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# Digital-Age Transportation: The Future of Urban Mobility

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# Foreword

CHANGE is coming to transportation, whether we're ready for it or not. You can see it in automakers' focus on next-generation vehicles, in the arrival of services that help urbanites get around without owning a car, in the widening recognition that the "information everywhere" world will utterly disrupt the transportation status quo.

Every feature of the automobile, from its drive train to its communication with the world around it, is being rethought. "Smart infrastructure" projects are becoming commonplace. Sharing rides, bikes, and cars and other entrepreneurial business models are spreading, built on the recognition that empty car seats and idle vehicles form an immense "wasted asset." The ability to gather road and transit mobility data—from smartphones or dedicated transceivers—and push information back to users is changing everything from infrastructure planning to commuters' daily experience. The question of who pays for transportation—and how, and under what circumstances—has become ever more lively as the ability to track vehicles and to use electronic means of payment spread.

With all this in mind, Deloitte convened a session following the Transportation Research Board's 2012 annual meeting in Washington DC to consider the various permutations of what lies ahead. The session included a distinguished array of transportation visionaries, thinkers and doers (see appendix for a full list of participants). The wide-ranging and thought-provoking discussion produced intriguing points of agreement about the features and qualities that the coming transportation system might contain—or, at least, might contain if we take full advantage of the technological and organizational breakthroughs that are already apparent.

This report builds from that session. It consists of three parts: a brief discussion of the forces and innovations that underlie the quickening pace of change; the basic features of the coming system that are likely to shape the ways in which we get around; and three different—though often complementary—scenarios for what that system might look like. Its purpose is not to discern the details of the future. Instead, it recognizes that the future is fast approaching and that whatever it looks like, the regulatory, tax and funding structures we rely on today were built for a transportation system that is being superseded. To be sure, infrastructure itself is notoriously slow to evolve—whether it's expanding in the face of congestion or adapting to new transport capabilities—and on that front change is arriving more slowly.

But new ways of using existing infrastructure more efficiently are coming on the scene with great speed. They offer the chance to rethink our mobility challenges—and prepare for a transportation system undergirded by a very different set of features from the one we grew up with. The challenge that policymakers face—and that everyone from auto manufacturers to transit officials to for-profit and nonprofit entrepreneurs confront every day—is how to respond. This report is an effort to begin to lay out an answer.

**William D. Eggers**
Global Director, Public Sector Research
Senior Advisor, GovLab

# Executive summary

INCREDIBLE innovations within the transportation sector are being driven by the growing recognition that cars, once synonymous with freedom and ease of mobility, have become a victim of their own success. In cities around the world, congestion is undermining mobility, imposing huge costs not just on commuters or people out to run a simple errand but on society as a whole. According to the Texas Transportation Institute, the average American commuter spent 34 hours delayed in traffic in 2010, up from 14 hours in 1982. If things don't change, commuters can expect to spend more than 40 hours annually sitting in traffic by 2020.[1] All told, the annual cost of congestion in America alone now exceeds $100 billion.[2]

The problem that confronts transportation planners is that adding new infrastructure capacity to relieve congestion is notoriously slow and costly. Given the environmental issues to be explored, land to be acquired, permits obtained, people moved, and construction undertaken, it can take years, if not decades, to go from conception to delivery. Yet there are innovative new ways of making more efficient use of existing infrastructure already coming onto the scene.

With this in mind, Deloitte convened a distinguished array of transportation visionaries, thinkers and doers to consider the various permutations of what lies ahead. The wide-ranging and thought-provoking discussion produced intriguing points of agreement about the features and qualities that the coming transportation system might contain—or, at least, might contain if we take full advantage of the technological and organizational breakthroughs that are already apparent.

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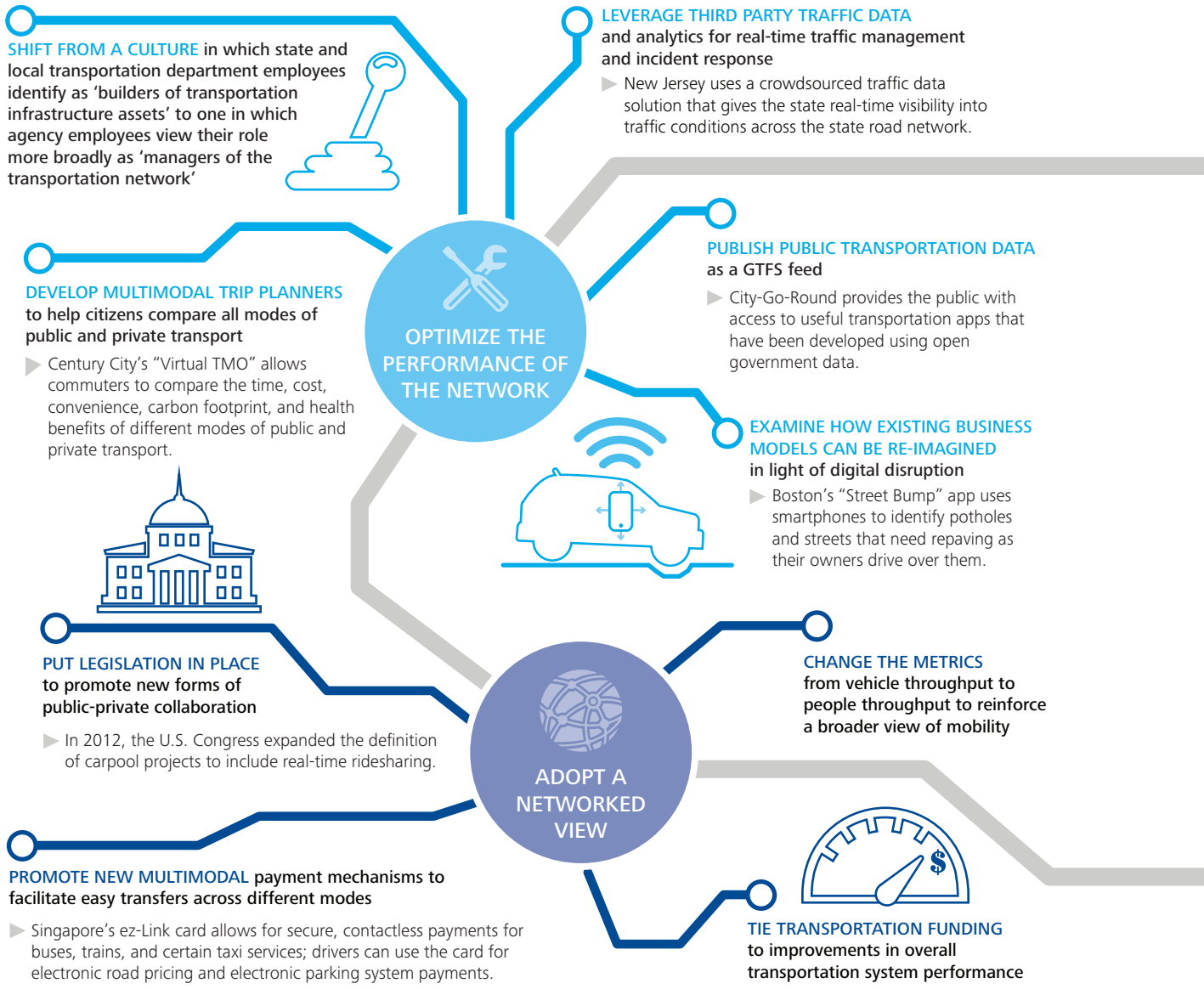
The arrival of the "information everywhere" world has opened up new opportunities to make the existing transportation network far more efficient and user friendly. Coupled with new transportation capacity, the changes spurred by technological change and the innovations it inspires will help preserve freedom of mobility in the 21st century.

Services like real-time ridesharing and car sharing, for instance, are helping urbanites get around without owning a car—and are making the private vehicle a de facto extension of the public transportation system. New apps are allowing commuters to compare the time, cost, convenience, carbon footprint and health benefits across all modes of public and private transport, broadening their range of choices and allowing for on-the-fly decision making that takes into account real-time conditions. For their part, automakers are focused on next-generation "connected vehicles" that can access, consume, create and share information with other vehicles and surrounding infrastructure in real time—improving traffic flow and safety. And dynamic pricing mechanisms for roads, parking spaces and shared-use assets are helping balance supply and demand, much the same way the airline and hotel industries have been pricing seats and rooms for years.

The result of these innovations—and of the ecosystem of creative players that have been drawn to transportation, from information technology companies to ridesharing pioneers

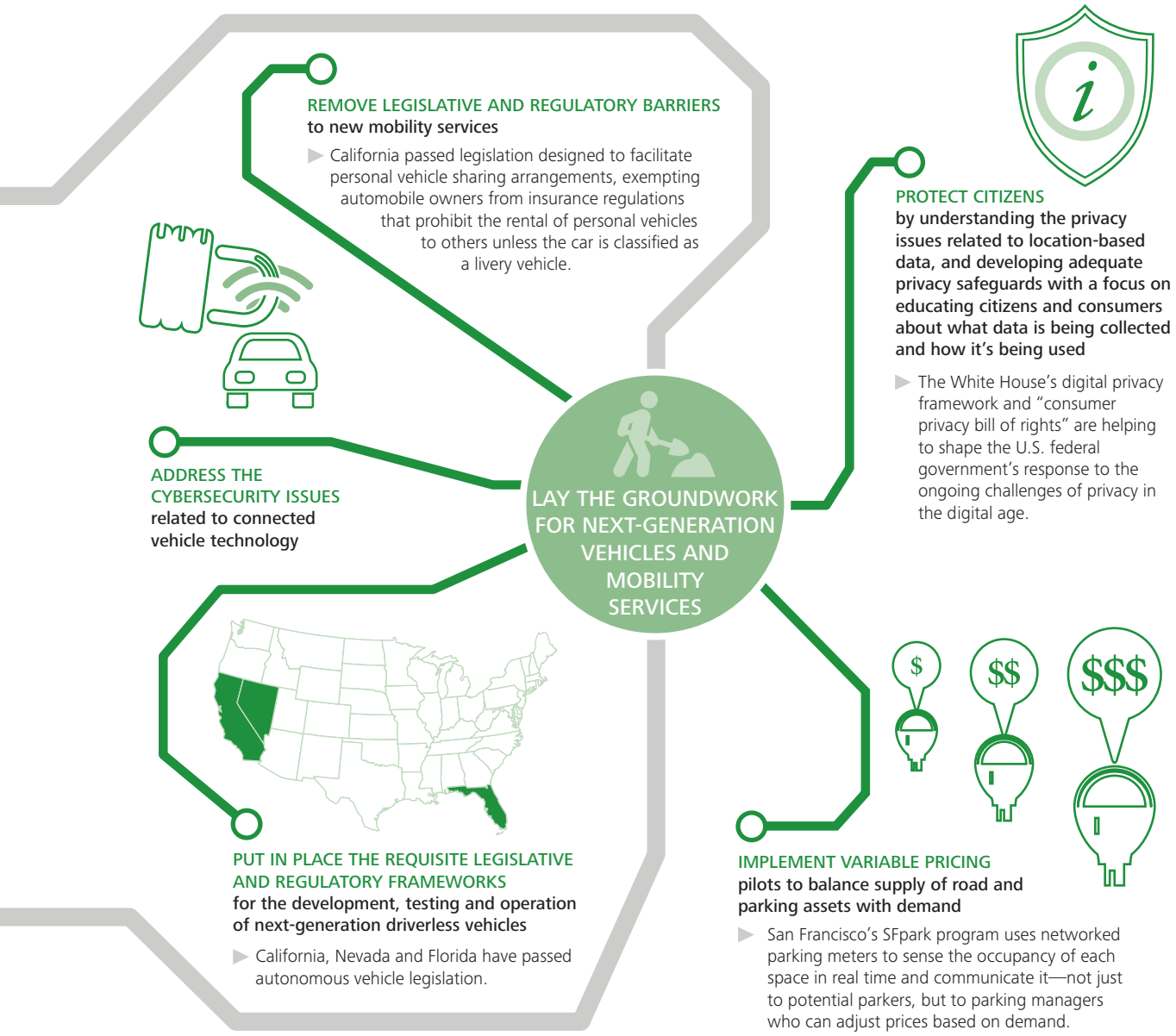
**Figure 1. Preparing for the future urban transport system: A roadmap for public transportation officials**



to app makers—is that the mobility field will look very different going forward. It will be:

- **Massively networked**, with ubiquitous connectivity throughout the system
- **Dynamically priced**, so as to balance supply and demand
- **User centered**, taking into account users' needs, priorities, data flows, and dynamic responses to conditions
- **Integrated**, so that users can move easily from point A to point B, regardless of mode, service provider, or time of day
- **Reliant on new models of private-public collaboration**, which take advantage of the increasingly diverse ecosystem of public, private, and nonprofit entities that are working to meet the mobility challenges of the 21st century

To take advantage of these innovations, policymakers must start laying the groundwork for a digital-age transportation system (see figure 1).



