Geospatial Interoperability Return on Investment Study

National Aeronautics and Space Administration
Geospatial Interoperability Office

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Booz | Allen | Hamilton
90 years delivering results that endure

Contents

Executive Summary

NASA's science information has demonstrated uses by scientists, as well as broad cross-sections of decision-makers and citizens. The Geospatial Interoperability Office (GIO) is responsible for exercising leadership to see that this information is fully utilized. To accomplish the important work of increasing the access to and use of NASA's scientific information, the GIO sponsors the development of geospatial interoperability standards, system architectures, and data management strategies.

Geospatial Interoperability is the ability for two different software systems to interact with geospatial information. Interoperability between heterogeneous computer systems is essential to providing geospatial data, maps, cartographic and decision support services, and analytical functions. Geospatial interoperability is dependent on voluntary, consensus-based standards, as set forth in OMB Circular A-119. These *geospatial standards* are essential to advancing data access and collaborations in e-Government, natural hazards, weather and climate, exploration, and global earth observation.

One of the promises of geospatial information has been the possibility of reusing data and software code. The ability to use and reuse geographic data among different applications has been viewed as a way to lower the costs of data acquisition and enrich and extend the basis for performing geographic analysis. For this reason, geospatial interoperability has been viewed as an important objective in achieving the goal of reuse. For an agency like NASA, which collects terabytes of data daily, data interoperability is essential if the data are to have maximum utility. Standards, more specifically *geospatial interoperability standards*, are increasingly seen as a means to promote interoperability and thereby foster data and code reuse.

While much anecdotal evidence exists that geospatial information standards provide utility, little systematic analysis of the value of geospatial information standards has been conducted. The purpose of this study is to measure, both qualitatively and quantitatively, the return on investment (ROI) to organizations implementing geospatial standards, standards specifically developed to promote interoperability between a wide variety of different applications. This study uses cost-benefit methodologies to quantify the value of geospatial interoperability standards and to determine to whom the benefits accrue and when they accrue.

Summary of Key Findings

The following sections summarize the key findings from this study. Case Study 1 refers to a project using a high degree of open geospatial standards, and Case Study 2 describes a project using few open geospatial standards.

General

- Of the projects considered for this study, the project that adopted and implemented geospatial interoperability standards had a risk-adjusted ROI of 119.0%. This ROI is a "Savings to Investment" ratio. This can be interpreted as for every $1.00 spent on investment, $1.19 is saved on Operations and Maintenance costs.

- Overall, the project that adopted and implemented geospatial interoperability standards saved 26.2% compared to the project that relied upon a proprietary standard. One way to interpret this result is that for every $4.00 spent on projects based on proprietary platforms, the same value could be achieved with $3.00 if the project were based on open standards.

- Standards lower transaction costs for sharing geospatial data when semantic agreement can be reached between parties. The cost of achieving semantic agreement can be high, especially for data models. This cost is reflected in the higher implementation costs for Case Study 1. However, these costs are more than recouped in lower operations and maintenance (O&M) costs. In this study, risk-adjusted costs for Case Study 1 was 30.3% lower than those for Case Study 2.

- Standards lower transaction costs for sharing geospatial information when interfaces are standardized and can facilitate machine-to-machine exchange. Service-oriented architectures offer the promise that users who need to acquire data can search a catalog for data that meet their criteria using HTTP protocols that search service metadata. Case Study 1 again shows that standards-based projects have lower O&M costs than those relying exclusively on proprietary commercial off-the-shelf (COTS) products for data exchange.

- Case Study 2 had almost double the risk premium in Planning and Development costs. Moreover, Case Study 2 had a roughly 50% increase in risk in Acquisition and Implementation costs than did Case Study 1. Case Study 2 also had almost double the risk premium in M&O. Part of this increase in risk was due to the original cost structure developed by Case Study 2, where the majority of its costs (89%) were M&O costs. Because Case Study 2 had most of its costs in this category, and this category is exposed to the greatest risk over time, Case Study 2 had the largest increase in risk-adjusted M&O costs.

- The results indicate Case Study 2 Planning & Development costs increase 27.4% over the base year, Acquisition & Implementation increase 33.2%, and Maintenance & Operation (M&O) increases 59.6%. Most notable is the increase in M&O costs, which suggests that the use of proprietary models limits the flexibility and adaptability of the program over time. As M&O is the largest single contributor, this risk is the primary driver in the program's 56.6% total increase in cost. For Case Study 1, the total cost increase due to risk is only 24.6%, which is significantly lower than Case Study 2. More important to Case Study 1 is the fact that M&O costs are a lower percentage of total costs than in Case Study 2.

- Technical convergence is driving demand for interoperability and connectivity between an increasingly wide array of devices such as networked computers, cellular telephones, personal digital assistants (PDAs), global positioning system (GPS) receivers, Radio Frequency Identification (RFID) tags, and other sensors. The demand to synthesize and integrate these disparate data sources extends to geospatial information as well, raising the demand for geospatial interoperability. Geospatial interoperability specifications are necessary to show how to connect these information sources and to move value up the service chain from hardware to software to user applications.

- Geospatial standards clarify investment decisions by making the technology and the process of implementation understandable.[1] The Geospatial Interoperability Reference Model (GIRM) is a

[1] Martin Libicki, James Schneider, Dave R. Frelinger, and Anna Slomovic, *Scaffolding the New Web: Standards and Standards Policy for the Digital Economy*, MR-1215-OSTP (Santa Monica, CA: RAND Corporation, 2000), available at http://www.rand.org/publications/MR/MR1215/.

useful addition to the literature because it serves as a reference guide to the standards and how they fit together to address a broad range of data modeling and software interface issues.[2]

- Standards sometime fail to meet expectations. The failure of standards to be adopted is usually due to the long lead times for developing a complete schema or the daunting task of implementing complex specifications. While there are compelling reasons for striving to develop a standard that is complete and universal, industry frequently moves on rather than waiting for the complete standard. This evidence suggests that standards that begin small in scope and proceed incrementally have a much better chance of adoption. For example, Case Study 2 uses a profile of the FGDC Content Standard for Digital Geospatial Metadata (CSDGM), which requires users to submit metadata from only a few key sections of the entire specification. In this case, the project was successful in obtaining more and better metadata than would have been the case if they had required compliance with the full specification.
- Successful standards development and adoption rests on the ability of three key groups—government, industry, and the standards development community—to come together for a common good. This finding was consistent with both case study projects.

Project Objectives and Methodology

The value of geospatial standards can only be measured where standards have been implemented. To measure this value, NASA asked Booz Allen Hamilton (Booz Allen) to identify two programs, projects, or enterprises that have implemented differing levels of geospatial standards and to compare the costs, benefits, and risks associated with these two projects. The study team examined two government applications of geospatial technologies: one project utilizing a high degree of open geo-interoperable standards and another project implementing none or few of these standards.

The following seven tasks were outlined for this study based on the findings from the project comparison:

- **Task A:** Qualitatively and quantitatively demonstrate, through analysis, the ROI for federal, state, tribal, and local or industry who implement geospatial interoperable open standards solutions. Use the GIRM version 1.1 as the reference model. Assume an evaluation period or life cycle of 5 years.
- **Task B:** Discuss the likely ROI for industry who implement geospatial interoperable, open standards-based solutions in the market place. Use the GIRM version 1.1 as the reference model for related analysis and discussion.
- **Task C:** Discuss the likely cost benefits of access to geospatial data through non-proprietary, GI-open interface standards. Use the GIRM version 1.1 as the reference model for related analysis and discussion.
- **Task D:** Develop recommendations regarding geospatial interoperability that are balanced between the technological and budget realities by conducting a trade analysis of associated pros and cons.
- **Task E:** Provide estimates of cost benefits, life cycle costs, and other financial metrics for implementing geospatial interoperability. Assume an evaluation period or life cycle of 5 years.

[2] Geospatial Interoperability Reference Model, Version 1.1, December 2003, prepared by the FGDC Geospatial Applications and Interoperability (GAI) Working Group, edited by John D Evans, available at http://gai.fgdc.gov/girm/

- **Task F:** Provide lessons learned and findings as a result of conducting the GI ROI study.
- **Task G:** Conduct business case studies from the two selected examples above and discuss results and recommendations—that is, the economic and other related benefits (including technology) rational for the U.S. government and industry to implement geospatial interoperable open standards-based solutions. Discuss rationale to not implement geospatial interoperable open standards-based solutions, if applicable. Assume an evaluation period or life cycle of 5 years.

Booz Allen used the Value Measuring Methodology to examine these projects and to evaluate the relative impact of geospatial standards across five broad value factors:

- Direct user value (or customer)
- Social value (or non-direct, public)
- Government foundation/operational value
- Government financial value
- Strategic/political value

Booz Allen also worked with a broad section of the geospatial community to develop an evaluation framework to independently measure the two "target" projects. Using this evaluation framework, the two projects of similar size and composition were compared. The costs and other project information were consolidated, and scores were calculated for each of the projects based on this framework.

Project Scope

This study focuses only on those standards and specifications with a specific geospatial focus. These standards and specifications include the abstract standards developed under the auspices of the International Organization for Standards (ISO) Technical Committee 211 (ISO/TC211), in particular the ISO 19100-series standards, the specifications developed by members of the Open Geospatial Consortium (OGC), and the standards sponsored by the U.S. Federal Geographic Data Committee (FGDC).

