

# Sustaining Infrastructure

## A Bentley White Paper

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## Introduction

The mission of Bentley Systems has long focused on helping our users improve the world's infrastructure. We do this by providing software solutions, products, and services that improve the productivity and quality of the work performed by infrastructure professionals through the lifecycle (design-build-operate) of infrastructure assets. Given the fundamental importance of services provided to society at large by infrastructure, this mission is certainly a worthy and significant endeavor.



However, there is now an increasingly significant level of urgency surrounding the world's infrastructure as well. There is an expanding spectrum of critical global issues in which the world's infrastructure has an important role to play. These issues include CO<sup>2</sup> emissions, climate change, the availability of clean water and sanitation, chronic hunger, unsafe bridges, earthquakes, severe weather, terrorist attacks, civil wars, coastal flooding, hazardous waste, and depletion of nonrenewable resources. The world's infrastructure – as well as the professionals around the world who design, build and operate the world's infrastructure assets – will play a fundamentally important role in successfully addressing them.

For Bentley, these many and complex challenges fall under the broad umbrella of sustainability. This paper explains Bentley's interpretation of sustainability. It lays out our view of the role of infrastructure in creating a sustainable world; how our users are meeting these challenges today; how they can better address the challenges in the future; and how Bentley's solutions and products are positioned to support them.

## Infrastructure and Sustainability

Before detailing how Bentley users contribute to global sustainability today and will contribute in the future, it is useful to discuss the relevance of infrastructure to society at large and to creating a sustainable world.

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### **Infrastructure Defined**

Infrastructure provides the basic facilities, services, and installations required for a community or society to function. This includes facilities – which we'll refer to as *infrastructure assets* – such as transportation and communications systems, water and power lines, structures to house public institutions including schools, post offices, and so on.

An infrastructure asset and the services it provides are typically location-specific; that is, the asset is located in a specific geographic location. It is a capital good, usually capital-intensive, providing a collection of services to the community, city, or country in which it is located.

Individual infrastructure assets often exhibit an economy of scale in terms of the incremental investment required to increase the capacity or level of service provided by the individual asset. Infrastructure networks, such as transportation, communications, power, and utility networks – like most networks – benefit from the network effect and can exhibit an economy of *scope*. The value of the services provided by the infrastructure network can increase geometrically as the nodes and the connectivity within the network increase.

Infrastructure assets generally do not provide services until they are completed. For example, a power plant or bridge that is 50 percent complete doesn't provide any services. The services aren't available until it is 100 percent complete.

Finally, infrastructure assets are long-lasting (as compared to manufactured goods), with expected useful lives spanning decades and perhaps centuries.

Some examples of infrastructure assets are:

- Roads
- Bridges
- Rail and transit facilities, including tracks, stations, and maintenance facilities (but not the rolling stock)
- Factories (but not the products produced by the factory)
- Communications networks
- Power generation facilities

- Residential and commercial buildings
- Campuses (including airports, government, schools, military bases, hospitals, etc.)
- Mines and metals processing facilities
- Oil and gas production facilities
- Electric and gas utilities
- Water and wastewater facilities
- Pipelines

In many ways, infrastructure is the *interface* between people and our planet. For society to advance much beyond a very basic agrarian lifestyle requires infrastructure. Nearly all of our day-to-day interaction with the environment is mediated in some way by services provided by infrastructure. Systems to provide clean water, sanitation systems to remove human waste, schools, hospitals, roadways to distribute food, power plants to deliver electricity, factories to provide manufactured goods, and on and on – these are all forms of infrastructure.

Given the scope of infrastructure and the central importance of infrastructure to society at large, infrastructure is necessarily a central factor in achieving our sustainability objectives. Our collective quality of life, the sustainability of human society, and the sustainability of our planet are directly dependent upon the services provided by infrastructure.

### ***Sustainability Defined***

The next important task is to define exactly what we mean by *sustainability*. The available definitions are many and, as is often the case, these definitions can easily become self-serving. They can be molded to conform to the solutions, products, or services offered by the organization offering the definition. An authoritative definition should be comprehensive and come from a source not promoting specific commercial interests.

Perhaps the first definition of sustainability, as we now consider it, was given by the report from the [Bruntland Commission](#) in 1987. In this report, *sustainable development* is defined as “*development that meets the needs of the present without compromising the ability of future generations to meet their own needs.*”

Another definition comes from [The Natural Step](#), a non-profit research, education, and advisory organization. Formed in 1988, it uses a science-based framework to help individuals, organizations, and communities move toward sustainability. There are currently Natural Step chapters in 12 countries, with a number of significant Bentley users among their clients. Natural Step’s simple definition of sustainability is “*creating new ways to live and prosper while ensuring an equitable, healthy future for all people and the planet.*” It has also articulated a more [formal definition](#):

*The practice of sustainability is about creating new ways to live and prosper while ensuring an equitable, healthy future for all people and the planet. In a sustainable society, nature won’t be subject to systematically increasing:*

*Concentrations of substances extracted from the Earth’s crust;*

*Concentrations of substances produced by society;*

*Degradation by physical means;*

*And, in that society, human needs are met worldwide.*

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Thus, in a sustainable world we do not continue the accelerating depletion of nonrenewable resources, nor the consumption of renewable resources faster than the environment can regenerate them. We minimize the accumulation of waste from human activity and increase recovery and reuse of these by-products. We don't continue to systematically reduce the productive capacity of the Earth through processes such as overharvesting, soil erosion, destruction of green (CO<sup>2</sup>-absorbing) areas, and so on. At the same time, in a sustainable world, everyone can live with a quality of life in which all their basic human needs are met.

This definition is not limited to "green" initiatives or climate change or even traditional environmentalism, though they are certainly important elements of sustainability. Likewise, it is not limited to buildings alone, as it has relevance to *every* type of infrastructure asset. It speaks to not only being good stewards of our planet but also to meeting the needs of *all people* on the planet.

Meeting the basic human needs of everyone on the planet and the generations to follow inevitably implies development – electricity, clean water and sanitation systems, shelter, transportation and communication systems to provide access to critical services, and so on. In short, meeting the basic human needs of all people in the world means *more and better infrastructure*.

All too often, however, these twin objectives – being good stewards of the planet while developing more infrastructure to meet the basic needs of a growing global population – are seen at odds with one another. However, the logical result of this limited view – constraining development to achieve sustainability – either denies a large portion of the developing world the opportunity to live with the quality of life we in the developed world enjoy, or requires those in the developed world to live with a significant reduction in their quality of life.

Not only are these alternatives unworkable, they can easily become totalitarian if carried to their logical conclusion. Meeting these twin objectives thus depends on *how we choose to grow*. It requires that we apply all of our human ingenuity, adaptability, and pragmatism to a project of *possibilities*, not *limits*. As [Thomas Friedman](#) of the *New York Times* has observed, all of our commendable efforts to reduce carbon emissions in the developed world will be "devoured" by the "exponential growth" in Asia. Only "a transformational breakthrough in the energy space" will suffice.

### ***Sustainability Issues***

Achieving the sustainability objectives outlined here requires that we address a number of pressing issues. We've categorized those issues into interrelated categories – societal, environmental, and professional.

