IBM Institute for Business Value

The world's 4 trillion dollar challenge

Using a system-of-systems approach to build a smarter planet

IBM Institute for Business Value

IBM Global Business Services, through the IBM Institute for Business Value, develops fact-based strategic insights for senior executives around critical public and private sector issues. This executive report is based on an in-depth study by the Institute's research team. It is part of an ongoing commitment by IBM Global Business Services to provide analysis and viewpoints that help companies realize business value. You may contact the authors or send an e-mail to iibv@us.ibm.com for more information.

By Peter Korsten and Christian Seider

Our world is fraught with inefficiency – US$15 trillion worth to be exact. We've reached this point because businesses, cities and governments optimized as best they knew how, which was around a particular function, within an organization or along an extended value chain. But if we can change our approach so that it considers the overall system we're part of, we have a chance to elevate our world to an entirely new level of performance.

In an age in which consumers, businesses and governments are increasingly focused on socially responsible actions, much of our planet's natural and financial resources are being squandered simply by conducting business as usual: More than 50 percent of the world's food supply never makes it to consumers.[1] Nearly 35 percent of all the water used each year is frivoled away by poor agricultural water management.[2] And road congestion, poor routing and other traffic issues around the globe waste enough crude oil annually to meet the total demand of Germany and the Netherlands for two years.[3]

Much – if not most – of this inefficiency can be attributed to the fact that we have optimized the way the world works within silos, with little regard for how the processes and systems that drive our planet interrelate. We've tuned these processes to generate specific outcomes for individual communities, nations, enterprises and value chains.

However, as the world grows more interconnected day by day, the ineffectiveness of this siloed approach is increasingly apparent – with economists now estimating US$15 trillion in waste and lost resources each year globally.[4] These complex, systemic inefficiencies are interwoven in the interactions among our planet's core systems and the different subsystems and entities they comprise.

No business, government or institution can solve these issues in isolation. To root out inefficiencies and reclaim a substantial portion of that which is lost, businesses, industries, governments and cities will need to think in terms of systems, or more accurately, a system of systems. We'll also need to collaborate at unprecedented levels. Certainly, no single organization owns the world's food system, and no single entity can fix the world's healthcare system. Success will depend upon understanding the full set of cause-and-effect relationships that link systems and using this knowledge to create greater synergy.

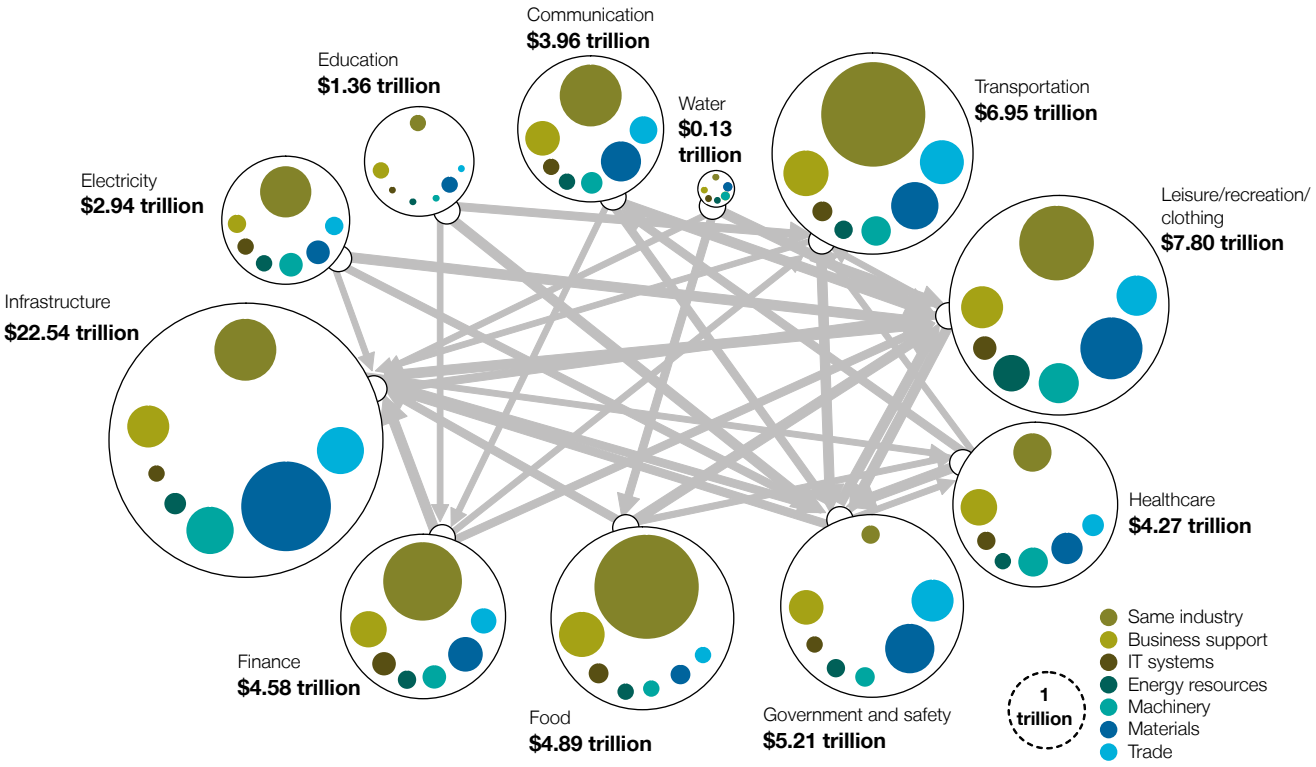
Clearly, technology can assist in driving this concept forward. In fact, history has shown that technological advances have been precursors of tremendous economic and social progress. We believe the stage is set for the same to happen today. Although we previously lacked the technological means to optimize across systems, our planet is now more instrumented, interconnected and intelligent than ever before. Collectively, we have the opportunity – and a US$4 trillion motivation – to substantially improve how the world works.

