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RE-IMAGINING INFRASTRUCTURE

Mark Gerencser

When we turn on a faucet or flip a light switch, we rarely consider the vast networks and complex systems behind them. But vast and complex they are: More than 160,000 miles of high-voltage transmission lines bring power to the farthest reaches of our country; people and goods travel to their destinations along nearly four million miles of roads; our water comes to the tap by way of nearly 55,000 separate drinking water plants.

One of the more remarkable aspects of infrastructure is how little we think about it. Hardly anyone grasps that infrastructure is to a society what the circulatory system is to a human body: a series of vital, interwoven transmission belts for moving not just things but also people, services and ideas. We think even less about the history of this vast circulatory system as an expression of our political culture. America's power, water and transportation infrastructures have long been correctly regarded as marvels of the modern age. More important, perhaps, is that in a nation proud of private initiative and responsibility, and of government both small and Federal, infrastructure has long forced us to adapt our ideology to necessity. Roads and canals, and eventually railroads, telegraphs and electricity grids, all evolved over the course of our nation's history into government obligations requiring varying degrees of investment, management and maintenance on behalf of what was well understood to be critical to both our economy and national security. Our infrastructure's history is thus composed not just of invention, engineering and construction, but also of finance, management and planning. It reflects a synergy of action between a variety of players from the market economy and in government at the municipal, county, state and Federal levels.

These days, Americans are noticing infrastructure more than usual, and at least some are trying to think about it—because it's failing, with disturbing consequences. The American Society of Civil Engineers (ASCE) generously awarded it, in its 2009 *Report Card for America's Infrastructure*, an overall grade of D. This is not only a problem because the U.S. military counts on our infrastructure as part of its increasingly

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complex and far-flung global supply chains, but also because America's economy can only grow if those infrastructures allow it. Studies have shown, for example, that a 30 percent increase in air passenger volume in just one region of our country could create more than 50,000 new jobs.[1]

Many observers attribute our infrastructure deficit mainly to inadequate government funding, which has left us with crumbling bridges and a dearth of the cutting-edge technologies needed to meet the challenges of the future. It is certainly true that we have not spent enough on infrastructure in recent years. The United States today spends less than 2 percent of its GDP on infrastructure, while China and India, admittedly starting from a much lower base of fixed assets, are spending 9 and 5 percent, respectively. Our underinvestment has not been caused by a lack of money, however. Serious funding constraints on government investments are of relatively recent vintage and so cannot explain underinvestment in key systems over the past quarter century. Furthermore, there is still enough money in the hands of private investors, if not government, to meet our infrastructure needs. So, it's not the money nor is it any significant deficits in technology, skill or know-how. What, then, has gone wrong, and how can we make it right?

Things Fall Apart

Let's start with the basics. The U.S. government defines 18 of America's infrastructures as "critical" to the nation (see figure 1).[2] Each is governed independently and each now finds itself in a different stage of its lifecycle. Some are mature, old even (water and waste water systems). Others are new (information technology). Still others are now being transformed (banking & finance). Of the 18 categories, three are basic, underlying "lifeline" infrastructures: energy, transportation and water. As it happens, all three are beyond mature; they are nearing the end of their useful operating lives and are in desperate need of recapitalization and modernization to accommodate both new needs and the increased demands of our population growth.[3]

More than a quarter of the nation's bridges are structurally deficient, and by every measure the quality of highways and roads continues to decline. Transportation congestion has worsened to the point that Americans now spend some 4.2 billion hours a year in traffic delays. Total fuel wasted on the road has climbed from 1.7 billion gallons in 1995 to 2.9 billion gallons in 2005. Drinking water systems in dozens of major metropolitan areas are contaminated, corroded water pipes leak as many as seven billion gallons of clean drinking water per day, and broken sewage systems send billions of gallons of untreated wastewater into streams and rivers each year. Of the 85,000 dams in the United States, more than 4,000 are deficient, including 1,819 high-hazard-potential dams, and the average age of all dams is about 51 years. Finally, electricity distribution lines have become "bottlenecks", with outages costing more than $180 billion annually and getting worse, rendering many parts of the electrical grid stressed or unreliable.

Along with its sobering grade of D, the ASCE report card defined the infrastructure crisis as a $2 trillion problem and growing. In some ways, the report's specific findings are even more alarming than the stark $2 trillion figure itself:

- America's drinking water systems face an annual shortfall of at least $11 billion to replace aging facilities that are near the end of their useful lives and to comply with Federal water regulations.

- Of the 257 locks still in use on the nation's inland waterways, thirty were built in the 1800s and another 92 are more than sixty years old. The cost to replace the present system is estimated at more than $125 billion.