We'll briefly outline the scope of these issues in the following sections.

#### ***Societal Issues***

Clearly, infrastructure is fundamental to maintaining and improving quality of life on a global basis. However, it is just as clear that today's infrastructure is globally inadequate. In the developing world, for example, there is a critical need for the most basic infrastructure in order to sustain life above a minimal subsistence level. According to the [World Health Organization](#), approximately 1.1 billion of the world's 6 billion people do not have adequate access to clean drinking water, and 2.6 billion do not have adequate sanitation services.

Even in the developed world, continually reinvesting in the existing infrastructure is critical. For example, the 2005 "[Report Card for America's Infrastructure](#)" by the American Society of Civil Engineers (ASCE) grades 15 aspects of infrastructure for adequacy and safety. Their overall grade is a D, down from a D+ a few years earlier. In the report, the ASCE estimates that overcoming the "infrastructure deficit" – the shortfall in terms of minimum standards of adequacy, safety, and security – will require an investment of \$1.6 trillion over the next five years.

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Infrastructure is also fundamental to mitigating the effects of extreme events, both natural and man-made. This is particularly important given the continuing growth of the global population and the global patterns of human migration. In 2008, for the first time in history, half of the world's population will be living in [urban areas](#). This means 3.3 billion urban dwellers, growing to almost 5 billion by 2030.

This increasing density of global population also increases the vulnerability to natural or man-made disasters, since the impact of each severe event in an urban area, in terms of both human lives and cost, will continue to rise. This vulnerability is further compounded by the fact that many of the world's largest urban areas are located near the seacoasts, which are susceptible to extreme events, particularly flooding.

If sustainability means meeting the basic human needs for everyone on the planet, then poverty is a fundamental issue. As reported in J. F. Rischard's book "High Noon," half the world's population, roughly 3 billion people, live on less than \$2 per day, including 1.2 billion living in extreme poverty on less than \$1 per day.

The long-term solution to global poverty is not simply more charity from the developed world, though there is much more that could be done. It will depend on economic development in the poverty-stricken areas of the world. For example, according to the World Bank's 2005 report, [Connecting East Asia: A New Framework for Infrastructure](#), economic development in East Asia over the prior 15 years resulted in lifting [250 million people out of poverty](#). Investments in infrastructure were critical to achieving this result.

Our collective ability to meet human needs, and the infrastructure that enables it, is also susceptible to changes – political, economic, technological, climatic, demographic, and others. Adapting to these changes requires an adaptable infrastructure, which speaks to how we design as well as the productivity of design and build activities. In the end, putting aside potential policy decisions (such as ending subsidies for flood insurance in areas susceptible to flooding), it is infrastructure that will provide the means of meeting the human needs in terms of safety, security, and adapting to change.

A focus on expanding, improving and maintaining the world's infrastructure addresses many aspects of sustainability. Given the global infrastructure deficit – basic infrastructure in the developing world and inadequate infrastructure in the developed world in terms of performance, safety, and adaptability – lives are at stake *today*.

### **Human Development Index**

Simple comparisons between conditions enjoyed in the richest countries and those endured in the poorest countries can be quite stark. When confronted with an image of extreme poverty, there is no question or ambiguity about the need – they need everything. There are many alarming statistics as well, several of which are quoted above, such as the 1.2 billion living on less than \$2 per day. While useful and informative, anecdotal images and gross statistics don't help us measure the magnitude of the problem in a particular country; they don't help us measure year-on-year progress in any sort of detail; nor do they help us uncover hidden problems or successes.

To help measure the state of the world and progress toward a better one in more meaningful detail, the United Nations developed the "[Human Development Index](#)" (HDI) in 1990. The purpose of the HDI is to go beyond simply economic measures, even per capita measures, to assess the condition of a population. To do this, it incorporates three dimensions of human development – health and longevity; knowledge and education; and standard of living. The United Nations publishes an annual report on human development, known as the [Human Development Report](#). This report provides the current HDI, along with a wealth of other statistics and indicators, for each country, for the world, and a number of intermediate groupings.

In the simplest terms, the HDI ranges from 0.0 to 1.0, where the higher the number, the greater the development. In the most recent [report](#), the HDI ranged from .336 to .968, with the global HDI being .743. The countries are grouped into three categories:

- **High Human Development** (HDI  $\Rightarrow$  0.8)

There are 70 countries in this category and it includes the expected nations in North America, Europe, the Pacific Rim, and portions of Central and South America. The upper third includes most of Western Europe, the U.S., Canada, Australia, and Japan. Countries such as Russia, Brazil, and Saudi Arabia occupy the bottom third.

- **Medium Human Development** ( $0.8 > \text{HDI} \Rightarrow > 0.5$ )

There are 85 countries in this category. It includes countries such as Venezuela, the Ukraine, and Thailand at the high end, and Haiti, Zimbabwe, and Uganda at the lower end.

- **Low Human Development** (HDI  $< .5$ )

This category includes the 22 countries that are the poorest of the poor. Among them are Senegal, Nigeria, and Guinea near the top and Mozambique, Niger, and Sierra Leone at the bottom.

The Human Development Index is certainly an imperfect number. Even one of its creators, Indian Nobel prize winner Amartya Sen, referred to it as a “vulgar measure.” But it can certainly help us understand the relative standing of different countries and different regions of the world as well as progress toward societies and a world where human beings have greater opportunities to realize their full potential. **Clearly, improving standards of living, education, and health will depend heavily on investments in infrastructure. Our goal should be nothing less than enabling all people to live in conditions that reflect High Human Development.**

### ***Environmental Issues***

If the imperative to improve and expand the world’s infrastructure wasn’t reason enough to justify Bentley’s focus on infrastructure, there are additional urgent needs associated with investments in infrastructure. The first is the global challenge to the Earth’s environment, including the long-term availability of nonrenewable resources, concentrations of pollution and waste from human activity, and global climate change. For example, the recent report from the [Intergovernmental Panel on Climate Change](#) (IPCC) couldn’t have been clearer regarding the impact of human activity on global climate change and its potential impact on the planet. Reasonable people may disagree on the exact nature and severity of the impact, but there is near-universal acknowledgement that the planet is warming, the climate is changing, and resources are being depleted.

