Get Smart

Pouring more concrete will not by itself answer our infrastructure prayers. Look instead to the transformative power of information technology.

BY JOEL GARREAU

In 1876, Western Union decided that telephones would never replace telegram messengers. In 1971, AT&T turned down the opportunity to run the Internet as a monopoly. In 1980, Ma Bell concluded that cell phones would never replace landlines.

These moments come to mind as that painfully unglamorous word *infrastructure* is increasingly heard on Capitol Hill. Our roads and airports are jammed. Drought threatens from Tucson to Atlanta. Floods are a plague from the Chesapeake to California. Our air conditioners and computers are straining the capacity of our electrical grid.

We can't go on like this, goes the hand-wringing refrain.

Turns out that's true, in an ironic way. Our industrial-age solutions *are* approaching their limits. Not only are they crumbling into decrepitude, but they have reached levels of physical absurdity that spark kamikaze political resistance, from 17-story-tall electrical transmission towers despoiling rare and pristine landscapes to interstate highways approaching the width of the Bosporus.

The business-as-usual interests lining up for more tax dollars rarely mention the impending obsolescence of their favored projects. Yet increasingly, infrastructure depends as much on wires a few molecules wide, and biology that produces energy, as it does on steel and concrete. The means to fundamentally control matter, energy, and life itself are emerging so fast that it is hard to imagine any existing infrastructure technology not being shaken to its core in the next decade or two.

These game changers can be dated to 1965—six years after the first commercial computer chip appeared. An obscure physical chemist named Gordon E. Moore noticed that the number of transistors you could put on a piece of silicon at the cost of a dollar was doubling every year. He boldly predicted that these doublings would continue for 10 more years.

Little did he know. Moore, who would become one of the founders of Intel and a billionaire several times over, will probably be best remembered for what is now known as Moore's Law. That axiom, which has become the core faith of the global computer industry, is usually stated this way: "The power of information technology will double every 18 months, for as far as the eye can see."

A doubling is an amazing thing. If we think of progress as a staircase, it makes each step as tall as all of the previous steps put together. Such doublings every 18 months describe a geometric curve. The 20 years behind you are not a guide to the next 20 years; they are at best a guide to the next eight. And your previous 50 years are not a guide to your next 50; they are at best a guide to the next 14. For example, a single iPhone has more processing power than all the computers at the disposal of

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the North American Air Defense Command in 1965, when Moore prophesied.

Even more startling is how Moore's Law opens entirely new vistas, especially in what I call the GRIN technologies, for the genetic, robotic, information, and nano processes. Each is following its own curve of exponential change.

When sequencing the human genome was first proposed in 1985, many thought it could never be accomplished, or would cost the earth. Yet scientists managed the feat by 2000, for a fraction of the anticipated cost. That's because the computers required to make it happen conformed to the inexorable price-performance curve of Moore's Law and accelerated the future into being. Soon you will be able to get your own genome sequenced—all 3.5 billion bases—for $1,000. Nathan Myhrvold, the former technology chief of Microsoft, expects the price eventually to drop to $10.

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As the price of oil soars and the cost of computing approaches zero, there is an enormous spur to make infrastructure smarter. The industrial-age way to address congestion, for example, is to pour more concrete. But there is already vastly more capacity in the American road system than we remotely need. If we could find a way to fill the front passenger seat of just 20 percent of the cars on the road, traffic jams could be eliminated tomorrow.

How would you do that? One way would be to have your madly clever cell phone alert the world to your desire to go from here to there. The idea would be to create a market of trustworthy people heading in the right direction who might pick you up in the next five minutes in exchange for, say, the price of gas and tolls. Think eBay organizing rides on the fly.

Navigation systems already give directions to drivers—today's cars have far more computers than light bulbs. Nissan and other auto manufacturers are well on the way to fielding smart cruise controls that communicate with other cars and with sensors on the road ahead to maintain high speeds, plan alternate routes to avoid traffic snarls, and prevent accidents.