The chief obstacle that remains is mindset – moving from short-sighted to long-term perspectives, from siloed to system-of-systems decision making. To that end, we're offering businesses, governments, industries and cities an initial framework for solving real-world problems using a system-of-systems approach. We're not suggesting it as a cure-all for the world's ills, but, rather, as a starting point to elicit discussion, innovative ideas and, ultimately, actions that help us collectively build a smarter planet.

Our world is a complex system of systems

At a fundamental level, our world consists of 11 core systems (see Figure 1). Each system has evolved over time to serve a specific need or want of society. Collectively, they form a global system of systems, representing 100 percent of our worldwide gross domestic product (GDP).

Each individual system is an amalgamation of public and private sector organizations that span multiple industries. For example, Healthcare includes doctors, hospitals, pharmacies, insurers, researchers, drug manufacturers and more – all the entities that contribute to keeping people healthy, whether government-sponsored or private enterprise.



Note: Size of bubbles represents systems' economic values. Arrows represent the strength of systems' interaction.
Source: IBM Institute for Business Value analysis of Organisation for Economic Co-operation and Development (OECD) data.

Figure 1: **We live and work within a complex, dynamic and interconnected US$54 trillion system of systems.**

In the same way, the Transportation system is about moving people and goods from place to place. It involves a number of industries – such as automotive, railways, travel, aerospace, logistics providers, energy and petroleum – and virtually every level of government, from city councils to national transport authorities.

Our planet's systems are not simply interrelated; they are highly dependent on each other.

These core systems are interrelated through cause-and-effect relationships, some of which are immediate; others involve substantial time lags. However, saying these systems are interrelated is an understatement – they are actually highly dependent upon one another. In our analysis, we found that input from other systems, on average, contributes 47 percent of each system's output.[5] The world's Transportation and Food systems are the most dependent, with more than 60 percent of their output relying on external inputs.

Inefficiency costs us one-quarter of everything we produce

"*Frustration over the inefficiency in organizations grows each year among workers, managers and consumers – it takes an emotional and psychological toll on each group.*"

– Economist, U.S. university

Although mankind's system of systems has evolved to meet many needs and wants, it is not particularly efficient. For example, in the United States alone we are wasting approximately 2.3 billion barrels of crude oil each year on unnecessary street traffic.[6] With that squandered fuel, we could satisfy all the oil needs of Germany and the Netherlands for two years.[7] In addition to direct costs, this inefficiency also has a ripple effect on oil prices, consumer discretionary spending, pollution and even the amount of talent available in the labor market.

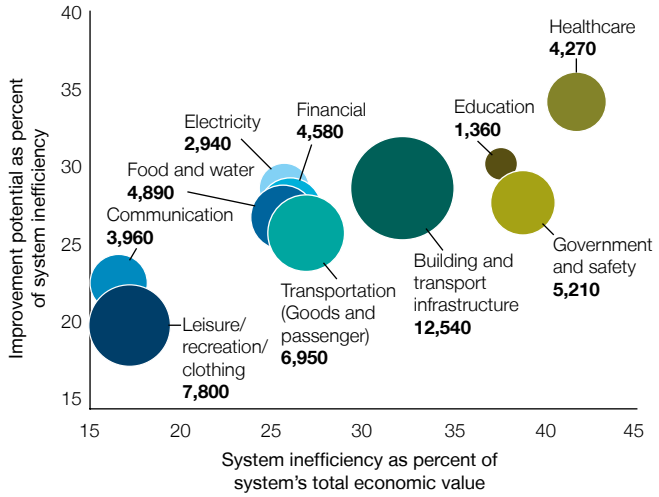
Our electric grids are extremely inefficient as well. One-quarter of the electricity generated each year is never consumed.[8] The amount of energy we're wasting could power the United States, China and the entire continent of Europe for half a year.[9] Put another way, eliminating this inefficiency would allow us to retire 1,300 coal-fired power plants.[10]

