of the system to control congestion. Some argue that the accounting system needed for congestion pricing will be an invasion of privacy, but it is possible to prevent this by using numbered accounts. Others argue that congestion pricing discriminates against the poor. Yet the current system of transportation finance is not at all neutral with respect to income, and a system of direct charges for actual benefits gained from using the system is inherently fairer than a complex system of cross subsidies. For many trips, the proposed approach would provide for a lowering of trip costs in comparison with the current means of pricing travel. And it would surely be possible to offer lifeline rates to the poor.

Personal mobility and the transportation system will be deeply affected by IT during the coming decades. Many applications of IT to traffic congestion relief will be the product of innovations by private firms. Within just a few years, for example, and without government intervention, we will be reserving our parking spaces electronically as we approach airports and shopping centers, rather than cruising for an available vacant space.

Using history as a guide, it would seem that we have the technical means at hand with which to finally solve the congestion problem. Thus, the most significant determinants of the future use of IT for traffic control will be political rather than technical. Based on the history reviewed here, I believe that in approaching the future, the goal of policymakers should not be to eliminate traffic congestion but rather to try to strike a new balance between growth, congestion, and the political acceptability of the measures by which we can eliminate that congestion.

Recommended reading

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