# Introduction

YOU might begin by asking the question, "Who says that the current transportation system is being superseded by a new one?" For most people in the United States, this doesn't seem to be the case. Americans, for example, take 1.1 billion trips a day, according to the federal Bureau of Transportation Statistics, and the vast majority of them are on roads and highways: 87 percent of trips are in personal vehicles (cars or light trucks) unless you're just talking about commuters, in which case the figure rises to 91 percent.[3] There's nothing new there.

Nor does it look like the automobile is going to be replaced anytime in the foreseeable future as the "personal vehicle" of choice. As Chris Borroni-Bird, director of Advanced Technology Vehicle Concepts at General Motors (GM), puts it, "No other means of transportation offers the same valued combination of safety, comfort, convenience, utility and choice of route and schedule."[4] Americans go every which way every day, and cars help us get where we want to go when we want to go. Whether because of personal choice or community design, the vast majority of Americans consider everything else—at least for their daily trips—a second-best option. Between 1990 and 2009, personal vehicle use remained the transportation mode of choice, accounting for 83.4 percent of trips in 2009.[5]

Yet this does not mean that the future is secure for gasoline-powered automobiles that can carry at least five people and a trunkful of luggage but usually don't. There are powerful forces at work changing the average trip taker's—and car buyer's—calculus.

For one thing, the world as a whole is urbanizing: the United Nations expects that 60 percent of the global population will live in urban areas by 2030, and residential density generally means reduced vehicle ownership. In the United States, nearly 85 percent of Americans are expected to live in urban areas by 2020, with over a quarter of them living in areas with more than five million people.[6] Failure to create smaller, cleaner and smarter vehicles for dense cities, Borroni-Bird observes, "may result in declining automobile ownership as cities may take further actions to promote bicycle and public transport usage and to deter usage of conventional automobiles."[7]

There is a robust debate among thinkers focused on the urban future about whether the growth of central cities like Atlanta, Chicago, and San Francisco represents a permanent shift away from the auto-dependent suburb or reflects a mere subset of relatively affluent, college-educated elites who are separating themselves from the middle-class majority that prefers the suburbs. To at least one venture

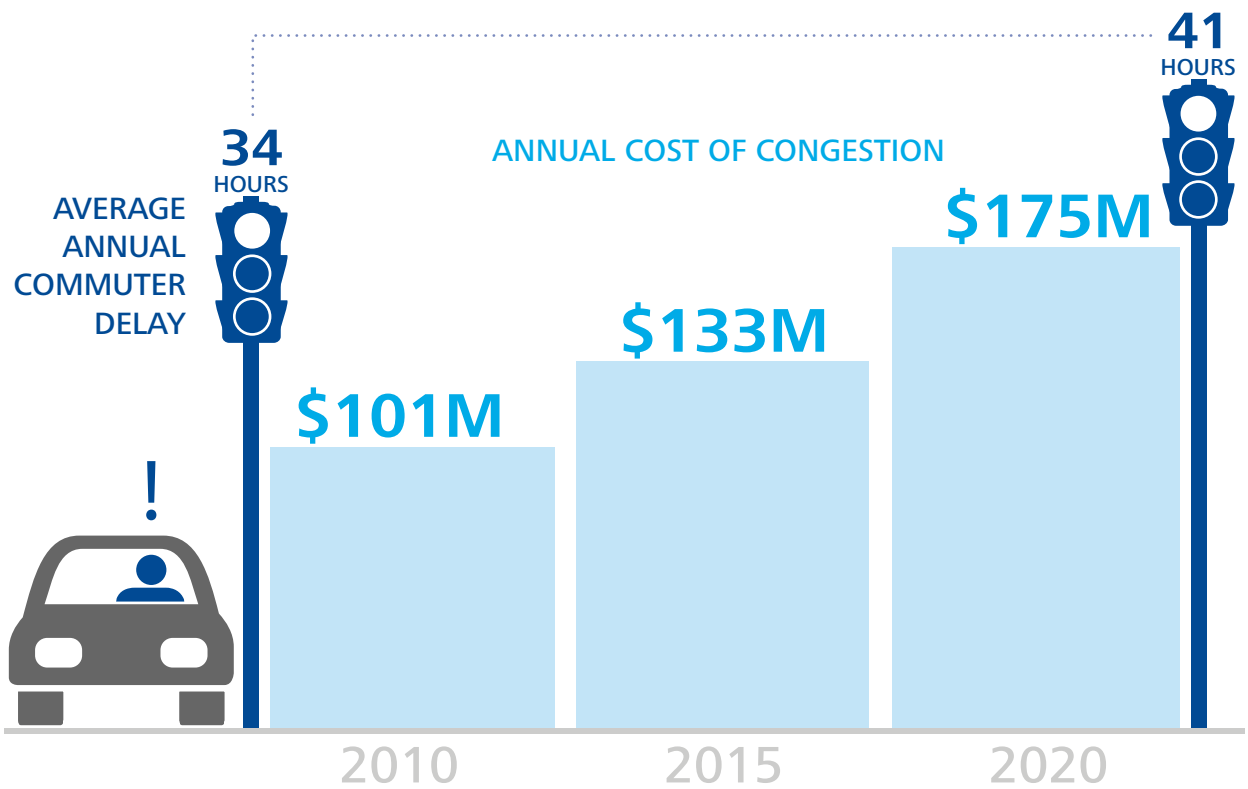
capitalist betting on the future, the trends favor density. "Transportation is becoming an increasingly wasteful and unsatisfactory experience," says Ryan Popple, a partner at the venture capital firm of Kleiner Perkins Caufield & Byers (KPCB). "If you look at where young people want to live when they're coming out of school, where a lot of businesses are setting up and where real estate has maintained value, it's around more efficient lifestyles. Time is more valuable. People want to live closer to where they work."[8]

This may be because, whether within cities or in the expansive suburban ring around them, the United States, as well as other countries, has shown little ability to get a handle on traffic congestion. According to the Texas Transportation Institute, the average American commuter spent 34 hours delayed in traffic in 2010, up from 14 hours in 1982. Congestion is becoming a bigger problem outside of 'rush hour,' with about 40 percent of the delay occurring in the mid-day and overnight hours, creating an increasingly serious problem for businesses that rely on efficient production and deliveries.[9] The annual cost of congestion now exceeds $100 billion.[10] And this was all in the midst of a recession; the problem will only get worse once the economy is working at full steam (see figure 2). Efforts to improve matters by building or widening roads can take years to get into the funding pipeline, much less complete.

## New transportation landscape

WHAT is most striking about the mobility world these days, however, is not that people are being forced to change their behavior, but that the enticements to change are growing exponentially. New possibilities and opportunities are transforming the transportation landscape (see figure 3). These range from the technological (the rise of social networking and peer-to-peer networking, the spread of smartphones, and the development

**Figure 2. The cost of congestion in the United States**




Source: *2011 Urban Mobility Report,* Texas Transportation Institute

> "If we do nothing, the sheer number of people and cars in urban areas will mean global gridlock. Now is the time for all of us to be looking at vehicles the same way we look at smart phones, laptops and tablets: as pieces of a much bigger, richer network."
>
> — **Bill Ford**, executive chairman, Ford Motor Company

of connected vehicle technology) to the cultural (growing willingness—especially among younger Americans but by no means limited to them—to engage in so-called "collaborative consumption") to the entrepreneurial (the recognition that governments alone are unable to solve mobility challenges opens huge opportunities for business).

These changes are promoting new modes of transport, from next-generation autonomous, connected vehicles under development, to an array of new services: renting fractions of a Zipcar's time; using Avego to share rides with strangers or GoLoco to share them with friends; using peer-to-peer car sharing services like RelayRides or Getaround, and new, on-demand car services like Uber.

## Digital-age transportation

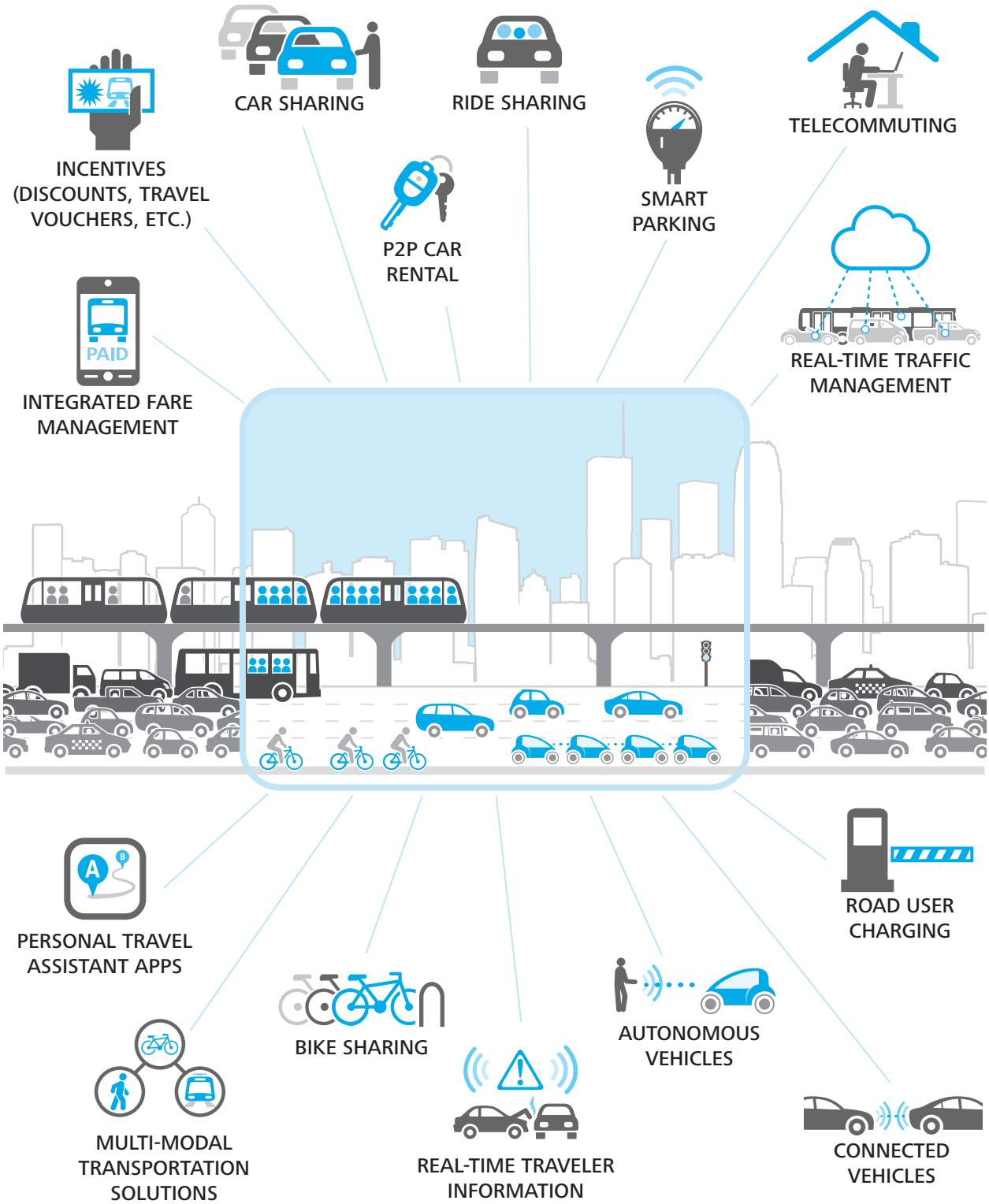
THE most revolutionary changes are coming from the encounter of information technology (IT) with... well, you name it. According to Thilo Koslowski, who leads the automotive practice at the Gartner Group, "Similar to the way telephones have evolved into smartphones, over the next 10 years automobiles will rapidly become 'connected vehicles' that access, consume, and create information and share it with drivers, passengers, public infrastructure, and machines including other cars."[11]

San Francisco's SFpark program has installed sensors in the street below thousands of parking spaces and in garages, collects the information, and makes it available to a Website and app allowing drivers to get real-time data about open spaces. Waze relies on its users to crowdsource road conditions and show real-time information about speed, traffic jams, directions, and even the location of speed traps.