Based on in-depth analysis of global GDP and a survey of more than 500 economists worldwide, we estimate that our planet's system of systems carries inefficiencies totaling nearly US$15 trillion, or 28 percent of worldwide GDP.[11]

At a system level, Healthcare, Government and Safety, and Education carry the most bloat, each with estimated inefficiency beyond 35 percent.[12] In the Healthcare system alone,

approximately US$2.5 trillion is wasted annually.[13] This is roughly equivalent to the combined amount spent each year on healthcare by the United Kingdom, France, Germany, Japan, India and China.[14]

Economists also shared their opinions on how much inefficiency could actually be eliminated from these core systems. They acknowledged that some level of inefficiency is inescapable, and that some inefficiencies are less costly than their remedies. However, the majority of economists agreed that substantial improvement is possible; they estimated an annual global savings potential of US$4 trillion.



Note: Size of the bubble indicates absolute value of the system in US$ billions
Source: IBM Institute for Business Value analysis based on inefficiency and improvement potential estimates reported during 2009 survey of 518 economists.

Figure 2: Of the US$15 trillion in inefficiencies within our global system, approximately US$4 trillion could be eliminated.

The Healthcare system has the largest opportunity for efficiency gains, with economists estimating that the current level of inefficiency could be reduced by nearly 35 percent. Education, building and transport infrastructure, and electricity are also ripe for improvement, with economists citing the potential for reducing almost 30 percent of these systems' inefficiencies.

Economists believe we have the chance to reclaim wasted resources equivalent to 7 percent of global GDP, if we address fixable inefficiencies.

In examining these inefficiencies, we must remember one major principle: these systems are part of a larger, interconnected system. And because of the high degree of interdependence among systems, this inefficiency lies not only within individual systems, but also within their interrelationships. Since nearly half of each system's economic output depends on another system, it is logical to assume that interrelationships are responsible for a significant percentage of the inefficiency as well.

Conventional optimization has limited effectiveness

"Enterprises need to think long-term. Think globally. Realize that profit can be made from 'doing the right thing.'"

– Economist, U.S. university

When attempting to eliminate inefficiency, most businesses, industries, cities and governments are naturally inclined to use a traditional optimization approach centered on their own value chains or agendas, with little consideration of extended interrelationships. However, this perspective offers no transparency across "the system." Organizations are often unaware of the indirect impacts of their own behavior. Because decisions are optimized for a particular organization, community or group, the effect on macroeconomic factors is often ignored.

For example, an electronics company, an apparel maker and a consumer products manufacturer could sit side by side on the same street in China, with each business shipping goods to North America and Europe. Even if each optimizes its own logistics processes, capacity across the entire transportation system is still sub-optimal.

In fact, industry averages suggest that nearly 10 percent of all global container capacity goes unused.[15] Carrying these empty containers requires approximately 400 ships at a cost of US$68 billion globally, not to mention the secondary effects of wasted fuel, higher pollution and more expensive products.[16]

Addressing global, cross-industry inefficiencies like these calls for a different approach: a system-of-systems perspective. By focusing on a specific want or need rather than on a particular value chain, systemic inefficiencies become more apparent. This holistic view facilitates global optimization by clarifying the impact of actions across the system of systems.

More than 80 percent of the economists surveyed think a system-of systems approach plays an important role in reducing inefficiencies in our global systems.

Continuing our previous logistics scenario, system-of-systems thinking might instead lead to an integrated, cross-industry logistics management solution. If these companies had visibility of each other's logistics supply and demand, they could share the same logistics infrastructure. Sharing logistics, in turn, would improve overall capacity utilization. In addition to benefiting the individual companies, this approach offers numerous advantages for our planet, such as reducing fuel consumption, avoiding manufacturing of additional means of transportation and reducing congestion and load on traffic systems. Lower transportation costs could also mean less expensive products, leaving consumers with more discretionary income to spend on other goods and services, which, in turn, could lead to economic growth.

As our world becomes smaller and flatter, optimizing at an atomistic level – whether enterprise, value chain, city, nation or international coalition – becomes less and less effective. Optimization of individual entities does not mean that the systems they are part of and interact with are optimized; on the contrary, micro optimization might cause even greater inefficiency at a macro level. Rather, eliminating systemic inefficiencies requires a comprehensive, coordinated and sustained effort across systems.

The basis for building a Smarter Planet

Improving the way the world works – or, as we call it, creating a Smarter Planet – is not an abstract aspiration. It's an increasingly urgent imperative. Across the globe, consider how much energy we waste, how gridlocked our cities are, how inefficient our supply chains are, how scarce water may soon become. Many of our everyday processes of business, government and life are not smart enough to be sustainable. As we move into the future, we're going to have to operate much more efficiently.