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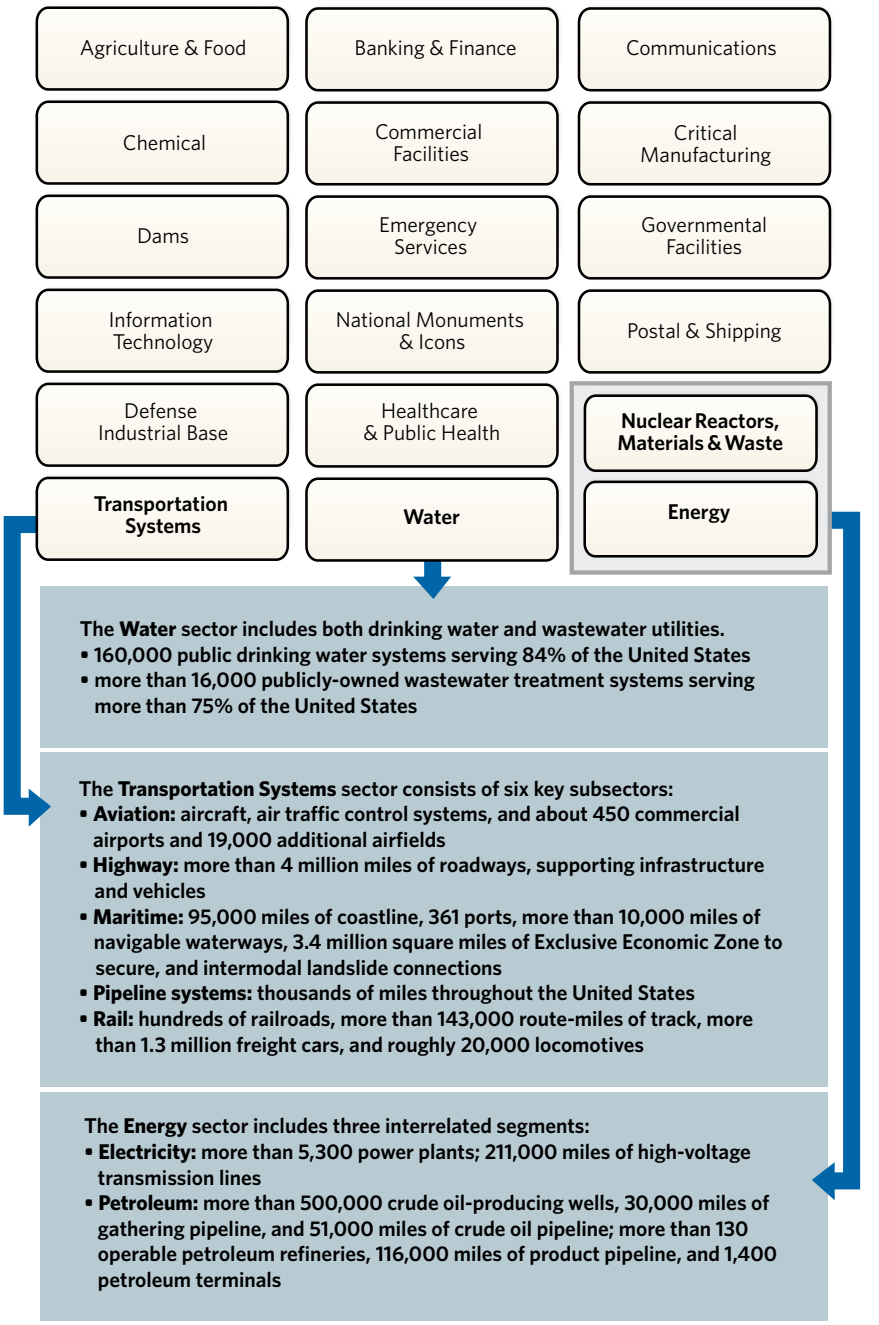
[1]Booz Allen Hamilton, "Analysis of Changes to Passenger Capacity and Airline Operating Costs with NextGen Technology" (May 2010).

[2]Department of Homeland Security, *National Infrastructure Protection Plan (Energy, Water, and Transportation Systems Sectors).*

[3]The Census Bureau projects a U.S. population of 439 million by 2050, a 46 percent increase from 2006 (300 million).

Figure 1



- Of the 100,000 miles of levees in the country, 85 percent are locally owned and maintained and of unknown reliability. Many are more than fifty years old. Rough estimates put the cost at more than $100 billion to repair and rehabilitate these levees.

- The Environmental Protection Agency estimates that the nation must invest $390 billion over the next twenty years to update or replace existing waste water systems and build new ones to meet increasing demand.

- About a third of America's major roads are in poor or mediocre condition, and 36 percent of the nation's major urban highways are congested. The current spending level of $70.3 billion for highway capital improvements is well below the estimated $186 billion needed annually to substantially improve the nation's highways.

But despite the staggering size of these figures, money is not our biggest problem, even in times of fiscal austerity. Our real problem is

at the same time conceptual, institutional and political—all summed to the issue of transformational leadership. History shows that modernizing infrastructures tends to be more problematic than creating them, thanks to the drag caused by legacy hardware and its human "software." Infrastructure officials get so locked into old engineering designs and associated management paradigms that they often cannot conceive of new ways of doing things. And even when some do manage to think anew, they are confronted with a stark reality: While incremental investments are organizationally and financially within reach, major transformations are dramatically harder because of both sticker shock and entrenched institutional interests. Efforts to overcome bureaucratic aging of this sort thus require transformational leadership, and that is precisely what we have lacked in recent years.