The arrival of "big data" is helping traffic control centers respond more quickly to accidents and backups, while helping individual travelers navigate their moment-by-moment decisions. According to David Hornik, a general partner at venture capital firm August Capital, "Everything is a big-data problem right now. [T]he biggest change is that every device, every vehicle, everybody is manufacturing huge amounts of information."[12] Cities are beginning to use the digital exhaust generated from these devices in powerful new ways. Boston, for example, developed an app called Street Bump that uses smartphones to identify

**Figure 3. Battling urban gridlock**

There's no silver bullet solution to the problem of gridlock—next generation urban transport systems will connect transportation modes, services, and technologies together in innovative new ways that pragmatically address a seemingly intractable problem.



The challenge, then, is to harness the extraordinary innovation taking place to make far more efficient use of the existing transportation system.

potholes and streets that need repaving as their owners drive over them.

There is no aspect of travel that is not being transformed by IT. Route planning, finding one's way while in the car or on foot, collecting fares or tolls, congestion and road pricing, traffic management, deciding among different transportation options for a given trip, reducing trips through telecommuting—all are evolving at dizzying speed.

Many of the innovations affecting transportation are geared toward giving individuals greater choice in how to get around. GM's prototype autonomous electric vehicle, the EN-V, isn't likely to become the only vehicle people own, Borroni-Bird said, but "maybe you have a larger vehicle and then for a large fraction of your trips—say for driving around the city center—you own or share a second, small vehicle."[13] Ridesharing services, mapping services, bus and light rail arrival apps, parking space sensors are all making getting around far easier than ever before.

This does not, however, mean that we've figured out how to use these developments to make travel uniformly more enjoyable or convenient. "Despite the proliferation of innovation across [the transportation sector], holistic solutions are just not coming together in a way that works for the user door to door," notes Susan Zielinski, managing director of the Sustainable Mobility & Accessibility Research & Transformation (SMART) program at the University of Michigan.[14]

The challenge, then, is to harness the extraordinary innovation taking place to make far more efficient use of the existing transportation system. Just what that will look like is uncertain. But, it is certain to have some basic features.

# Features of digital-age transportation systems

GIVEN the pace of innovation and the sheer complexity of transportation systems, it is foolish to venture hard-and-fast predictions about exactly what these systems will look like in coming years. But several key themes are emerging—not so much predictions as extrapolations from current developments.

To take advantage of emerging technologies, broader social shifts and new business models, a reenvisioned urban transportation system is likely to have five key features (see figure 4).

## Massively networked

INFORMATION is as much a part of the basic infrastructure of transportation as roads and rails are. Travelers need to know where they are and how to get where they want to go, whether on foot, by bike, by car, or by transit. Traffic managers and drivers want up-to-the minute data on accidents, weather conditions, and traffic flows. Transit passengers want to know when the next bus or train will arrive and how to get where they're going once they're dropped at their stop. Ridesharers want to know when the next possible ride is coming along. Planners and financial officers need to know how much it costs to operate a given stretch of road or transit route at any given time of day.

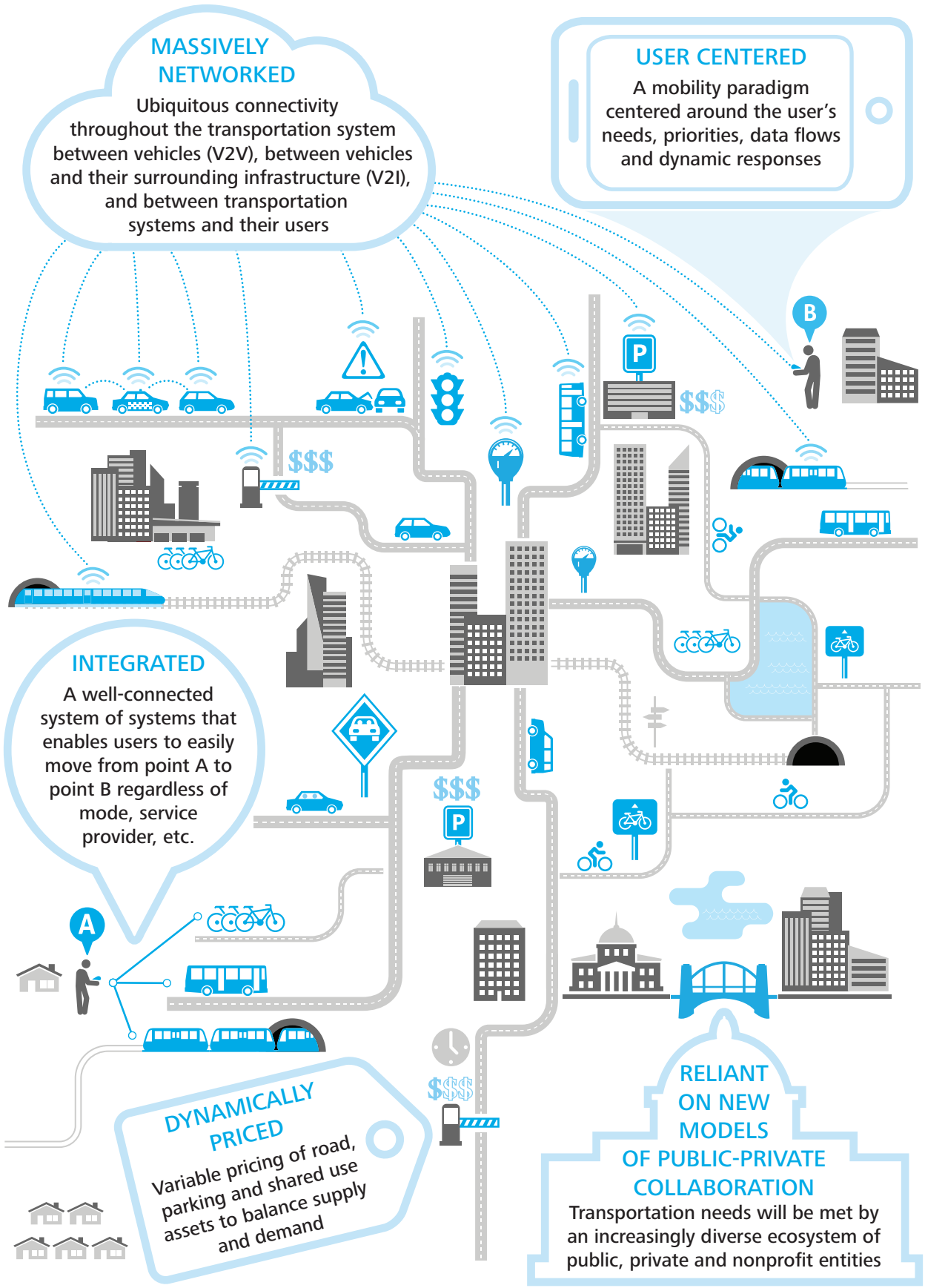
In a real sense, information undergirds mobility. So it shouldn't be a surprise that the movement of networked IT into everyday objects—the so-called "Internet of Things"—creates vast possibilities for reimagining mobility.

### Networked cars

The Internet of Things is already transforming automobiles.[15] Though automakers have focused much of their attention on connecting cars to existing voice and data networks, the real payoffs will come as vehicles become capable of sensing each other, and their surroundings and of communicating with their drivers, each other and the infrastructure around them.

The true value of these technological advances lies not so much in their technology, however, as in their being networked. As Paul Didier, a manufacturing solutions architect at Cisco, puts it, "The value of devices (and the

**Figure 4. Key features of digital-age transportation systems**



capabilities they represent) increases exponentially when they can communicate with other devices and systems." Sensing an obstacle in the road, he points out, does no good without letting the driver know the obstacle is there or signaling the brakes or steering system to take action. Even better would be alerting other cars and transportation authorities that there's a problem. "I like to think of it as on-machine, between machines and machine-to-cloud (or data center) communication," Didier says.[16]

The benefits of linking cars' information—speed, direction, sudden braking—and essentially creating safer, more efficient, and more orderly traffic on the road are significant. As executive chairman of Ford Motor Company Bill Ford describes it, "It will be the closest thing the industry has ever developed to autopilot." Moreover, he argues, "such ad hoc vehicle networks could be integrated with other transportation networks, from pedestrian cross-walk systems to connected bicycles, making your car a single node in a giant grid of multi-modal transit intelligence."[17] Ford is among the automakers developing "adaptive cruise control" (ACC) systems, which automatically keep a set distance between a car and the vehicle in front of it. Simulations have found that certain traffic jams could be prevented by harmonizing speeds and smoothing driver reactions if 20 percent of vehicles on a highway were equipped with advanced ACC.[18]

More advanced communication capabilities are not far off. The US Department of Transportation (USDOT) has been working for close to a decade to seed V2V technology development with an eye toward improving safety—trying to define standards, work with automakers and IT firms to craft pilot programs, and deploy enough models to determine whether the technology works as hoped.[19] In August 2012, the USDOT launched the largest road test of connected vehicle crash avoidance technology to date. The National Highway Traffic Safety Administration will use the data collected from the first-of-its-kind test to assess if and when connected vehicle safety technology should be incorporated into the fleet.[20]

## Benefits of a smart transportation network

While automotive advances are reshaping the driving experience—ultimately, perhaps, turning drivers into de facto passengers—opportunities for transformation are arriving on the heels of the explosion of mobile technology and especially the rapid spread of smartphones. In a sense, formerly clear lines—between humans and machines, between ownership and nonownership, between goods and services—blur when information generated and used interchangeably by people and machines becomes ubiquitous.

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New transport models made possible by mobile phones, apps, and smart card technology, like car sharing, are taking a good that sits idle most of the time and turning it into something else.

Social media, in particular, creates all sorts of new possibilities. Susan Grant-Muller, director of research at the Institute for Transport Studies at the University of Leeds, argues that social media turns travelers both into consumers of information and a particularly useful form of sensor. "With mobile technology," she says, "it's possible for people to build up profiles of our transport behavior."[21]

New transport models made possible by mobile phones, apps, and smart card technology, like car sharing, are taking a good that sits idle most of the time and turning it into something else. "You have to think of [the vehicle] as a service now," said Adam Greenfield, managing director of the boutique design firm Urbanscale. "It is not so much a product in space and time but... a proposition that is accessible by multiple people, at different rates and different times. Eight, ten or twelve people can use that car."[22]

A massively networked system is already creating new ways of maximizing the potential of existing vehicles and infrastructure. This system is the linchpin of the entire "collaborative consumption" movement, allowing Zipcar, Getaround, Avego, and their counterparts in other countries to operate. "It's taking the weight of the $8,000 a year we all spend on our cars and sharing the costs among the people actually using them," says Avego managing director Sean O'Sullivan. "All these approaches are enabled by cheap, connected computers."

The models enabled by a networked system have great potential to deliver concrete financial benefits to society. By Deloitte's calculations, doubling the number of rideshare commuters (which would simply bring the percentage back up to 1970 levels) and shifting 10 percent of lone drivers to car sharing, could take nearly 16 million lone drivers off the road and save 757 million hours annually wasted in congestion. Carbon dioxide emissions would decline by roughly 2 percent in the United States alone. If the government tried to match these savings by building new public transit, the bill would run over $27 billion.[23]

## Dynamically priced

TODAY'S consumers do not bear the true costs of mobility, and the consequences of this are profound. As Cisco's Andreas Mai and Dirk Schlesinger observe:

- *We consume as much as we can because we perceive [road and traffic services] as "free."*
- *Because the true cost of the inflated demand is not recovered, the public service provider is underfunded.*
- *The resulting demand/supply imbalance cripples road infrastructure and significantly inflates the societal cost of mobility.*[24]

In its final report, the National Surface Transportation Infrastructure Financing Commission wrote, "All too often the prices paid by transportation system users are markedly less than the costs of providing the transportation services they use (including pavement repair)—much less the total social costs (including traffic congestion and pollution)."[25] In 2006, the report noted, user fees, including the gas tax, covered just 58 percent of highway funding, while farebox revenues provided just 35 percent of transit funding.[26]

With the rise of mobile technology and the Internet of Things, new dynamic pricing mechanisms that would have been inconceivable just a decade ago are now possible—enabling pricing based on such variables as time of day, road congestion, speed, occupancy, and even fuel efficiency and carbon emissions. By pricing different stretches of road or transit routes differently—based on up-to-the-minute conditions—cities can divert drivers and passengers to cheaper routes, as well as collect payment for what it actually costs to maintain a roadway or system.

