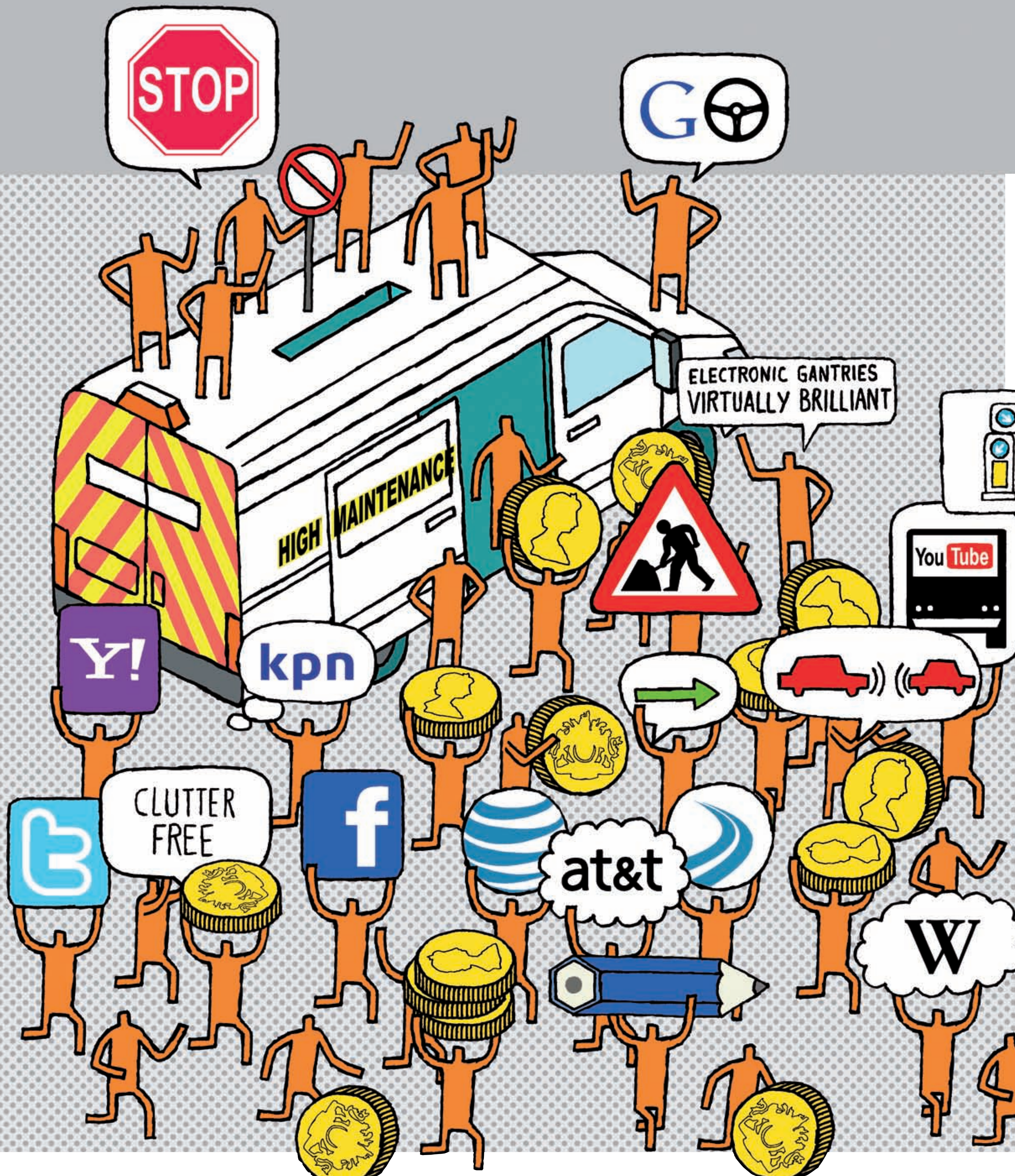
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Turn the corner