On the conceptual side of the problem, everyone realizes that infrastructures, like all machines, eventually reach a point where incremental adjustment simply makes no sense. Few people will pay to repair a transmission in an old car when it would cost more than the value of the whole vehicle. But infrastructure is more complicated than that. Upgrades demand major shifts in business models and operations as well as new technologies and materials. Unfortunately, we tend to focus on the hardware (the technologies and materials) and ignore the software (the people, management processes and institutional arrangements) that makes it all work.

For example, when politicians and policy wonks alike speak of the "smart grid", they usually mean it as shorthand for incorporating more sophisticated metering and command and control technology into our electrical production and distribution systems. While metering and flow control is important, those improvements don't even begin to encompass what a "smart grid" would need to work. The goal is to create a resilient network that efficiently and reliably stores and transports energy to consumers, regardless of where the producer or consumer of that power is located. To achieve that goal, we need more reactive power.[4] But since reactive power serves no tangible purpose to a consumer, utility companies lack any incentive to generate something they can't sell. Thus the current business model isn't suited for making a truly smart grid work. This explains why progress toward creating one is going approximately nowhere, despite the funds, rhetoric and attention thrown its way. We have the money and the technology; what we lack is a integrative leadership that understands the need to re-imagine the entire system, including its business models, stakeholder roles, relationships and purpose.

By historical standards this is a relatively new problem for the United States. In the past, we Americans were very good at imagining new infrastructures. For example, in the early 1800s, the Erie Canal opened up the Midwest to development. More than a century later, rural electrification made farming in America's heartland vastly more productive. By the mid-1950s, infrastructure acquired a new dimension: national security. President Eisenhower played a key role in promoting our national highway system after he failed to convince the auto industry to make the investment in roads in order to sell more cars. He envisioned the highway system not just as a public benefit and an economic driver but as a critically important mechanism for mobilizing troops and their equipment across the country.

As a rule, American leaders of all parties have understood that massive projects require leaps of imagination. Their imaginations have been agile enough, too, to realize that people, and organizations of people, are the critical variables for success. Such imaginative sprightliness has been a natural component of the American psyche, along with its boundless energy and optimism. This is not the place to speculate about why recent generations of American leaders seem to have lost the knack. But clearly, we

[4]Reactive Power is the loss of power arising from the production of electric and magnetic fields. Although reactive loads dissipate no actual power, they drop voltage and draw current, giving rise to the term "phantom power." Reactive power is essential for continuous, steady voltage on transmission networks and is produced to maintain the system rather than for end-use consumption. If elements of the power grid cannot get the reactive power they need from nearby sources, they will pull it across transmission lines and destabilize the grid.

must become as good at re-imagining infrastructures as we once were at imagining them for the first time, or we risk harming our quality of life, economic competiveness and national security.

There is no mystery as to how we must proceed. Our re-imagination must devise new business models and stakeholder roles that will create the right behaviors and avoid any perverse incentives (when incentive and accountability structures inadvertently lead to self-defeating outcomes). Currently, those most affected by infrastructure (individual citizens) lack the direct authority to approve it. And those who approve it (government commissions and/or utility regulators) are not primarily the ones who use it. Furthermore, those who use it most (citizens, corporations) often don't pay for all of its costs. And those who benefit from the construction of infrastructure (developers, construction firms) usually have the greatest voice in how it is designed and operated. As a military commander might describe the situation, there is no unity of command, and hardly even any unity of effort, in the infrastructure business these days.

To some extent, inefficiencies are built into our way of building, operating and maintaining infrastructures due to American political culture. Countries from China to France see no problem with government owning and operating most or all of a nation's major infrastructure, but most Americans do have a problem with that. American preferences have given rise to utility monopolies—privately owned operations that are regulated by government. This logic is unassailable; no American would want to sweep aside all the safety, environmental, zoning and public health concerns associated with a full-bore privatization of these utilities. But that same logic creates the need for hybrids of private industry and government relationships, and these hybrids have proved delicate, if not elusive, creatures.

There was a time when the political economy of U.S. infrastructure operations was not particularly problematic. Government at various levels played a dominant role, and all stakeholders benefited from a relationship rendered stable by the predictability of the technology and the social organization of the services involved. No doubt there were inefficiencies of many kinds in this arrangement, but since the economy was growing and the technologies at hand suited our purposes for long periods of time, these inefficiencies were absorbed more or less smoothly into the system. Thanks to the stability of these arrangements, we could also ignore most decisions about which level of government was most appropriate for overseeing various infrastructure systems as technology changed.

This arrangement, along with its business models, is now obsolete for three interwoven reasons: The role of government has become muddled; the stability of stakeholder equities is no more; and the velocity of technological change now outpaces the political and administrative rhythms of the old system.