The impact of human activity upon the environment is not limited to climate change alone. For example:

- [Poor land management and the overuse of fertilizer are causing land degradation, soil erosion, and desertification on a massive scale in agricultural areas from the Amazon to the Yangtze.](#) [ref]
- [In developing countries, 90-95 percent of sewage and 70 percent of industrial wastes are dumped untreated into the waters where they pollute the usable water supply.](#) [ref]
- [By 2050, the number of cars in China could rise to 500 million. In India, the number of cars could increase to 600 million. There are 200 million vehicles currently on the road in the United States – a vehicle fleet that already consumes about 11 percent of the world’s daily oil output.](#) [ref]
- [By 2020, roughly one-third of the world’s population – 2 to 3 billion people – could face an acute freshwater shortage.](#) [ref]
- [Irrigation accounts for 70 percent of the world’s water demand. More than half the water distributed by irrigation systems is lost due to leaks and wasteful practices.](#) [ref]

Clearly, action is required if we intend to sustain a planet that can support a human society in perpetuity that provides the opportunity for all people to realize the quality of life enjoyed in the developed world. **The choices we make as a global society in regard to infrastructure investments will directly affect the level of the quality of human life and the long-term health of the planet.**

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*Progress toward environmental sustainability ... can be accelerated by addressing both the numerator and denominator of the sustainability factor.*

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*Finally, successfully meeting these challenges will require investments in infrastructure – public and private – around the world.*

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### **Ecological Footprint**

In terms of measuring the overall impact of human activity on the environment, the concept of an “[ecological footprint](#)” may be useful in monitoring changes in impact of human activities. Developed in the early 1990s, it is an estimate of the amount of *biologically productive* land and sea area needed to indefinitely regenerate (if possible) the resources a given human population consumes and to absorb and render harmless the corresponding waste. Among other things, the footprint includes the area occupied by the built environment, the cropland required for food production (including pasture land), the forest land required to produce all wood and paper products, and the land required to absorb human waste products. In terms of energy, most models include the area required to absorb the CO<sup>2</sup> from energy production. Some (more conservative) methods also include the land mass required to produce the biofuel equivalent of the fossil fuel used in energy production.

There are certainly many reasonable disagreements over what should or should not be included in the models, how accurate the models are in an absolute sense, and so on. However, in a relative sense, the ecological footprint can be a good indicator of the human impact on the planet’s ecosystem, that is, a measure over time of whether the situation is getting better or worse. It also is a good relative measure of the impact of different behaviors or different geographical areas. For example, based on the ecological footprint, for everyone in the world to live the same lifestyle (have the same ecological footprint) as the average Philadelphian, seven planet Earths would be required. For the world’s population to live like the average North American, more than three planets would be required.

However, focusing solely on the ecological footprint as an indicator of progress (or lack of progress) toward a more sustainable world would be limiting. The ecological footprint is largely about *changing human activity*, but it can easily be interpreted simply as reducing human activity. There are billions – yes, billions – of people on this Earth whose ecological footprint is quite small, but who struggle merely to survive day to day. Where is the room for these people to attain a quality of life all deserve? We could succeed in creating a more “healthy” planet from an environmental point of view and yet completely fail to meet the other test of sustainability – meeting human needs *worldwide*.

The relevance of the ecological footprint is its relationship to the *bio-capacity* of the Earth – its ability to absorb human waste and CO<sup>2</sup>, the productivity of its farmland, its ability to produce energy from its natural resources, and so on. Therefore, in addition to reducing the ecological footprint per se, measures to sustain the environment could focus on *increasing* the bio-capacity of the Earth.

In that vein, it would be very useful to define a “sustainability factor” relating the ecological footprint to the bio-capacity of the Earth, where

$$\text{Sustainability factor} = \frac{\text{global bio-capacity}}{\text{ecological footprint}}$$

In this case, we have the opportunity to focus not only on *decreasing the denominator* but *increasing the numerator* as well. Defined in this way, *increasing* the sustainability factor is a good thing in terms of sustainability. In theory, the factor should be greater than 1.0. The one caveat would be that, just as in the case of the ecological footprint, the meaningful relevance of the sustainability factor is not necessarily its absolute value at a particular point in time, but rather its relative change over time. For example, in 1961 this factor was approximately 2.0, which could be taken to mean everything was just fine in terms of sustainability. However, given that this factor is currently about 0.8, the Earth’s sustainability was clearly deteriorating rapidly, even in 1960 (and [getting worse](#)). Progress toward environmental sustainability – improving the sustainability factor – can be accelerated by addressing both the numerator *and* denominator of the sustainability factor.

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*The availability of  
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### **Professional Issues**

Finally, successfully meeting these challenges will require investments in infrastructure – public and private – around the world. However, money alone is not sufficient to meet these challenges. Meeting these challenges also requires a robust global community of infrastructure professionals – engineers, designers, architects, managers, scientists, and business leaders. Unfortunately, today there is a well-documented global shortage of people possessing the requisite skills to design, build, and operate the global infrastructure required to meet the twin challenges of improved quality of life for everyone and maintaining a healthy planet.

The availability of infrastructure professionals is a critical issue. Reports from governments and private industry on this topic abound. Insufficient numbers are entering the engineering fields. A Google search on technical skill shortage will return over a million hits, listing page after page of white papers, news reports, seminars, conferences, government policies, and so on, all focused on assessing, mitigating, and overcoming the issue of an acute and growing shortage of technical skills.

In its *2007 Talent Shortage Survey*, Manpower Inc. – a global Fortune 500 firm focused on corporate human resource issues – interviewed nearly 37,000 firms in 27 countries to assess the impact of labor shortages in their respective regions. Globally, 41 percent of the employers reported difficulty in filling available positions due to a shortage of skilled prospects. According to the 2008 report by McGraw-Hill Construction, *Key Trends in the European and U.S. Construction Marketplace*, the construction work force labor shortage “has escalated into near-crisis mode for firms around the world.” Even India faces a critical shortage of people in the *construction industry*.

There are many factors affecting the available pool of specialized technical talent required to confront the issues we face related to the global infrastructure – aging populations, declining birthrates, societal changes, inadequate education programs, inadequate recruiting of young people to the technical professions, and so on. Again according to Manpower, Inc., “Talent shortages exist in many areas of the global labor force today, a situation that will grow more acute and more widespread across more jobs over the next 10 years – and could threaten the engines of world economic growth and prosperity.”

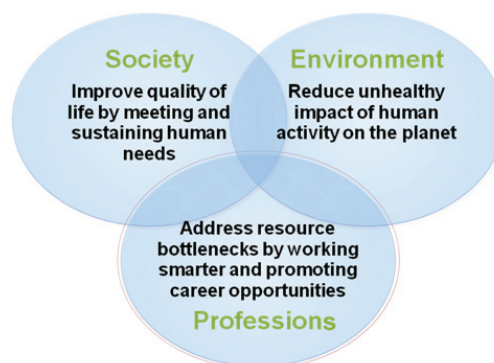
Addressing this growing shortage of infrastructure professionals will require recruiting more young people worldwide to infrastructure professions. It will also require tools and technology to enable existing infrastructure professionals to be more productive as well as to collaborate on infrastructure projects regardless of where those projects exist. **Responding to the sustainability imperatives for the world's infrastructure requires a sufficient pool of well-educated, motivated, and globally connected infrastructure professionals.**

### **Sustaining Infrastructure**

Based on the context described here, Bentley takes the view that creating a sustainable world through infrastructure requires addressing three interrelated and complex issues:

- Sustaining our society
- Sustaining the environment
- Sustaining the infrastructure professions

We have chosen to use the phrase “sustaining infrastructure” as an organizing concept for these activities. It is quite intentional that we chose a phrase that can be read in a number of ways in terms of our global sustainability objectives. Specifically, it refers to:



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*Typically, infrastructure assets are intended to have long useful lives, often measured in decades.*