Many of the geospatial standards and specifications that are the subject of this study reference or have other strong links to the more generic, broad-based information specifications developed under the auspices of the Organization for the Advancement of Structured Information Standards (OASIS) and the World Wide Web Consortium (W3C). These organizations also have formal agreements to coordinate and work together with OGC, ISO, and FGDC to insure that all specifications are harmonized and foster complete interoperability between applications. But because geospatial interoperability is not a central focus of OASIS and W3C, those specifications are not considered in this study.

This study also uses the Geospatial Interoperability Reference Model (GIRM) version 1.1 as a reference model. The GIRM is a formal framework that compiles the above standards and specifications into a unified, comprehensive technical "stack." It serves as a guidebook, making geospatial standards and specifications both accessible and intelligible to many users.

Standards Development

- Since 1990, voluntary, consensus-based standards, or more accurately *specifications,* are increasingly being developed by industry *consortia*. These consortia are *standards-setting organizations* (SSO), in contrast to *standards development organizations* (SDO), which are *accredited* and represent national interests in the development of international standards. Because consortia largely consist of industry representatives (but also include nonprofit, academic, and government representatives), they are viewed by many stakeholders as being more sensitive to market pressures than are traditional SDOs. Both types of organizations conform to the criteria in OMB Circular A-119 for voluntary, consensus based standards, specifically the following:

– Openness

– Balance of interest

– Due process

– An appeals process

– Consensus

Case Study 1 has partnered and shared costs with many smaller companies, and working through the OGC, has spurred the development and implementation of many of the specifications.

- The OGC was founded in 1994 to address issues of interoperability among rapidly growing GIS and image processing software platforms. The OGC "aimed to create a process that might (1) make more commercial as well as non-commercial geoprocessing choices available in the marketplace, (2) act as a sounding board for the user community to articulate its requirements to the developer community, and (3) speed up procurement by aligning the needs of the users with the product plans of the vendors."[3] The OGC has emerged as the leading voice for geospatial interoperability and has many liaisons with other key industry consortia such as Organization for the Advancement of Structured Information Standards (OASIS) and World Wide Web Consortium (W3C), as well as ISO/TC211 and the International Committee on Information Technology Standards (INCITS L1).

- For at least five years, Case Study 1 has been a leading contributor to the development of OGC specifications. This study suggests that participation in standards activities is a long-term investment that pays measurable dividends for government programs, industry partners, and the public.

- SDOs and SSOs need to implement policies on the disclosure of proprietary interests during the standards setting process. Recent high profile cases such as *Dell*, 121 F.T.C. 616 (1996) and *Rambus* vs. *Infineon,* illustrate the tension between industry collaboration and the intense competition to acquire monopoly or near-monopoly rights to certain key technologies. For this reason, OGC maintains a policy requiring participants to disclose any proprietary interest in a specification prior to voting on actions of the Technical Committee.

Government Actions and Policies

- Case Study 1 has worked extensively with the OGC to develop specifications and has partnered with many businesses to share the costs of developing the software and specifications, thereby boosting the geospatial segment of industry. This boost has had positive effects for those government agencies that implement the standards and software.

[3] Open Geospatial Consortium Web site, available at http://www.opengeospatial.org.

- Case Study I has shared costs with industry partners to effectively develop and implement geospatial standards and specifications. This cost sharing has led to positive network effects for cooperating industry because the standards have increased in importance.
- Profiles are an effective way to extend and tailor standards for more individual use. Both case study projects have made effective use of profiling, which in turn has increased the use of standards.
- The growing "arms race" in software patents may be harming the standards setting process, which in turn may be stifling innovation in information technology in the U.S.
- Several pieces of legislation have had a significant influence on standards development by defining the scope of collaboration among private industry. This legislation includes the National Cooperative Research and Production Act of 1984 (NCRPA), the National Technology Transfer and Advancement Act of 1995 (NTTAA), and the Standards Development Organization Advancement Act of 2004 (SDOAA).
- OMB Circular A-119 was revised in 1998 to conform with directives in the NTTAA. This circular directs federal agencies to use voluntary consensus-based standards in place of government-unique standards. As a result, responsibility for maintaining many Federal Information Processing Standards (FIPS) (e.g., United States Geological Survey Circular 878-A, FIPS 6, FIPS 70-10, and FIPS 173-1) is in the process of being taken up by the ANSI-accredited INCITS L1. INCITS L1 is charged with handling standards development for geographic information technologies and is the U.S. Technical Advisor to ISO Technical Committee 211 (ISO/TC211). INCITS L1 consists of representatives from industry, government, academia, and other geospatial industry trade groups.
- The SDOAA of 2004 protects SDOs from antitrust liability, but it does not extend protection to individuals and groups participating in the process.

Industry and Markets for Geospatial Technology

- Increasing integration into the global economy is driving support for standards. Governments outside of the United States frequently adopt a less *laissez-faire* stance toward standards and often stipulate that products must conform to ISO standards. These requirements for standards-compliant software products spur the support for standards by U.S.-based software vendors, data suppliers, and supporting technology vendors. Noncompliance costs the national economy in the form of technical barriers to trade (TBT). In 1998, TBT cost all U.S.-based industry between $20 billion and $40 billion annually.[4]
- Because the protections offered by the SDOAA does not extend antitrust protection to individuals participating in the process, participants need to determine how the legislation affects current and future behaviors in standards setting.
- Because standards aid in the diffusion of technology, demand for related services tends to increase as the technology penetrates market segments and produce network effects. Industry can be an effective contributor to standards development when different parties collaborate to advance pieces of the technology, minimizing risk to all participants.

[4] Richard E. Hebner, "Standards and Trade – Who Really Cares?," speech given at Fall 1998 Public Lecture Series: Technology Standards and Standardization Processes, Stanford University U.S.-Japan Technology Management Center.

Risks To Effective Standards Implementation

There are several major barriers to the successful implementation of open geospatial standards, including those related to stakeholder resistance, industry resistance, and government policy.

Stakeholder Resistance

- The users of geospatial technologies and information, both public and private, may be hesitant to adopt standards that appear at first to compromise business processes.
- The community may perceive that the upfront costs exceed the long-term return. The data provider for Case Study 2 has resisted efforts to provide more than the minimal data sets and metadata documentation it currently furnishes.
- Geospatial standards may not be perceived as applicable for the typical geospatial application (i.e., applications may be standalone within an organization and not networked, or standards may be perceived as not meeting business needs, not supporting required business processes).
- The practice of profiling, that is, extending, tailoring, or constraining a standard, is poorly understood in many areas of the geospatial community. These potential adopters reject standards, especially data content standards developed under federal auspices, because they do not perceive them as meeting their business needs.
- In spite of the poor understanding of profiling, there is a general recognition that standards are among the most economical ways to achieve a measure of data interoperability. However, most agencies are likely to adopt or develop a local standard rather than a national or international standard.
- Portions of the geospatial community feel "shut out" from the standards development process or cannot afford to dedicate the resources necessary to contribute to standards development. Both case study projects acknowledge the difficulty of getting a broad group of participants for the time required to develop specifications.
- Administrators sometimes take a parochial attitude, defining their business needs in the narrowest sense so their application domain extends only to the borders of their jurisdiction. Standards, they claim, are of no use to them, because their operations are self-contained. This attitude contributes to a "balkanization" of the community.

Industry Resistance

- The geospatial technology sector is reluctant to contribute to standards development when SDOs do not set clear policy related to intellectual property rights. This situation leads to the "prisoner's dilemma" outcomes in which suboptimal specifications are adopted or the standards process is hindered.
- Support for standards may be undermined by proprietary technologies and methods.
- Industry will be reluctant to contribute if it sees no tangible returns from standards setting, a drain on its intellectual capital, or both. The time horizon for realizing positive network effects may be longer than it is willing to wait for returns.

- Unlike companies that do significant business overseas where standards compliance is more frequently mandated by government, geospatial technology vendors that serve only the domestic market may feel little or no pressure (from market or government) to support geospatial standards.

Government Policy

- Policy failures can occur when government either tries to dictate the standard or when government does not act as enabler or sponsor or fails to give a legitimate role to industry and other stakeholders. Government antitrust legislation can affect how (and if) industry participates in standards development. Both case study projects acknowledge the role government has to play in maintaining equal protection and due process.
- The increasing use of software patents in an increasingly deregulatory environment threatens to stifle innovation by removing open, collaborative methods and procedures from free, public use.

Recommendations and Next Steps for NASA

NASA's role with regard to geospatial technologies is deep and extensive, contributing to the development of publicly available geospatial interoperability standards, geospatial data products, and their integration in to the applications of NASA's many partner agencies. Table 1 shows 12 applications of national significance where NASA plays a key role in supplying data to a federal partner and supporting important decision support systems.