Fortunately, we have three trends working in our favor:

- Our world is rapidly becoming instrumented. Embedded sensors – now plentiful and affordable – are creating a world of smart objects, capable of monitoring almost anything.
- Everything is increasingly interconnected. Beyond the nearly 2 billion people connected through the Internet, we're linking together trillions of smart objects and systems.
- Through a combination of powerful systems and advanced analytics, our processes are becoming more intelligent. We now have the capability to turn the data produced through greater instrumentation and interconnectivity into smarter actions.

But how do we take advantage of these opportunities? How do we use these capabilities to tackle systemic issues that are weighing down our planet? We would argue that conventional optimization strategies and collaboration methods will not be adequate; they don't expose what needs to be fixed.

Instead, we need an in-depth understanding of the interrelationships among systems and a determination to collaborate across industry and public/private boundaries. With a system-of-systems view, businesses, governments, industries and cities can together create solutions that benefit our planet as a whole.

From silos to system-of-systems: Why now?

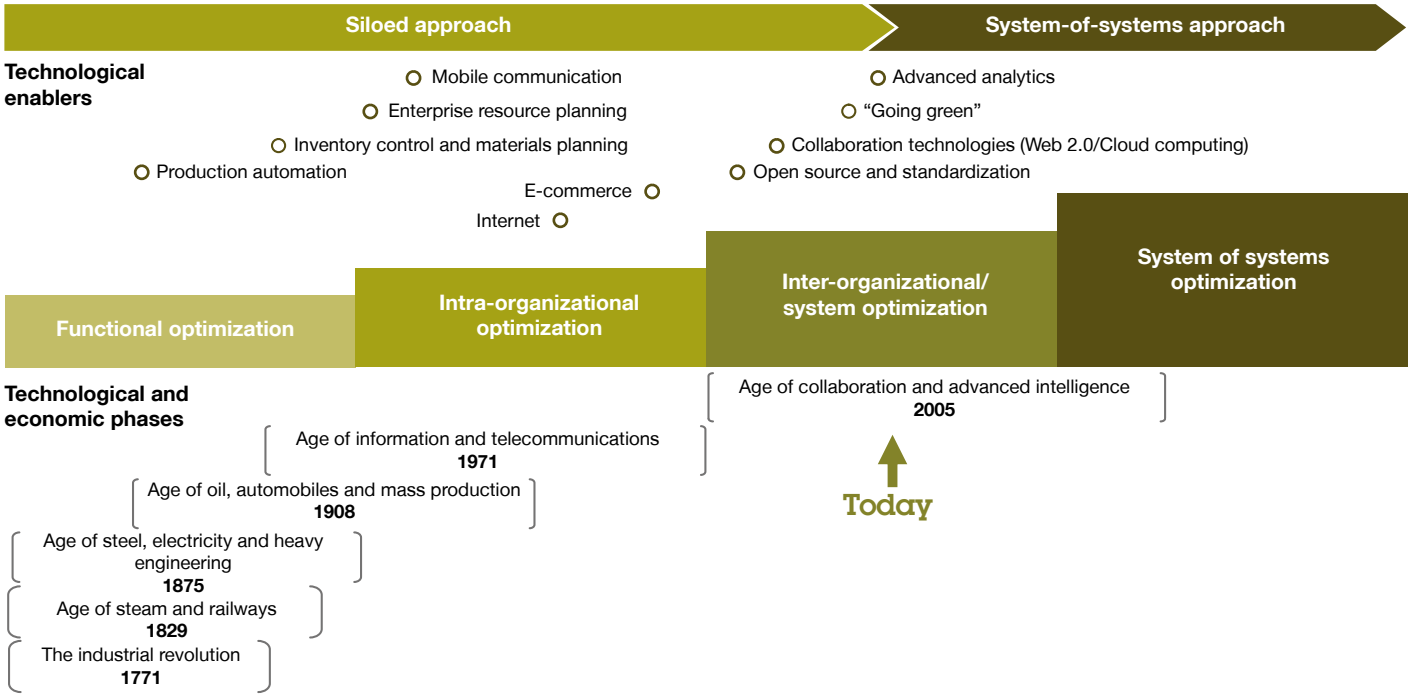
System-of-systems thinking is not new. It's been around for at least three full decades – primarily used by the likes of space shuttle designers and military strategists. Until recently, we lacked the enabling technology to make its application practical for the mainstream. Businesses, governments and cities could not realistically monitor, make decisions and manage in this manner.

For example, agricultural businesses watered crops on a fixed schedule (often over- or under-watering) because it was impractical to track soil conditions and temperatures in realtime. For similar reasons, cities could not effectively reduce congestion or redistribute load across trains, buses and private vehicles because they could not predict commuting patterns or exchange realtime information among transport modes.

Yet, throughout history, technological advances have ushered in new eras of economic progress (see Figure 3). Early technology enablers like production automation and inventory control systems made it possible to optimize particular functions. As technologies become more sophisticated, businesses, governments and cities began optimizing operations across their organizations, then with important suppliers and customers.