In their book *Reinventing the Automobile*, William Mitchell, Chris Borroni-Bird and Lawrence Burns lay out the rationale for dynamic pricing: "Clear, rational, responsive pricing of trips provides a sound basis for both individual decision making and the optimization of overall system behavior for society as a whole. From a driver's perspective, it makes the total costs of trips accurately and clearly evident and enables well-informed choices among alternative trip departure times, routes, and destinations. From an urban systems perspective, it enables the effective management by price of available urban space and infrastructure while providing tools for achieving social equity and other policy objectives."[27]

The only way to do this, though, is to use emerging technology. Existing systems, they point out, adjust prices only at relatively long intervals and tend to cover only portions of a road network, thus displacing traffic to untolled roads. The goal, they write, "is to make congestion pricing systems citywide, fine-grained in their spatial resolution, and frequent in their adjustment of prices as congestion levels fluctuate."[28]

### Parking lessons

While dynamic pricing may still be in the future when it comes to driving, it's fast arriving for parking. Donald Shoup, an urban planning professor at University of California, Los Angeles, and the author of *The High Cost of Free Parking*, notes that not only do parking space regulations waste valuable urban land, but at any given moment, an average of 30 percent of the cars in congested downtown traffic are actually just looking for a place to park. "Free curb parking in a congested city gives a small, temporary benefit to a few drivers who happen to be lucky on a particular day, but it imposes large social costs on everyone else every day."[29]

For that reason, San Francisco is garnering great attention for its SFpark program, which has installed networked meters that can sense the occupancy of each space in real time and communicate it—not just to potential parkers, but to parking managers who can adjust prices based on the overall occupancy of a given block and aim to set a price that keeps one or two spaces free on each block. As Shoup writes, "SFpark embodies two important ideas. The first is that you cannot set the right price for curb parking without observing the occupancy.... The second is that small changes in parking prices and location choices can lead to big improvements in transportation efficiency."[30]

## User centered

THERE'S a reason the automobile is as popular as it is: It puts the user's needs at the center of a trip. You don't have to worry about a transit agency's schedules, whether you'll get a seat, whether it's raining or whether (in most cases) you can actually get to your destination. For that comfort and convenience, most Americans are willing to put up with the

The technological developments of the past couple of decades offer the prospect of a very different paradigm—mobility centered around the user.

inconveniences of traffic, finding parking, and the cost of gasoline.

There's another reason the car is so popular: It gives its user the widest-seeming set of options within the existing transportation system. At the moment, transport solutions are designed, developed, and controlled by providers and government agencies, and users slot themselves into that system. Where roads go, when trains run, where metro stops are located, which bus routes get the most frequent service—all impose constraints on the choices that users can make.

## More choices

The technological developments of the past couple of decades offer the prospect of a very different paradigm—mobility centered around the user. According to Buzzcar and Zipcar founder Robin Chase, "The combination of the Internet, which holds the world's knowledge; wireless, which gives us ubiquitous and low-cost access to it; and smartphones that make our interfaces portable and cheap, is transformational."[31]

Some transportation experts take a dim view of forcing users to adapt to the system's needs, rather than the other way around. As Marcus Bowman, founder of 3G Mobility puts it, "We should not modify people's behavior–the system should be able to accommodate the person. It needs to provide choices for the user." Others point out that one purpose of dynamic pricing is, in fact, to encourage users to modify their behavior: to walk or take transit when streets are congested, to park farther away from their destination at times when the block it's on is heavily used, or to wait an extra half hour before using rail transit.

Still, the overall system needs to provide choices that not only permit everything today's system permits, but that improve on it, whether it's a trip to the grocery store or to visit family or the daily commute. It needs to meet the needs of an aging population (it's hard to imagine the baby boom generation settling for being shut-ins or relying on the occasional paratransit ride), and of the disabled, of the regular commuter traveling a fixed route at the same time every day, of people running errands or rushing to a last-minute meeting, of pedestrians and bicyclists, of people who like owning their own vehicles, and of people who wouldn't be caught dead owning a car. In other words, it needs to answer to the world as it is. Travel behavior is dynamic and multifaceted, and the provision of more choices that actually entice people—rather than forcing them into

one mode or another—ought to lead to a more balanced, optimally used system overall.

"We must have a wide range of options in transportation," says Chase, "because people go from being 0 years old to being 90; they have different amounts of money, different amounts of ability to move, different amounts of independence, different amounts of income. How you move a 2-year-old is not how you move a 28-year-old, or a 48-year-old with children. ... To answer transportation issues we really, truly do need to have a variety of possibilities."[32]

### Real-time information and open data

Making a dynamic, multi-modal transportation system possible requires a fundamental change in who controls information and how it is shared. Without comprehensive information at their fingertips—whether it involves public or private services—transportation users can't make the best choices for travel. So to understand their choices and make quick decisions, users need access to freely shared, up-to-the-minute information.

On the roads, this is precisely what companies such as INRIX and TomTom aim to provide: real-time information for subscribers about current traffic conditions. And within cities, the "open data" movement is pressing public transit agencies to make their data freely available in the widely used General Transit Feed Specification (GTFS) format so that developers can build route, schedule, and other applications on top of it. Success has been mixed, as City-Go-Round, a website that provides access to "useful" transit apps, makes clear: Only 220 out of 844 transit agencies in the United States have open data, though more are being added regularly.[33] The goal is clear: Transportation data needs to be provided in an open format, up to the minute, and readily accessible to anyone who needs it.

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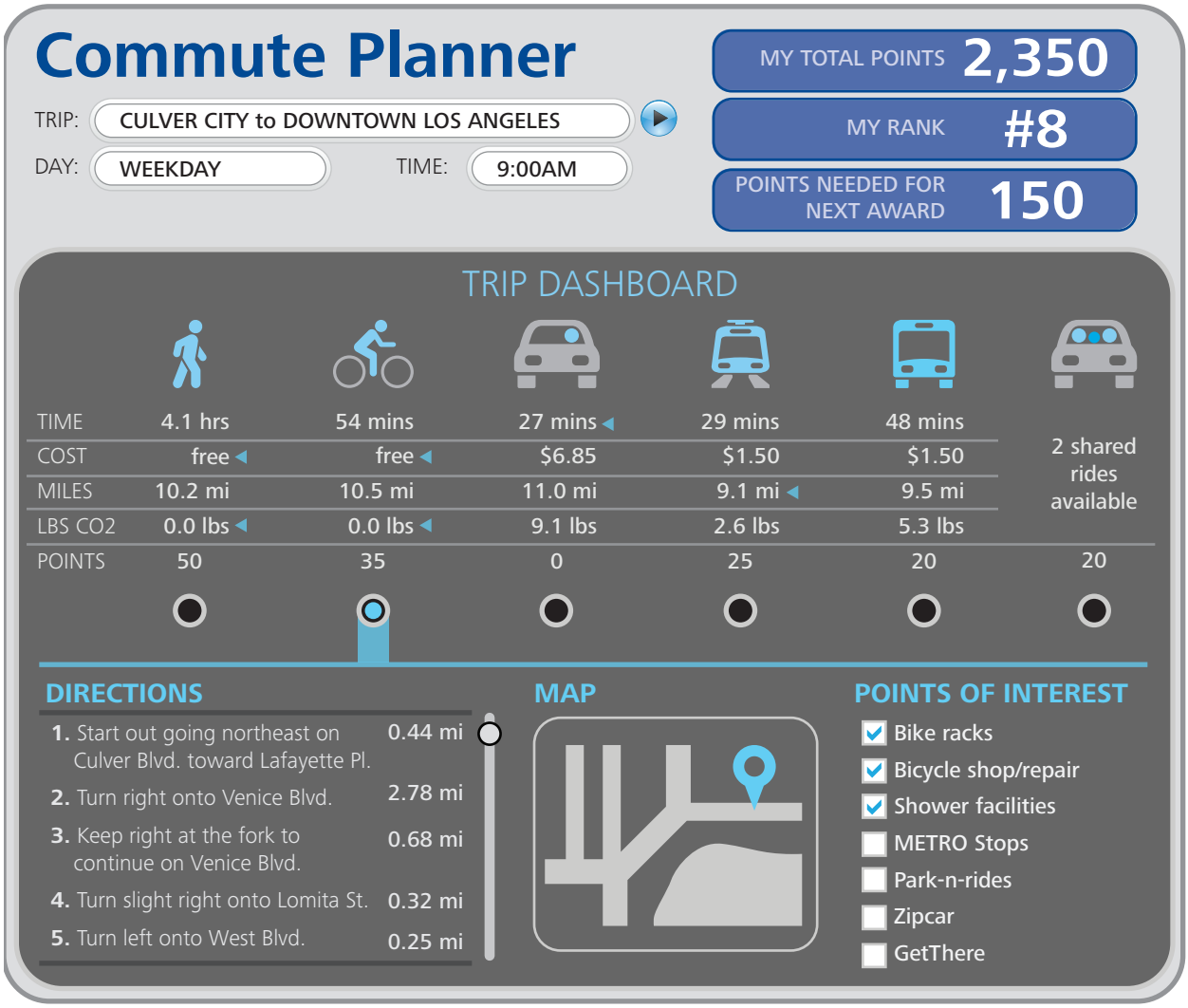
## Integrated

IF you live in an urban area, here's where you want the system to end up: You have got a mobile device, and it knows where you are because it's location aware. So you enter where you want to go and it gives you all your options, based on what's going on right now: it knows the best route, the existing traffic conditions, how much parking is available close by to where you're going, how the buses and trains are running, where the closest bike shares, Zipcar spots, and peer-to-peer car shares are located, and when someone in your ridesharing network is going to be coming by. And it can tell you what the best option is right now: Traffic is backed up, and there's a breakdown on the light rail line you would need, but there's a bike sharing station three blocks away from you, so right now that's your best bet (see figure 6). You walk over, wave your credit card or smartphone over a reader, and you're on your way.

It's a delightful prospect—and no longer as impossible as it might have seemed five years ago.

One vision of how to get there has been developed by RideAmigos Corp, which has developed the virtual Century City Transportation Management Organization (CCTMO) in Los Angeles. Its dashboard allows users to compare alternatives—transit, ridesharing, bicycling, walking—for cost, time, distance, and carbon dioxide output; tracks

**Figure 6. Illustrative multi-modal commuter dashboard**




commutes; provides options for buying transit passes; lists bike rack locations and shower facilities; matches carpools and vanpools within a user's company or throughout the community; and provides business listings, weather, traffic alerts, and so on.[34]

## Connected system of systems

The world is catching up to the notion that the centerpiece of a transportation network is the person or good that has to be moved, not the idiosyncratic needs of the organization that runs a particular mode of travel. Making movement as easy as possible means integrating a range of systems so that the transition from one system to the next is painless. According to SMART's Zielinski, "Transportation is not simply one mode that moves a person or a good from A to B. It is much more interesting and useful than that. It is a system, or rather a 'system of systems' connecting modes, services, technologies and designs according to the best option for the purpose."[35]

This is hardly far-fetched, given how ubiquitous this kind of connectivity has become in our lives. Take banking and retail, for example. As former IBM chairman and CEO Sam Palmisano, points out, "We take it for granted that we can transfer funds and make

payments among institutions. …We take it for granted that we can use the same payment and billing systems, regardless of store, website or industry. All these systems have standards and interfaces that permit information to flow."[36]

Transportation, he argues, isn't even close. The connections simply don't exist among vehicles and "pathways," government agencies, regulators, providers, and carriers, and to the goods and people being moved."[37]

## Total information awareness

Establishing a well-connected system of systems will take work. It means making sure that a number of capabilities are in place: Roadways, parking spaces, cars and transit vehicles are equipped with sensors. Ride share, car share and bike share systems know their assets' availability. Payment systems are integrated so that regardless of whether you're using a bicycle, taking a subway, or paying road tolls in three different states, you can do so electronically using just a single card or device. And the agencies—public or private—that run the various systems make their data available so that others can use that data to build the applications that make it possible for ordinary users to travel easily, fully aware of their options.