Table 1. NASA-supported National Applications

National Application	Partner Organizations	Decision-Support Systems
Agricultural Efficiency	USDA, NOAA	CADRE – Crop Assessment Data Retrieval and Evaluation (USDA)
Air Quality	EPA, NOAA, USDA	CMAQ – Community Multiscale Air Quality Modeling System AIRNow AQI – Air Quality Index
Aviation	DOT/FAA, NOAA	NAS-AWRP – National Air Space-Aviation Weather Research Program
Carbon Management	USDA, DOE, NOAA	CQUEST – Support to the Energy Act of 1992, Section 1605b
Coastal Management	NOAA, EPA, NRL	HAB – Harmful Algal Bloom Bulletin/Mapping System CREWS – Coral Reef Early Warning System
Disaster Management	DHS/FEMA, NOAA, USGS, SFS	AWIPS – Advanced Weather Interactive Processing System HAZUS-MH – Hazards U.S. – Multi-Hazards
Ecological Forecasting	USAID, NOAA, NPS, CCAD, USGS	SERVIR – Regional Visualization and Monitoring System
Energy Management	DOE, UNEP, NOAA, NRC	RETScreen – Energy Diversification Research Laboratory (CEDRL) NEMS – National Energy Modeling System
Homeland Security	DHS, USGS, NOAA, NGA, DOD	IOF – Integrated Operations Facility IMAAC – Interagency Modeling and Atmospheric Assessment Center

National Application	Partner Organizations	Decision-Support Systems
Invasive Species	USGS, USDA, NOAA	ISFS – Invasive Species Forecasting System
Public Health	NIH, CDC, DOD, EPA	PSS – Plague Surveillance System EPHTN – Environmental Public Health Tracking Network MMS – Malaris Monitoring and Surveillance RSVP – Rapid Syndrome Validation Project
Water Management	EPA, USDA, USGS, BoR	RiverWARE – Bureau of Reclamation decision-support Tool AWARDS – Agricultural Water Resources and decision-support Tool BASINS – Better Assessment Science Integrating Point and Nonpoint Source

NASA's also makes available rich sources of earth imagery to the public. Good examples of this include the WMS Global Mosaic at http://wms.jpl.nasa.gov/), the Distributed Active Archive Centers at http://nasadaacs.eos.nasa.gov) which distributes earth science information, and MODISWeb at http://modis.gsfc.nasa.gov that provide imagery that enhance our understanding of activities on the earth's surface. NASA also sponsors the Global Change Master Directory at http://gcmd.gsfc.nasa.gov/, which allows users to search for data in 13 topic areas.

Recently, NASA professionals have served in key positions for the Geospatial One-Stop program, provided leadership to the FGDC's Geospatial Applications Interoperability Working Group, and contributed technical expertise to the development of key specifications in the OGC. Based on Booz Allen's analysis of the standards landscape, NASA's contributions and leadership have had important effects that support both a growing geospatial services industry and resilient government agencies. This industry provides tools to make NASA's large data stores available to a wide array of government agencies and private users.

The GIRM is another example of NASA's technical leadership, which has practical applications that benefit the direct user. As a useful reference, the GIRM makes the arcane specifications intelligible by contextualizing them and making them accessible to a wider group of users. Users can refer to the GIRM to determine which specifications and standards they need to use and how they relate and connect to other pieces of the interoperability stack. Therefore, it is useful to think of the GIRM as a meta-model, or a guide to the geospatial interoperability specifications. This concept has benefits for management as well by clarifying the arguments for certain technical approaches. NASA should continue to revise and update the GIRM regularly to ensure that it stays in step with the developments in geospatial standards and specifications. The scope of the GIRM should be expanded to reach a wider constituency, such as tribal, state, and local users and managers of geospatial information.

Booz Allen therefore recommends that NASA continue to act as an enabler and sponsor of standards. The development of specifications, especially imagery specifications, remains an area where NASA lends considerable technical expertise. These specifications help NASA expose its data in an understandable format to multiple users and help develop new markets for data.

NASA, but more broadly, the government and SDOs and SSOs, should take active measures to increase the rate of participation by a greater cross-section of geospatial agencies, particularly at a sub-federal level. Many local, state, and regional governments have moved to develop their own standards that deal mostly with the content or exchange of digital geospatial data. Without representation by these groups, these important building blocks are overlooked, weakening the standards development process and undermining support for the final standards. SDOs and SSOs should increase efforts to educate the community of potential adopters about the practice of creating standards profiles. Increased awareness of and use of profiles could speed adoption and uptake of standards, leading to increased participation in activities such as building the National Spatial Data Infrastructure (NSDI).

1. Introduction

This section describes the current geospatial environment, examines the significant of geospatial interoperability, and discusses the potential impact of geospatial interoperability.

1.1 Current Environment and Background

Over the last ten years, geographic information has been incorporated into numerous applications in government and private sector agencies alike. The technologies have matured allowing geospatial information to routinely be embedded in the business processes and workflows of agencies at all levels of government, as well as in segments of the private sector. This maturity has been accompanied by a growing need for different systems to communicate, or interoperate, with each other. One imperative driving the requirement for systems interoperability is the need to save money and resources by reusing geospatial data. However, the data and software interfaces employed by respective systems are often dissimilar and incompatible. Moreover, different systems often have unique software and hardware platforms. In such an environment, geospatial interoperability standards and specifications for data formats and application interfaces are touted as a way to overcome the obstacles to system interoperability. These standards provide users, managers, and operators with direction related to data format and application interoperability to bridge the semantic and syntactical differences posed by a heterogeneous computing environment. This study examines the value of those standards in promoting geospatial interoperability.

1.2 Significance of Geospatial Interoperability

At any given time, our world has a number of problems and challenges that do not respect jurisdictional lines. Examples include invasive species, influenza epidemics, and national security threats. To effectively treat and solve these problems, geospatial applications need sufficient amounts of data at similar scales, accuracies, and currency to provide policymakers with usable analyses for formulating a responses to these problems. Numerous federal state, local, and tribal agencies, as well as private enterprises and nonprofit agencies, are engaged in collecting and maintaining accurate geospatial data. In addition, a growing number of commercial vendors are selling an increasingly rich variety of spatial data to address various needs. Examples include vendors who develop the street centerline databases used in car navigation systems and in Internet-based map services such as MapQuest and Google Maps. These data are being delivered to a growing array of devices, including personal digital assistants (PDAs) and cellular telephones. For these services to deliver consistent functionality across a wide ranges of devices and operating systems, it is necessary that they all communicate, or interoperate, with each other. By building applications with open specifications and formatting data to comply with a certain standard content and structure, the community can facilitate interoperability.

1.3 Potential Impact of Geospatial Interoperability

The impact of geospatial interoperability standards is potentially as large as the problems that geospatial data describes (e.g., climate change, AIDS, SARS, and avian flu). NASA, for example, recently partnered with the State of Kentucky to make available via the Internet satellite and digital airborne imagery, land cover, and land use to citizens and governments in Kentucky. This project offers new tools to solve problems that transcend jurisdictions, and it uses the Internet to foster interoperability between numerous computing platforms. The State is making the imagery available through a OGC-compliant Web Map Server (WMS) interface, allowing local government users to gain access with just a web browser.

The ability of different systems to interoperate means that people and agencies can recombine disparate information (such as NASA land cover imagery) and apply it in new, unforeseen ways to any number of problems. It means that federal agencies can incorporate highly accurate local data in their inventories and analyses, increasing the accuracy and currency of analyses of national significance. For public health or national security issues, this interoperability could translate in to lives saved. It might mean that states can use high-accuracy local data sources to manage state-owned properties and other assets. This use of local data sources could translate to significant savings in taxpayer dollars. Therefore, the impact of geospatial interoperability to government and society could be substantial.

The impact to industry could be nearly as substantial. The growing trend in organizations to embed geospatial information in routine business functions is accelerating as they recognize that geographic information is a key piece of business intelligence and information infrastructure. For example, geographic information is quickly becoming integrated into customer relationship management (CRM), business performance management (BPM), sales force automation (SFA), and so forth. As U.S. geospatial technology vendors enter new markets abroad, they are finding requirements to support local and international standards, which is driving increased support for these standards in their products.

2. Terms and Acronyms Used in This Study

The following geospatial-related terms and acronyms are used in this study.

De facto Latin for "in actual fact." Something that is in reality, actual and existing regardless of legal status. For this study, "de facto" refers to standards that have been established by convention, outside of the accredited standards development process.

De jure Latin for "by right." Contrasted to "de facto," it refers to standards that are created by a formal standards body rather than being simply used in practice.

GI-open Geospatial interoperable open

GI-open standards Voluntary, consensus-based standards developed collaboratively to support geospatial interoperability

Interoperability The ability of information systems to operate in conjunction with each other, encompassing communication protocols, hardware software, application, and data compatibility layers.[5]

Middleware Software that facilitates interoperability by mediating between an application program and a network, thus masking differences or incompatibilities in network transport protocols, hardware architecture, operating systems, database systems, and remote procedure calls. An example of middleware is the Object Request Broker (ORB), software that manages communication between objects.[6]

Open Source Computer programs or operating systems for which the source code is publicly available are referred to as open source software. Inherent in the open source philosophy is the freedom of a distributed community of developers to modify and improve the code. Perhaps the most widely known example of open source software is the Linux operating system.[7]

Open source software is characterized by the following:

- Free redistribution of software
- Source code distribution
- Derived works and modifications
- Integrity of author's code
- Non-discriminatory distribution
- Non-discriminatory toward fields of endeavor
- Distribution of license
- License not specific to a product

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[5] Interoperability Clearinghouse Glossary of Terms, available at http://www.ichnet.org/glossary.htm.
[6] University of Illinois AITS Glossary, available at http://www.aits.uillinois.edu/live/Site.xml?document=Glossary.xml&focus=N16.
[7] Informational and Educational Technology: Glossary, available at http://iet.ucdavis.edu/glossary/.