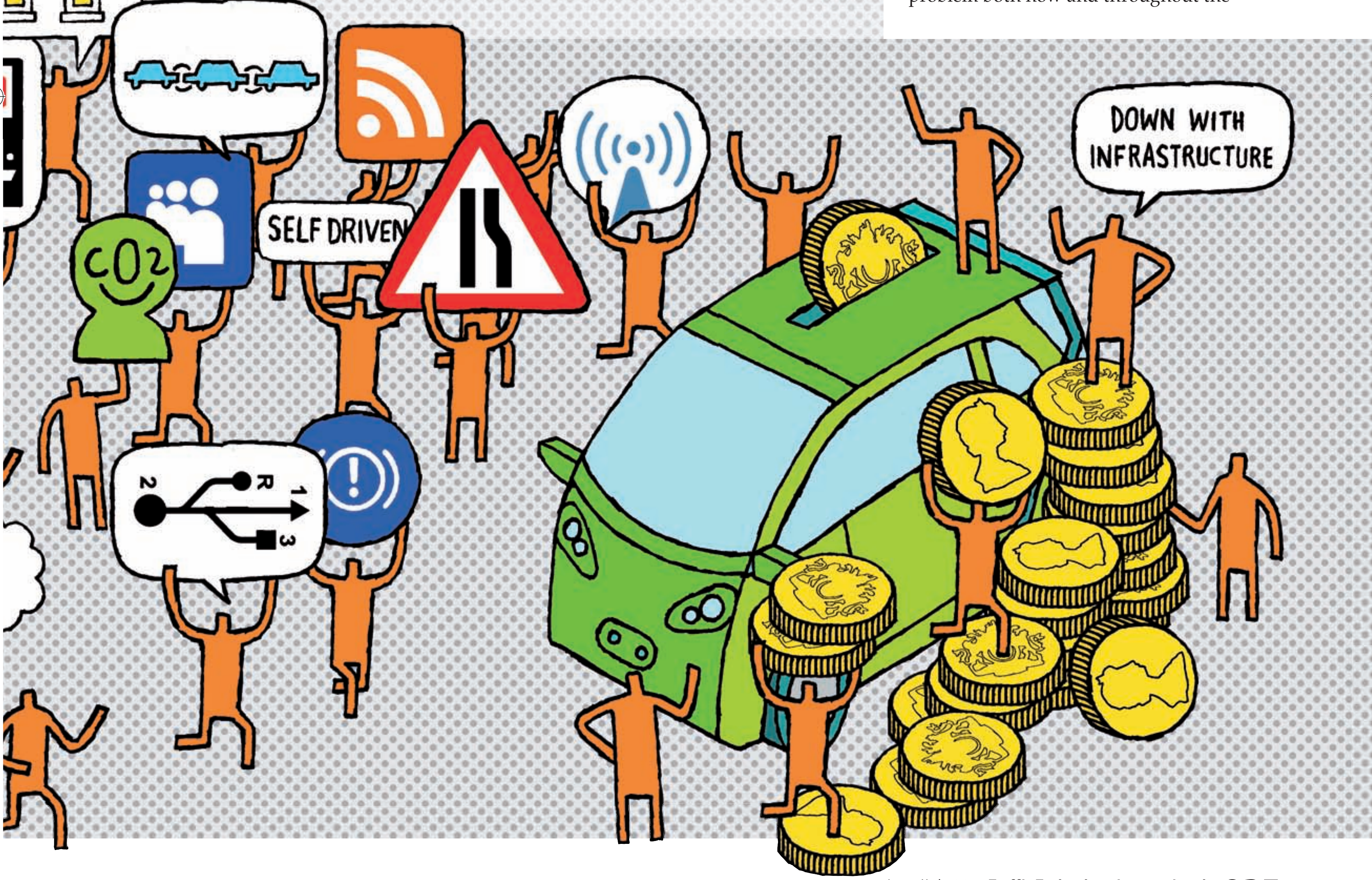
Changing expectations and rapidly developing technology means we need to review ITS research strategies constantly. **Bern Grush** asks if now is the time to think about relative investments in the development of in-car versus roadside instrumentation

Illustration courtesy of Tim Ellis

In the development of large, complex systems we are often challenged to plan some distance into the future. This holds true for healthcare, weapons, urban transit and – within the covers of this publication – intelligent transport systems. Depending upon what we are planning to develop, questions need to be asked that are relative to decades from now. How many people will be sick and with what? Where and how will our enemy engage? How dense will our city population become? What will automobility be like in 20 years?