In the post-Reagan era, it is easy to forget that the 20th-century American political economy was considerably more regulated than it is today, informally if not also formally. Government infrastructure monopolies or government-abetted monopolies-in-effect dotted the socio-economic landscape. For example, the Tennessee Valley Authority, or TVA, was created in 1933 by an act of Congress to help alleviate the effects of the Depression. Its charter was to provide navigation, flood control, electricity generation, fertilizer manufacturing and economic development to the region. Hence, TVA was envisioned to be more than an electricity producer; it had become a driver of regional economic development. Other examples are the power administrations such as Bonneville, Southeastern and Southwestern that market electricity from hydro-electric power plants on public lands operated by the U.S. Army Corps of Engineers. These were created by acts of Congress between 1927 and 1950, and still exist as Federal agencies today, delivering power to 34 states.

Deregulation, which began in earnest in the mid-1970s and accelerated into the 1980s and 1990s, may well have bequeathed short-term economic benefits, but it has also made long-range management, planning and investment decisions for infrastructure systems far more difficult. The parts of government that once took on this role have been overcome by a combination of this changing landscape as well as technological discontinuities and mission creep. At the same time,

the globalization of finance and capital flows has changed the stakeholder landscape almost beyond recognition in only the past twenty years. The infrastructure-related industries of the United States used to be part of a relatively stable public utilities market, but deregulation, corporate mergers and acquisitions, and outsourcing trends have put an end to that stability.

The biggest destabilizer, however, is new technology, which is rapidly forcing decisions on government and other stakeholder roles. To take only one example: Our next-generation air traffic control system, *NextGen* for short, promises that air travel will use less fuel, create less noise, cause fewer delays and be safer. To realize *NextGen*, however, the air traffic control infrastructure needs to migrate from the ground (radars, controllers and the like) to a distributed architecture across the ground, air and space. This will require major shifts in mindsets and operations. Local or Federal government currently owns ground assets that need to be part of *NextGen*, but commercial industry owns most of the airborne assets. Different commercial businesses, along with various government entities, either own or control the space-based elements of the system. So *NextGen* is much more than a technology challenge; it's a combined systems, business model and stakeholder challenge. As with the Smart Grid, astute leaders need to re-imagine governance system designs as a whole and then apply political power to induce the necessary changes.

The same basic requirement applies to virtually every infrastructure innovation we need to make. Indeed, as we shall see, the point also applies to the idea of a conceptually integrated infrastructural "system of systems" that must guide our way through this century and into the next.

Compounding Problems

The destabilization of our stagnant infrastructure business models and the administrative processes associated with them has left us confused. We are saddled with legacy systems that generate their own, often dysfunctional momentum, and we are at a loss for how to renew them. We envy countries with emerging economies that now rapidly design, fund and build new infrastructures with more capacity and capability than ours. We are chagrined, for example, that it has taken longer to complete a rail link from downtown Washington, DC to Dulles Airport in Virginia than it took China to build three entirely new airports from scratch.

While other nations are forging ahead, we are reduced to incremental improvements. This failure to see over the transom of our own imagination is compounding our problems. Simply inserting incremental technology fixes without re-conceiving the whole often creates unintended consequences elsewhere in the infrastructure. Consider the initiative launched in Texas in the 1990s that attempted to bring new wind-generated energy from the breezy plains and mesas of west Texas to the most populous eastern part of the state. Energy developers and entrepreneurs began building a series of wind farms and planned to piggyback distribution on extant power lines. As the wind farms proved successful, they multiplied to the point at which existing power lines lacked the capacity to carry the additional load. This led to legislation mandating additional power transmission lines at a cost of $5 billion. The project was ultimately stalled by unexpected opposition from landowners, who had aesthetic, environmental and cost concerns.

Another pitfall with incremental upgrades is that it makes an infrastructure more vulnerable to natural disasters or deliberate attacks. As we automate older processes, for example, we create more complexities in the system without "baking in" security precautions or adding capacity and redundancy for enhanced resilience. This vulnerability is most pronounced when we place new control and administration systems on top of old processes and aging technology in critical infrastructures such as the transmission of electricity, transportation of gas and oil in pipelines, water distribution and traffic control systems. Doing this not only runs a risk that old systems will not fit with new monitoring and control devices; it sometimes creates unplanned or unforeseen interdependencies, a trend has been building for decades and has accelerated dramatically in recent years as we introduce more sophisticated cybernetic controls. Incremental upgrades have already created failure points hidden in one infrastructure

that can jeopardize the reliability of others. For example, we often use the telecommunications infrastructure to carry the control signals that facilitate the automation of other infrastructures. Hence, a disruption in telecommunications could impair our water systems.

This raises two critical issues—the interconnectivity of infrastructure systems and what that implies for our governance processes. Half a century ago, the degree of causal interdependence between our electrical power, transportation, water and communications systems was modest at best. We could afford to segment these functions and apply the principle of subsidiarity to their management. Today, however, the information technology revolution has caused infrastructure systems and functions to converge and overlap such that it is difficult to treat them as independent functions.

