Dynamic road pricing is the only way to cut congestion

Track vehicles in real time to ease traffic with demand-driven charges, urge Peter Cramton, R. Richard Geddes and Axel Ockenfels.

*Nature*, forthcoming, August 2018

Traffic congestion costs us time, money and health. In 2016, the average US driver spent 42 hours in congested traffic during peak hours; Los Angelenos spent more than 4 days of their lives that way (104 hours)\(^1\). New Yorkers walk as fast as vehicles crawl along streets in central Manhattan (7.6 km/h)\(^2\). And it is getting worse, not better, as the chart shows for the top-5 most congested cities.


Being stuck in traffic is frustrating and stressful. Jammed, cars can burn up to 80% more fuel\(^3\). This leads to more pollution and CO2 emissions and increases the incidence of heart attacks, strokes, asthma and poor infant health\(^4\), 5 among city residents.

The global economic damage exceeds $1 trillion each year. And these costs are rising as the world’s population grows and urbanizes. The five most congested countries are Thailand, Indonesia, Colombia, Venezuela and the United States\(^6\).

The habitual response is to call for more roads. But that doesn’t diminish traffic\(^7\). Instead more drivers move in. Nor will artificial-intelligence systems, ride-hailing services and autonomous cars ease the gridlock. Navigation systems like Google Maps and Waze attract more drivers to certain routes and can spread congestion to formerly quiet neighbourhoods and side streets. Uber and Lyft have increased traffic, as people make more car journeys. One survey of the Institute of Transportation Studies at UC Davis found, for instance, that around half of such trips would have not been made at all without ride-hailing, or would have used walking, biking or transit instead\(^8\). Self-driving cars reduce accidents and use roads and fuel efficiently. But those gains may be swamped by an increased desire for cheap and easy transport\(^9\).

We believe the answer lies in dynamic road pricing. Cars can now be tracked to within a few centimeters. This makes it feasible to measure and price road use in real time according to demand. If the price was set right, enough car drivers would choose to drive at a different time or via a different route or mode to eliminate congestion. Limited road space would be managed, like airfares, electricity, hotel rooms and train journeys. Uber manages demand and supply via surge pricing.

Overall, dynamic pricing does not drive motorists away. It can double the capacity of a congested route in peak times by avoiding traffic jams\(^10\)—just as managing fisheries can ease overfishing. Pollution and stress would decrease. The funds raised could be used for improving roads and public transit and to reduce fuel and other taxes.

Fixed pricing schemes have been tried in a limited way. Since 2015, 5,000 volunteers in Oregon have been trialing a tax on miles travelled. Germany, Austria and Switzerland and a dozen other countries follow a similar approach for trucks. Also, over the past decades, some cities in the US and elsewhere, including Singapore and Stockholm, have experimented with electronic charging for roads in their inner zones.

But such schemes do little for congestion, as prices often do not meaningfully change with demand and supply conditions\(^11\). A low price does little to mitigate congestion at peak times. A price fixed high to eliminate congestion at peak times would be as inefficient and unacceptable as having Thanksgiving airfares all year.

Instead policymakers and city managers need to track cars’ positions and adjust charges continuously depending on how busy the roads are.

What has been stopping them? There are three research gaps: technology needs refining to accurately measure cars’ road use at low cost; an equity and privacy framework needs hammering out;
and the implementation of network-wide, real-time road pricing needs better economic and computational modelling.

Free ride
Congestion is pervasive because motorists do not take account of the cost they impose on others. Prices should instead reflect the impact of motorists on each other. The system would operate similarly to an electricity market, rendering road space a commodity that can be bought and sold. An independent system operator would determine prices on each road segment to balance supply and demand, and thereby maximize the network’s value to users whilst keeping traffic flowing.

Prices would be levied on all roads in a region. Charges would vary with time and place every 10 minutes, say, according to traffic conditions. Prices would thus respond to lane closures, weather and sporting events as well as peak commuting times.

Research is needed to estimate market-clearing prices. Most of the time they would be near zero. On popular routes in Europe or the US an urban commute might be as high as $20—but the trip would take 30 minutes rather than, say, 45 to 90 minutes. The actual price would depend on how easily drivers can shift away to other times or modes.

Fees would be tailored to vehicle types. Lorries would pay more. An autonomous vehicle, driven using algorithms to promote free flow and possibly being coupled with other cars to decrease distance, uses less road capacity than a standard car and thus would pay less.

An advantage of dynamic pricing is that it includes the means with which to charge the full social cost of a vehicle’s use—both congestion and pollution. Prices could be varied to keep air-quality measures, such as particulate matter, within limits. Although this would not affect the number of cars at peak times, it would increase the price of dirty cars and thus make room for more clean cars on the roads. Electric cars, for instance, would pay less. This would be a cheaper and less intrusive way to fight pollution than banning diesel cars from town centres, which Germany is discussing.

Prices would be tracked with navigation apps, like Google Maps and Waze. Such tools would present both real-time information as well as forecasts of future prices, much as they do today for trip duration. Prices would be integrated into taxi and ride-hailing fares.