In other words, says Georgia Institute of Technology assistant engineering professor Kari Watkins, who helped create the Seattle-area transit app OneBusAway as a graduate student, "You need the underlying infrastructure where you're measuring all these things; you need agencies that are forward-thinking enough to share this data; and then you need folks who are innovative enough to figure out how to develop the applications that lay on top of each other, so that we can get a system where the focus really is on mobility itself and taking care of transportation customers."[38]

## Activating network effects requires system coordination

The development of discrete systems is only a first step; it is their integration and spread that will produce real benefits. As Stephen Ezell of the Information Technology and Innovation Foundation points out, "If a region or state makes all its roadways intelligent with real-time traffic data, such efforts do little good if motorists do not have telematics in their vehicles (or on mobile phones) to receive and act on that information." Similarly, a collection

> "Transportation is not simply one mode that moves a person or a good from A to B. It is much more interesting and useful than that. It is a system, or rather a 'system of systems' connecting modes, services, technologies and designs according to the best option for the purpose."
>
> — **Susan Zielinski**, managing director, SMART, University of Michigan

> "We're focused on vehicle throughput, but we have to care about *people* throughput. We don't look at this big mobility picture and how can we get people around the entire community in a better way."
>
> — **Kari Watkins**, assistant professor, Georgia Institute of Technology

of independent electronic toll collection systems is far less efficient or convenient for travelers than one that covers jurisdictions all across the country. "Thus," Ezell says, "many intelligent transportation systems are subject to network effect and scale challenges, thus requiring extensive system coordination."[39]

The problem is not just that such coordination and integration don't yet exist but also that it is unclear whether the organizations currently overseeing the system of transportation systems in the United States or other countries know how to make it happen. "We're focused on vehicle throughput, but we have to care about *people* throughput," says Watkins. "We don't look at this big mobility picture and how can we get people around the entire community in a better way."[40]

## Reliant on new models of public-private collaboration

THE hardest question when looking at the future of transportation, of course, is how change is going to be organized and paid for. Interestingly, you can see the outlines of an answer in the status quo.

The assumption about most roads, bridges, and other auto-related infrastructure in the United States, has always been that they are a public good, and therefore should be funded partially by users through gasoline taxes and tolls, and partially through public subsidies ultimately paid by the general tax base. Financing has been largely provided by the private sector in the bond markets. But in recent years, as the gap between available public funds and infrastructure needs has grown ever wider, another model has taken hold: the public-private partnership, or PPP, which involves the use of private sector equity and risk sharing. This has been the force behind the creation of high-occupancy toll lanes near Fort Lauderdale, Florida; the new management of the Indiana Toll Road (a deal in which the Cintra-Macquarie venture is paying the state $3.8 billion to lease the road over 75 years); and the creation of HOT lanes in the DC suburbs of northern Virginia.

If a new transportation system is going to come into being, government will neither be

able to fully fund it nor take primary responsibility for it at current taxing or toll levels; it is having enough trouble just keeping up with the status quo. Moreover, the sheer complexity of a transportation system that works for everyone—unlike the current system—argues that many players will have to be involved.

One way that government can prime the private sector's creative pump is through challenges that arrive at transportation solutions without calling for heavy public spending on research and development. The USDOT has a handful of such challenges, though only one—asking for innovative uses for DSRC wireless technology—has really tackled a core mobility issue.[41]

## The new transportation ecosystem

A transportation system that works for everyone must be complex and fine-grained at multiple levels—which means that there are a multitude of potential niches for private-sector involvement. In almost every aspect of transportation—from electrification of cars and up-to-the-minute information for drivers to ways of reducing the "wasted capacity" of empty seats and improving the experience of public transit passengers—new, private efforts are pouring into the field. There is a sense of great entrepreneurial possibility in addressing the myriad problems created by the current tilt toward the single-occupancy vehicle model.

Take just one small slice of the emerging transportation market: ridesharing. "Whatever's going to happen, there's a whole bunch of players who need to work together in helping these technologies be adopted by the world," says Avego managing director O'Sullivan. His company happens to be focused on the daily commute. Carpooling.org, which lets drivers offer up their empty seats online and passengers book them much the same way they would a train ticket, already has 3.6 million members.[42] There are others that appeal specifically to students on college campuses, or to people looking for intercity transportation. For its part, the US Congress expanded the definition of carpool projects in 2012 to include real-time ridesharing.

ITNAmerica, a not-for-profit, has developed an innovative business and payment model geared toward improving mobility for seniors, regardless of their income. Similarly, a small constellation of firms—TomTom, INRIX, Garmin and others—are exploring different ways of guiding and informing drivers, whether through dedicated dashboard devices or smartphone apps or the new data hubs being installed in cars. Different aspects of mobility, in other words, are generating their own "ecosystems" of players.

Venture capitalist Ryan Popple and his firm, KPCB, got into transportation because they saw a similarity to a field they had been investing in—smart grids and renewable energy. "As we spent time in those sectors and realized how much waste was in the basic grid, we found some great software and hardware companies that were really the IT of the grid," Popple says. "The more time we spent around the [transportation] system we realized the paybacks and the return-on-investment around just eliminating waste were huge. We like the comparison of finding the smart-grid companies of the highway and roads system."[43] And at this particular moment, he believes, the field is wide open—or as he puts it, "We think there are lots of 'ands' and fewer 'ors' in the market."

Which is why there is also great opportunity for the public and private sectors to collaborate—for each to help the other where appropriate. The US federal government, through the DOT's Research and Innovative Technology Administration, has already been a significant player in promoting V2V and V2I technology, while the Federal Highway Administration has seeded everything from new toll highways and rail corridors to bus rapid transit projects and ridesharing pilot programs around the country.

There are clear payoffs to cooperation between the public sector and a company like Avego, which has worked with local governments and the federal government to launch

> "We are making the private car part of the public transit network."
>
> — **Sean O'Sullivan**, managing director, Avego

pilot ridesharing initiatives around Seattle, in northern Virginia and elsewhere. Avego benefits from the knowledge it gains at each iteration of its rideshare efforts, as well as from government's help in building a critical mass of drivers and passengers—a crucial element of success in ridesharing. The public sector, in turn, gets a chance to explore a new way of looking at "public" transit.

As Avego's Sean O'Sullivan explains, "The average American commutes 17 miles from their home to work. If we automatically make available stops along that route... it makes it very convenient for people traveling along the road as they normally do to just let the computer tell them to pull over in 500 meters, there's somebody waiting for a ride. We are making the private car part of the public transit network. The single car becomes a public/microprivate partnership where the consumer is making their asset, empty seats, usable."[44]

Public transit agencies have for the most part embraced this notion, O'Sullivan says, because rush hour is their most expensive time period—so adding commute capacity without adding buses or trains helps them keep their costs down. The public-private partnership can also be more explicitly visible, as in a pilot project funded by the Federal Highway Administration and the Virginia Department of Transportation, and managed by the Northern Virginia Regional Commission, to recruit Department of Defense personnel to use Avego's ridesharing app in an effort to cut down congestion along Northern Virginia commuting corridors.

# Three scenarios for digital-age transportation

So what do these five features—massively networked, dynamically priced, user centered, integrated, and developed by both public and private players—add up to? It may be a fool's game to make confident and detailed predictions about the future of urban mobility, but it's not so hard to extrapolate from current trends.

What follows are less alternative scenarios than parallel ways of grouping developing trends. Indeed, the future is likely to contain elements of all three: widely connected vehicles, or "the Internet of cars"; pricing that aligns supply with demand; and the spread of social networking into transportation decision-making (see figures 7-9). How these ultimately take shape will depend on the complicated interplay of a range of players—the public sector, manufacturers, entrepreneurs, and a host of others—and how they go about resolving the issues that each "scenario" presents.

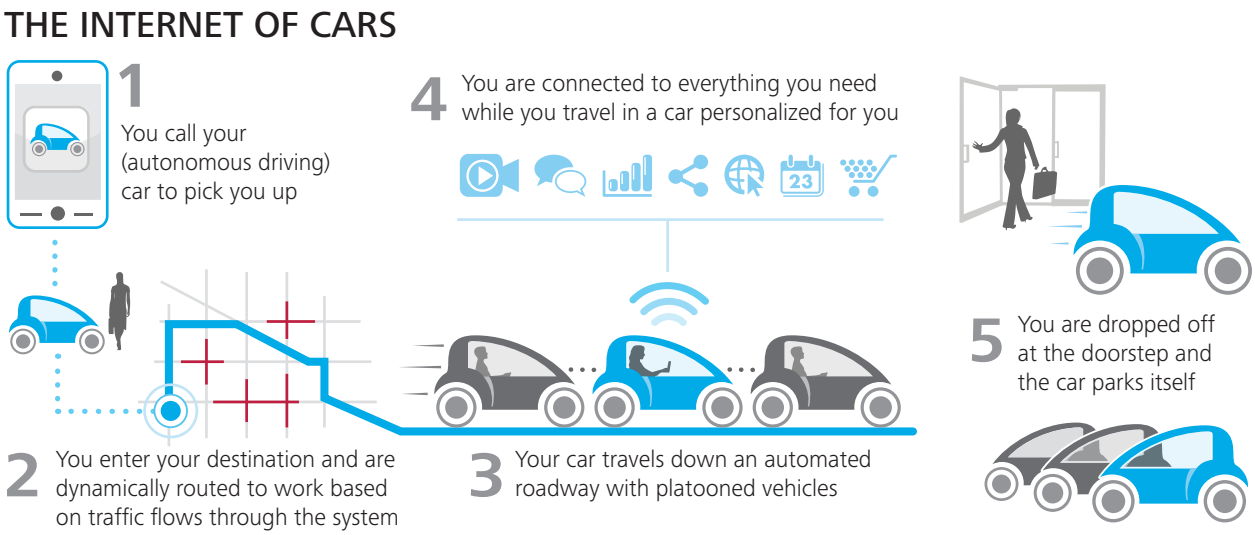
## Scenario 1: The Internet of cars

If you were plucked from 1912 and set down on a city sidewalk today, you'd know immediately what you saw driving past in the streets. The cars might not look like the Metz Runabouts and Brush roadsters of your day, but there'd be no doubt they were cars.

As GM's Chris Borroni-Bird notes, "The same DNA is in today's autos as in the autos of 100 years ago." They have four wheels, an engine in front with a passenger compartment behind, an internal combustion engine fueled by petroleum, mechanical controls that rely on a driver, and drivers who are unconnected to other drivers and the surrounding infrastructure.

Now, Borroni-Bird points out, all this is changing. Power sources are diversifying to include biofuels, electricity, and hydrogen fuel cells. Cars can be controlled electronically

**Figure 7. The future of urban mobility: Scenario 1**



and his company and others—most notably Google, along with Massachusetts Institute of Technology's CityCar effort—are working on the suite of capabilities that would allow cars to drive themselves. As revolutionary as all this may be, though, perhaps the most game-changing possibilities lie in the fact that cars are about to join the information superhighway.

"It is no longer enough to sell personal transportation," write Cisco's Andreas Mai and Dirk Schlesinger. "People want a personalized driving experience that keeps them connected to everything that is important to them—friends, information, music, maps, schedules, and more. Connected cars could do for the automotive industry what smartphones did for the phone industry."[45]

> "Connected cars could do for the automotive industry what smartphones did for the phone industry."[46]
>
> — **Andreas Mai** and **Dirk Schlesinger**, Cisco

The market has recognized this. According to a recent report by Globis Consulting, "Vehicles are the last major market for connectivity, now that homes and businesses are linked to the Internet."[47]

## Beyond infotainment

At the moment, much of the action is happening piecemeal, and much is focused on infotainment. Cell phone calls can be handled through the audio system; some manufacturers are using embedded modules to connect cars to mobile phone and data networks; others are making it possible to connect to social networking sites, Internet radio, and the Web in general. Still, some firms have focused on car-specific services: GM's OnStar division offers "concierge" services and roadside assistance for drivers; the Mercedes-Benz mbrace app allows remote doorlocking and services such as driving directions and restaurant listings through the navigation system; Nissan's CARWINGS allows electric-vehicle drivers to control functions remotely.

But the possibilities inherent in vehicles connected to each other, to the infrastructure around them, and to data streams go far beyond entertainment, navigation, and roadside assistance. Cars might automatically scan the Web, for instance, for information about problems ahead or parking spaces at one's destination and suggest alternative routes or even switching to a different mode of travel if traffic is too heavy.