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- **Creating *infrastructure* that sustains human *society***  
As we've outlined here, infrastructure is absolutely vital to realize the global sustainability objectives for society at large, specifically as it relates to meeting the basic human needs of all people on our planet. The basic needs of all people will not be met without investments in infrastructure.
- **Creating *infrastructure* that *sustains* the global *environment***  
Infrastructure assets mediate the impact of human activities on the environment. Infrastructure assets themselves impact the environment. The impact in both cases can be either sustaining or destructive. Infrastructure can remediate the destructive impact of past activities and even increase the regenerative capacity of the planet. Therefore, the nature of our investments in infrastructure will have a direct impact on sustaining our planet.
- ***Sustaining* the world's *infrastructure* so that it can continue to provide critical services to society and the environment**  
Infrastructure assets are long-lived, but they are subject to entropy and degradation as well. In order to continue to provide the services to sustain society and the environment, these assets must themselves be sustained.
- ***Sustaining* the global *infrastructure* professions to provide the brainpower to design, build, and operate *sustaining infrastructure***  
Creating and sustaining the infrastructure that our objectives for society and the environment demand requires people with a wide range of technical, managerial, and financial skills. It is incumbent on every organization involved in the infrastructure community to reach out to young people everywhere to attract them to these rewarding professions. The message is clear – we are calling on them to literally save the world.

The challenge we face is to provide *all* people a basic standard of living that enables them to look beyond surviving for another day while at the same time becoming good stewards of our planet by ensuring that we interact with the environment in a sustainable way. If we wish to translate this challenge into rough quantitative terms, our sustainability goals should include a Human Development Index of 0.8 for all people and a Sustainability Factor above 1.0. This is undoubtedly a tall order, but it is a challenge that must be met head on and will require all the focus and innovation that we can collectively muster.

## **Meeting the Sustainability Challenge**

There are many approaches to meeting the challenges of sustainability through infrastructure. Within the infrastructure community, Bentley users work this problem one project at a time. In this section we outline strategies for creating a sustainable world by sustaining society, sustaining the environment, and sustaining the infrastructure professions. In many cases, innovative project examples from Bentley's BE Awards of Excellence program are highlighted.

### ***Sustaining our society***

In terms of the definition of sustainability used here, sustaining society is primarily about meeting human needs worldwide. It involves meeting basic human needs, improving quality of life, and improving safety and security.

### ***Meeting basic human needs***

Approaches to sustaining our society by meeting basic human needs relate to delivering infrastructure globally to provide a basic quality of life for all people that includes:

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*Nearly all infrastructure assets are subject to catastrophic external events, both natural and man-made.*

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- **Basic infrastructure** – This refers to the delivery of basic infrastructure to people in the greatest need. For example, this would include creating the infrastructure required to provide clean drinking water and meet basic sanitation requirements in the developing world. This is not limited to rural areas. Given the significant migration to urban areas, particularly in the developing world, this also refers to providing the basic infrastructure services – housing, water, sewer – to support growing low-income populations in urban areas. The following projects completed or currently being worked on by Bentley software users have delivered basic infrastructure to those in greatest need:

*2007 BE Award Nominee – Mumbai Sewage Disposal Project, p. 105* – The objective of this project is to provide a healthier and improved environment for people living in the city of Mumbai, India, while minimizing the impact of wastewater on the natural environment. This will be achieved by increasing the quality and reliability of wastewater collection, treatment, and disposal. Mumbai’s water, sewer, and drainage network is almost 150 years old and the municipality did not have updated information on its existing facilities.

*2006 BE Award Nominee – International Partnership, p. 103*

*Red Cross – Tsunami Recovery Effort – Bentley supported*

*Engineers Without Borders – Bentley supported, program under development*

*HOPE Worldwide – Bentley supported, program under development*

- **Access to non-infrastructure services** – This refers to providing the means of access (roads, bridges, and communication systems, for example) to facilities (buildings, hospitals, and so on) for non-infrastructure services such as basic health and medical services, education, food distribution, and so on. The following are good examples of projects undertaken by Bentley users to create infrastructure for access to services:

*2006 BE Award Nominee – Road Design in Tanzania, p. 58* – This project was a detailed engineering design for 487 kilometers of roads in the East African country of Tanzania, one of the poorest nations in the world. Improved roads are seen as key to facilitating socio-economic development there. Using MicroStation, InRoads, and customized standards, the project was shortened by about six months; some of that saved time was used to train locals as an investment in the future

*2007 BE Award Nominee – Multi-sector Project for Rehabilitation of Infrastructure in Jammu and Kashmir, India, p. 60*

- **Developing the soft infrastructure** – This refers to efforts supporting the development of the local “soft infrastructure.” By this, we mean the awareness, education, and training for the local population in the availability, use, operation, and maintenance of the infrastructure and its related services. That is the goal of HOPE Worldwide:

*HOPE Worldwide – Bentley supported, program under development*

### **Improving quality of life**

Beyond meeting basic needs, infrastructure provides the means for societies to thrive and grow, as enabled by approaches such as the following:

- **Improve services provided by infrastructure assets** – This refers to initiatives to increase the quality, scope, and choice of services provided by infrastructure that go beyond fulfilling the infrastructure requirements to meet the most basic human needs. For example, this might entail expanding the options for long-distance transportation; relieving traffic congestion; increasing the bandwidth provided by the broadband network; making more recreational area available; and so on. The following projects improved services provided by infrastructure assets:

*2006 BE Award Nominee – Construction of Line III of First Phase of Delhi Metro Rail, p. 54* – The traffic on roads in New Delhi is a heterogeneous mix of bicycles, scooters, buses, cars, and rickshaws jostling with each other, and that traffic is increasing at an enormous rate. Road accidents kill an average of five, and injure 13, people per day. The objective of the Metro Rail project is to help provide safe, quick, and comfortable commuting for New Delhi's 13.8 million people.

*2006 BE Award Nominee – i21 Intervention Suite for the 21st Century, p. 38*

*2007 BE Award Nominee – Planning, Design, and Construction for Peripheral Ring Road for Bangalore, p. 54*

*2007 BE Award Nominee – New Bangalore International Airport, p. 64*

- **Improve the availability of infrastructure services** – This would include increasing the scope of the services provided by facilities such as schools and hospitals; providing electricity and communications that are more stable and less prone to interruption; adding handicap access to existing facilities; and so on. Examples of projects that improved the availability of infrastructure services include:

*2006 BE Award Nominee – Reconstruction of Roads in Tbilisi, p. 48* – From May to December 2005, 50 kilometers of major roads in Tbilisi, Georgia, were reconstructed to help sustain the improving economy. Tbilisi had no useful design drawings, coordinate reference system, or survey basis, so ARCADIS established the latter two and created a digital terrain model. The result was a 3D model that let the firm optimize the drainage system of the road and calculate the capacity of the sewer system.