- License does not contaminate other software.[8]

Open Systems Those systems that can be supplied by hardware components from multiple vendors and whose software can be operated from different platforms. Open systems are considered the opposite to closed or proprietary systems.[9]

or

As defined by the IEEE POSIX 1003.0 Committee, a system that implements sufficient open specifications for interfaces, services, and supporting formats to enable properly engineered application software to be ported across a wide range of systems with minimal changes to interoperate with other applications on local and remote systems and to interact with users in a style that facilitates user portability.[10]

Profile A standards profile is a technique of referencing (in contrast to defining) technical specifications (e.g., standards and specifications). A standards profile permits the creation of a bundle of standards, each one tailored, extended, or constrained to meet the needs of the committee developing a standards profile.[11]

SDO Standards development organization (e.g., International Organization for Standards [ISO] and American National Standards Institute [ANSI]) meeting the criteria for open, voluntary consensus-based standards found in OMB Circular A-119

SSO Standards setting organization (e.g., Open Geospatial Consortium [OGC]) meeting the criteria for open, voluntary consensus-based standards found in OMB Circular A-119

Standard A set of criteria (some of which may be mandatory), voluntary guidelines, and best practices. Examples include application development, project management, vendor management, production operation, user support, asset management, technology evaluation, architecture governance, configuration management, and problem resolution [Federal Enterprise Architecture Framework].[12]

Specification A clear and accurate description of the technical requirements for materials, products, or services, which specifies the minimum requirements for quality, construction of materials, and equipment necessary for an acceptable product. In general, specifications are in the form of written descriptions, drawings, prints, commercial designations industry standards, or other descriptive references.[13]

Z39.50 Search Protocol The ANSI/NISO Z39.50 search protocol is a computer-to-computer communications protocol designed to support the searching and retrieval of information, full-text documents, bibliographic data, images, and multimedia in a

[8] Chris DiBona, Sam Ockman, Mark Stone, eds., *Open Sources: Voices from the Open Source Revolution* (Sebastopol, CA: O'Reilly & Associates, January 1999).
[9] BBDSoft Automation and Real-time Computing Terms, available at http://www.bbdsoft.com/glossary.html.
[10] Israel Ministry of Finance, Information Systems, Glossary of Terms, available at http://www.mof.gov.il/micun/gloss1.htm
[11] See ISO/IEC JTC1 SC36 N0312.
[12] Interoperability Clearinghouse Glossary of Terms, available at http://www.ichnet.org/glossary.htm.
[13] SGIA's Glossary of Terms, available at http://www.sgia.org/glossary/Ss.cfm.

distributed network environment.

3. Project Description

This section describes the geospatial interoperability standards return on investment study, including its objectives, stakeholder groups, hypotheses, assumptions, and key considerations, risks, and costs.

3.1 Objectives

To measure the value of geospatial standards, this study compared projects that have taken different approaches to implementing geospatial standards. In this study, two programs, projects, or enterprises were identified, each with differing levels of geospatial standards implementation. For both projects, costs, benefits, and the associated risks were compared. One project used GI-open interoperable standards and specifications to develop its entire system architecture and shared costs with private industry to develop key applications. The other project relied on proprietary, commercial off-the-shelf (COTS) products to meet its needs and implemented only those standards needed to support critical business processes. Both projects are government projects that operate at the federal level. The study team conducted numerous interviews with staff from both project teams and compiled cost estimates based on information furnished by representatives from both "target" projects.

The study team used the Value Measuring Methodology (VMM) to examine these projects and evaluate the relative impact standards have had across five broad value factors. The Value Measuring Methodology is recognized as a federal CIO Council Best Practice and is particularly well suited to evaluating the costs and benefits of government programs because it quantifies costs and benefits that accrue outside a strict financial domain. This quantification becomes apparent when considering the five value factors:

- Direct user (or customer) value
- Social (or non-direct, public) value
- Government foundation/operational value
- Government financial value
- Strategic/political value

To complete this study, the study team worked with a broad section of the geospatial community to develop an evaluation framework for independently measuring these two projects. The framework was developed in a one-day Expert Choice session in which participants ranked pairs of measures and metrics and arrived at a rank order of importance for each of the factors. (Please refer to Section 4 for a thorough description of the Value Measuring Methodology.)

Each of the two projects were compared in an alternatives analysis. In this study, the two projects serve as alternatives to each other. In addition, cost information was consolidated and scores were calculated for each project based on the evaluation framework.

3.2 Stakeholder Groups

Geospatial standards and specifications have four main groups of stakeholders. These groups can be broadly defined as:

- Government
- Industry
- SDOs/SSOs

- Public, or society

Government stakeholders include federal, state, local, tribal, and regional entities, as well as other organizations, including academic and nonprofit organizations and consortia. (Note that government is both a data user as well as a data producer and hence, often adopts behaviors associated with commercial enterprises.) Government may create and edit geospatial data on a transactional basis as in creating property records, developing a representation of the transportation network, or tracing planimetric features off of a digital image. Government may also import and use geospatial data for analysis or decision support.

Industry stakeholders include commercial geospatial software providers and other commercial companies offering products that create, edit, analyze, manipulate, or store geospatial data. These stakeholders includes commercial companies that sell geographic enabling technologies (e.g., global positioning systems [GPS] and location-based services). Geospatial data providers are part of the industry segment, which includes commercial imagery providers, value-added vendors (e.g., weather, terrain and elevation, and street centerline), and data conversion services.

Principal SDO and SSO stakeholders include the ISO Technical Committee 211 (ISO/TC211), the International Committee on Information Technology Standards (INCITS L1), the Open Geospatial Consortium (OGC), and the U.S. Federal Geographic Data Committee (FGDC). These groups are primarily responsible for developing geospatial standards and specifications, and their members are drawn from the community of geospatial professionals as well as universities and other academic and research institutions.

Public stakeholders include everyone who uses or benefits from the results of geospatial analysis, including non-direct users in federal, state, and local governments, the U.S. military, as well as the public at large. Public stakeholders also include businesses and individuals whose decision-making may be supported by spatial information. Note that the public is regarded as an indirect stakeholder; only the government, industry, and SDOs are active participants in the standards development process.

3.3 Hypotheses and Assumptions

To conduct this analysis, the study team started from certain assumptions and developed testable hypotheses about standards and their application. Currently, in the world of GIS and geospatial technologies, the software solutions for delivering geospatial information can be loosely characterized along a rough continuum as follows:

- Proprietary software/not GI standards-compliant
- Proprietary software/OGC-specifications and/or ISO-standards compliant
- Open source software/not GI standards-compliant
- Open source software/OGC specifications and/or ISO-standards compliant

For organizations and individuals to meet the challenges described earlier, a desirable end state is a homogeneous interoperable solution for all end users because it would greatly lower the costs of sharing geospatial information, developing shared services, and improved models for decision support systems (DSS's). Therefore, a starting assumption of this study is the following: that interoperability between different installations of geospatial technologies is generally a good thing.
This assumption led to the following hypotheses, also considered in this study:

- Geospatial data, services, and models can be applied more broadly than is currently the practice.

- Interoperability between decision support systems, geospatial portals, and geospatial systems is the most effective manner in which geospatial information can be shared most broadly.
- Implementing voluntary, consensus-based, geospatial interoperability standards is the most efficient and cost effective way to achieve broad sharing of geospatial data.

A number of assumptions about the case study projects accompany these hypotheses. These assumptions are based on current industry trends and organizational practices in widespread use at the time of this study, as well as best practices for studies of this type. The assumptions most critical to this analysis include the following:

- **Distribution:** It is assumed that the projects selected for this study are distributed using the Internet or an intranet—that is, the method for delivering application is distributed through TCP/IP (or a similar) networking protocol.

- **Comparable Scales:** To control for effects that may be causes by processes other than geospatial interoperability standards, the projects chosen for this study were selected to be as comparable as possible. Choosing comparable projects yields results that can be broadly applied while minimizing other biases. Factors that determined comparability were the size of the project budget, the scope and reach of the project, and whether the project had multi-agency support.

- **Taxonomy of Standards:** It is important to understand the landscape of standards and how geospatial standards are classified. There are three main types of standards: 1) *de facto* standards, 2) *de jure,* or voluntary consensus standards, and 3) mandatory standards, such as health and safety or other regulatory standards.[14] *De facto* standards are those that emerge in the marketplace of convention, rather than the accredited standards development process, and are usually proprietary. In contrast, the geospatial standards central to this study are *de jure* standards, and meet the criteria for open, voluntary consensus standards set forth in OMB Circular A-119. In the U.S., the National Technology Transfer and Advancement Act of 1995 (NTTAA) mandates the use of these standards by federal agencies, where applicable and advisable. (For a complete discussion on the taxonomy of standards, see Appendix A.)

- **Meaning of "Open":** There has been a great deal of discussion in recent years about "openness," as in the need for "open" systems, standards, specifications, open data formats, and open source software. In each of these examples, the meaning of "open" is both unclear and imprecise. Regarding standards development, "open" means standards that are developed in an open, consensual process where all stakeholders have been invited into the process.[15]

  The American National Standards Institute (ANSI) process adds additional requirements for openness, requiring consensus or agreement among stakeholders and due process in the form of a ballot and appeals process.[16] Furthermore, it requires parties that hold intellectual property rights (IPR) to identify themselves and any proprietary interest during the process of standards development.