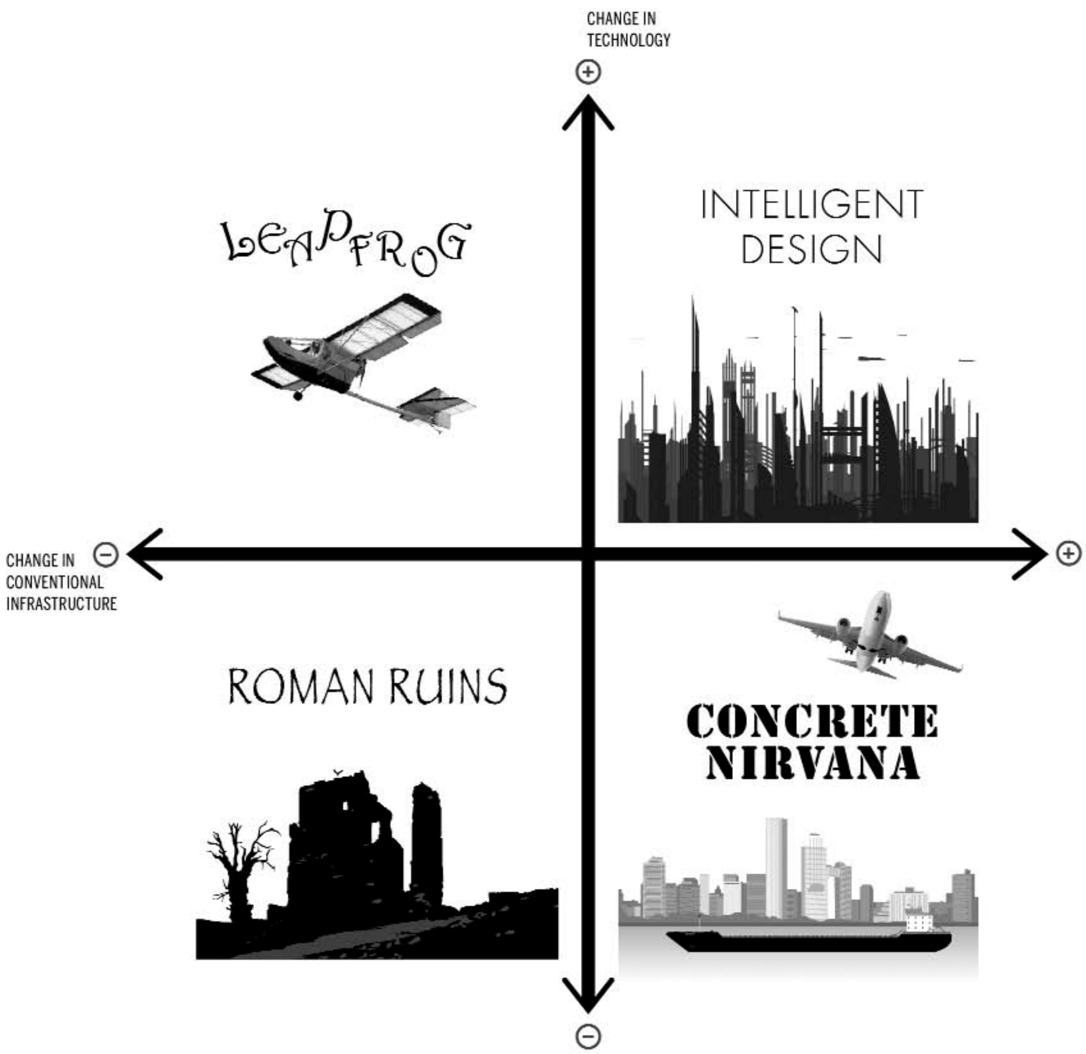
The more urgent our problems—such as global warming—the more likely we are to reach out to our amazing new technologies for solutions. Oil at $100 a barrel is a serious incentive. Already geneticists at companies such as LS9 Inc. are commercializing life forms that eat cellulose and poop gasoline for what is promised to be about a buck a gallon. Craig Venter, who sequenced the human genome in 2000, believes he will have a critter next year that will devour climate-ruining carbon dioxide and turn it into gasoline.

But solar power is the real solution to the energy crisis. As it happens, that low-hanging fruit is one of the first targets of nanotechnology. Several companies, such as Nanosolar Inc., are going commercial right now with processes that produce endless sheets of thin plastic with astoundingly tiny energy-converting semiconductors printed on them in nano-ink. If the technology rolls out as hoped, it will be able to turn sunshine into electricity priced as cheaply as power from coal-fired plants. A National Association of Engineers panel recently predicted that solar power will scale up to produce enough energy to meet the needs of everyone in the world in 20 years.

Would that profoundly change the infrastructure challenge? You bet. What is now a top-down hierarchy dominated by big generators, big transmission lines, and big coal would become a bottom-up network in which every consumer could also be a creator. Just as the Internet has chewed up the television, radio, movie, newspaper, music, and telephone worlds, distributed GRIN technologies could cause an upheaval in the world of utilities.

Slightly farther out on the commercialization horizon are nanotechnology membranes like those developed at UCLA that promise to slash the cost of desalinating water. Along with biotech, they also promise to mitigate the effects of pollutants. None of these are lab curiosities.

