# Geomatics for Sustainability

## Background

Practice, Education and Research for Sustainable Infrastructure (PERSI) is an initiative of the infrastructure community. The initiative of PERSI is to advance and incorporate concepts and knowledge of sustainability into the standards and practices used throughout the life cycle of infrastructure systems.

The PERSI Technical Committee met on September 18, 2006. The purpose of the meeting was to plan and budget for the assessment of current practices and knowledge and to develop agendas for:

1. Implementation of best available practices,
2. Development of improved practices to exploit available knowledge,
3. Research to fill important gaps in knowledge, and
4. Education of current and future infrastructure professionals and technicians.

A task committee structure was recommended. There were six project level task committees, eight infrastructure systems level task committees, and four task committees to address additional areas of practice that are relevant to all infrastructure systems. The six project level task committees address the following topic areas: project environmental management; land use, landscape, archeological and cultural heritage; ecology and biodiversity; water and air issues; energy; and use of materials. The eight infrastructure systems level task committees address the following areas: buildings; transportation; water resources and treatment; solid waste; energy; communications physical infrastructure; flood and storm surge control systems; and global warming effects in cold regions. Last, the four areas of relevant practice task committees included: measurements of sustainability; planning for sustainability; geomatics for sustainability; and education for sustainability. The objective of the geomatics for sustainability task committee is to determine the availability and access to spatial and geographic information that can be used in developing sustainable decisions in the planning, design, construction, operation and maintenance of infrastructure systems.

The Task Committee on Geomatics is comprised of Terry Bennett (Autodesk), Carolyn Merry (The Ohio State University), and Milo Robinson (Federal Geographic Data Committee, U.S. Geological Survey). We met with the PERSI Governing Assembly on February 25, 2008. The principal topics at the meeting included a discussion of case studies of PERSI's assessment protocol, and reports from the task committees focused on education, planning, and geomatics.

The Task Committee on Geomatics agreed to develop an initial report defining the following topics: sustainability and infrastructure and the potential uses of geomatics in this area; the national geospatial databases available for use by the infrastructure community; and the challenges of information sharing, database compatibility, education, and the available technologies.

## Definition of Geomatics

Geomatics is a relatively new term in the engineering community that has replaced the area of practice called surveying (Wolf and Ghilani 2006). The reason for the name change is that the scope of surveying has changed dramatically over the past 20 years. New technology and improved electronic instruments have given surveyors and engineers enhanced tools and methods for measuring and collecting spatial data on $x,y$ ground locations with the corresponding $z$ component of elevation. The traditional transit and tape in surveying have been replaced with automatic total stations and high quality global positioning systems (GPS). There are aircraft systems capable of providing high-resolution aerial photographs and images that are precisely located to a ground coordinate system using on-board GPS and INS (inertial navigation systems). Ground-based and airborne systems of LiDAR (Light Detection and Radar) provide detailed point clouds of elevation. With these new data collection platforms providing vast amounts of data quickly and in near real time, geographic information systems (GISs) have been used to integrate these various data sources in the context of a common reference frame. Computer software has also developed to allow for improved display and processing of the data. Satellite systems for imaging the earth's surface using high-quality positioning systems have provided images that cover large areas of the earth's surface.

There are some very serious challenges facing our world's infrastructure. These challenges are providing the motivation to develop new approaches and technologies that will fundamentally change how we design, build, operate, and maintain buildings and infrastructure. Along with these challenges is a rethinking of handling and processing the digital data and the overall infrastructure information that is used in all of these processes. While these new technologies and processes are designed to address challenges in the Architecture, Engineering and Construction (AEC) industries today, these technologies and processes are also going to impact other sectors as well. Example sectors include the initial urban planning, associated emergency planning, and once constructed, the operations and maintenance of the infrastructure. Other sectors include the first response to emergencies of all types, including infrastructure failure, and how sustainable design needs to move forward to prevent such catastrophes.