  In the context of the OGC, specifications "open" means that standards and specifications:

[14] Thomas Hemphill and Nicholas Vonortas, "U.S. Antitrust Policy, Interface Compatibility Standards, and Information Technology" (Washington, D.C.: The Center for International Science and Technology Policy, September 2003), available from http://www2.gwu.edu/~cistp/PAGES/antitrust.pdf.

[15] Pamela Caplan, *Patents and Open Standards* (Bethesda, MD: National Information Standards Organization, 2003).

[16] Ibid.

- Are created and maintained in an open, collaborative process
- Are freely distributed and publicly available
- Are non-discriminatory and non-proprietary
- Are vendor and technology neutral [OGC].

It is useful to point out that "open source" is not necessarily synonymous with "open standards." However, some similarities exist between "open source" and the OGC specifications. The concept of open source generally means access to the source code, but it also extends the traditional notion of property rights to include specific distribution rights. Software could be "open source" (e.g., Linux), but not implement or support "open standards" (particularly open GI standards). Software can also be proprietary and still support and implement GI-open standards. Furthermore, certain open source licensing schemes allow for the development and distribution of open source proprietary software.

3.4 Key Considerations

In the conduct of this study, the study team uncovered several factors that affect the adoption and implementation of standards. In this study, these factors are often found where the need for interoperability intersects with other critical business needs, such as meeting the mandates of the organizational mission. These key considerations include the following:

- **Maturity of Standards:** Some standards are more mature than others and are therefore further along in their development. Some standards have matured from their initial development as abstract standards first to implementation test beds and then to refined operational specifications. Other standards have not yet completed the first round of consensus development, or they need to be harmonized with other standards to avoid conflicts during implementation. In this way, the utility of standards is directly proportional to their maturity and refinement.

- **"Hybrid" Projects:** Very few projects are 100 percent proprietary or 100 percent standards-compliant. Rather, most projects lie along a continuum between proprietary and standards-compliant. Because of business and organizational imperatives to "get the job done," most projects mix proprietary products and data models with standards-compliant models and interfaces. The project chosen for this study represent two different levels of implementation, although they do not represent one extreme or the other.

- **Program Maturity:** The date when the project case studies were established may have an effect on the level of standards adoption. Programs that need to show quick results may be less concerned with adopting *de jure* standards than with having something to demonstrate for their efforts (and budgets). These programs often opt for proprietary solutions, which may include *de facto* geospatial standards, and are bundled as complete packages, rather than niche solutions.

- **Use of Third Party Middleware:** Third party middleware is often seen as an alternative to pure proprietary or standards-based solutions. However, third party middleware still does not free users from having to manually configure the mappings between local and standardized data schemas.

These considerations stem from the study team's observations of two widely varying levels of implementation designed to meet different business needs. The imperatives of each organizational mission also drive how and when organizations adopt standards—and to what degree. These considerations indicate that both project case studies use different techniques as proxies for standards to meet business rules and engage in interoperability. One project case study relied on proprietary market-based *de facto* standards, and the other project case study developed from government-sponsored, collaboratively developed open standards.

3.5 Key Risks

The risks uncovered in this study help illustrate the perception of standards in the geospatial community. Some of these perceptions are due to the immaturity of some of the standards. For example the Geospatial One-Stop standards for geospatial information, which at this writing are in the first round of public comment adjudication and when submitted for ballot will exist only as abstract standards. Some of the risks can also be attributed to a lack of awareness of the standards setting process and its practice, which has very specific protocols not well known outside of the standard setting community. And lastly, as the Internet matures and alters the price of information, these risks show that there is a tension between tradition notions of intellectual property ownership and the uncertainty surrounding the future information economy.

The following risks were considered applicable to this study:

- **Lack of Industry Support:** The geospatial segment of industry, including COTS vendors and geospatial data providers, may be slow to offer support for voluntary, consensus-based standards if they feel there is a better chance of achieving similar goals and outcomes through a proprietary solution. This view is reinforced by the conventional thinking that industry can develop and bring a proprietary solution to market more quickly and better than the slower, consensus-based approach to development. There is also a well-established belief among some within the geospatial industry that "standards sell in volume"—in other words, that in order to effectively set a *de facto* standard, a company needs only to establish market dominance.

- **Internal Cultural Resistance:** Internal cultures exist within any large organization. These cultures may resist the adoption of standards imposed by an external agency or policy either because the standards do not meet their business needs or the cost of compliance and conformity is too great. There is a common perception that the agency that retools to support a standard will bear the total cost and reap none of the reward. In reality, these organizations, usually government agencies, are addressing a shortcoming where markets have failed to provide these goods.

- **Lack of Management Support:** Proper management needs to be in place to ensure the success of any standards implementation. Without proper guidance, few organizations will be willing to change from their status quo or realize the benefits of standardization.

- **Lack of Understanding of Standards Development:** Many users and agencies in the geospatial community agree, at least in concept, that standards are important or at least necessary. However, their level of awareness of standards development organizations, their understanding of the standards setting process, and their understanding of how to plan for and implement standards is low. Consequently, participation by local, state, tribal and other sub-federal organizations in national standards activities is also low.

3.6 Key Costs

Table 2 illustrates the key cost drivers for any IT investment. For this study, costs were captured at the 1.0 level only (see Appendix B). This limitation was a requirement for both of our project case studies, as both organizations have been disguised for confidentiality purposes. While this limits the granularity of the analysis, it does not constrain the risk-adjustment analysis.

Table 2. Cost Element Structure

1.0 System Planning & Development
- 1.1 Hardware
- 1.2 Software
- 1.3 Development Support
- 1.4 Studies
  - 1.4.1 Security
  - 1.4.2 Accessibility (508 Strategy)
  - 1.4.3 Data Architecture
  - 1.4.4 Network Architecture
- 1.5 Other
  - 1.5.1 Facilities
  - 1.5.2 Travel

2.0 System Acquisition & Implementation
- 2.1 Procurement
  - 2.1.1 Hardware
  - 2.1.2 COTS Software
  - 2.1.3 Customized Software
- 2.2 Personnel
- 2.3 Training

3.0 System Maintenance & Operation
- 3.1 Hardware
  - 3.1.1 Maintenance
  - 3.1.2 Upgrades
  - 3.1.3 Life cycle Replacement
- 3.2 Software
  - 3.2.1 Maintenance
  - 3.2.2 Upgrades
  - 3.2.3 License Fees
- 3.3 O&M support
  - 3.3.1 Program Management Oversight
  - 3.3.2 Operations
  - 3.3.3 Security
  - 3.3.4 Helpdesk
- 3.4 Recurring Training
- 3.5 Other O&M

These costs represent the investment both organizations required to design, implement, operate, and maintain their projects.

The key cost differences between the two project case studies reveal the different management and design philosophies of the two organizations. Case Study 1 devoted additional resources to designing an application that would require lower operations and maintenance (O&M). In fact, Case Study 1 will have spent 74% of its total budget on implementation costs and only 20% on operations and maintenance. This cost philosophy is in contrast to Case Study 2, which will have spent only 6% of its total costs on implementation and 89% of its total costs on O&M. Part of the disparity between the two project case studies' cost structures is a result of the budget process both projects undergo annually. Case Study 1 had a five-year time horizon to complete its tasks, and it structured its costs accordingly. In contract, Case Study 2 is required to develop its budget on a year-to-year basis, and it underwent significant changes due to security constraints imposed after 9/11. Overall, both cases spent roughly the same percentage of their overall budget on system planning and development, with Case Study 1 spending 5.8% and Case Study 2 spending 4.3%.

The cost projection for both project case studies appears in Table 3.

Table 3. Cost Projections for Project Case Studies

Case 1	2004	2005	2006	2007	2008	2009	Total
1.0 System Planning & Development	$119,708	$125,694	$42,272	$44,386	$46,605	$48,935	$427,601
2.0 System Acquisition & Implementation	$1,780,036	$1,869,038	$410,396	$430,915	$452,461	$475,084	$5,417,930
3.0 System Maintenance & Operation	$374,368	$393,086	$163,219	$171,380	$179,949	$188,947	$1,470,949
Total	**$2,274,112**	**$2,387,818**	**$615,887**	**$646,681**	**$679,016**	**$712,966**	**$7,316,480**

Case 2	2004	2005	2006	2007	2008	2009	Total
1.0 System Planning & Development	$46,075	$48,379	$50,798	$53,338	$56,004	$58,805	$313,398
2.0 System Acquisition & Implementation	$68,400	$71,820	$75,411	$79,182	$83,141	$87,298	$465,251
3.0 System Maintenance & Operation	$965,808	$1,014,098	$1,064,803	$1,118,043	$1,173,946	$1,232,643	$6,569,342
Total	**$1,080,283**	**$1,134,297**	**$1,191,012**	**$1,250,563**	**$1,313,091**	**$1,378,745**	**$7,347,991**

The 2004 numbers were obtained from project case study participants, and both project case studies are in U.S. dollars. Additional information for both cases was also provided to create an accurate cost projection for the future years (i.e., 2005-2009). Note that these projected costs do *not* represent the actual budget information for the future years. Rather, the future spending information was developed as a realistic example for each project case study.