*2006 BE Award Nominee – Interlinking of Water Works in Mumbai Metropolitan District, p. 98*

*2007 BE Award Nominee – Model for Transforming an Intermittent Into a 24x7 Water Supply System for Developing Countries, p. 104*

- **Increase the adaptability of infrastructure** – Typically, infrastructure assets are intended to have long useful lives, often measured in decades. When measured against the increasingly rapid pace of change – political, environmental, technological, social, and so on – many infrastructure assets will undoubtedly need to be adapted or repurposed to provide expanded services, better services, or different services at some point, perhaps at multiple points, in their useful lives. To the degree infrastructure assets can be more easily adapted to new purposes; be modified more productively; and be more effectively reused, the more valuable and sustainable the asset becomes. This concept encompasses everything from designs that make the asset more adaptable to methods for recycling material or existing structures to tools that enable changes to an asset to be made faster and more economically. The following project and group demonstrate how changeable form advances sustainability:

*2007 BE Award Nominee – United States Courthouse, p. 27* – Dewberry teamed with Koetter/Kim & Associates Inc. to plan and design a new \$87 million federal courthouse for the General Services Administration in Rockford, Ill. The new facility will accommodate the 10-year space requirements of the District Court and court-related agencies on a site large enough to also accommodate its 30-year expansion requirements. The courthouse will house five courtrooms, additional clerks' space, and 52 secure interior parking spaces below the building.

*SmartGeometry 2007 – Changeable Form*

### **Improving safety and security**

Even a thriving society will be subject to unexpected events or pressures – natural and man-made – that can threaten its stability and viability. Infrastructure is an important tool enabling society to protect itself against such unexpected events and mitigating their effects.

- **Improve the safety of infrastructure assets** – This refers to improving the safety of the services provided by

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*The second sustainability challenge is to become good stewards of our planet, including its environment and its resources.*

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infrastructure assets, for example, monitoring or improving the structural integrity of bridges and buildings. It also refers to improving the safety of the users of the asset by improving the security of the asset, making it less vulnerable to external threats. Finally, this would also include improving the safety of the asset during other phases of the lifecycle, such as during construction, when the safety of the construction personnel could be improved through better planning with a focus on safety. Bentley solutions users were important participants in the following projects designed to improve the safety of infrastructure assets:

*2007 BE Award Nominee – Design of New Jubilee Bridge, p. 72* – Originally constructed in 1887, the Jubilee Bridge provides an important railway link across the river Hooghly in West Bengal, India. Although it is still operational, the bridge has severe speed restrictions, so Eastern Railway planned to construct a new one. It commissioned RITES to carry out the detailed studies and recommend a location for the New Jubilee Bridge. RITES designed a 415.60-meter three-span rail bridge with continuous superstructure used – a first at Indian Railways.

*2007 BE Award Nominee – Montgomery Lock and Dam Lift Gate, p. 72*

*2007 BE Award Nominee – Maintaining Water Network Fire Fighting Capacity, p. 102*

- **Mitigate impact of catastrophic events** – Nearly all infrastructure assets are subject to catastrophic external events, both natural (earthquake, tsunami, fire, severe weather, flooding) and man-made (vandalism, acts of terror, armed conflict, industrial accidents). There are many strategies for mitigating the impact of catastrophic events. Among them are hardening the infrastructure assets to better withstand potential extreme events, better planning for evacuation and recovery, better forecasting of extreme events, and better tools for first responders. Examples of projects whose aim was to mitigate the impact of catastrophic events include:

*2006 BE Award Nominee – Building Landslide Disaster Forecasting System, p. 96* – Japan Conservation Engineers developed the Landslide Disaster Forecasting System using a 3D GIS to provide spatial information on the hazards from varying perspectives. The system currently manages a variety of documents – from surveys to design and construction documents – and assists in the design of preventative structures. It also has 3D capabilities for landscape simulation, hydrological and geological modeling, and geomorphologic analysis. Bentley software made possible otherwise impossible tasks, including 3D visualization of a damaged area.

*2006 BE Award Nominee – Expertise in Civil Safety at Ville de Saguenay, p. 85*

*2006 BE Award Nominee – Interagency Performance Evaluation Taskforce 7*

*2006 BE Award Nominee – MC118 Cartographic Module for Emergency Dispatch System, p. 88*

*2006 BE Award Nominee – Katrina Evacuee Relief Fold Map, p. 90*

*2006 BE Award Nominee – Rio Verde Area Drainage Master Plan, p. 97*

*2007 BE Award Nominee – Harlingen Downtown Drainage, p. 57*

*2007 BE Award Nominee – Standing Tall (Before and After), p. 89*

- **Adapt to climate change** – Regardless of the long-term success or failure of initiatives to reduce climate change, the climate will change. It *will change* due to human activity. It will change on its own accord through its natural cycles. Therefore, preparing to adapt to the multiple effects of climate change is a fundamentally important component of sustainability.

The growing population and increasing density of urban areas, particularly near the coasts, renders this an important component of sustainability, even in the face of modest climate change. There are multitudes of activities that can enable us to adapt to climate change. These include restoring forest land to minimize erosion and mudslides, restoring coastal reefs and wetlands, more efficient land management,

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*The bio-capacity of the Earth can be increased by recovering bio-capacity lost to prior human activity.*

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better storm water management, updating building codes, addressing issues that will be exacerbated by climate change (such as disease eradication), updating zoning regulations to minimize exposure to climate change effects, new farming methods, better predictive modeling (for flooding, for example) and risk assessment of the climate change effects, as well as adaptive “engineered ecosystems,” to name just a few. The following projects by Bentley solutions users were carried out in efforts to adapt to climate change:

*2006 BE Award Nominee – Mississippi Valley Division Collaboration, p. 135* – The U.S. Army Corps of Engineers Mississippi Valley Division (MVD) reaches from Minnesota to New Orleans. In the wake of Hurricane Katrina in September 2005, MVD decided to implement ProjectWise across its six districts and its engineering and research development center in Mississippi. Today, MVD professionals use ProjectWise to collaborate on projects such as a plan to improve navigation while ensuring sustainable ecosystems on the upper Mississippi River and Illinois waterways through 2050.

*2006 BE Award Nominee – Rio Verde Area Drainage Master Plan, p. 97*

*2007 BE Award Nominee – Harlingen Downtown Drainage, p. 57*

### ***Sustaining the Environment***

The second sustainability challenge is to become good stewards of our planet, including its environment and its resources. One element of sustaining the environment is increasing the sustainability factor above 1.0 and then keeping it there, maintaining sufficient bio-capacity to continue renewal while accommodating current and future activities by humans. Approaches include increasing bio-capacity, reducing ecological footprint, and more efficient use of nonrenewable resources.

### ***Increase bio-capacity***

The following approaches to sustaining the environment are examples of *increasing* the numerator of the sustainability factor. This includes not only increasing the bio-capacity of the Earth per se, but taking advantage of the existing, untapped bio-capacity of the Earth. Finally, this would include initiatives to increase the bio-capacity of infrastructure itself, such as buildings that are net producers of power or factories that emit clean water as a by-product.