This tendency toward integration offers great opportunities to introduce new efficiencies and to realize gains in performance, reliability and safety, but it requires us to think and manage very differently than we have in the past. It requires those in charge of different infrastructure functions, in industry and government, to talk to one another and to budget and plan together. At the conceptual level, the challenge resides in learning how to take advantage of a systems approach to infrastructure as a whole without disrupting the efficiencies afforded by distributed networks. Centralized conceptual approaches are fully compatible with decentralized management processes, but we have yet to work out how to do this in the course of our infrastructure renewal. We lack the integrative leadership that understands the new imperatives, and, consequently, we lack a governance venue in which we can even discuss the problem. Ask yourself this simple question: Where in the U.S. government, at any level, do stakeholders in infrastructure regularly come together to review, assess and plan for the future of the system as a whole? At the Department of Transportation? Homeland Security? Interior? The FAA? Any single Congressional committee? If you know your government well enough to have answered, "There is no such place", then you understand the crux of the challenge.

What We Need to Do

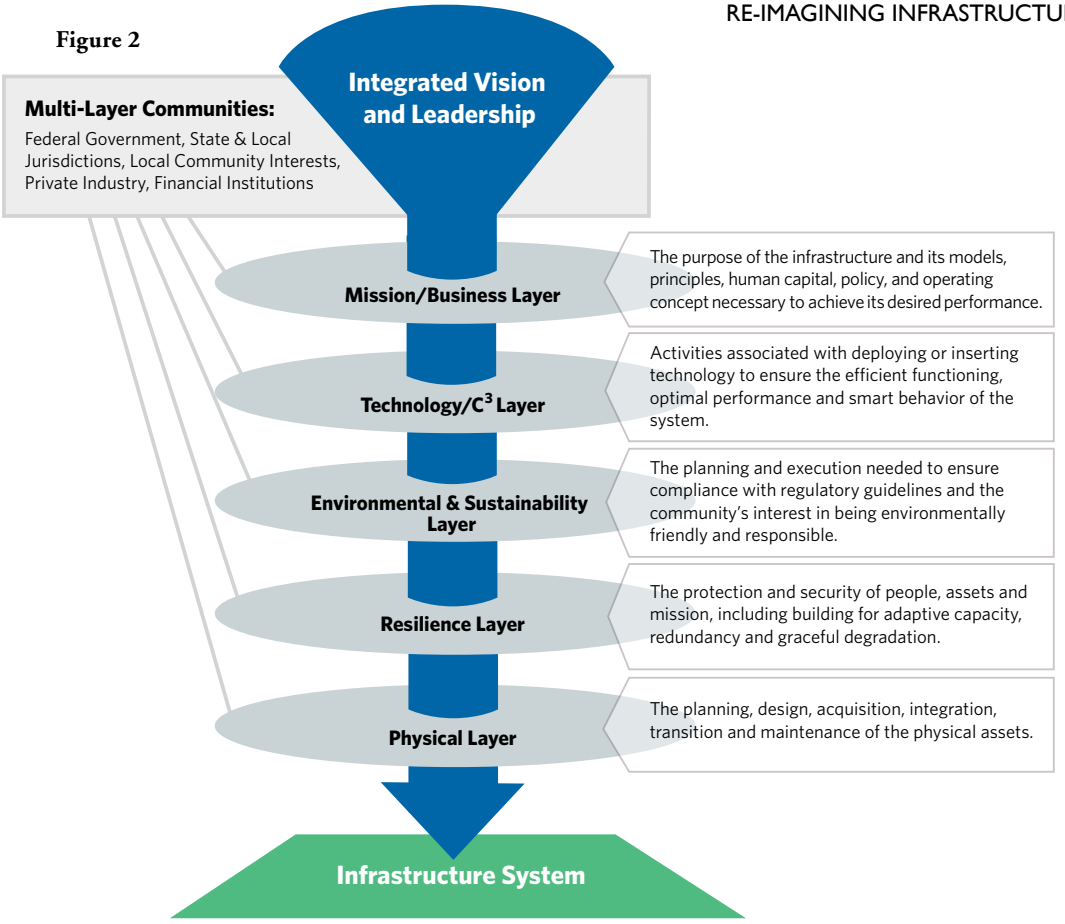
We in the United States have the capabilities in hand for developing innovative and effective infrastructures. We have the talent, the engineering capacity, the construction know-how, materials, processes and experience to complete major new infrastructure projects of all sorts. Indeed, the irony is that much of the best infrastructure now being developed around the world is based on American invention and technology. Contrary to popular impressions, too, we also have the money to fuel major projects, especially when we take into account new financing models and the vast private capital that can be unleashed.[5] What is lacking is an integrating calculus and governance mechanism to achieve the ends we desire.