## You have a tweet from…your car

Toyota has joined forces with Salesforce.com to allow its electric vehicles and plug-in hybrids to communicate with their owners—"Hey, your battery needs recharging"—through Twitter and other social networking tools. Car sharing, more efficient fleet management, the capture of real-time traffic data—all are made possible by connected vehicles. So, too, is what GM calls "a sophisticated, integrated, intelligent transportation system that dynamically manages large transportation flows using the latest communications and computer controls."[48]

## Automated driving

Finally, of course, there is the possibility of the "automated roadway," platooned vehicles and, when combined with advances in sensing technology, fully autonomous driving—all of which, their supporters argue, will make driving safer, more convenient, less wasteful, and more efficient. "It may not be obvious," says Borroni-Bird, "but platooned vehicles might even match or exceed the passenger throughput of rapid transit bus systems."[49]

## The promise of connected vehicles: A focus on people, not cars

Ubiquitous connectivity will almost certainly speed the day when cars are seen as just one piece of the larger transportation system, not the standalone vehicle of choice they are now. In other words, transportation will evolve beyond selling cars to integrating cars into a vehicle-to-grid system.

One example of this will be the degree to which rideshares and peer-to-peer car shares become part of a "public" transport system, in essence weaving what had been private space into the transport options that are publicly available at any given moment. Moreover, Borroni-Bird notes that vehicle connectivity "facilitates communication with the public transport system so that drivers could be made aware of rapidly changing schedules, for example, or make seamless plans for intermodal transport while traveling."[50]

All this carries with it the implication that as vehicles connect to the larger transportation ecosystem, make their drivers more aware of alternatives, and induce industry and government to think more systemically, the *users* of cars, rather than the cars themselves, will come to be at the center of transportation thinking. Or to use Kari Watkins's formulation, the system will be more open to focusing on people throughput, rather than simply vehicle throughput—on getting users from their multitude of points A to their profusion of points B without giving primacy to any particular mode of travel.

### *How do we get there?*

#### 1. Combine vehicle communications in single platform

The road to that point, however, is long. To begin with, a car these days may be fully connected, but only because of a plethora of devices for telematics, radio, Wi-Fi, toll paying and so on. It makes far more sense to combine vehicles' communications into a single platform.

This, say Cisco's Andreas Mai and Dirk Schlesinger, would save 25 percent of the one-time hardware and software costs, and another 40 percent each year of operating costs.[51] Moreover, they believe that a networked vehicle would then open the door to a set of capabilities that "could create an annual benefit pool of $1,400 for each connected vehicle." Such benefits might include payments to traffic-guidance and navigation services, emergency services, and insurance companies able to charge based on miles driven and location; lower costs to service automobiles; cost savings to users from spending less time stuck in traffic and possibly lower fuel and insurance costs; and lower costs to society from fewer accidents and lower traffic and toll operation costs.[52] If their calculation is right, unlocking that annual benefit pool will be a key to funding the "Internet of cars."

There is no question that both the private and public spheres are headed in that direction. The USDOT's Research and Innovative Technology Administration (RITA) and its Intelligent Transportation Systems (ITS) research program have been funding research since 2004 in a range of arenas: developing systems that can deliver up-to-the minute weather and road condition information; collision avoidance systems; integrated safety systems; and a range of connected-vehicle applications.[53] RITA's Connected Vehicle Core System project is focusing on wireless communications among pretty much everything that moves along and beside a roadway—cars, trucks, transit, pedestrians, cyclists—linking them to each other and to the infrastructure.[54]

Private sector initiatives, too, are proliferating. Vehicle manufacturers, of course, are heavily invested both in remaking their products' basic DNA and in adding connectivity. Moreover, through the Car Connectivity Consortium (CCC), leading automotive companies are working closely with mobile communications and consumer electronics companies to develop global standards for smartphone in-car connectivity. Globis's Barrie Kirk also expects the mobile carrier industry,

app developers, and content providers to play significant roles—along with universities, which as he points out are developing network protocols for vehicle and sensor networks, as well as ways of diagnosing vehicle malfunctions and transmitting that data to the navigation system.[55]

Of course, there are a host of issues that the market will have to sort out as plans develop. Will consumers prefer wireless embedded in the car—which allows communication with the car even when the driver and their smartphone are elsewhere, but which might also be outdated within a couple of years—or a way of linking their smartphones to in-car displays? Nokia and other providers are working on "terminal mode" standards, under which "mobile devices could be tightly connected with in-car systems such as digital displays, steering wheel buttons, rotary knobs, and car audio systems. Consumers could use a mobile device via the car controls, as if the device and its apps were integrated into the car itself."[56]

There are other questions, too: What kind of software—apps or Web-based access—will developers use? What role will the cloud play? What role will the insurance industry play, given its interest in standardized usage data—as well as in the potentially costly matter of distracted driving?

### 2. Progress connectivity standards

There are also specific efforts around connectivity standards—which are already underway—that will have to bear fruit. Avego's Sean O'Sullivan points out that the key to making transit information readily available in many cities was the development of shared standards for information. Google's collaboration with TriMet (based in Portland, Oregon) has produced the open GTFS standard, which may serve as a basis for a broader standard. Google promulgated the standard, urban transit agencies wrote their data to conform with it, and a small army of college students learned how to mine the data and get it to anyone with a smartphone.

All this makes the CCC's willingness to work on open standards—and especially on the Terminal Mode standard—significant. As Andrew Updegrove, a Boston attorney specializing in high-tech standard setting, noted after the announcement of CCC's founding, car manufacturers seem to have bought into the notion that it's easier to let mobile devices bear the burden of adapting to changing technology. "True," he wrote, "the automotive manufacturers have had to give up any remaining hopes of tying customers to them via proprietary telematic systems, but customers weren't going to buy into that kind of world anyway—they simply wouldn't have bought proprietary vendor options and services—and perhaps the cars that offered them—at all. At the end of the day, the automotive industry appears to have decided to take the classic standards route of adopting a standardized platform, and then preparing to compete on value-added features and services (some of the latter doubtless on a paid subscription basis)."[57]

Other standards efforts are also underway at the International Standards Organization, which has a committee responsible for intelligent transport systems. Meanwhile, US European, and Japanese auto manufacturers and government officials have also met to talk about cooperating on standards for connected-vehicle technology.

But cooperative efforts do not always translate quickly into concrete progress. On the automakers' side, interoperability standards for vehicle-to-whatever communications have proceeded far enough that some European manufacturers plan to include the capability in their 2015 models, while *Thinking Highways* associate editor Richard Bishop expects to see it in US models by 2018. But that may just be for vehicle to vehicle. While infrastructure providers are also working on cooperative systems—especially in Europe—it is far from certain that they will be ready anytime in the near future. Infrastructure-focused ITS initiatives, Bishop says, tend to take far longer than their optimistic boosters anticipate. "I expect

it will occur much slower than anyone on the vehicle side would prefer," he argues.[58]

### 3. Address security

There remain a host of other issues to address. Clearly, for instance, security will be vital to every aspect of the system. A hacked connected-car network would create chaos. As GigaOM blogger Kevin Fitchard points out, "Such networks aren't just transmitting information, they're acting on it. Introducing false vehicle data into the stream could cause our cars to respond to phantoms, swerving to avoid vehicles that aren't there and braking for gridlock that doesn't exist."[59] Or as one German academic says, "Most people would rather have malicious software running on their laptop than inside their car braking system."[60]

### 4. Resolve privacy issues

Issues related to privacy will also need to be resolved. While it's one thing for electronic loops embedded in highways to transmit anonymous information to monitors about vehicle numbers, speed, and so on, when vehicles themselves start transmitting that data, that's another matter. As we see later, there is great public resistance to the prospect of being tracked by some "Big Brother" agency, whether it's public or private.

## Scenario 2: Dynamic pricing

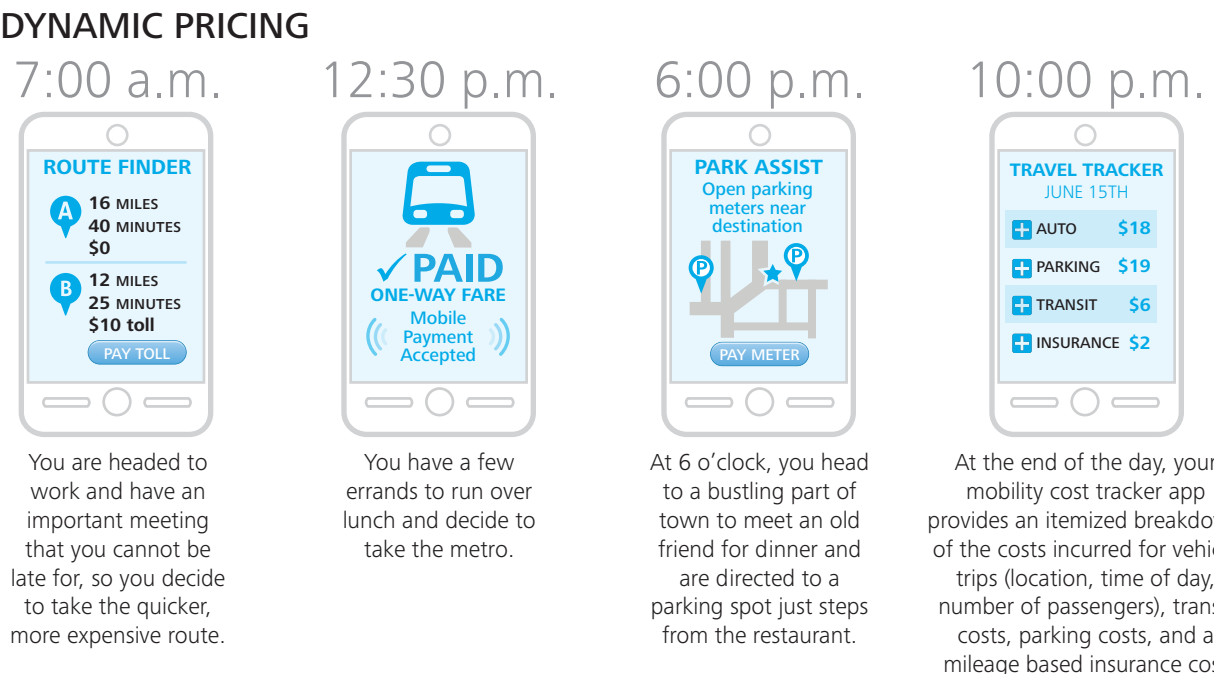
THE world is moving inexorably toward the notion that goods and especially services need not be priced statically. Airlines and hotels, of course, have been pricing seats and rooms dynamically for years. Electric utilities have been installing smart meters that will, among other things, allow them to respond to changing demand by changing prices.

Transportation stands on a similar frontier, made possible by the spread of mobile technology, location-based services, and "contactless" payment systems.[61] These will ultimately allow for two key values to be embedded in transportation pricing:

- **Users pay a more direct portion of the actual costs** of the services and modes they use.
- **Prices respond to demand** to increase the overall efficiency of the transportation system.

The benefits, as outlined earlier in the features of digital-age transportation systems

**Figure 8. The future of urban mobility: Scenario 2**



Real-time reporting of traffic conditions and predictive forecasting should make it possible for drivers to be able to choose between the lowest cost and the quickest routes to their destination, with full knowledge both of their cost and travel time.

section, would run throughout the system. Drivers and passengers would get clear signals about the cost of a given choice, allowing them to make decisions about their timing, route, and mode of travel that take into account both their own needs and the overall system's. Transportation managers and providers would be able to set prices according to availability, cost, congestion, demand, the desire to attract customers, and other considerations. Ideally, the result would be to optimize the efficiency of the entire transportation system, lessening the peaks and valleys for everything from seats on a bus to use of a downtown street to parking in the most popular shopping and entertainment districts.

## Making trade-offs explicit

In the end, pricing mechanisms for the users of transportation services—in other words, for drivers, parkers, transit passengers, bike-share and rideshare users, among others—should provide clear signals about the range of options they might consider, using new technologies to make the trade-offs readily apparent. If a subway system is straining under the load of rush-hour passengers right now, you want to make sure that potential passengers know that the amount they pay will be lower if they just wait a half hour—or take the bus instead. Drivers using the relatively scarce and expensive space of a downtown street at rush hour should know both the cost and the relative price and trip time of alternatives. Real-time reporting of traffic conditions and predictive forecasting should make it possible for drivers to be able to choose between the lowest cost and the quickest routes to their destination, with full knowledge both of their cost and travel time.

But there's an additional consideration: "Real-world" pricing will also depend on technological advances that make it possible for providers to understand their customers' behavior, price accordingly, and facilitate switching from mode to mode. In other words, it should be a simple matter to use a tolled roadway and then park, switch to rapid transit, and hop in a shared ride to your destination.