Not yet one mind

There are a large variety of opinions regarding the future of roads and cars. Most predict greater congestion. Many predict an electric fleet. Some predict self-driving vehicles and convoys. Many would like to see safer vehicles. Some would like to see more roads. But none of us can reliably describe an automotive utopia. It is safe to say that we have a very large and complex problem both now and throughout the



imaginable horizon – a problem that we will not solve perfectly. It is also safe to say that those who are optimistic are optimistic for a variety of contradictory reasons. Exactly the same can be said of the pessimists.

The solution to mechanized human mobility has multiple optima – each is elusive and none have been conclusively described. With no single 'best way', even the mere setting of criteria for solutions to safety, congestion, access, as well as competing modalities such as cycling, transit, walking, and telework, becomes complicated. This complication is exacerbated because each of these modalities – with their benefits and drawbacks – has champions who sometimes argue bitterly with one another and, especially in the case of the automobile, even among themselves. I am a participant on the CON-PRIC listserv hosted by the University of Minnesota. Its members – all generally advocates of road pricing – have been known to engage in some fairly corrosive dialogue. If you suspect exaggeration here, search the keyword 'pezzotta' on *tollroadsnews.com* (but be wary of the characterization that you read there, however).

> The connected vehicle provides an opportunity to reduce the amount of roadside infrastructure deployed on the highway, with consequent reductions in operating costs and maintenance delays

(Above) **SARTRE is a synthesis of personal and public transport to allow cars to be daisy-chained and auto-controlled by a lead vehicle** (Below) **Managed motorways on the M42 in the UK**

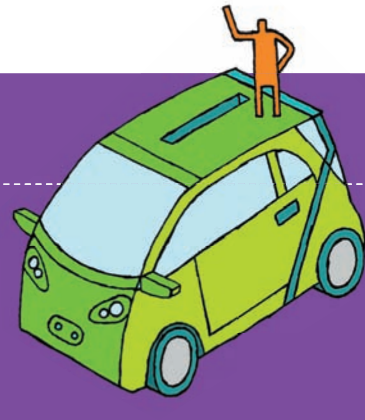
Even if we were to agree on where we should, could or will be in 10 or 20 years, the design problems would still be difficult. So, let's look at the forces in play…

The broadest vision for ITS – i.e. the vision that instruments all vehicles and perhaps generous portions of the roadside to address safety, optimization, infrastructure performance (e.g. cars per lane-hour), traveler services and user fees with dozens of integrated features – keeps growing. The technology we can use for these systems is changing dramatically. Sensors are rapidly improving and getting cheaper, roadside equipment is also improving (albeit less dramatically), and ideas about what we could or should do change with new enablers.

We have a moving systems target – and it moves along multiple dimensions. Each new idea or new technology does not automatically point the way to an optima or even a best practice. When we cannot reliably predict outcomes, every investment carries greater risk.

Until recently, the shepherds of the ITS research vision have been CVIS in Europe, IntelliDrive (previously VII, now the Connected Vehicle) in the USA and the research facilities of numerous automotive manufacturers. Here there are already critical biases. Government labs prefer to focus more on aspects such as speed management, traffic calming, signage, demand management, road pricing, traffic signals, pedestrian and bicycle safety and public acceptance. Automotive manufacturers are biased toward navigation, traveler information, and crash avoidance. Of course,

ITS: then and now



ITS got its start in the 1980s in Europe with DRIVE and PROMETHEUS. DRIVE, or Dedicated Road Infrastructure for VEhicle safety, was targeted to improve traffic efficiency and safety and the environmental effects of motor vehicles. It focused on the infrastructure requirements, traffic operations and technologies of the road transport system. Meanwhile, PROMETHEUS, or PROgraM for European Traffic with Highest Efficiency and Unprecedented Safety, aimed at developing IT, telecommunications, robotics and transport technology to provide information to drivers. This would be to aid them in an informative way, establish a network of communication between vehicles and to establish systems for efficient use of the road network. (see *Acceptability of In-Vehicle Intelligent Transport Systems to Young Novice Drivers in New South Wales*, K. Young et al).