## Spatial Data Infrastructure

A variety of geospatial information is used to enhance our understanding of the world. In particular, Federal agencies maintain national data sets that are built upon local level data wherever possible. For example, the U.S. Geological Survey is the lead agency for Geographic Names, Elevation, Orthoimagery, and Hydrography. In addition, the U.S. Geological Survey provides spatial information on Transportation and Structures. Other federal agencies also maintain spatial data sets. All federal agencies follow the policy found in the Office of Management and Budget Circular A-16, which sets the policy for the coordinated use of geospatial data sets known as the National Spatial Data Infrastructure (NSDI).

The following sections provide descriptions of spatial data themes that the U.S. Geological Survey makes available in the public domain. These data sets are available at various scales, depending on the source data.

### Elevation

Elevation data consists of gridded terrestrial digital elevation data with 10-m or finer resolutions, and raw and processed data that can support 10-m or finer gridded elevation data. The data may be derived photogrammetrically or processed from laser, radar or other technologies. The data may be obtained from aircraft, satellite, or ground-based methods.

### Geographic Names

The Geographic Names Information System (GNIS) is the principal vehicle for the U.S. Board on Geographic Names to promulgate the standard form and spelling of geographic feature names. The GNIS is designated as the authoritative database for geographic names.

### Hydrography

The National Hydrography Dataset (NHD) is a comprehensive set of digital spatial data that represents the surface water of the United States using common features, such as streams, rivers, canals, ponds, lakes, and oceans. This data is designed to be used in general mapping and in the analysis of surface water systems using geographic information systems.

### Orthoimagery

The orthoimagery data theme is digital orthorectified imagery of 1-m resolution or better, acquired in a five-year cycle for the United States and its territories and possessions. In addition, digital orthorectified imagery of 1-ft resolution or better is acquired in a two- to four-year cycle for the 133 urban areas. Imagery type may be natural color, color infrared, or panchromatic.

### Structures

The structures data theme comprises the geospatial location, classification, and other characteristics of manmade facilities. These requirements are primarily driven by the homeland security and disaster response communities. Data includes the form, function, name, reference location, and selected contact on the included features. The national structures dataset and model are designed to meet the needs of the broad user community.

### Transportation

The transportation data theme consists of the geographic locations, interconnectedness, and characteristics of roads, railroads, airports, and other associated transportation features. The data represents a national data inventory of consistent, seamless, integrated data that is continuously improved.

## Geospatial One Stop

Last, the Geospatial One-Stop web site (www.geodata.gov) is the portal used to discover the availability of spatial data sets in the United States. Geospatial One-Stop is an E-Government initiative by the Federal Office of Management and Budget (OMB). The portal is designed to facilitate communication and sharing of geographic data and resources to enhance government efficiency and improve citizen services by making it easier, faster and less expensive for all levels of government and the public to access geospatial information.

## The Industry Challenges

The AEC industry is one of the most important markets in the world. Its members across all areas are responsible for generating close to $2.3 trillion, of which $1.2 trillion was spent in the U.S. alone in 2006-2007 (**US Annual Construction Spend**). This effort also drives many other industries and is often a gauge of the health of world economies. Tied to this age-old effort, there are several challenges facing the AEC industry that are outlined below. Those challenges are motivating the adoption of new technologies, such as building information modeling (BIM), 3D visualization, simulation and analysis, and model-driven design, including standards for interoperability (for example, LandXML.org, International Alliance for Interoperability (IAI), the BuildingSMART Alliance, and Open Geospatial Consortium (OGC) standards).

***Aging and Failing Infrastructure.*** Aging infrastructure is expected to be an increasing prominent issue in many parts of the world. Every two years the American Society of Civil Engineers (ASCE) prepares a Report Card for American Infrastructure (**2003-2005**). One of the sectors that the ACSE evaluates is roads, highways, and transit. In 2003 the ACSE awarded this sector a grade of D+ and in 2005 a grade of D, which translated means just barely passing. To place this in context, the ASCE estimates that traffic congestion costs the U.S. economy $67.5 billion annually in lost productivity and wasted fuel. Even more serious, the Federal Highway Administration (FHWA) reports that outdated and substandard road and bridge design, pavement conditions, and safety features are factors in 30% of all fatal highway accidents. In the U.S. on average, there are more than 43,000 fatalities every year. The ASCE also reports that motor vehicle crashes cost U.S. citizens $230 billion per year, or $819 for each resident for medical costs, lost productivity, travel delay, and workplace, insurance and legal costs. The ASCE estimates that an investment of $1.6 trillion over five years is required to bring the U.S. infrastructure to a good condition.