As in other markets, changes in pricing should be smooth to avoid ‘shocks’. And consumers need time to react. Advance purchase, such as buying a pass for the daily commute, would let consumers plan and avoid the risk of expensive real-time prices. This could be done automatically by the market operator as part of a default road-use plan. Service providers could compete for road use in forward markets and offer alternative plans to consumers in a retail market, similar to what is done today in many electricity markets.

Not everyone will need to respond to prices. Dynamic pricing would still reduce congestion even if most drivers do not react. Yet more motorists would adapt as they became familiar with the system. Some would commute earlier or later; others would cycle or take the train or bus. In the long-run, other adjustments, such as household relocation, more work flexibility, investments in public transit and smarter mobility technologies, are possible. We make similar trade-offs already, where the price of road use is delay.

There is much to learn about how best to manage a road network and target investments to improve it. Aggregate data about pricing and transport choices will need to be publicly available. This would allow researchers and innovators to glean insights about the effectiveness of different measures and to develop apps that help motorists.

Concerns
Equity Road-pricing schemes are often criticized as perpetuating inequality. Poorer people may be less able to afford to drive at popular times of day than richer ones. More research on such consequences is needed. But the problem may be smaller than people fear. Pricing can make everybody better off—even before the revenue from congestion pricing is redistributed. For instance, suppose the left lanes of a multi-lane highway are priced at peak times. Because this increases throughput on the left lanes, there are fewer motorists on the right lanes, so that everybody on the right lanes must be better off. Because motorists on the left lanes can choose to switch to the not-priced right lanes, but decided not to do so, they must be better off, too.

Even a poor worker, who absolutely must be at work at 8 am and who has no access to public transit or other travel options, and even if all lanes on all roads are priced, can be better off. Suppose the free-flow travel time is 30 minutes, the expectation is 60 minutes and the maximum is 90 minutes. Today the worker must depart at 6:30 am. With efficient pricing, if she cannot afford the price to depart at 7:30 am, she can continue to depart at 6:30 am at say zero cost but her travel time will be halved and fuel costs and pollution will be reduced. Moreover, the revenue from congestion pricing may be given back to motorists, for example through a lower road tax and fuel duty. It could also be invested to improve public transit.

The current situation, by contrast, is unfair. The use of roads being free is equivalent to governments subsidizing people who impose the biggest congestion and pollution costs on society. Roads are an essential service. The norm for other essential services like electricity, gas, water and communications is for consumers to pay for what they use. The fact that road use has not been priced is a fluke of history—until recently technology did not allow measurement and communication of pricing.

Skepticism Voters and politicians underestimate the benefits of pricing. Happily, public support builds once people experience such schemes. Before Stockholm introduced a €2 charge during peak hours for vehicles entering the inner city, two thirds of residents were against the plan. About two years later, the measure had reduced traffic by 20 percent, two thirds were in favour. After a similar scheme was trialed in Milan, eighty percent voted for extending charges to more roads and vehicle types. More research is needed on how to communicate the impact of road pricing to people who are not familiar with the benefits of a market solution.
Privacy  Road pricing raises concerns about personal data. Monitoring and enforcement require that the system operator know the location of each vehicle during use. Technically this is easy and cheap. Each vehicle would have a GPS device for this purpose. To mitigate privacy concerns, the transport market’s system operator would have strict rules that no individual data would be shared with others, as is standard in telecommunications and related industries. Modern cryptography even makes it possible for the system operator to run the market without any human having access to the individual data and still prove that the market rules are faithfully followed16. Research is needed on whether such advanced systems give motorists comfort, although the advent of navigation apps and ride-hailing suggests that users are happy to accept some loss of privacy for improved services.

Make it happen
The first step is to get devices in vehicles to measure road use. Singapore plans to install tracking and payment devices in all cars beginning in 2020. Oregon’s volunteers have on-board GPS equipment, enabling the state to levy a per-mile fee. These are excellent starting points.

Governments and city authorities could make incremental progress by establishing independent traffic system operators, who would be in charge of introducing time-and-location prices, based on estimates of demand and supply conditions, and of eventually adjusting prices in real time to keep demand below free-flow capacity.

Along the way researchers should study the impacts on motorists’ behavior, traffic conditions and pollution, the distribution of benefits and costs to motorists, and public responses. This will involve studies by behavioral scientists of individual perceptions and changes in driving behavior, studies by transport engineers, economists and computer scientists of aggregate traffic flows throughout the network, and studies by market designers to evaluate the effectiveness of the underlying incentive mechanisms.

Service providers, such as Google, Apple, Uber and Lyft, will have an incentive to develop and offer service plans that will let consumers simply express preferences and make informed decisions. Plans would be informed by past driving behavior. Consumers could purchase this expected usage on a forward basis to reduce real-time price risk—while still retaining the right to drive whenever and wherever they like. Service providers would also compete for users by providing useful apps that integrate the relevant price information in innovative ways.

Dynamic pricing is the only way forward for roads.

Peter Cramton, University of Cologne
R. Richard Geddes, Cornell University
Axel Ockenfels, University of Cologne