4. Methodology: Business Case Process Using the Value Measuring Methodology

This business case was prepared using the Value Measuring Methodology, an analytical framework compliant with guidance from the Office of Management and Budget (OMB), which incorporates best practices from both the private and public sectors. The VMM framework provides a structured and comprehensive assessment mechanism that extends the boundaries of traditional business case analysis. Utilizing VMM, the cost of the investment can be captured and quantified to show the full range of value it will provide to direct users, stakeholders, and the government itself. The VMM approach also provides the framework for considering and understanding project risks that might decrease the methodology's effectiveness and the uncertainties that might blur standard analysis. The completeness of this approach provides decision makers with the information required to explore, understand, and make decisions based upon the relationships between value, risk, and cost.

4.1 The Value Measuring Methodology

The Value Measuring Methodology consists of three steps: developing the decision framework, analyzing case studies, and pulling together the information. These steps are described in this section.

Step 1: Develop the Decision Framework

The decision framework represents the cornerstone of the methodology. As such, it consists of the following three structures:

- **The Value Structure:** The Value Structure describes and prioritizes value (or benefits) in two layers. Within the first layer are the five Value Factors or major categories of value (Direct User Value, Social Value, Government Financial Value, Government Foundation/Operational Value, and Strategic/Political Value) that must be addressed when considering the full value of an initiative.

  Direct User Value captures value associated with customer or end-user needs and requirements. This Value Factor answers the question: What do users and customers want? Social Value captures benefits realized by individuals or organizations that are neither direct users of the service nor the service provider or initiative leader. The Social Value Factor refers to benefits that accrue to society or taxpayers at large. Government Financial Value captures benefits that have a direct impact on the government service provider and other federal government budgets. In short, it captures cost savings and cost avoidance to the government as a whole. Government Foundation/Operational Value captures benefits that may be achieved in the operations of both current services (operational) and in preparation for future demand (foundational), e.g., improvements in efficiency and effectiveness of processes and operations. Lastly, Strategic/ Political Value captures benefits that move an organization— and/or the government as a whole—toward fulfilling broader mission or strategic goals.

  Prioritization of the five Value Factors is completed by both senior-level government staff and private individuals representing commercial interests. This process is facilitated by using an Analytical Hierarchy Process (AHP) tool, Expert Choice, at a moderated session attended by these individuals. For the purposes of this business case, data on the prioritization of the Value Factors was taken from a November 2004 moderated session with NASA, U.S. Geological Survey (USGS), OGC, National States Geographic Information Council (NSGIC), Census Bureau, FGDC committee members, as well as others in the geospatial community. The Expert Choice survey was also administered to another group that included representatives from the Department of Defense, the U.S. Geospatial Intelligence Foundation, the Office of Management and Budget, and the State of North Carolina.

Within the second layer of the value structure, project- or initiative-level staff and analysts work with representatives of user communities and partner agencies to identify and prioritize measures that specifically define value (benefits) within each of the five Value Factors. The definition of each measure includes the identification of a metric, a target, and a normalized scale. By identifying a metric for each identified value measure, it is possible to measure and determine whether an initiative has delivered the desired benefits. By translating (or normalizing) performance measurements onto a single scale, it is further possible to compare both objective and subjective measures of value. (The normalized scale used in this business case ranged from 0 to 100, where 100 is the best possible score.)

For this business case, analysts, with input from representatives of the user and partner communities, prioritized the benefits within the Value Factors, assigning each with a "weight," and developed corresponding metrics.

- **The Risk Structure:** The Risk Structure articulates the risks associated with the initiative, including those that impact costs (risks associated with cost overruns) and value (risks that may jeopardize the realization of the benefits). For a detailed list of risks, see Appendix C.

- **The Cost Structure:** The purpose of the Cost Structure is to define a hierarchy of cost elements used for estimating costs and developing the foundational basis of estimate. The project-specific cost element structure (CES) is based on a standard CES developed for IT projects and initiatives, and it was tailored to incorporate the specific requirements of the project case study being analyzed. The foundational basis of estimate captures global assumptions (e.g., economic factors such as the discount and inflation rates), as well as project-specific drivers and assumptions (e.g., assumptions about the number of users of a system) derived from developing the Value Structure and articulating the associated project-specific benefits and performance metrics.

Step 2: Analyze Case Studies

During this step, two distinct project case studies were examined to determine the impact that the level of geospatial standards implementation has had on the given organization. These project case studies represent the various alternatives organizations have to provide the functionality that the initiative under analysis requires. Each project case study is analyzed against the parameters of the decision framework created in Step 1: performance for each value measure is predicted and scored on the normalized scale; cost are gathered for each cost element; and the risk profile of each case study is defined. Finally, a basis of estimate for costs is tailored and documented to identify specific cost drivers and assumptions associated with each case study.

Using statistical simulation software tools, both estimated ranges of cost and value are analyzed to determine the expected or "most likely" costs and value (benefits). Using this approach, in lieu of developing point estimates, is required to account for the differences between the two project case studies. Finally, risk analyses are conducted to determine the impact and probability associated with each identified risk.

Step 3: Pull Together the Information

Using outputs of the analyses conducted during Step 2, analysts aggregate the total cost, value (value score), and risk (risk score) for each alternative. Using this information, the effect of risk (risk score) on both cost and value are determined. In addition, this information provides the data necessary to develop two decision metrics for each alternative: the return on investment (ROI) and an index reflecting the level of benefits, or value, achieved for each alternative. The calculation used to develop the index for comparing the value associated with each alternative in the context of its cost is a simple division problem: the value score of an alternative is divided by the investment cost of the alternative. Decision-makers may use this index to perform an "apples-to-apples" comparison of alternatives to determine which will provide the greatest amount of value "bang-for-the-buck." This comparison is possible because each alternative was analyzed against the same decision framework in which all value was translated onto a single scale.

4.2 Business Case Selection and Development

In selecting project case studies, it was decided that both project case studies would remain anonymous to ensure that this study is not used as a critique of an organization, its mission, or its management staff. To this end, the study was designed to ensure that the ROI measures only analyze the costs, values, and risks derived from the use of the chosen method of data transmission. Characteristics such as end user experience, management style, or organizational constraints were not considered as part of this analysis. However, the scope of the different cases does impact the result, due to the relative size differences of the projects.

Both project case studies were required to interact with other government agencies, as well as with commercial organizations. In addition, it is important to note that at the start of both projects open interoperable geospatial data standards were in their infancy. Case Study 1 chose to adopt OGC standards when they became available, while Case Study 2 chose to rely on its internally developed standards. Both project case studies have limited time frames; however, they will both be reviewed at the end of their design life to determine if further benefits can be derived from the project. This specified vision formed the basis for selecting the two case studies briefly described in Table 4.

Table 4. Summary Description of Alternatives

Case Study	Description
Case 1	Initially used a unique standard, which was abandoned once the OGC/FGCD/ISO standards reached a threshold level of maturity. Used this open standard for the majority of the project life cycle.
Case 2	Created a unique data standard that was specific to the task at hand. Referenced some FGDC standards regarding metadata, etc.

Section 5 provides a more detailed description of the two project case studies examined in this study.

4.3 Value/Benefit Analysis

The decision framework tailored for the geospatial interoperability ROI study—specifically the Value Structure with its five Value Factors—provided the roadmap for predicting the value outcomes for the two project case studies.

To tailor this portion of the decision framework, the five Value Factors were prioritized during a working session attended by senior staff from NASA and other organizations, as explained in Section 4.1. Working with these stakeholders, value (benefit) measures in four of the Value factors (all but financial value) were defined and—through group discussion—refined. Performance metrics and targets associated with each of the value measures were also identified. Based on commercial benchmarks and stakeholder input, these comprehensive metrics were used to determine the projected value that would be gained under each alternative. For the fifth Value factor, Government Financial Value, two standard measures—cost savings and cost avoidance for all federal agencies—were defined by the study team.

As a result of both the senior-level and project-level input and prioritization sessions, the five Value Factors and geospatial interoperability initiative-specific value measures were assigned weights. These weights are listed in Table 5. The aggregate weights of the five Value Factors equal 100%. Within each of the Value Factors, the aggregate weights of the identified value measures also total 100%.

Table 5. Summary Scoring of Expert Choice Session

Direct User Value		**26.5%**	
	Data Availability	38%	10.1%
	Ease of Use	37%	9.9%
	Broad Data Sharing Capabilities	25%	6.5%
Social Value		**28.7%**	
	Better Decision Making Ability	27%	7.8%
	Extra-Governmental Coordination	20%	5.8%
	Minimal Barriers	20%	5.7%
	Institutional Effectiveness	20%	5.6%
	Efficient Use of Taxpayer Resources	13%	3.7%
Government Foundation/Operational		**24.4%**	
	Ease of Integration	23%	5.6%
	Intragovernmental Collaboration	17%	4.1%
	Public Participation and Accountability	15%	3.7%
	Interagency Collaboration	14%	3.4%
	Reuse, Adaptation, and Consolidation	14%	3.3%
	Mainstreaming of GIS	11%	2.7%
	IT Performance	6%	1.5%
Government Financial Value		**11.6%**	
	Total Cost Savings	62%	7.2%
	Total Cost Avoidance	38%	4.4%
Strategic/Political Value		**8.8%**	
	Close Working Relationship	30%	2.7%
	Supports Improved Decision Making	30%	2.7%
	Supports NSDI	28%	2.4%
	E-Gov Support	12%	1.0%
Total			**100%**

Note that Table 5 provides abbreviated titles for all of the benefits. The Value Measuring Methodology and Basis of Estimate (see Appendix C) provide complete definitions for all value measures, including their associated metrics and normalized scores. The assumptions and results of the value analysis conducted for each alternative is discussed in the following sections. Table 6 illustrates the original and risk-adjusted costs and VMM value and risk-adjusted scores for the two projects.