Four Infrastructure Futures



Changes in technology and conventional investment will shape the future. In the "Intelligent Design" scenario both increase. In "Concrete Nirvana" investment grows but technology does not. "Roman Ruins" is the worst of both worlds. In "Leapfrog," new technologies overcome crumbling infrastructure.

They are burgeoning businesses that are ramping up now. The question isn't whether the technologies work, it's whether the economics do. If so, they could affect quite a few dam, canal, and treatment plant calculations.

Will these game-changing technologies become commercially viable in time to solve all our problems? Who knows? But if they do, a transformation on the scale of those that roared past Western Union and AT&T is a serious possibility.

The prospects I describe pose two critical questions: First, will we quickly address all our infrastructure problems by pouring concrete and deploying all the tried-and-true industrial-age solutions as fast as we can? There's a huge range of possibilities between yes and no. Second, will game-changing technologies come on line quickly, cheaply, and with no unanticipated consequences?

Graph those two uncertainties as axes (see p. 61), each with a negative and positive pole, and you get a vision of four possible worlds we might be entering in the next 10 or 20 years.

If we don't pour all the concrete, and the new technologies don't live up to their promise, we're looking at a minus-minus world one might call "Roman Ruins." Worst case, our cities contract, our fields dry up, our lowlands are covered by ocean, and our economies collapse. You've seen the disaster movies—*The Day After Tomorrow,* for example.

That's a serious scenario. Could happen. Look at New Orleans.

In another world—call it "Concrete Nirvana"—it turns out that the new technologies do not rapidly live up to their promises, but we do start listening to all the alarms from our belt-and-suspenders engineers, bless their hearts, who warn about rolling blackouts and empty faucets. In that world of one minus, one plus, we recognize that our civilization is at stake and rapidly decide that there are worse things than building scores of coal and nuclear power plants, waste treatment facilities, dams, and dikes. Roads are widened, rail undergoes a new renaissance, and dramatically enlarged airports and seaports attract awed visitors from around the world.

Again, could happen. All it takes is political will. And a lot of lobbying dollars.

Diagonally across from "Concrete Nirvana" on the matrix is the one-plus, one-minus world we might call "Leapfrog." In this world, new technologies come to market so fast that old infrastructure worries become quaintly obsolete. Now that cell phone service covers 98 percent of Bangladesh—thanks to Grameenphone, an offshoot of the Nobel Prize–winning microlending outfit Grameen Bank—can anyone remember why we ever worried about how much it would cost to cover the planet with landlines?

Diagonally across from "Roman Ruins" is "Intelligent Design." This is the plus-plus world in which we recognize all the problems, recognize all the possibilities, try everything we can dream up, and see what sticks. In this world, for example, we recognize ways to transform air travel: deploy many more jet taxis like those already developed by Honda, Cessna, Adam Aircraft, Eclipse, and Embraer that are smart, efficient, and can safely and quickly make the hop from a short runway near your house to a short runway near your destination without needing massive hubs and enormous investments in air traffic controllers. Insurance companies mandate that the only way to travel on highly congested roads is to turn the driving over to smart navigation bots that never get drunk or distracted and are far better than people at avoiding accidents. As a side benefit, these bots safely pack many more cars—bumper to bumper, at speeds of 80 miles per hour—into the same amount of space as in the old world, ending traffic jams forever.

The way we get to "Intelligent Design" may be by recalling that, historically, the infrastructure solutions that work best are public-private partnerships. Think private passenger planes landing on public runways, or private cars traveling on public roads. All-private solutions, such as investor-owned toll roads, and all-public ones, such as subways, have their place. But they are specialized tools.

The public-private partnership I most want to see is the one that quickly provides "big broadband" of between 100 million and one billion bits per second to every home in the land. Between 1999 and 2006, the United States fell from third place to 20th in the International Telecommunications Union's measure of average broadband speeds, behind, oh, Portugal. This is disastrous for the American economy. It means the markets for next-generation information companies will be elsewhere. Just as with that earlier critical economic and social enabler, the telephone, there are few if any market reasons for private-sector providers to install fat information pipes the last mile to every home. That's why the governments of states such as California and Kentucky have stepped up to the plate, launching innovative public-private partnerships.

Whatever does the job, let's do it. Now. One idea—surely there are others—is for the federal government, the states, and the private sector together to spend on the task in each of the next four years about what it cost to build Boston's Big Dig. However we do it, the important idea is for all of us to hook up quickly to imagine mind-blowing solutions to our novel challenges together.

Is that a credible "Intelligent Design" scenario? You decide. ■