- **Take advantage of natural energy potentials** – The Earth provides many natural energy potentials, such as solar, wind, geothermal, ocean temperature gradients, hydroelectric, nuclear, and so on. The technology for taking advantage of these potentials for commercial energy production has long been a reality. For many, exploiting them more fully requires technical innovation, overcoming economic barriers, or achieving economies of scale. The following projects tapped natural energy potentials for sustainable generation of electrical power:

*2007 BE Award Nominee – Lihir Geothermal Power Station, p. 141* – Lihir Gold Limited retained SMEC to add 20 megawatts of capacity to the company’s 30-megawatt geothermal power plant. The geothermal plant is one of the first Clean Development Mechanism projects in Papua, New Guinea, and is one of only roughly 200 worldwide.

*2006 BE Award Nominee – Flatrock Wind Farm, p. 103*

*2006 BE Award Nominee – Kaheawa Wind Project, p. 116*

*2007 BE Award Nominee – Sauda Hydro Power Project, p. 19*

*2007 BE Award Nominee – Tarucani Hydroelectric Power Plant, p. 137*

- **Expand ability to absorb waste** – This refers primarily to increasing the natural ability of the Earth to

absorb greenhouse gases by increasing green space through recovery of waste sites, plankton growth in the oceans, reforestation, recovery of arid land, increased urban green space, green building roofs, and so on. It also includes implementing [carbon sequestration](#) projects to absorb carbon dioxide from the atmosphere through approaches such as underground storage, ocean storage, chemical storage within minerals, storing the carbon by-products of [power generation](#), and so on. Reducing greenhouse gases was the goal of the following projects undertaken by Bentley users:

*2006 BE Award Nominee – [Chalupnik House](#), p. 35* – The Chalupnik House is a sophisticated home for six constructed on a challenging site in Prague. It has an open western elevation, a rather closed eastern elevation (with the minimum amount of openings), and an almost closed northern elevation. There is no southern elevation, as the volume of the house slides into the slope. As a result, it was decided to make the roof literally green: It has grass planted on it.

*2006 BE Award Nominee – [Fukuoka Island City Central Park GRINGRIN](#), p. 25*

- **Remediate impact of human activity** – The bio-capacity of the Earth can be increased by recovering bio-capacity lost to prior human activity. This includes solutions such as hazardous waste recovery and disposal; treatment of polluted water; cleaning polluted air (with urban forests, for example); recovering green spaces lost to activities such as mining and landfills; mining landfills for resource recovery; and so on. The following are a few of the many infrastructure projects designed to remediate the impact of human activity:

*2006 BE Award Nominee – [Sydney Water Bondi Sewage Treatment Plant](#), p. 121* – The Bondi Sewage Treatment Plant services approximately 500,000 people and includes underground excavations, cut from sandstone. These include large chambers and tunnels in large rock excavations, as well as numerous smaller ones. When expanding the plant, traditional site measurements were considered impossible. Accurate definition of existing tunnels was performed with 3D laser scanning. The resulting 3D model was then used to design the new plant installation alongside the existing plant, allowing a phased changeover without compromising capacity.

*2006 BE Award Nominee – [The Hollansch Diep Sediment Storage Facility](#), p. 67*

*2006 BE Award Nominee – [Norris Lake Water Treatment Plant](#), p. 115*

*2006 BE Award Nominee – [Rochester Water Reclamation Plant Expansion and Upgrade](#), p. 128*

*2006 BE Award Nominee – [Wastewater Treatment Improvement Projects](#), p. 129*

*2007 BE Award Nominee – [St. Augustine LPRO Water Treatment Plant](#), p. 121*

*2007 BE Award Nominee – [Eastern Treatment Plant: Sludge Augmentation Project](#), p. 138*

*2007 BE Award Nominee – [Nan Zhi Wastewater Treatment Plant](#), p. 142*

### **Reduce Ecological Footprint**

These approaches to sustaining the environment are examples of decreasing the denominator of the sustainability factor – reducing the ecological footprint resulting from continuing human activity.

- **Reduce or eliminate greenhouse gas emissions** – This is currently perhaps the most visible and active area in terms of reducing the ecological footprint as it relates to mitigating global warming and resultant climate change. The multitude of approaches include designing buildings with “green” materials; designing buildings with a greater degree of natural cooling, heating, and lighting; more accurate assessment and optimization of building performance during the design phase; real-time monitoring and optimization of building energy usage; and so on. This also encompasses “clean” (without CO<sup>2</sup> emissions) electricity

generation (with some overlap with increasing bio-capacity approaches) and alternatives to petroleum products for transportation. Reducing or eliminating greenhouse gas emissions was the goal of the following projects:

*2006 BE Award Nominee – Integration of the Measurement of Energy Usage Into Road Design, p. 53–*

The goal of the project, undertaken jointly by the Czech Republic, France, Ireland, the Netherlands, Portugal, Sweden, and the United Kingdom, was to develop software to evaluate energy usage in both the construction and operation of a road. Different routes could then be compared in terms of energy use. On average, it was found that the energy used by the vehicles on the roads over a 20-year period is 18 times greater than the energy used in the road's construction.

*2007 BE Award Nominee – National at Docklands, p. 11*

*2007 BE Award Nominee – Kanselarij Cluster Restructuring Project, p. 32*

*2007 BE Award Nominee – Buckley AFB Army Aviation Support Facility, p. 33*

*2007 BE Award Nominee – Renewable Energy Corp., Moses Lake Expansion, p. 121*

- **Reduce or eliminate detrimental environmental impact** – This refers to the well-known and longstanding initiatives to reduce the overall environmental impact of new infrastructure projects. It also includes initiatives to reduce pollutant emissions from commercial facilities. This includes designing new facilities that produce less pollutant waste; retrofitting existing facilities to capture or process pollutants; repurposing waste products for use in other processes; and so on. The following projects were designed to minimize detrimental environmental impact of infrastructure:

*2006 BE Award Nominee – Pacific Coast Highway, p. 93–* When rainwater flows across the Pacific Coast Highway, it becomes contaminated with metal from brake pads, ground-up tire rubber, trash, and oil. Vertical Mapping Resources provided CALTRANS digital orthophotographs, digital terrain models including two-foot contours, and design-scale planimetrics for several large sections of the highway. CALTRANS will use the information in its efforts to prevent or treat highway runoff.

*2006 BE Award Nominee – I93 Environmental Impact Statement, p. 65*

*2006 BE Award Nominee – Tailings Management Facility Zelazny Most Reservoir, p. 86*

*2006 BE Award Nominee – CHP Suszec: Mine Gas Utilization Genset 4MW, p. 111*

*2006 BE Award Nominee – Mitchell & Mountaineer CPS Treatment Plants, p. 119*

*2006 BE Award Nominee – Plant Gaston Unit 5 SCR, p. 131*

*2007 BE Award Nominee – U.S. 24: Fort to Port Project, p. 56*

*2007 BE Award Nominee – WFGD Retrofit: Sioux Power Plant, p. 141*

- **Extend life and reuse infrastructure assets** – Another mechanism for reducing the ecological footprint is to eliminate the footprint from material production and transportation, construction, debris and waste removal, and so on associated with new construction by extending the useful life of infrastructure assets as well as adapting them for new uses. Extending the useful life of infrastructure assets was the goal of the following project:

*2007 BE Award Nominee – Kanselarij Cluster Restructuring Project, p. 32–* This project includes nearly 800,000 square feet of renovation, rebuilding, and refurbishment on King Street in Brussels' Royal Quarter. Many of the buildings in this sector date back to the 17th century. In particular, integrating 21st century technology into two classical buildings proved a challenge for both designers and engineers. The ultimate design integrates a number of green features, such as sun-protected building development, recycling of rainwater, ground heat exchange, cogeneration, heat recovery on ventilation units, and daylight control.