Table 6. VMM Scores for Two Target Projects

	Case Study 1	Case Study 2
Original Cost	$7.3 million	$7.3 million
Risk-Adjusted Cost	$9.1 million	$11.5 million
VMM Value Score	84.0	53.5
Risk-Adjusted Score	72.3	46.5

Figure 1 shows the results for the two project case studies as two scores: as a *standard* score and as a *risk-adjusted* score. The simplest way to interpret this figure is to find the case with the highest value relative to cost. In this case, as both project case studies have roughly the same total cost, Case Study 1 has a higher value as scored by the VMM framework. The arrow shows the impact of adjusting the values due to risk, where larger changes in the score show higher impacts due to risk.

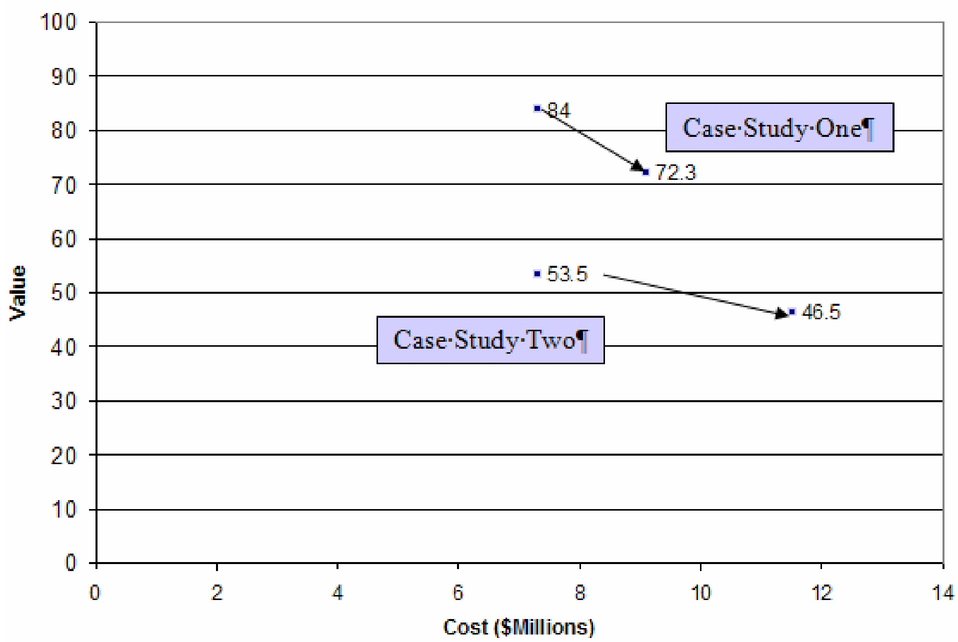

Figure 1. VMM and Risk Adjusted Scores

The impact of risk on any project is to increase its cost and decrease its value. This impact can be seen in the downward slope of the arrows: the value score is lowered and the costs increase.

5. Project Case Studies

This section describes the projects used in this study to test the hypotheses about the value (i.e., ROI) of geospatial interoperability standards. The project case studies were selected to be as similar as possible to control for factors other than standards utilization that could influence the results. As a result, both projects are national in scope, have comparable budgets, and illustrate comparable developmental timelines.

5.1 Case Study 1

The Case Study 1 organization that was approached to represent the use of "open interoperable standards" is a nationwide project that operates at the federal level of government. This organization has used open geospatial interoperability standards as a cornerstone of its project. The project began approximately five years ago with a five-year budget totaling roughly $40M; it recently received another $40M for the next five-year cycle. (Note: This study only captures $7.3M of this total $40M. Essentially, the study looks at a subset of the total project due primarily to the study team's inability to obtain complete cost information.)

The Case Study I program is a national partnership initiative that seeks to build a spatial data infrastructure and provide tools to access data and services. It does not provide a centralized Web map service, but instead it provides a central online access point to search for multiple geospatial databases, tools, and services. The program also promotes open standards and partners with participating agencies at other levels of government. By relying on standards-based services, developers can create different applications that share the same geospatial data. The services this program provides are intended to be offered across a broad spectrum: government at all levels, industry, academia, non-governmental organizations, and other agencies, including the OGC, the USGS, the FGDC, and the public at large. Apart from the implementations of voluntary, consensus-based specifications for core services, and the documentation for specifications that are currently being developed for the Web site, there is no "center" to this program.

5.1.1 Architecture

Case Study 1 has a distributed infrastructure based on a Web service architecture. The main Web site serves as the central point for the spatial data infrastructure, which is deployed via a URL-accessible Web server. Services are invoked using an HTTP "get" or "post," and parameters are passed using the CGI or XML conventions. The Web service platform enables services to be located anywhere on the Internet.

In addition to providing services, the Case Study 1 agency provides a directory of spatial data. The directory contains complete, standardized descriptions of geospatial data and the organizations that provide them. Users can search for data using spatial, temporal, keyword, and textual constraints or by browsing the directory contents. The agency promotes sharing and compatibility of geospatial data by defining a common set of framework data. Framework data is the set of continuous and fully integrated geospatial data that provides context and reference information for the country, such as roads and boundaries.

Other participants (data suppliers) share their data through the central portal. An open distributed architecture enables each participant to manage his or her data on his or her own server without having to send data to a central repository. A registration process ensures that participants' data is both standardized and searchable. The agency provides a simple interface for complying with file standards, writing metadata, linking content to the central portal, and establishing search protocols. Developers can embed online geospatial tools, including an interactive map, coordinate entry tool, or gazetteer into their own applications. These software components are provided without charge. Developers can also embed Web Application Programming Interface (Web API) calls in their applications to do predefined Internet searches for geospatial data.

5.1.2 Standards

To ensure that the Case Study 1 program is compatible with activities at the global level, international standards from the ISO and the OGC have been adopted where appropriate. Several members of the agency participate in the development and promotion of relevant standards through the work of an architecture working group.

Standards and specifications have been documented for the following areas and components of the Case Study 1 system:

- Geospatial data exchange format = GML
- Web Map Service = OGC-compliant WMS technologies
- Web Feature Service = OGC-compliant WFS
- Metadata standards = the FGDC "Content Standard for Digital Geospatial Metadata" (CSDGM). It is anticipated that this agency will also adopt ISO 19115 as a standard for its geospatial data.
- Search protocol = Z39.50 FGDC/GEO geospatial search protocol.

5.2 Case Study 2

Case Study 2 reflects another organization that is national in scope, that employed proprietary COTS software, and that developed an internal standard, primarily to facilitate data submissions. The Case Study 2 project was initiated to satisfy the government's need to have an up-to-date inventory of a critical infrastructure and its associated utilities.

This project is an inventory of the location and selected attributes of a nationally critical infrastructure and is maintained by a federal regulatory agency to insure health and safety standards are met, as well as the need for critical resources. This program was developed as a joint effort between government and industry and originally consisted of infrastructure and facility data voluntarily submitted by industry operators. The data collected is necessary for regulatory oversight and for monitoring the security of the infrastructure. Therefore, public access to the data is limited.

Two joint advisory teams composed of government and industry officials were formed to represent the interests of the government and private industry. The first team analyzed the cost-effectiveness of various alternatives for mapping the infrastructure and recommended several long-term strategies. These strategies included developing, promoting, and communicating infrastructure and facility mapping data standards that are consistent with FGDC standards; developing and maintaining a national database through formalized partnerships with government agencies and industries; promoting the use of mapping standards with one-call systems; and creating a repository for the information. The second team was formed to implement these long-term strategies.

5.2.1 Architecture

A national repository provides the backbone of the Case Study 2 program, which acts as a conduit between facility operators and governmental agencies, industry, and the general public. The repository serves as a processing and storage facility for specific infrastructure data submitted by operators. The repository also authenticates the submissions and conducts quality control checks on the data before making it available to users.

The management application was developed by the government agency to safeguard the critical infrastructure information in the database. The software is available for use by registered operators and federal, state, and local governmental officials. The government agency validates users and provides an Internet-based public access tool that displays operator contact information for a specified geographic area searchable by county or zip code.

The program participants established data standards for submission that are consistent with FGDC standards to facilitate its role as a processing facility and clearinghouse for critical infrastructure location information. This format is also used to communicate information back to system users through an Internet mapping application. Digital data is the preferred format for submissions, although hard copy maps are also accepted. Four types of data are required for any submission: geospatial data (location information), attribute data (descriptive information), metadata, and contact information for the operator of the facility.