Today, with sophisticated sensors, massive computing power, advanced analytics and realtime connections not only between IT systems but also among a world of smart objects, we're equipped for the next level of optimization.

The economists we spoke with generally agree. Sixty-six percent believe that we've reached an inflection point where today's current technology is sufficient to substantially improve systemic efficiency. So, if technology is not the obstacle, what is?



Source: IBM Institute for Business Value, adapted from: Perez, Carlota, *Technological Revolutions and Financial Capital*, 2002.

Figure 3: **Technological advances are once again setting in motion a new wave of optimization.**

The obstacle – mindset

"The problem lies not in technology, but in a lack of common objectives and an incomplete understanding of the importance of efficiencies in the planet's system, a united long-term view and a system for global optimization."

– Economist, Asia Pacific

As it turns out, the top barriers for enterprises, governments and cities alike are related to mindset. With overwhelming consistency, economists from various industries, academia and national and local governments around the world cited short-term focus as the most significant barrier to solving systemic issues. Changing this focus will not be easy. But we believe addressing another common top obstacle – inadequate understanding of how inefficiencies in one system impact other interrelated systems – will pave the way to a longer-term view.

Two-thirds of the economists surveyed think we can make significant efficiency gains using technology that is already available.

According to the economists, education, incentives and support for systems thinking are critical to counteracting organizations' tendency toward short-term thinking and isolated optimization (see Figure 4). Many suggest changes to academic systems to instill this thinking – or perhaps possible new career paths for systemic efficiency analysts.

The voice of the economists

1. Education

- Tie information and education to performance indicators
- Use education and regulation to provide short-term incentives for long-term behaviors
- Improve the level and extent of scientific education
- Deliver the message through the educational system
- Develop a concerted program of education, demonstrating the benefits of the alternatives.

2. Incentives

- Develop better economic pricing incentives, with external effects internalized into the prices charged for economic activities
- Align and change incentives to favor long-term benefits
- Encourage long-term thinking and global impact through tax incentives and regulations
- Establish proper incentive mechanisms, including tax structures and investment incentives
- Get the incentives right to reward longer-term thinking and broader optimization.

3. Thinking

- Promote consistent thinking and information about systemic externalities and proactive attitudes toward absorbing economic and social costs of required reorganizations
- Convince people that their actions matter to the system
- Support non-governmental organizations that promote systemic thinking.

Source: IBM Institute for Business Value 2009 survey of 518 economists. Diagram created using www.wordle.net.

Figure 4: **How to change mindsets regarding short-term thinking and isolated optimization – in economists' own words.**

While economists believe that governmental regulation was a chief contributor to inefficiency, they also acknowledge the importance of government's role in providing necessary incentives. Some also suggest that governments establish common incentives across countries.

"*We need to share different cities and countries' innovation systems for solving inefficiencies. We should organize international education and training centers for diffuse innovation and research.*"

– Economist and independent researcher, Mexico

Making it happen

"*What if compensation for long-term decisions was paid long term and pay for short-term decisions happened only for the short term? No more options, repricing, etc. Make it real and cut the excuses.*"

– Economist, U.S. university

Optimizing efficiency of virtually any system involves governments, cities, industries and enterprises. By the nature of their roles, mayors and other levels of government integrate systems into a system that provides their citizens an attractive place to live and work. In many ways, our cities, in particular, are a microcosm of our planet, inefficiencies and all. So, system-of-systems thinking may naturally align with and support these leaders' agendas.

CEOs, on the other hand, are primarily driven by microeconomic factors like profit, revenue growth, cost of goods sold and market share. However, the reality of globalization and recent strong reminders of how connected we are – economically, socially and environmentally – is causing business leaders to adopt a broader perspective.

Industry associations also play a vital role in resolving systemic inefficiencies. They can help facilitate consensus among members and even lead and coordinate complex industry-wide changes.

To apply a system-of-systems approach to real-world efficiency problems, we believe businesses, industries, governments and cities should consider five major steps:

1. Determine the most relevant systems and interrelationships
2. Identify and quantify inefficiencies
3. Analyze root causes and key improvement levers
4. Determine benefits
5. Develop a change approach.

Clearly, the actions recommended in this framework are not a definitive answer to our planet's challenges; they're simply a starting point. In fact, our hope is that this framework will be a catalyst for collaboration among stakeholders, collectively improving the ideas and methods as we move toward system-oriented thinking and action.

1. Determine the most relevant systems and interrelationships

"*One of the main reasons for inefficiency is the fact that the consequences of wasteful use of resources are not borne by those who waste them.*"

– *Economist*

For cities and governments, this involves selecting the systems that have the most impact on their high-priority goals and issues. For some, unemployment and pollution may be the top issues; for others, it could be innovation, poverty and economic growth.