After that, the UK established the Road Traffic Advisor (RTA) project. RTA was a collaborative project between a number of leading companies, academic organizations and government departments that ran from 1997 to 2001 on the M4 from Cardiff to London. The RTA technology provided location-specific information relevant to the road and direction being driven by the user and could collect information about recent past performance on that road for both road management and driver information purposes.[1]

"Mistakes were made," suggests Robert Cone. "Too much was spent on infrastructure but not enough on instrumenting the vehicle. What was proven, however, was that data could be delivered with accuracy to the vehicle when required and without distracting the driver. There were a lot of advantages to this. We could get VMS information at the right time to the right vehicle. We could blend both fixed and dynamic information. We could monitor the driver and deliver info during periods of inactivity. We could also feed information from one vehicle to another.

"Launched in 2006, the European projects, CVIS, SAFESPOT and COOPERS, used much more compact and versatile technology to demonstrate more traffic, safety and convenience applications that could take advantage of both dedicated and commercial infrastructures. Rolling out a lot of infrastructure over a large region might be unworkable but providing infrastructure at hot-spots is viable. The fully integrated solution allows the driver to get both long- and medium-range information from commercial networks and short-range safety information from other road users and roadside networks. Everybody wins, the driver pays for the device and the service level required, the industry has a platform to develop and sell new services, there'd be capital expense savings, reduced risk of casualties, improved environmental and aesthetics and reduced costs of revenue."

[1] 2002 abstract on IEEE-Xplore

there are areas of common interest such as safety, weather mitigation, self-driving vehicles, platooning, liability and data mining (although, perhaps for different ends).

Where are we headed?

An example of recent excitement involves self-driving cars – à la Google, a company very new to the automotive sector. Self-driving cars have been envisioned for several decades – mostly in science fiction. DARPA has had real ones operating in isolated desert environments for several years, largely with a military appeal and, of course, festooned with incredible and expensive sensory and control equipment. And now suddenly reaching the public imagination (but admittedly still very early), we can watch YouTube videos of self-driving vehicles in traffic on city streets. According to some sources, there have been approximately 10 research labs experimenting with driverless vehicle technology in the past decade alone.

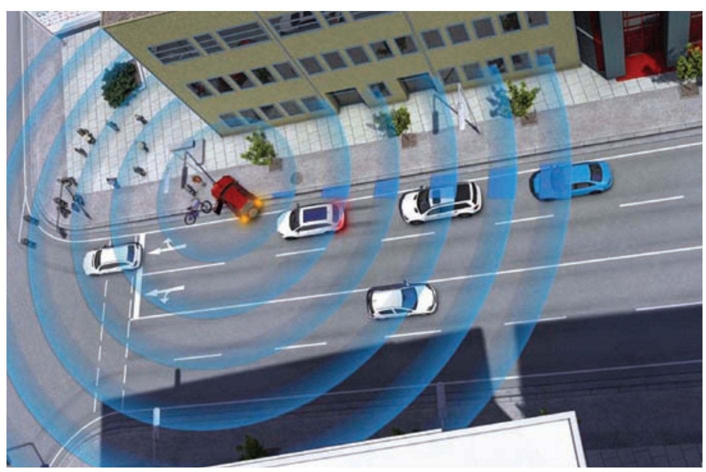
I am unwilling to predict when a standalone, self-driving vehicle – i.e. with no driver – will be feasible (much less legal) but I am willing to believe that convoys of passenger vehicles, dozens of vehicles long with only one driver in the lead, will be feasible in the very near future.

My observation is that ITS is in the midst of a corner-turn that started in the decade just past. The trend in innovation has been toward autonomy – i.e. with all the instrumentation inside the car. Volvo- and Google-inspired self-driving versus the Epcot-inspired 1960s guided vehicles of my youth and the virtual gantries of GNSS tolling versus the physical atavism of RFID/DSRC tolling gantries are just two examples. Others apparently on the near-horizon include in-car signage versus VMS and more investment in V2V communication versus V2I communication.