### *How do we get there?*

#### 1. Promote wireless payments

Great strides are being made on the technical front. VeriFone is experimenting with contactless payment cards on bus systems in Turkey. Austria's WESTbahn is working to make it possible for travelers with smartphones enabled with near field communication (NFC) simply to tap their devices on a conductor-held iPad to make their payment. China Telecom integrated its mobile network with Beijing's transport cards, allowing commuters to simply swipe their mobile phones to make bus and subway fare payments.[62] In the United States, New Jersey Transit is working with Google to bring the wireless Google Wallet payment system to its routes. The Utah Transit Authority, which has been a pioneer in contactless payment, is moving toward using both Google Wallet and Isis, a rival NFC-based application. Southeastern Pennsylvania Transportation

Authority is working to introduce its own contactless payment system.[63]

The benefits to users in terms of ease of use are obvious, but the benefits to transit agencies and their planners may be even greater. "Transit agencies need to understand how riders are using the system. Right now, it's hard to tell where riders are going—you can count them, but it's hard to track a full linked trip," Utah Transit's Gerry Carpenter said. "With NFC tapping, each customer has a unique identifier— either an ID or credit card—which enables us to tell that an individual customer went from point A to point B and arrived at point C, all without violating their privacy."[64] This capability will, in turn, allow transit agencies to begin introducing more dynamic pricing for their services.

### 2. Explore new payment models

Taking a new approach to the issue, the insurance industry and state regulators are exploring how to link cars' actual use to the premiums their owners pay. "Pay as you drive" (PAYD) insurance, or usage-based insurance, has been around for a decade, but insurance companies have only recently amassed enough data to accurately price risk based on driver behavior. Progressive Insurance's PAYD program, Snapshot, uses a small on-board device to measure when drivers use their car, how far they drive, and how often or hard they brake, and offers drivers discounts based on the data gathered by the device.[66] The prevalence of PAYD plans is increasing. Eight of the top ten U.S. insurance companies now offer usage-based plans.[67] The point in all this is not to discourage driving. Rather, the goal for insurance companies is to more accurately price their services, recognizing that previous payment models for insurance were essentially blunt instruments.

PAYD insurance may, however, have another side effect: accustoming drivers to the idea of reporting their mileage. According to Robert Atkinson, president of the Information Technology & Innovation Foundation, "People will get marginally used to the notion of paying by the mile. Then it's less of a big emotional or intellectual shift."[68] Just as people using the telephone once limited their long-distance calls to nights and weekends to take advantage of lower rates, and airline passengers understand that flying on Fridays and Sundays will cost them more than flying on a Tuesday or Saturday, greater price transparency will undoubtedly lead drivers and other transportation users to change their behavior.

### 3. Anticipate resistance

This is an issue, because there is certain to be resistance to some aspects of dynamic pricing. While there is growing acceptance of the idea of dynamic pricing for parking, *driving* may be another matter. As Ken Laberteaux, senior principal research scientist at Toyota Research Institute of North America, notes, "Any change will look like a stick, rather than a carrot, because the current cost of transportation for each user is so low."

## MINNESOTA EXPERIMENT

Spurred by the harsh reality that as fuel consumption drops, the gasoline tax will be even less reliable a funding source for infrastructure than it is now, states are interested in finding ways of charging drivers for miles driven. Minnesota's DOT, working with Battelle, is testing a mileage-based user fee that relies on smartphones programmed with a GPS application that allows motorists to submit information. The idea, says Battelle's Rob Zimmer, is to keep the strategy as simple as possible. "We hope to demonstrate that a mileage-based user fee could be successfully deployed using infrastructure that's available right now. Consumers are already carrying smartphones with them in their vehicles. There's no need for a state to deploy a million-dollar system to do this. We already have the computers in cars today."[65] The effort, which began in 2011, is aimed at finding ways to reduce the state's reliance on the gasoline tax—from which proceeds have been shrinking—as a way to fund roads and highways.

> "Any change will look like a stick, rather than a carrot, because the current cost of transportation for each user is so low."

— **Ken Laberteaux**, senior principal research scientist, Toyota Research Institute of North America

Indeed, according to a survey commissioned by the task force studying Minnesota's mileage-based user fee (MBUF), "Minnesotans tended to be unfavorable toward an MBUF system that charges differential rates based on time of day, level of congestion, [and] location of driving."[69] Since those are precisely the variables most likely to come into play in any dynamic road pricing scheme, the politics of instituting such a scheme could get sticky. A set of focus groups conducted by the Texas Transportation Institute (TTI) found great skepticism about the need to switch from the gas tax to user fees and cynicism about government's ability to administer fees effectively and fairly.[70]

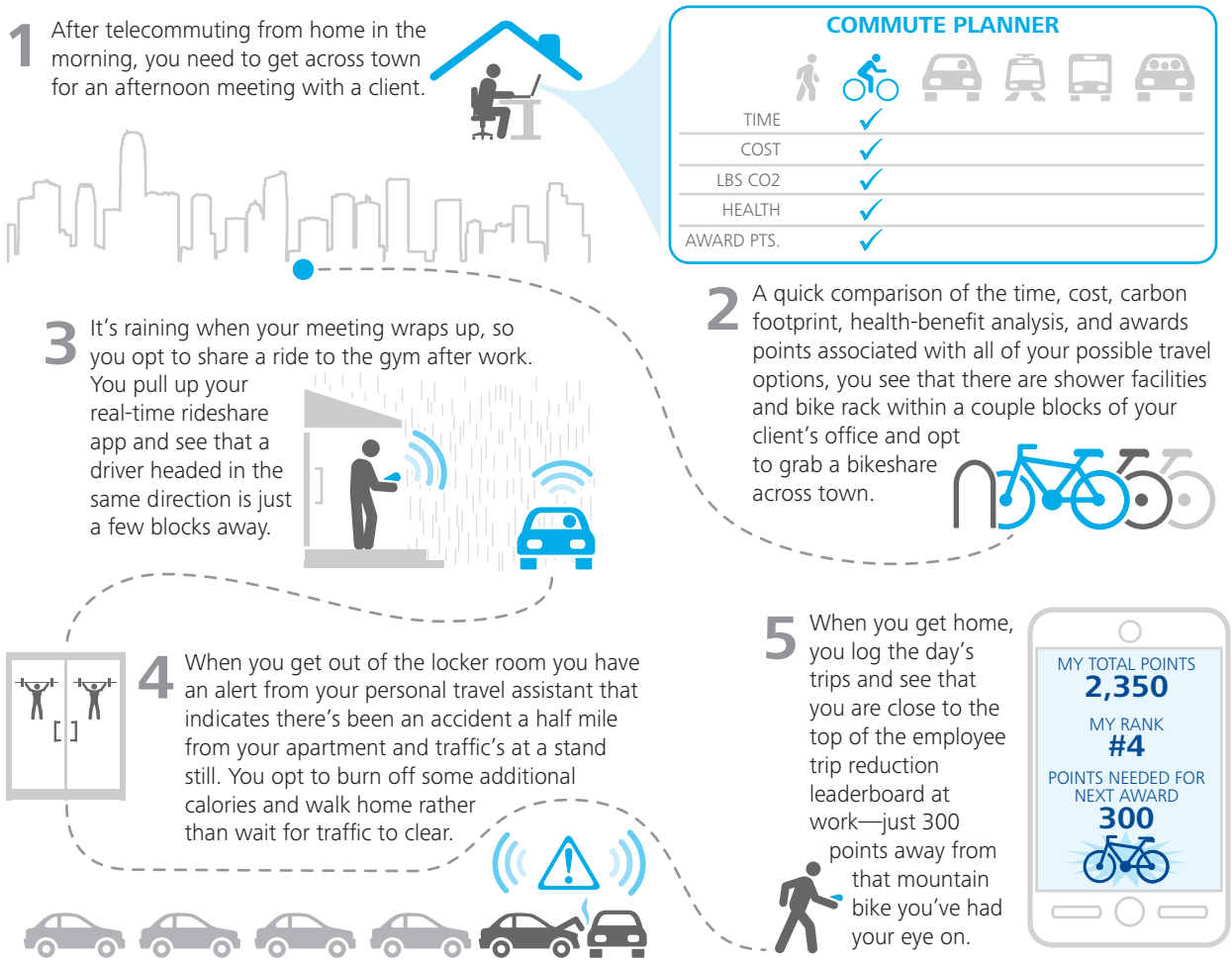
### 4. Obtain consensus on what the market in transportation should look like

Finally, there is a larger question that will need to be settled. While there may be overall agreement about the need for transportation users to pay a higher portion of the cost of what they use, there is less agreement about the next step. Should each service or mode—government-owned or privately-tolled roads, for example, versus transit versus rideshares—simply set prices without regard to any concerns but their own? In other words, should there be an entirely free and potentially competitive market in transportation? Or should the pricing of different modes also reflect community or social benefits—so that if, say, you make choices in your commute that produce an environmental or congestion benefit, you get credited for that choice in some way? If so, who determines what counts as a "benefit" and what as a "detriment" or "negative externality"? How do you make sure that in setting prices, the overall impacts get weighed: the contribution to economic vitality that a robust road network and the freedom to drive provide, for instance, versus the economic cost of congestion? And if we're going to reap the greatest benefits of dynamic pricing, shouldn't operators of each mode be in constant touch with each other—along with the banking sector—so that they can all adjust pricing according to the realities of the entire system at any given moment?

## PRIVACY: A BARRIER

As the TTI's focus-group members in the United States point out, privacy will also become an issue. Many cellphone users are happy to have their locations tracked as long as the service is useful to them alone. But there is great resistance to the notion that the government or private companies should also be able to hold onto and use that data. When a story broke last year about companies collecting location data from smartphones without users' knowledge, the result was hearings on Capitol Hill and the introduction of several bills to strengthen privacy protections for location data—both from cars and from mobile devices.[71] Transportation experts, though, worry that the bills might also limit "the collection of aggregate and anonymous location data of the kind that is critical for vehicle probe data services for generating real-time traffic reports."[72] It remains to be seen whether drivers will allow themselves to be tracked by the government for other purposes, such as paying user fees. There are, to be sure, technical ways of overcoming this problem, including having an onboard data unit simply talk to a gas pump, so that the fee is calculated from one fill-up to the next.

**Figure 9. The future of urban mobility: Scenario 3**




## Scenario 3: Social transport

THERE is a fundamental disconnect at the heart of the current transportation system: It's a *system*, yet its parts don't talk to one another directly. With the advent of networked cars and infrastructure, location awareness, and social networks, however, that may be coming to an end.

In fact, at the Deloitte session, when participants were asked to coalesce around the most compelling vision created in the room that day, here is what they chose:

*The transportation system of the future will be built on collaboration among neighbors, communities, governments, and traffic managers on everything from traffic planning to signal timing to commute planning.*

The key concept in that vision, "collaboration," suggests that transportation can become something more than simply the aggregation of millions of people's individual decisions about how to get where they want to go. The day is not far off when their decisions can be informed by other people's advice, broader system-level objectives, real-time travel conditions, crowdsourced information, and even community values.

### Socially-informed decision making

Some of this is already happening. You might notice on a website that there's a ball game at the stadium you pass on your way home from work, or see a tweet from a friend that there's a 15-minute delay on the rail transit system. If you're waiting for a rideshare or

The transportation system of the future will be built on collaboration among neighbors, communities, governments, and traffic managers on everything from traffic planning to signal timing to commute planning.

using a peer-to-peer car-sharing service, you're also relying on the service—through the experiences of people who've already used it—to make sure that the person who'll be giving you a ride or renting your car is trustworthy.

### Mapping transport to social objectives

You can also see the outline of a different way of thinking about transportation emerging in a nonprofit endeavor like ITNAmerica, a ridesharing service aimed at seniors. It is built on the willingness of hundreds of people in a given community to collaborate on the common goal of making transport available to people who either can't drive anymore, or have chosen to give up their cars. Its members pay into "personal transportation accounts" with cash, by sharing space in their own cars, or by volunteering their labor. And they offer rides—and, later, ask for them—for any number of reasons: because they want to help others or they consider it more environmentally friendly, or they find that it saves them money. The point, says ITNAmerica founder and president Katherine Freund, is that "People have a lot of different reasons for making the choices they make. So you have to think about them, understand them, and build a system that pays attention."[73] In other words, you have to build in the ability to capture motivations and behaviors that go beyond simply trying to get from point A to point B in the fastest, most convenient way possible.

The problem is that all this information, from real-time commute problems to your neighbors' values when it comes to transportation, remains scattered. It is hard to get a more holistic view.