This is no easy task, to be sure. Since infrastructures are complex systems that involve a number of disparate stakeholders across government, industry and society, integrated leadership is central to renewing them. The government piece of the puzzle by itself is complex because our federal system recognizes state and local municipality rights. Thus we need leadership that works across these jurisdictions as well. In short, we need to recreate government's integrator role without creating either new monopolies or a larger, more centralized government. Four key steps can lead us there.

First, we need to re-imagine the form and function of our old infrastructures. We must view infrastructures as a single network of complex systems comprised of different assets, jurisdictional authorities and stakeholders. Second, we need design principles that make future infrastructures robust and adaptable as technology advances, funding changes and the needs of our citizens evolve. Third, we need leadership

[5] A 2008 New America Foundation study estimated that $400 billion in global funds is available for equity investment in infrastructure, with the funds available to support the debt component amounting to several trillion dollars if global central bank reserves, global pension funds and sovereign wealth funds were included (as they are in Europe, unlike in the United States, which relies significantly on municipal bonds to for debt investment).

Figure 2



that succeeds by convening, integrating and aligning the interests and actions of disparate sets of stakeholders. Finally, we need a national vision for America's infrastructure that defines the function and performance of the whole system over its entire lifecycle. Only with such a vision can we devise an integrated policy that spans government bureaucracy silos and enables key stakeholders (public, private, non-profit) to operate in alignment. Only with such a vision can we ensure long-term, stable funding that benefits from private capital and appropriate levels of government investment. Let's look at these four steps in more detail.

Re-imagining Complex Infrastructures: Infrastructures are complex networks of people, processes and technology that range across multiple jurisdictions to deliver a needed end-service. It helps to view this network as a complex system having multiple, interdependent "layers" ranging from its physical components at the foundation to its purpose at the top. Figure 2 depicts this interdependent multi-layer notion and describes each layer. Surrounding the layers are communities of stakeholders, each with their own interests and motives. When we re-imagine infrastructures, we must take all layers into account, as each needs to change as part of the renewal of the whole system. It's not just about the technology or physical assets layer. More often than not, the business model piece of the puzzle is more important.

Re-imagination requires optimizing and integrating all these layers as a unified whole and effectively engaging the stakeholder communities, convincing them to take the long view and move beyond their near-term self-interest. The Department of Defense Base Realignment and Closure (BRAC) process has set the precedent for this. It can be done.

Design Principles of Future Infrastructures: We need a set of design principles that accommodate future technological change and the new needs of our citizens. In other words, infrastructure systems must be easily upgradable when new technologies come to fruition. They must also be sustainable and environmentally friendly to pass political muster and meet the

needs of future generations. And they must be resilient enough to recover from disruption. These qualities don't emerge by accident; they must be designed in. They are integral to our telecommunications and computer industries today, but they are largely absent in our lifeline infrastructures.

One important means of accelerating infrastructure adaptability is modularity within an open architecture design. Modularity allows the larger infrastructure system to adapt to changing conditions without disrupting its function as a whole. There is some modularity in current support infrastructures, but this has resulted more from happenstance than design. We must strive to achieve the same level of modularity that makes the iPhone work—a common operating system that runs a set of constantly improving applications.

Modularity is also good for resilience—the capacity to absorb or mitigate the impact of hazardous events while maintaining and restoring critical services. While a relatively new concept to engineering, achieving resilience requires creating capacity and redundancy in infrastructure systems to rapidly return to normal operating levels under duress. Designers of resilient systems analyze all the ways a system could lose functionality, and then devise counter-measures to deal with each possibility in a series of if/then scenarios. Such measures are often automatic responses that may resolve the problem on their own—or prompt the system's operators to take immediate action. If that action is fast enough, it can be as effective as a redundant or backup system**.** Building in resilience is more effective than managing risks, but it introduces additional cost without initially appreciating the benefit of the investment—that is, until we need it.

A second design consideration borrows the Defense Department's planning philosophy, called pre-planned product improvement (P3I), or evolutionary acquisition by another name. This approach yields a system design that incorporates technologies known to be important but not yet mature or affordable enough to include in the current implementation. Provisions, interfaces and accessibilities are included in the system's design and plans so that the deferred technology, process or capability can be incorporated in a cost effective manner when it is either ready or affordable. Using P3I, we can field infrastructure projects as phased solutions that anticipate additional capabilities, innovations or upgrades.

A third design consideration is sustainability. Sustainable infrastructure benefits the environment, the economy and social well-being, now and for future generations. Environmental design features should include reduced use of potable water, increased use of recycled water, reduced emissions of greenhouse gases, use of renewable energy sources, and systems that allow disassembly, recycling and material reuse. Economic design considerations include life-cycle costs, community growth and economic development (employment gains are important, too). Social design considerations address improved access for communities, protection and enhancement of cultural features, social equity and improved availability to the public.

Integrative leadership—Megacommunities: Leadership of infrastructure renewal requires a collective vision. Stakeholder communities are wired to pursue their own self-interests; this is as it should be, more or less. It is leadership's job to broker and enforce a functional common ground by which stakeholders can align their interests with the common good. There is no invisible hand that will make this happen all by itself.