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## More efficient use of nonrenewable resources

Given the current global dependence on many nonrenewable resources, consumption of nonrenewable resources continue for the foreseeable future. More efficiently extracting, processing, and consuming these resources will extend the window for replacing them with renewable sources. Infrastructure projects that result in more efficient use of resources have the potential of improving both the numerator and denominator of the sustainability factor.

- **More efficient consumption** – The obvious initiative in regard to nonrenewable resources is to consume them more efficiently. This involves, for example, greater energy efficiency; alternate modes of transportation (such as mass transit); elimination or replacement of unnecessary activities (by telecommuting, video conferencing, and so on); and use of new materials that require less energy to produce and transport. These are all examples of more efficient consumption. Likewise, designs which result in products that are more readily and efficiently recycled, including “Cradle to Cradle” certified products, are further examples of more efficient consumption. The following projects targeted more efficient consumption:

*2006 BE Award Nominee – Coupling Water Demand Prediction Model to Hydraulic Network Model in Real-Time Operation, p. 99* – Sabesp developed a real-time water distribution system operation for the water main system of the metropolitan region of Sao Paulo, Brazil. An interface between a hydraulic network model and an existing water demand prediction model was developed. With the prediction model, the operations are now more efficient due to a decrease in not only the number of valve position and pump status changes, but also in energy costs—by approximately 20 percent—due to a reduction in pump operations.

*2006 BE Award Nominee – Land Development of Hwaseong Dongtan, p. 108*

*2006 BE Award Nominee – Sugarmill vrdy-Bioethanol, p. 118*

*2007 BE Award Nominee – Ferrara Incineration Plant, p. 142*

- **More efficient production** – In addition to consumption, there are opportunities to more efficiently produce by-products from raw materials, including processes that consume less energy and produce less waste; processes that produce a higher yield for the same raw material; more efficient means of transport; reuse of by-products; and so on. More efficient production was the goal of the following projects:

*2007 BE Award Nominee – Intelligent Mining Solution, p. 111* – The Intelligent Mining Solution is a geospatial information management system created to manage mine-related requirements for the South African Assmang Iron Ore Mines. The project pulls data from independent systems such as weather stations, dust-monitoring stations, and water quality analysis laboratories. Previously, workflows were all manual and paper-based. Now, a web interface reports real-time information from these independent systems. The solution saves the client \$51,000 per year.

*2006 BE Award Nominee – Eni Power Combined Heat and Power Plants, p. 122*

*2007 BE Award Nominee – Oil Field Development, p. 51*

- **Expand global resource supplies** – Given the ultimate limits on nonrenewable resources, expanding the global resource supplies is also an approach to extending the availability of nonrenewable resources, and ensuring their continuing availability even as they are being replaced for some uses by renewable sources. These approaches could include more complete and efficient extraction methods; more effective and accurate exploration; more eco-friendly exploration and extraction; and so on. The following projects are examples of efforts to expand the availability of global resources:

*2007 BE Award Nominee – ConocoPhillips Drill Site Technologies, p. 135* – By reusing project data,

VECO Alaska was able to simultaneously engineer two drill sites for ConocoPhillips Alaska Inc. This allowed ConocoPhillips to generate new drill sites more quickly and with reduced engineering costs.

*2006 BE Award Nominee – West-Salym Field Development, p. 114*

*2006 BE Award Nominee – Alvheim Field Development Project, p. 126*

### ***Sustaining the Infrastructure Professions***

Meeting the challenges to sustain both society and the environment requires a global pool of infrastructure professionals armed with effective knowledge and tools. Our pool of infrastructure professionals is increasingly inadequate. Initiatives intended to overcome these shortages include attract and educate, renew, and enable.

#### ***Attract and educate***

Critical to expanding the pool of infrastructure professionals is both attracting students to the infrastructure professions and providing them with the appropriate education in the infrastructure professions to enable them to contribute to global sustainability.

- **Attract students to sciences and engineering** – The most fundamental requirement in the long term is to attract young students to the sciences and ultimately the technical fields, such as engineering, relevant to infrastructure. Approaches to this include supporting elementary and middle school programs to promote interest in science and math such as the National Engineers Week Future City Competition. Equally important is supporting high school programs to promote interest in engineering with programs such as the Wooden Bridge Contest and robotics competitions. Programs dedicated to attracting students to the sciences and engineering include the following:

*National Engineers Week Future City Competition – Bentley supported*

*Future Cities India 2020 – Bentley supported*

*ACE Mentor Program – Bentley supported*

- **Focus undergraduates on infrastructure professions** – Once students have chosen to pursue a technical career, it is also necessary to attract them to the infrastructure professions. Initiatives to do this would include supporting university programs and competitions focusing on infrastructure (the Solar Decathlon, for example), as well as supporting university-level volunteer programs working on projects in the developing world, including Engineers Without Borders, HOPE Worldwide, and others. In addition, implementing active internship and co-op programs within infrastructure-related companies will also support this objective. Dr. Howard Turner was awarded a BE Award of Excellence for his work in attracting undergraduates to infrastructure professions:

*2007 BE Award Nominee – Dr. Howard Turner, p. 160*

- **Support, focus, and leverage university research** – There is significant anecdotal evidence that university-level research is not leveraged to the degree possible. There are many factors contributing to this. Unlike the aerospace, automotive, and defense industries, the infrastructure community is very diverse, highly fragmented, and often operates locally. Thus there are not large budgets available for broad, long-term initiatives to study fundamental infrastructure issues. Most research is funneled into industry through consortiums or by hiring the researchers directly. Corporate involvement is largely through modest monetary grants. What is required is the active *engagement* in and support of research by the members of the infrastructure professions. This will enable practitioners to realize the research results

more directly, as well as help focus the research initiatives on issues that are immediately relevant to the infrastructure industry. Bentley efforts to support, focus, and leverage university research are advanced by the Bentley Applied Research team:

*Bentley Initiative – Bentley Applied Research*

*University of Pennsylvania, Virginia Tech, MIT, Polytechnic University, Johns Hopkins, McGill University (Canada), Technical University of Delft (Netherlands), Strathclyde University (UK)*

## **Renew**

Maximizing the effectiveness of existing infrastructure professionals requires continuous renewal of the appropriate skills.