Enterprises and industries must understand which systems have the greatest impact on their operations and output, looking beyond the traditional value chain to focus on indirect effects that may be of high importance. They will also need to consider which parts of the planet's system of system are impacted most by their products and services. Here again, identifying indirect linkages that extend beyond the bounds of traditional value chains is critical.

Key questions to ask

Do you understand how different entities interact within the system (or systems) you're part of?

How do these systems impact your business, city or nation?

Which systems have the greatest impact on the social, environmental and economic issues you want to address?

2. Identify and quantify inefficiencies

"*Someone is benefiting from the inefficiencies…Correcting them is a matter of incentives.*"

– *Economist, U.S. corporation*

Each core system within our planet's system of systems has a set of key performance indicators (KPIs) that can be used to uncover areas of inefficiency (see Figure 5). Cities, governments, industries and enterprises can identify which of these KPIs are most relevant to the systems and interrelationships they defined in step one.

Once selected, these KPIs become the framework for an efficiency scorecard of sorts. Before organizations can take action, however, they will need to know actual performance against the selected KPIs. This may involve implementing newly available technology capable of measuring the factors involved. Once they have collected actual values, organizations can identify target values for efficiency improvements. The gaps – or inefficiencies – identified in this step then become the object of further analysis in step three.

Key performance indicators

- Percent increase in healthcare sending per annum
- Child mortality rate
- Cost of incorrect diagnosis as a percent of total spending
- Cost of repeat diagnosis as a percent of total spending
- Cost of unnecessary procedures/time delay as a percent of the total cost
- Healthcare spending per capita
- Life expectancy at birth
- Number of doctors per 100,000 people
- Number of primary healthcare centers per 100,000 people
- Overall quality of the healthcare service

Source: IBM Institute for Business Value.

Figure 5: **Key performance indicators for the Healthcare system, for example.**

Key questions to ask

Which system-to-system interactions fall short of expected performance?

Do you know how much these inefficiencies cost – both in actual dollars and in lost opportunities?

What are the most significant systemic inefficiencies restraining your entity? What problems are you creating for other systems?

3. Analyze root causes and key improvement levers

"Among businesses and governments, there's a lack of a willingness to share risk to the extent needed to make a difference."

– Economist, consulting company, Canada

The purpose of step three is to determine the root causes of the inefficiencies and the most critical levers for eliminating those inefficiencies. To determine which root causes to focus on, organizations should consider both the degree of inefficiency caused by a particular driver as well as how difficult it will be to reduce or eliminate it.

As part of this analysis, it's important to note which stakeholders – cities, governments, industries and enterprises – are most critical for the solution. Cities and national governments may want to identify specific geographical areas within their domains that offer the best leverage points for improvement. Similarly, enterprises and industry associations should identify participants with significant influence and proactively engage them in developing solutions.

Key questions to ask

Have you traced these inefficiencies back to their real root causes, or are you working only on surface-level symptoms?

Which entities have the most influence over the root causes?

How difficult will it be to fix this inefficiency? What factors make it more or less difficult to resolve?

What solutions can help overcome the root causes?

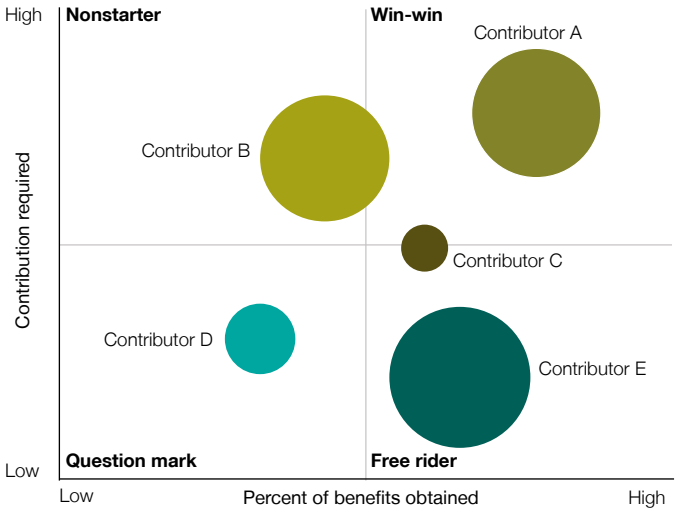
4. Determine benefits

"We must seek ways to share the benefits from solving boundary-crossing problems."

– Economist, U.S. university

By their very nature, systemic inefficiencies involve multiple actors. Step four involves identifying and understanding the role of each stakeholder involved in resolving the inefficiency – and its motivation for doing so.

To create an impetus for improvement, it's important to understand stakeholders' level of contribution relative to the proportion of the benefits they derive (see Figure 6). Where the expected level of benefits is low, the contribution required is high and the stakeholder plays a critical role in the system, additional incentives may be required.