A new engagement type, known as a megacommunity, recognizes that complex problems and transformational projects cannot be resolved by a single stakeholder or even by circumscribed groups of stakeholders.[6] All sectors must participate: business, government and civil society. The idea of a mega-, or larger, community is critical—forming an expansive, self-sustaining network that puts people with the right resources in the right place at the right time. A megacommunity is not just another term for a public-private partnership. A public-private partnership focuses on a relatively narrow purpose and is formed, governed and constrained by a static legal agreement. A

[6]Gerencser, Reginald van Lee, Fernando Napolitano, Christopher Kelly and Walter Isaacson, *Megacommunities, How Leaders of Government, Business, Non-profits Can Tackle Today's Global Challenges Together* (Palgrave-Macmillan, 2008).

megacommunity is a sphere in which stakeholders voluntarily join together around a compelling issue of national importance and follow a set of practices and protocols that make it easier for them to achieve results. The participants remain interdependent because their common interest compels them to work together, even though they might not see mutual problems in the same way.

Perhaps the most powerful aspect of the megacommunity is that it does not discourage self-interest; it actually promotes it. Overlapping vital interests, the essential goals the stakeholders share, unite megacommunity members around a common purpose and encourage them to act.[v] This allows organizations to participate without worrying about giving up their identities or betraying core constituencies, whether they be voters, stockholders or contributors. Through a collaborative approach, stakeholders "optimize" rather than "maximize." That is, they see how working toward the good of the whole pays better than a parochial, competitive approach.

An Infrastructure Vision: We need a national vision that brings together a definition of our long-term needs, a policy framework that integrates the separate policies of energy, environment and transportation, and stable financing throughout the renewal lifecycle. We must create more stability in long-term funding, performance requirements and functionality, and policy leadership. Every successful large infrastructure program requires stability in all three of these areas.

Developing a clear vision is the *sine qua non*. The magnitude of the challenge we face requires bold thinking and the mobilization of our national political will. President Obama and several Congressional leaders on both sides of the aisle have proposed creation of a National Infrastructure Bank, initially capitalized at $50 billion. Other proposals would fund, separately, the Department of Transportation, the Department of Energy, the Environmental Protection Agency and the Department of Defense (the largest Federal energy user). These efforts, though laudable, do not match the magnitude of the challenge at hand, nor do they enable the integration of national efforts toward a common vision.

A national vision would provide an explicit road map that sets priorities. Each of our infrastructures is governed independently, but, as mentioned earlier, many are mutually dependent, and increasingly so. Accordingly, we recommend launching a presidential commission (comprised of members of the Executive Branch, Congress, state and local governments, the private sector, universities, nonprofit organizations and associations) to formulate major recommendations for action. This commission should convene several national fora to elicit broad stakeholder involvement and build momentum for the long-term campaign at hand. The monumental achievements of our past were made possible by a clear vision and focused effort on a national scale. Such a vision will be a critical first step in creating the stable foundation for a modern America.

Vision is vital but not sufficient. An accompanying regimen of laws, regulations and policies at the Federal level may be necessary to induce integrative changes. Given that Congress itself is segmented by its committee structure, a special congressional infrastructure committee could ensure integrated policy and budget formulation.

National infrastructure legislation will need to set new integrated policy mandates, authorize a range of financing approaches, refine new agency responsibilities, provide oversight and target specific appropriations. Coordinated legislative enactments need to create a menu of approaches for infrastructure development by Federal agencies, states, localities, utilities and the private sector. One size will not fit all, and it is imperative that policies, programs and funding mechanisms remove barriers and create meaningful incentives for bold actions.

Above all, this unified approach to new regulations must provide a framework in which the private sector can invest in our nation's infrastructure. The action plan will require regulatory reform across all agencies to deliver

[7]See Reginald Van Lee, Mark Gerencser, Christopher Kelly, and Robin Portman, "Collective Leadership and Overlapping Vital Interests: The Unrealized power of Megacommunities", *Innovations: Technology, Governance, Globalization* (April 2009).

Table 1

Finance Mechanism	Notes
Acquisition/Direct Funding	• Highest first-cost approach; limits "skin in the game" among megacommunity members • Most easily enables application of conditions for award, including performance specifications, and use of auctions/reverse auction acquisition methods
Grants with Matching Requirements	• Traditional federal approach for transportation • Matching level requirements may vary to reflect social good or appropriate federal role (theoretically) • May include other conditions on infrastructure development (service levels, technical performance, business model)
Revolving Loan Funds	• Existing uses include state water/wastewater treatment facilities • Repayment provides liquidity for future loans, and may spur additional private investment • Loan terms and conditions may reflect social objectives for project
Loan Guarantees	• Usually justified by need to correct perceived market failures by which borrowers, regardless of creditworthiness, lack access to credit • Issuer backstops either the credit risk of the borrow or the performance risk of the project, thereby unleashing private capital • Guarantees contain significant terms and conditions regarding project performance and other matters
Other Credit Enhancements	• Beyond loan guarantees, other actions that would reduce risk associated with the deployment of private capital • Examples could include funding a loan loss reserve, or providing a letter of credit for a specific project
Self-finance via Bond Issuance	• Historically low default rates of municipal bonds were tested by economic crisis of 2008–09 • Extensive legal restrictions on use of bond issuance proceeds
Self-finance via User Fees	• Most appropriate for transportation and water/wastewater treatment, but still not commonly deployed • Offer significant benefits in revenue generation, resource allocation, conservation incentive, and others • User fees can take many forms depending on the infrastructure, including tolls (roads), landing fees (aviation), public benefits charges (utilities), and others

more impact from existing grant funds and formulas, while enabling the use of significant private capital. Specific areas of focus for regulation must include:

- Integrated grant funding to deliver more impact from existing grants and formulas. Grants must span agencies, be allowed to combine with private capital, and permit grant-winners to use any technological solution that will achieve the grant's goals.

- Private sector investment in U.S. infrastructure. Acquisition processes must reflect service- and performance-based projects where the lowest cost is not usually the best value. Program management processes will need to be adapted to monitor new performance metrics.

Finally, there may be merit in creating a permanent commission to oversee our infrastructure renewal agenda. An alternative approach would be to elevate this role to the Council level, similar to the National Economic Council or Domestic Policy Council, both of which are responsible for coordinating, overseeing and reporting on progress to the President and Congress. A third alternative would be to constitute a congressionally mandated interagency task force, as has been done with the 13 agencies comprising the U.S. Global Change Research Program. Whatever option is selected, coordination and accountability for the system as a whole are key.

Who's Got a Dollar?

One thing is certain about America's infrastructure renewal: It will be costly. There are compelling strategic reasons to invest in a re-imagined infrastructure, with economic competitiveness and national security foremost among them. But the measurable economic return on infrastructure spending can be compelling in its own right. It could produce $1.59 in additional GDP for every dollar spent, by some estimates.[8] First-class infrastructure technology and development know-how are also exportable and promise to help right our trade imbalances. The key question right now is where will that dollar come from?

Re-imagined infrastructure needs re-imagined approaches to funding that recognize the megacommunity nature of infrastructure and unleash private capital. A megacommunity engagement model for infrastructure finance would offer at least two key benefits.

First, it would better allocate risk and reward among members of the megacommunity. As long as a range of financing methods is available, private sector gains would be matched by an appropriate level of risk for private sector members. Likewise, social benefits would be matched by an appropriate level of public sector funding and risk.

Second, it would provide better project selection. In a megacommunity, giving a greater voice to members produces a sense of commitment, ownership, and thus oversight. This would help to avoid the mistakes made during Japan's infrastructure investment during the 1990s.

At a practical level, there have been many legislative proposals to increase infrastructure development funding. The idea of a National Infrastructure Bank, which would use a variety of finance mechanisms to encourage significant private capital investment and would also complement existing funding programs, has received the most attention. Regardless of whether the selected approach is a stand-alone entity requiring new legislative action (such as National Infrastructure Bank), or a centrally orchestrated approach to integrate the activities of existing agencies (as described above), what matters most is the availability of a full range of financing mechanisms. This would also apply to a megacommunity convened and led by a non-federal entity. Table 1 provides a significant but not exhaustive list of financing mechanisms.

A re-imagined approach to infrastructure finance needs access to a spectrum of these mechanisms, to ensure that every dollar of funding comes from sources in proportion to the benefit and engagement enjoyed by those sources. Used in combination or alone, these approaches are the keys to reinforcing the megacommunity engagement model for infrastructure development.

The United States is locked into an obsolete pattern of dealing with infrastructure investment and renewal at a time when our population growth and technological advances have raced ahead. Standard patterns of government interaction with business and other stakeholders in infrastructure have not changed appreciably in many decades, and the business models that have arisen from these bureaucratic habits now misalign incentives among those who build and produce infrastructure, those who buy it and those who use it. We have abdicated the key design function of government: the need to re-examine the way we work. Now we are paying the price for that failure.

We owe it to ourselves to think hard about how we proceed, for our infrastructure crisis also presents a great opportunity. We have it within our power to re-imagine America's infrastructure as a system of systems, with revolutionary advances in information technology as the nerve center of that new multi-layered system. We have it within our power to adjust the relevant business models that will enable the system to work with the proper balance of centralized and decentralized functions. But to seize that opportunity we need a new form of leadership to re-conceive the relationships of infrastructure stakeholders and then to institutionalize a new path forward. If we fail at this, we risk our nation's future—not only our quality of life, but our economic competiveness and our national security. We will also miss the opportunity to benefit from recreating a world-class industry to renew or build the infrastructures desperately needed both here and abroad. We must not fail. We have too much at stake.

[8]Mark Zandi, Chief Economist at Moody's, 2008 testimony before Congress: "The boost to GDP from each dollar spent on building new bridges and schools is large—an estimated $1.59—and there is little doubt that major infrastructure investment is needed."