- **Institutionalize continuous learning** – The concept and value of continuous learning is generally well understood. However, within “episodic” (largely project-based) domains such as infrastructure, investments in training are often ranked fairly low among the investment priorities of many organizations. Continuous learning applies not only to professionals within the infrastructure community, but initiatives to retrain people from other industries in infrastructure-relevant skills. This would also include adopting programs to enable colleagues to gain certification in sustainability related areas such as Leadership in Energy and Environmental Design (LEED). The following Bentley software users were nominated for BE Awards of Excellence for their success in institutionalizing continuous learning:

*2006 BE Award Nominees – [Well-Trained Organizations](#), p. 135*

*2007 BE Award Nominees – [Well-Trained Organizations](#), p. 150*

- **Implement new forms of learning** – The effective implementation of continuous learning requires new forms of learning, those that go beyond traditional classroom instruction. This is particularly true given the distributed nature of projects and enterprises within the infrastructure community. Distance learning, self-service online content, and “just-in-time” learning are some of the methods that can facilitate continuous learning. The following program is an example of implementing new forms of learning:

*[Denver’s Road Home BEST Work Exchange Program](#) – Bentley supported*

- **Foster communities of infrastructure professionals** – The communities of infrastructure professionals are necessarily distributed all around the world. However, the near universal connectivity made possible by the Internet opens the possibility of creating online, worldwide communities of infrastructure professionals. Concepts like social networking can be extended into the infrastructure community to create focused virtual communities for sharing ideas and experiences, collaborating on projects, education, and other activities. The purpose of BE Communities is to foster communities of infrastructure professionals.

*Bentley Initiative – [BE Communities](#) (under development)*

## **Enable**

The work accomplished by the existing pool of infrastructure professionals can be increased by equipping individual professionals, work groups, distributed project teams, and the entire supply chain for infrastructure projects with more effective tools for performing their work.

- **Tools for increased productivity** – This refers to expanding the use of existing information technology tools for all phases of the infrastructure asset lifecycle, along with better tools from technology ven-

dors, to improve productivity and quality. This also includes increasing reuse of information, particularly through the adoption and widespread use of industry standards. It also includes specific, high-return initiatives such as more direct use of design information in support of construction and construction management tasks. The following are examples of Bentley users who used their software tools for increased productivity:

*2006 BE Award Nominee – Flint Global V6 Engine Plant Expansion*, p. 28 – The Flint Global V6 engine plant in Michigan is the second in a four-project series using 3D-enabled lean construction across the design/fabrication/construction supply chain. Design and construction of the 417,000-square-foot facility were completed almost five weeks early and with zero change orders due to increased coordination. The project provided real project metrics that 3D building information modeling (BIM) can deliver projects faster, better, safer, and at lower cost than conventional 2D paper-based approaches.

*2007 BE Award Nominee – Wells Fargo Home Mortgage*, p. 34

*2007 BE Award Nominee – Digital Factory: Integration of Process Data*, p. 35

*2007 BE Award Nominee – 5D Construction*, p. 37

*2007 BE Award Nominee – Rose Unit*, p. 122

- **Tools to design, analyze, and assess for sustainability** – This refers to information technology tools – either by adapting existing tools or creating new built-for-purpose tools – that directly address the sustainability issues raised here. The following Bentley products are used to design, analyze, and assess infrastructure for sustainability:

*Bentley Products – Structural Analysis & Design*

*Bentley Products – Engineering Analysis*

*Bentley Products – Water Solutions*

*Bentley Products – Building Services & Simulation*

- **Tools to globally connect infrastructure professionals** – One immediate mechanism for increasing the availability of infrastructure professionals, particularly for a specific project, is through the widespread adoption of technology to connect and enable collaboration among globally distributed professionals. The following projects exemplify successful connection of infrastructure professionals in distributed enterprises:

*2006 BE Award Nominee – HDR ProjectWise Implementation*, p. 49 – Distributed work sharing is one of the keys to HDR's business success. In these operations, the firm found that moving drawings and documents over e-mail and FTP poses unacceptable risks that files will be overwritten or corrupted. To overcome these and other challenges, HDR implemented the ProjectWise system of collaboration servers as its primary document management system.

*2006 BE Award Nominee – CPAI Managed Environment*, p. 110

*2006 BE Award Nominee – Hatch workSMART Data-Centric Environment*, p. 112

*2006 BE Award Nominee – Mississippi Valley Division Collaboration*, p. 135

*2007 BE Award Nominee – Managing Complexity: Facilitating 3D-Enabled Delivery on a Series of Automotive Projects*, p. 44

*2007 BE Award Nominee – Kennedy Interchange Reconstruction*, p. 74

*2007 BE Award Nominee – Jamnagar Export Refinery Project*, p. 143

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*The road to a sustainable world will be paved by the vision, commitment, innovation, open-mindedness, and pragmatism of infrastructure professionals.*

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## Conclusion

Sustainability is not a single issue. It's not limited to global warming, climate change, pollution, chronic hunger, unsafe bridges, public health, or contaminated water – it is all of these and more.

It's not a problem that we'll solve and then move on – it will require constant, continuing, and unrelenting attention. The issues and challenges surrounding sustainability are broad, complex, and interrelated.

To completely satisfy our sustainability objectives will mean more investment in infrastructure, not less. It will mean more economic development, not less.

As has been convincingly argued by some, until people reach a certain level of affluence, concerning themselves with global sustainability is a luxury they cannot afford. For the 3 billion people living on less than \$2 per day, the primary sustainability objective is simply to sustain themselves and their families for another day. If our goal is for all people to be concerned with global sustainability, then the prerequisite is to enable all people to enjoy a quality of life that affords them that luxury. This is a significant challenge for society, a significant challenge for the world's infrastructure, and a challenge for all of us as members of the infrastructure professions.

In order to meet this challenge, technology companies such as Bentley must provide solutions that are comprehensive, interoperable, and productive. However, when it comes to addressing the elements of sustaining infrastructure – society, environment, and the infrastructure profession – vision, commitment and engagement are just as important as individual features of software applications.

In the end, sustainability is about nothing less than how we, as a global society, *choose* to live on this planet. Science alone will not dictate the steps we need to take to create a sustainable world. Science can only help us predict the consequences of the *choices* we make.

Likewise, the market alone will not guide us to a sustainable world. The market's invisible hand will efficiently optimize our investments within the bounds of its regulations and incentives, but we must make the fundamental *choices* as to those regulations and constraints. Science and the market are powerful tools, but they are only tools – not altars.

The road to a sustainable world will be paved by the vision, commitment, innovation, open-mindedness, and pragmatism of infrastructure professionals.

“It is astonishing to see how many philosophical disputes collapse into insignificance the moment you subject them to this simple test of tracing a concrete consequence. There can be no difference anywhere that doesn't make a difference elsewhere – no difference in abstract truth that doesn't express itself in a difference in concrete fact and in conduct consequent upon that fact, imposed on somebody, somehow, somewhere, and somewhen. The whole function of philosophy ought to be to find out what definite difference it will make to you and me, at definite instants in our life, if this world-formula or that world-formula be a true one.

A pragmatist . . . turns away from abstraction and insufficiency, from verbal solutions, from bad a priori reasons, from fixed principles, closed systems, and pretended absolutes and origins. He turns towards concreteness and adequacy, towards facts, towards action and towards power . . . It means the open air and possibilities of nature, as against dogma, artificiality, and the pretence of the finality in truth.”

- William James, 1885



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