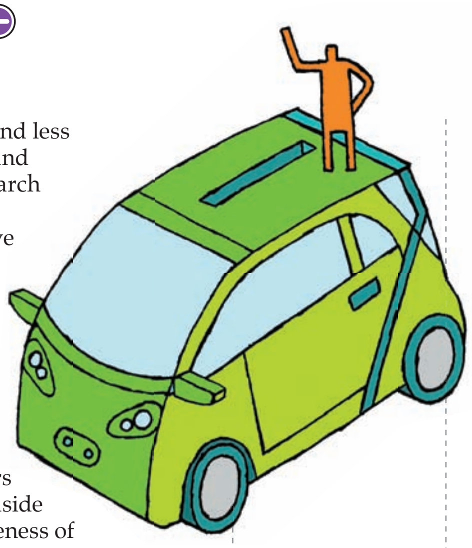
The trend toward autonomy will become a juggernaut fueled by the 'connected vehicle', 4G, software innovation, sensor innovation, social computing, and companies such as Google that see the potential of the dashboard as the next expansion of the web. (Did you think you would be reading a newspaper in your self-driving car as they simulate on the Volvo YouTube videos? You'll be reading online – because you'll be shopping). And already the telcos such as AT+T and KPN are joining the parade.

An ideal state of automobility would have autonomous vehicles move among and relative to each other, as do birds in a flock or fish in a school. Yes, this is science fiction. But how close can we get? And if we explicitly treat autonomy of movement as a design criterion, as Google's engineers obviously do, where would most investment dollars be spent? I would never suggest that we need nothing beyond concrete and guardrail for our highway infrastructure,

V2V communication will be integrated in the refined telematics platform of vehicles on the road



but I suggest that we spend less on roadside innovation and instead spend more research dollars on in-car smarts.



Besides its disincentive to autonomy, there are several other problems with roadside equipment that are more easily overcome with V2V and V2N/N2V (vehicle to net) telematics.

Safety: Reflecting on years of responsibility for roadside infrastructure and awareness of the lives lost to car-to-roadside collisions, Robert Cone, who currently chairs the PIARC-FISITA Joint Task Force for the Connected Vehicle and was past director of roads at the Welsh Assembly Government as well as a past ITS UK chairman (see sidebar on previous page), recently wrote to me: "Many of us dream about the uncluttered highway disappearing off into the sunset. This may be unrealistic but there is a huge potential for reducing the amount of fixed and variable signage, making the most of the ability of in-vehicle systems to do the job better, all in the service of making our roads and our trips safer." Of course, Cone is referring to the opportunity for using telematics to reduce roadside equipment, but his point is perfectly made. More in-car intelligence and fewer roadside hazards equates to greater safety.

Cost: Derek Turner, director of Network Delivery and Development at the Highways Agency in the UK, agrees. "In the longer term, the connected vehicle provides an opportunity to reduce the amount of roadside infrastructure deployed on the highway, with consequent reductions in operating costs and maintenance delays." Certainly, maintenance and maintenance delays also put roadside workers and drivers at some risk.

Taxpayer expense: Roadside equipment is almost always necessarily paid for by the taxpayer, while telematics devices are more likely to be paid for by drivers or private partners with commercial (and regulated) interests.

Flexibility: In-vehicle telematics can do so much more: they can change more nimbly; they can integrate dozens of functions; they can scale. Similar to smartphones, higher-end devices can be tried by a minority until perfected and prices drop for the majority. The opposite is true for roadside equipment, which soon becomes a barrier to change. Consider how odd it is that we often struggle to change things only to design replacements that then prevent change.

Extensibility: In-vehicle telematics can operate everywhere. A change to the network software can extend their range from a region to a state or from a country to a continent.

Innovation: In an era of wireless communication, cheap sensors, miniaturization, near-free processing and storage, cheap redundancy and some pretty amazing software, one of the best ways to stifle ITS innovation and halt its evolution is to install roadside equipment in concrete. As Google engineers had no choice but to operate on the roads and with the road markings that were already in place and the cars that happened to be there already, they could innovate independently of any new taxpayer-paid roadside equipment.

Non-pervasive: Uniformly capable roadside equipment cannot be pervasive – i.e. on every road segment and every street corner. Telematics can be. Car-attached systems (especially aftermarket installs) can change and multiply rapidly and dramatically as smartphones did.

Monolithic: Roadside equipment is necessarily simple, large, heavy and immobilized. And it has constrained intelligence.