Note: Size of bubbles represents economical value of the incentive computed based on:
1. Degree of contribution
2. Degree of criticality to the system of systems
3. Percent of improvement's made
4. Effectiveness and sustainability of the solution

Source: IBM Institute for Business Value.

Figure 6: **Leaders must design incentive structures that keep contributors out of the nonstarter category.**

Key questions to ask

What corporate and governmental players are critical for building a comprehensive solution?

Does each stakeholder have sufficient incentive to collaborate? How can you create additional benefits for critical players with little motivation to participate?

What is the time horizon for addressing this inefficiency?

Can the solution be architected in a way that provides some nearer-term benefits? If not, are the incentives strong enough to garner support for longer-term objectives?

Develop change approach

"To evoke change, we must build better, faster, more insightful feedback loops."

– Economist, United States

Rarely is there a single "owner" of a system or a single entity that can be charged with solving systemic problems. That's not to say it must stay this way. Though it may sound farfetched today, future solutions may involve establishing a system owner. But whether the system has a single owner or not, resolving inefficiency will almost always involve multiple stakeholders. Developing a viable collaboration model and incentive structure is critical to engaging the right players.

As they formulate their remediation approach, cities, governments, industries and enterprises should also consider how technology – through greater instrumentation, interconnectedness and intelligence – can help create a smarter system. What can they monitor and measure that they previously could not? Which parts of the system can now be connected to achieve greater speed, accuracy and quality? What kinds of advanced analytics and decision support systems are now possible?

Through such analysis, cities, governments, industries and enterprises can begin outlining changes that resolve the inefficiency. These changes may also include new or modified regulations or laws, or call for updated industry or cross-industry standards.

Key questions to ask

What sort of governance and change approaches will work best, given that no single entity "owns" the system or systems involved?

How can contributors collaborate more effectively?

How can you use technology to drive out inefficiency and derive new intelligence from increasingly abundant information?

How can you change organizational and individual behavior?

Future Scenarios

Outlining the foundation for a system of systems approach provides, we hope, the catalyst for meaningful discussions about how entities and enterprises can collaborate to recover a substantial portion of the US$15 trillion wasted each year. One important aspect of the future state we propose is how a system of systems approach will affect the lives of the everyday worker, consumer, employer, etc. For illustration of possible impact, we present the following futuristic scenarios. At the present time, each of the scenarios is out of reach for practical application. However, with innovation and initiative, some variant of these scenarios is not only possible, but likely.

The Farmer of the Future

Interaction: food, government & safety, infrastructure, utilities, healthcare, communication, transportation, water

It's 5:00 a.m. on a farm near a major river. As the proprietor/farmer begins his day, he accesses to his mobile communications device. He has an urgent message. The semiconductor manufacturer three miles upstream on the river is ready to release to him his daily quota of water. Used the night before by the plant to cool its production machinery and wash newly fabricated circuit boards, the water has been cleaned and placed in a holding tank awaiting the farmer's instructions. On a normal day, the farmer would approve the release of the water and it would be pumped through a dedicated pipeline to holding tanks on his property, where it would be used to irrigate crops and for other non-consumable applications.

Today, however, another message from the government weather service tells him it will be raining all day, at times heavily. So he will not need the water. As a result, the plant will divert the water to a wastewater treatment facility. The farmer is the last in a chain of enterprises that have formed a water consortium. The most upstream company takes water from the river and sends it via dedicated pipeline to the next user. The most downstream user then sends the water to a treatment facility for return to the river. Through reuse of water, the consortium has reduced its total water consumption by 35 percent. The consortium is one of 10 along a 150-mile stretch of the river.

Another beep – this time from his logistics partner in the city. A multi-container shipment of produce is scheduled to leave the dock in four days via rail. Two of the containers are not full. If he can move his previously scheduled shipment up two days, he can cancel his original plan to ship by truck and piggyback the rail shipment. He will realize a 10 percent price reduction and eliminate the need to put two trucks on the road.

Tonight, the farmer will be accepting his region's Sustainable Farm of the Year award for his efforts toward reducing his carbon footprint and his dedication to providing alternative fuel sources. Two years ago, he began earmarking 15 percent of his crop for biofuels. Further, he has a composting operation that reclaims methane from decomposing/spoiling crops, which has the dual benefit of providing a fuel source and keeping a greenhouse gas out of the atmosphere.

As he gets ready to depart for the awards dinner, he receives his final alert of the day from the World Health Organization – doctors in a west Africa nation have noticed a marked drop in visual acuity for the 6-to-12 year-old population and are blaming the trend on poor nutrition, specifically a Vitamin A deficiency. The last thing he does before getting into his hybrid car is use his mobile phone to reprogram his GPS-enabled, robotic seeder to increase the acreage his farm devotes to carrots.