Here is the ideal: When it's time to get somewhere, you plug in your commute or your itinerary, and the network gives you every option, whether you're going to work or just to do some shopping across town. It lets you know about traffic conditions, whether a rideshare possibility is passing your way, what time the next bus or train gets to a nearby station, and how long it would take you to walk. In a sense, as KPCB's Ryan Popple puts it, "The idea would be that you can travel to any city in the world and have technology provide the same experience as if you were there with a trusted friend who could tell you exactly what road you should be on at that time of day, or how to complete a trip using multiple modes of transportation."[74] The system might also take

### RIDEAMIGOS CORP'S VIRTUAL TMO

The CCTMO created by RideAmigos doesn't just compare the cost and time of different travel modes, it also does a carbon dioxide and health-benefit analysis, and awards points to members on a tiered basis—biking to work gets more points than carpooling. Users with the highest point totals are awarded free bikes, transit passes, and other goods funded by local government, businesses, and nonprofits that have joined in the effort. All of these insert a social component into what had been purely individual decisions.

advantage of real friends, who post to your social network advising on how to get a ride-share or taxi discount, for instance, or alerting everyone to a particularly convenient route they've discovered.

But in the vision laid out by participants at the Deloitte session, the network would do more than promote cost and travel efficiency. It would also take into account your lifestyle preferences and what you don't like—maybe it would give you information about how to walk to where you're going, given your desire to burn off calories. And embedded in it would be not only information about road and transit conditions and dynamic pricing levels, but also information about what friends and neighbors are doing and some reward system, like that of RideAmigos Corp, to encourage particular choices. The challenge, as Freund puts it, is to "connect transport to human motivation beyond just saving time and money."

### *How do we get there?*

In some ways, the building blocks for this scenario are already in place. As Cisco's Mai and Schlesinger say of automobiles, "Ubiquitous vehicle connectivity not only allows automakers to ride the wave of smart mobile technology, but also enables a fundamental strategy shift from merely building cars to selling personal travel time well-spent."[75] The same can be true for any mode of travel—and for a definition of "well-spent" that goes beyond being entertained while you are in transit.

#### 1. Design the user dashboard

The challenge, as transportation shifts to a freer, more user-centered paradigm, is how to create incentives that broaden users' worldviews and take into account the community and the system as a whole. Or, as Susan Grant-Muller puts it, "The notion is to incentivize people to make choices that are not just optimizing for themselves but optimizing for the system as a whole at the same time."[76]

There is, of course, the straightforward approach. Incentives can be provided by employers or governments or, as in Century City, a community of institutions interested in changing behavior. Discounts, travel vouchers, certificates to restaurants or stores—all might have an impact. So might out-and-out cash. In Palo Alto, Stanford University computer scientist Balaji Prabhakar has used a $3 million research grant from the USDOT to set up a lottery—commuters who travel to campus during off-peak times could win up to $50 in their paychecks. As a result of Prabhakar's work, Singapore is considering a similar system for transit riders where a trial run lowered rush-hour ridership by 10 percent.[77]

But as RideAmigos Corp's Jeff Chernick argues, information in and of itself can be a powerful motivator. Price, time, and cash incentives matter, of course, but so might the carbon emitted by each choice, the calories burned, the times when neighbors headed in the same direction are leaving their homes, even the bottom-line costs of a car ride versus a bus ride versus a bike ride. You need look no further to see the power of this approach than the changes in driving habits of Toyota Prius owners as they seek to boost their gas mileage or Nissan Leaf owners as they try to increase their efficiency. This is also the thinking that underlies Opower's customer engagement platform, which includes "home energy reports" that help power providers give customers detailed information about their energy usage and compare it to their neighbors'.[78] Dynamic, up-to-the-minute information from both private and public sources that is readily available to users will help them make decisions that, on a grand scale, should lead to a more efficient and effective system.

#### 2. Gamify the experience

Opower's insight—that allowing people to compare their usage with their neighbors' might change behaviors and yield less energy consumption—helps explain the rising interest in the gamification of behavior. The appeal to users' competitive instincts (whether in actual competition, in trying to amass points, or simply by comparison), holds the promise of

## THE PROMISE OF PROJECT SUNSET

In Europe, Project SUNSET is exploring the impact that incentives and gamification might have. "We can think about it in terms of a points system a bit like air miles, and the idea that you accrue points by making sustainable choices or choices that are in line with your higher level objectives within the transport system," says Grant-Muller.[79]

The EU-run project arises from a belief among European transport thinkers there that the spread of technologies putting users at the center of the transportation system will ultimately offer only marginal improvement to overall mobility unless individual choices can be brought into line with broader system-level objectives. Project SUNSET sits "at the interface between ICT technology, infrastructure and the individual traveller," in the words of Grant-Muller and her University of Leeds colleague, Frances Hodgson. "Its goal is more efficient, safer and environmentally aware transport network management."[80]

What may be most intriguing about the project is that it is being spearheaded by players and firms in the information realm. They include providers of location-based services and mobile-phone operators, as well as local and national governments and university research centers. The project will connect urban mobility managers with users—and users with one another—through a smartphone app, allowing users to receive information tailored to their particular travel behavior; the more they use the app, the more it learns about their mobility patterns. SUNSET will also link with existing roadside sensors to provide real-time traffic information. Users will be able to share information about their own experiences on roads or transit, and track their progress in meeting particular goals—walking more, say, or reducing carbon emissions. "We're going to develop the opportunity to reach out to people to personalize incentives to try and encourage the kind of behavioral change that is part of people-centered mobility," says Grant-Muller.[81]

encouraging them to think about what they do (whether it's using energy or driving solo to work) in ways that other approaches haven't succeeded in doing.

### 3. Create network effects

In order for efforts like these to have any real impact, though, they will have to scale up. They will, in other words, have to develop into a network, with all the benefits that accrue from creating linkages and critical mass.

Opower pointed the way to one possible answer last fall, when it partnered with Facebook and the Natural Resources Defense Council to create a Facebook app allowing users to track—and boast about—how much electricity they're using. People on opposite sides of the world can compare themselves to one another, and users can compare themselves to Facebook friends or even people on Facebook in similar-sized homes. Moreover, Opower said in its press release, "People will be able to benchmark their home energy use against a national database of millions of homes. All benchmarking will be done on an aggregate level, ensuring complete data privacy."[82]

Of course, this places Facebook in a role that it never envisioned and wasn't really designed for. "What we don't want is to have a lot of users with a lot of trust, faith, and commitment in a particular social networking brand and for something to happen that undermines that trust," says Grant-Muller. "These sites need to evolve a growing sense of social responsibility and awareness of their role in influencing behavior within a wider arena than they were originally set up for."[83]

Moreover, she points out, there is a risk of the "digital divide" spilling over into transportation. "Will people who, for whatever reason, can't access the network become second-class citizens because they won't have up-to-date transport information?" she asks. "Will they lack the ability to influence or engage, or to benefit from the rewards that will be part of such networks?"[84]

# Looking ahead

IF anything, the dizzying pace of change in transportation is likely only to accelerate. The players pouring into the field—consumer electronics, mobile communications, app makers, smart infrastructure and smart transport entrepreneurs, forward thinkers in the automotive industry—are transforming it and creating opportunities for even newer players. Others are arriving with experience in solving problems in other fields — energy conservation, for instance, or telecommunications—and bringing fresh insights with them that, in turn, strike new sparks among existing transport thinkers.

As the scenarios above suggest, we are already seeing aspects of what this new world might look like. Smartphones are expanding their reach in both numbers of users and phone capabilities, and thus creating new models for getting people from point A to point B. Social networking is abetting new ways of thinking about organizing communities and motivating change. Insights into human behavior—think gamification—are rewriting how we approach transportation problem solving. And, of course, emerging technologies are changing pretty much every aspect of how we get around. As a field, transportation has become rich with possibility.

The challenge, especially for government, is to find its footing in this dizzying environment (see figure 1 for a roadmap of where to get started). This means asking hard questions: Are there existing laws that need to be changed or updated to meet tomorrow's realities? How can the public sector best get out of the way of innovation, yet also meet the need for a public conversation and possible legislation on such issues as privacy and dynamic pricing? If government is going to seize fresh opportunities to lay the groundwork for emerging technologies and entrepreneurial models, how can it make the wisest use of its limited resources?

There remains a lot of work to do. Standards for the technology that will be crucial to the new mobility have yet to be finalized. Frameworks for public-private partnerships must be put in place, monitored, and adapted as needs change. The simple notion that people's mobility, rather than vehicle throughput, ought to be at the center of the system will demand a change in culture throughout public transportation departments. There will undoubtedly be a public role, perhaps a central one, in making it easier for travelers to experience an integrated transportation system. Providing safe and reliable infrastructure with the capacity to handle demand will undoubtedly remain a core government function, even if the models for how to finance and create it change.

Still, what is most exciting about this particular moment is that the opportunities seem unlimited for both the private and public sectors to make human mobility cleaner, safer, more efficient, and more enjoyable. Finding our way into this new era may take work, but there's no question that we have crossed its brink.

# Appendix: Forum participants

DELOITTE convened a one-day session that brought together a distinguished array of leading innovators, policymakers, technologists, and subject matter experts at the forefront of the transformation of mobility to consider how emerging trends in technology, business and society could transform the transportation landscape in the coming years (a list of forum participants is included below). The wide-ranging and thought-provoking discussion produced intriguing points of agreement about the likely features and qualities a digital-age transportation system would contain if we take full advantage of the technological and organizational breakthroughs that are already apparent. The session was held on January 26, 2012, at the Waterview Conference Center in Arlington, Virginia, following the conclusion of the Transportation Research Board's 91st Annual Meeting in Washington, D.C.

**Alexander Bayen**
Assistant Professor, Civil and Environmental Engineering
University of California, Berkeley

**Chris Borroni-Bird**
Director, Advanced Technology Vehicle Concepts
General Motors

**Marcus Bowman**
Founder
3G Mobility, LLC

**Joe Butler**
Data & Systems Group Manager
California Center for Innovative Transportation

**Jeffrey Chernick**
CEO and Cofounder
RideAmigos Corp

**Ken Clay**
Global Account Manager
TomTom

**Nick Cohn**
Senior Business Development Manager
TomTom

**Patrick DeCorla-Souza**
P3 Program Manager
Federal Highway Administration

**Tiffany Dovey Fishman**
Manager, Public Sector Research
Deloitte Services LP

**William Eggers**
Global Director, Public Sector Research
Deloitte Services LP

**Stephen Ezell**
Senior Analyst
Information Technology and Innovation Foundation

**Katherine Freund**
Founder and President
ITNAmerica

**Eric Gilliland**
General Manager
Capital Bikeshare

**Adam Greenfield**
Founder and Managing Director
Urbanscale

Ian Grossman
Vice President
American Association of Motor Vehicle Administrators

Jenn Gustetic
Associate Director, Strategic Engagement & Communications
Phase One Consulting Group

Stephen Keathley
State Transportation Market Offering Leader
Deloitte Consulting LLP

Ken Laberteaux
Senior Principal Research Scientist, Future Mobility Research Department
Toyota Research Institute of North America

Joung Lee
Deputy Director, Center for Excellence in Project Finance
American Association of State Highway and Transportation Officials

Felix Martinez
Strategic Relationship Manager
Deloitte Services LP

Martine Micozzi
Management and Policy Specialist
Transportation Research Board

Paul Minett
Cofounder, President and CEO
Trip Convergence Ltd

Dan Morgan
Lead Associate, Open Government and Innovation Practice
Phase One Consulting Group

Sean O'Sullivan
Cofounder and Managing Director
Avego

Ellice Perez
Regional Vice President
Zipcar

Gabriel Roth
Research Fellow
The Independent Institute

Adam Schlicht
Management Analyst
US Department of Transportation

Amy Schlappi
Fleet Manager
Zipcar

Avi Schwartz
Senior Manager
Deloitte Financial Advisory Services LLP

Sonali Soneji
Research Manager
Arlington County Commuter Services

Alene Tchourumoff
Manager
Deloitte Consulting LLP

Jim Templeton
Specialist Leader
Deloitte Consulting LLP

Tom West
Director
California Center for Innovative Transportation

Yu Yuan
Research Staff Member, Connected Vehicles and Mobility Internet
IBM

Mohammed Yousuf
Office of Operations R&D, Turner-Fairbank Highway Research Center
Federal Highway Administration

Jim Ziglar
Senior Vice President
Deloitte Corporate Finance LLC

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