***Declining Productivity.*** The AEC industry is highly competitive. Firms must continually improve their productivity to remain competitive. This challenge of continual productivity improvement has reached crisis proportions in many parts of the world. Statistics published by the U.S. Bureau of Labor Statistics show that the productivity of the construction industry has actually declined in the last 40 years, while non-farm productivity has increased by over 200% during the same period. At a time where budgets are tight, and challenges are many, we are trying harder, but doing less in many respects. This has spurned a rethinking of how projects are done.

## Challenges of Information Sharing

The traditional lifecycle of the world's infrastructure involves planning, designing, construction, operations and maintenance, and decommissioning – and then the process starts all over again. Infrastructure includes buildings, highways and roads, and network infrastructure, such as telecommunications, power, water, wastewater, and gas networks. There are many different disciplines with discipline-specific software applications that are required to plan, design, build and finally maintain this network of infrastructure and buildings, when examining all the subcomponents and trades.

For example, in the case of a building, disciplines involved include land developers, surveyors, architects, civil and structural engineers, potentially environmental and geotechnical engineers, heating and ventilation specialists, plumbers, telephone companies and utilities, and road departments of local governments. Scalable to the size of the project, larger projects often involve many more professionals and software. The software applications used include architectural design, structural engineering, civil engineering, GIS, geospatial, and surveying applications. Traditionally each discipline has been isolated from the other and each has maintained its own island of technology or *silo* of design and engineering information and work product (Figure 1).

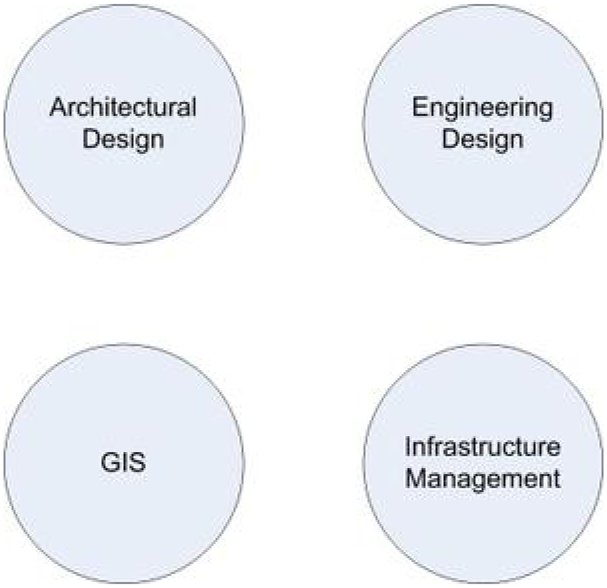

Figure 1. Traditional *silos* of expertise domains in infrastructure.

However, the lifecycle of infrastructure, whether we are talking about a building or highway network, is being compressed. In addition, organizations, especially owners and operators, are concerned about the costs of operating and maintaining these structures both above and below ground, which over the lifetime of the structure, could be 90% of the total cost as a rule of thumb. Coupled with the changes needed for new processes that are more environmentally friendly means – design in a silo and data or information that is not exchangeable is problematic.

Disciplines, such as architecture, structural engineering, construction, civil engineering, and GIS, are classic information silos, both by design in which projects are traditionally done, but also in the form and function of the database to support each group. Each maintains its own information comprised of design applications, standards and data, creating islands of information. This has created a nightmare for operations and maintenance, emergency planners and responders, urban planners, and others who require seamless access to urban terrain, including building interiors and exteriors, roads and highways, and above ground and underground utilities. The biggest challenge is not typically data, because the data that would help already exists because much of the data are created when buildings and infrastructure are designed. The biggest challenge is that islands of information and technology make it difficult to integrate existing data in a seamless view. For example, emergency responders responding to a terrorist threat, exploding gas main, a bridge collapse, or a building fire need immediate and seamless access to information about the building where an emergency is occurring, including the interior, surrounding buildings and access roads, telecommunications and utilities, aerial information, as well as underground information. At the present time they would need to be trained in many applications from a multitude of vendors to be able to access all of the different design and geospatial files that would help them deal with an emergency.