Anti-evolution: Most things that work well mature during long periods of evolution. Small, light, changeable and autonomous things evolve faster than heavy, fixed ponderous things. Instrumentation that private enterprise finds profitable (even when regulated) evolves faster than large, expensive, government-supplied equipment.

Voluntary: The greater the autonomy of any ITS system – i.e. the greater the ability for a single vehicle to participate in

> Time and roadside equipment tends to automatically turn intelligent transportation systems into unintelligent transportation systems – and sometimes this implies less not more safety

Before ITS...

John Senders is Professor Emeritus, Industrial Engineering at the University of Toronto. He has worked on a wide diversity of problems including the mathematics of visual attention, especially as it pertains to the demands of automobile driving. I was his student in 1973/1974. In the mid-1960s, before ITS became ITS, Senders and some colleagues at Bolt Beranek and Newman (now BBN Technologies), carried out some seminal Human Factors studies attempting to model the role of human attention in operating a vehicle safely.[1] Back then it was about the man-machine interface and 'information

theory'. The BBN researchers were interested in how many bits per second a driver needs to process to successfully drive a car. Understanding this would impact dashboard design (similar to issues of aircraft cockpit design). Today, 45 years later, this work is being revisited in the context of 'distracted driving' and texting.

It is this kind of modeling of human behavior that can be exploited by instrumentation inside the vehicle but not by roadside equipment. I predict that within 10 years distracted driving will be managed by cheap, autonomous, in-car, aftermarket sensor systems that require no driver action to function. Assisting drivers by having them attend more reliably or by driving for them will save more lives in the long run.

[1] *The attentional demand of automobile driving*, Highway Research Record, 195, 15-33, 1967

From toll booths to ORT, tolling is a prime example of infrastructure finding it hard to keep apace with telematics development, such as those being explored in the DARPA Grand and Urban Challenges of the past decade

a safer mode of operation – the easier it is for a driver to volunteer participation. Voluntary participation reduces capital expense, increases acceptability, permits greater trial and error, attracts thoughtful use (and feedback), and promotes evolution.

Aesthetics: Our landscapes are cluttered with many roadside artifacts, many of which linger after use due to the expense of removing them. Increased autonomy of instrumentation reduces this problem.

Technical impedance

Roadside infrastructure can never keep pace with telematics development. You can see this in the entrenchment of older-style E-ZPass gates in the face of GNSS tolling that utilizes virtual gantries instead of steel and electricity. You can even see it in the newer-generation E-ZPass devices that lower emissions and reduce congestion by enabling open-road tolling (ORT).

Technical impedance is a measure of the differential rates at which technologies evolve and the fact that the ones with the slowest rate of evolution set the pace for the others. The Pennsylvania Turnpike (the roadway itself) started as a railbed in the 1880s and was built out as a highway in the late 1930s and has seen little change beyond extensions, an additional tunnel, bypasses to decommission three other tunnels, and some widening and repaving. Hence the technology on this turnpike changes once every 65 years or less.

The toll collection system on that turnpike has changed once since its initiation in 1940, when it went electronic with E-ZPass in 2001. Hence, this tolling system changes once every 35 years or so. The median age of the vehicle fleet that uses the highway is currently under 10 years, and the median age of the aftermarket electronic gadgets inside those cars and trucks (cell phones, GPS navigators, etc) is well under two years. What this says is that aftermarket instrumentation, especially if it can be self-installed, is easiest to meaningfully innovate, because its turnover is measured in years. Factory-installed instrumentation has a turnover measured in decades. But roadside evolution, measured in quarter-centuries, has far less opportunity for innovation.

There will always be strong, positive correlation between the volume and expense of fixed infrastructure and rapid obsolescence. Everything we build into the roadway will be with us long after its relative intelligence declines. Since the slow change of fixed infrastructure impedes change, ITS cannot long be mounted in concrete because that automatically discounts their intelligence year over year. Time and roadside equipment tends to automatically turn intelligent transportation systems into unintelligent transportation systems – and sometimes this implies less safety rather than more.

• *Bern Grush is the principal at Bern Grush Associates. If you would like to contact him, feel free to email bg@berngrush.com*