The Driver of the Future

Interaction: government & safety, electricity, transportation, utilities, communication, leisure/recreation/clothing, communication

Marie is planning a weekend trip to the beach for her family. She uses her mobile device to reserve an all-electric station wagon from her local transportation cooperative.. She elects the option to rent a fully charged lithium-ion battery. Her personal battery – industry standard in every respect – needs to remain at home. It has been unusually hot over the past week and the local utility has requested to "buy" power from its customers who keep their solar-charged batteries on standby for the power grid when not in use with their vehicles. For her contribution, she will get a substantial credit on her monthly power bill.

The night before the trip, Marie downloads to her mobile device a travel plan that provides the optimum route and suggested stops for recharging, snacks and breaks. When she takes possession of the station wagon, she syncs her mobile device with the car's onboard computer.

When it is time for a rest stop, the car, with which she communicates through advanced speech recognition software, tells her that her brand of sunscreen is available at the next stop, and even offers a discount coupon. At the stop, she plugs the car battery into a quick charge station and gets set for the next leg of the journey. The car tells Marie tire pressure, washer fluid and other maintenance items are within specifications.

Marie uses her phone to pay for her items and returns to the road. She is barely away from the charging station when she gets a priority message from the government's intelligent traffic system. Congestion and emergency road repair along her preferred route are causing delays. Her route is being reconfigured in realtime to avoid congestion and maintain optimal travel time and fuel consumption.

Yet, even under the most carefully monitored situations, mishaps occur. The driver in the lane next to hers has lost focus and is drifting into her lane. Not only does Marie's car chirp a warning to her, but it also instructs the offending vehicle to warn its driver.

As she drives into the resort town, Marie's mobile device alerts the hotel that her arrival is imminent. Porters are waiting outside to take her bags. Her preferred refreshments are waiting in the room. Her phone tells her the temperature of the ocean water is 82 degrees F and that waves are perfect for surfing. She uses her mobile device to reserve surfboards for the whole family.

The Tenant of the Future

Interaction: water, government & safety, infrastructure

Xiang-Wei left the transit station and turned onto her street with foreboding in her heart. She looked down the street, and her fears were confirmed: her building's skin, normally a healthy green, was discolored with purple streaks. How embarrassing – their building was overdrawn on its water allotment. It wasn't her fault. That morning, alerted by feedback in their apartment, she and her husband had skipped their showers and made certain that their children used no more than their ten liter allotments.

It was difficult, as well, to believe their conservation-minded building mates were to blame. Her husband thought that there was a leak somewhere in the building. That seemed unlikely to her, because most appliances monitored their resource usage and sent out requests for assistance when out-of-band consumption events occurred. But not everything was instrumented – pipes for example – and a leak was possible. Xiang-Wei had even heard rumors that vague enemies had hacked the resource monitoring system with the aim of embarrassing them. She thought that was unlikely. The penalty for hacking into resource control systems was severe.

Xiang-Wei reached her building, and hurried up the walk through the front garden, feeling her cheeks color. Fortunately she had come home early, and there weren't many people on the street. There was just one thing to do: organize a vote of the co-op to ask the resource authorities to turn on fine-grained monitoring. That would enable them to identify any leaks, or to put the finger on who was wasting resources.

Conclusion

If we examine one business, one city or even a group of businesses and cities within one nation, we might see some very efficient operations. But when we look at our planet as a whole, a different story emerges. A system-of-systems view exposes an entirely new realm of inefficiency engrained in how our systems interact.

Already, more than one-quarter of our world's GDP is being wiped out by systemic inefficiencies. How much waste is too much? How low must our supply of natural resources go? How costly must our global supply chains, financial systems and healthcare systems become before we change the way things work?

Although the issues are serious, this is not about environmental or social alarmism. It's just that we now have the opportunity to pragmatically address some of these issues – if our field of optimization is not too narrow.

Obviously, system-of-systems thinking is not a panacea. But it can make the causes of inefficiencies more transparent – and help identify the stakeholders involved in resolving them.

However, this shift in mindset won't happen by chance: it must be intentional. Silo-focused decision making is deeply embedded in compensation structures, tax laws and pricing mechanisms. To break from these molds, cities, governments, industries and businesses must collaborate. Organizations may even need to establish formal teams charged with surfacing opportunities from system-of-systems analysis. Indeed, we believe solving systemic inefficiency can have a substantial upside – not just for the planet, but also for individual organizations. A business might find opportunities for horizontal diversification; a city may find a role as an innovation hub.

Regardless of the benefits, the right parties are unlikely to come together by happenstance. Organizations must proactively engage the appropriate stakeholders to effect change.

By definition, systemic inefficiencies are not the responsibility of a single system, much less a single enterprise, city or nation. The question is: will your organization continue to allow inefficiency to creep in between systemic cracks, or will it take the first step toward a collaborative solution?

About the authors

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For more information

To learn more about this research or discuss how your organization can benefit from system-of-systems analysis, you can e-mail one of the authors.

We invite you to visit our Web site for other research from the IBM Institute for Business Value: **ibm.com/**iibv

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Notes and sources

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