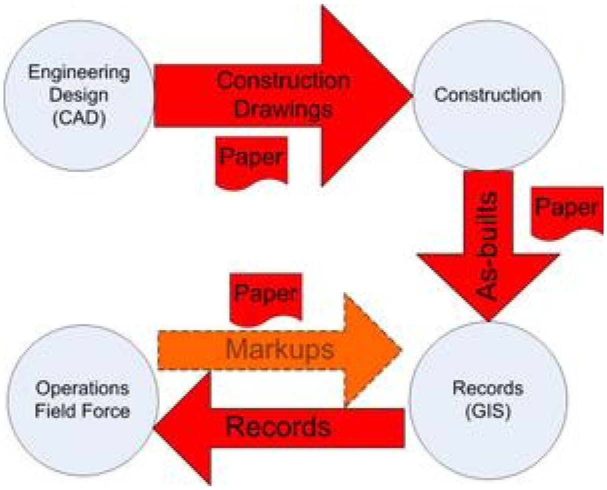

Figure 2. Utility and telecommunications management structure of infrastructure.

As a concrete example, all of the world’s utilities (water, sewer, power) and telecommunications firms manage infrastructure in essentially the same way and are facing similar challenges. In analyzing the information flow in these organizations, the most striking problem is islands of information. The engineering group uses CAD applications, construction uses large format paper, the records or network documentation group may use GIS tools, and operations uses paper or a handheld viewer (Figure 2). The information flow between these groups is more often than not paper. The result is a very inefficient process that is characterized by data redundancy, duplicate processes, and poor data quality.

Several years ago the National Institute of Standards and Technology (NIST) commissioned a study on **Interoperability** to attempt to quantify the efficiency losses in the U.S. capital facilities industry. These losses resulted from inadequate interoperability including design, engineering, facilities management, and business processes software systems, and redundant paper records management across the entire facility life-cycle. NIST estimated that in 2002 poor interoperability cost the U.S. capital facilities industry $15.8 billion. In addition, additional significant inefficiency and lost opportunity costs associated with interoperability problems were identified that were beyond the scope of the NIST analysis. This suggested to NIST that the $15.8 billion cost estimate developed in the study is likely to be a conservative figure. The NIST estimated that two-thirds of these costs are borne by owners and operators, predominantly during ongoing facility operations and maintenance. This has to change if we are to address the challenge of an exploding world population, the need to double the world’s entire infrastructure in the next 45 years or so, coupled with fixing the entire aging infrastructure we have today. The challenge will involve a redefining of the process and technology sharing among professionals.

## Future of Design and Collaboration – Removing Information Silos

Leveraging the concept of Project Alliancing developed in Australia, Integrated Practice or Integrated Project Delivery (IPD) is examining how relationships between the design professionals tasked with fixing or building our infrastructure of tomorrow works.

The goal is more focus on the design – with a mantra to mitigate issues, not litigate them. This requires more collaboration, not just coordination, early in the design process. This more open sharing of information using BIM and other databases allows for the visualization simulation and, more importantly, an analysis of a design, finding the mistakes in the office so they can be corrected before it ever reaches the construction site. This effort is aimed at more efficient and less error prone construction, while also allowing for better designs that are more sustainable to meet our future needs. But sharing of information process-wise means we must look at how the technology itself must change to accommodate this new way of collaborating between professionals. In a recent report from the University of Columbia Business School (need reference?), they state that mistrust between professionals (and in this context the concern about liability, hence the lack of sharing design models), doubles the cost of a project. At a time where we are looking for better efficiencies in infrastructure – this seems like an area ripe for change.

## References Cited

Wolf, P.R. and C.D. Ghilani, 2007. *Elementary Surveying: An Introduction to Geomatics*, Eleventh Edition, Pearson Prentice-Hall, Upper Saddle River, New Jersey, 916 p.