5.2.2 Standards

To ensure that the Case Study 2 program is compatible with industry activities, as well as government needs, the program has implemented a small set of standards. Standards and specifications have been documented for the following areas and components of the system:

- Geospatial data exchange format (default) = ESRI shape file (.shp)
- Data content standards = ad hoc
- Metadata standards = agency profile of the FGDC "Content Standard for Digital Geospatial Metadata" (CSDGM).

In addition to these standards and specifications, the agency, in consultation with industry, has developed standards for data submissions sent to the repository. These guidelines spell out a file naming convention consistent with the DOS 8.3 character convention. The format for attribute data is specified with rules and in the attribute field definitions tables. Operator contact information is also defined with an attribute field definitions table. Metadata submissions are required to be created with the metadata template software and must accompany all hard copy and digital geospatial data submissions. The agency only collects mandatory information or information critical for a clear understanding of the operator submittal. All geospatial data submissions must meet certain geodetic requirements—that is, they must be submitted in North American Datum (NAD) 1983 or NAD 1927 coordinate system; projection of Universal Transverse Mercator (UTM), State Plane, or unprojected; have a minimum accuracy of ±500 feet; and scale between 1:24,000 (1"=2,000') and 1:1,200 (1"=100') with spatial accuracy clearly stated in metadata.

The agency offers flexibility in the submission of geospatial data by accepting a variety of well known proprietary formats. These formats include ArcInfo exchange (.E00); ArcView shapefile (.shp); Intergraph FRAMME Loader SEF; Intergraph .DGN; MapInfo Interchange File (MIF); AutoCAD .DWG; and ASCII coordinate pairs. Commonly accepted digital media includes CD-ROMs, diskettes, zip disks, and Internet transmissions. Minimum system requirements for the software include a 486-processor that uses Microsoft Windows 95, 98, 2000, or Windows NT with 8 megabytes of RAM and a CD-ROM drive.

Because this program deals with a critical infrastructure, unrestricted access through an Internet mapping application is not provided by this agency. Several commercial software products offer the capability to view and analyze the information to approved users. Those software products include, but are not limited to the following: ArcExplorer; AGIS for Windows; GeoConsult; PCI Geomatics; TravelGIS.com; TNTlite; JShape; GeoMaitre; Ecological Software Solutions; CartoMAP Viewer; and Blue Marble Geographics.

6. Study Results and Analysis

Applying VMM to the two project case studies has yielded insights for many of the actors in the geospatial community. This section presents the results of this analysis, as well as discusses the implications of these results, with special emphasis placed on impact to stakeholder groups.

6.1 VMM Results: Scoring of Target Projects

The VMM results are presented in three ways: through VMM scores, through cost and risk-adjusted costs, and through ROI values.

6.1.1 VMM Scoring Results

Table 7 illustrates the VMM scoring results for Case Study 1.

Table 7. Case Study 1: VMM Scoring Results

	Value Factors & Benefits	Weight	Weighted Score	Risk Adj Wgt Score
1	**Direct User**	**26.50%**	**22.7**	**19.6**
1.1	Ease of Use	9.81%	8.1	7.0
1.2	Broad Data Sharing Capabilities	6.63%	5.1	4.4
1.3	Data Availability and Accessibility	10.07%	9.6	8.2
2	**Social Value**	**28.70%**	**26.9**	**23.1**
2.1	Institutional Effectiveness	5.74%	5.1	4.4
2.2	Efficient use of tax payer resources	3.73%	3.7	3.2
2.3	Minimal Barriers exist to finding and obtaining data	5.74%	5.5	4.7
2.4	Citizens are able to make better decisions	7.75%	7.5	6.4
2.5	Extra-Governmental Coordination	5.74%	5.2	4.4
3	**Government Foundation/Operational**	**24.40%**	**19.6**	**16.8**
3.1	Intra-governmental collaboration	4.15%	3.1	2.7
3.2	Mainstreaming of GIS technology	2.68%	2.7	2.3
3.3	Interagency Collaboration	3.42%	2.8	2.4
3.4	Reuse, Adaptation, and Consolidation	3.42%	3.4	2.9
3.5	Public Participation and Accountability	3.66%	2.4	2.0
3.6	Ease of Integration	5.61%	4.0	3.5
3.7	IT performance	1.46%	1.1	0.9
4	**Strategic/Political Value**	**8.80%**	**7.9**	**6.8**
4.1	Supports improved decision making	2.64%	2.4	2.0
4.2	Supports NSDI	2.46%	2.1	1.8
4.3	Close Working Relationships	2.64%	2.3	2.0
4.4	e-Gov Support	1.06%	1.1	0.9
5	**Government Financial**	**11.60%**	**7.0**	**6.0**
5.1	Total Cost Savings	7.19%	4.3	3.7
5.2	Total Cost Avoided	4.41%	2.6	2.3
	Total		**84.0**	**72.3**

Figure 2 shows the variation in the Expert Choice Results. Each line represents a different participant from the Expert Choice data. Note that only 8 participants are represented in the chart for clarity. The text below the line shows the standard deviation within the given category. Direct User Value had the most variation, as seen with a standard deviation of 0.020, and Strategic/Political Value the least with a standard deviation of 0.005. It is also interesting to note that people who voted higher than average for Direct User voted lower than average for Social Value, and vice versa.

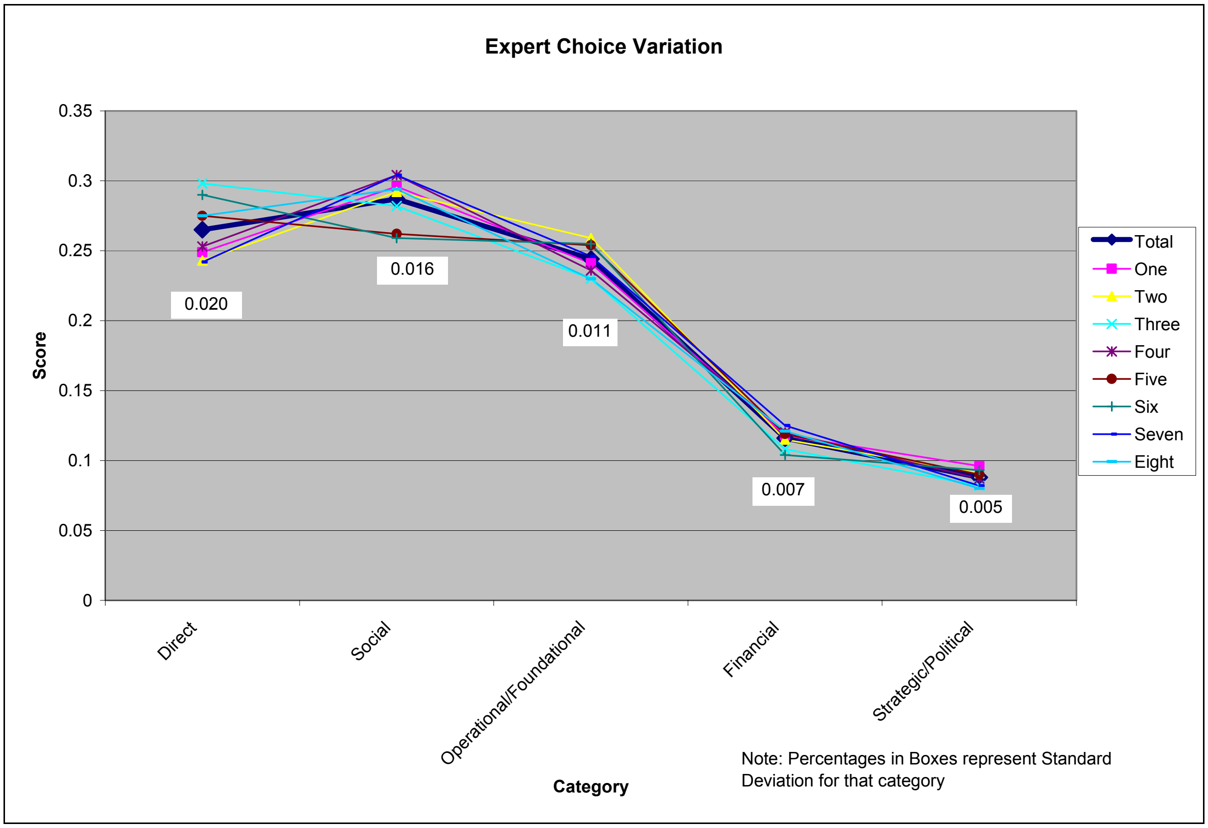

Figure 2. Expert Choice Results

Table 8 illustrates the VMM scoring results for Case Study 2.

Table 8. Case Study 2: VMM Scoring Results

	Value Factors & Benefits	Weight	Weighted Score	Risk Adj Wgt Score
1	**Direct User**	**26.50%**	**11.8**	**10.3**
1.1	Ease of Use	9.81%	5.1	4.5
1.2	Broad Data Sharing Capabilities	6.63%	2.6	2.3
1.3	Data Availability and Accessibility	10.07%	4.0	3.5
2	**Social Value**	**28.70%**	**17.6**	**15.3**
2.1	Institutional Effectiveness	5.74%	4.0	3.5
2.2	Efficient use of tax payer resources	3.73%	3.4	3.0
2.3	Minimal Barriers exist to finding and obtaining data	5.74%	3.2	2.7
2.4	Citizens are able to make better decisions	7.75%	3.6	3.1

	Value Factors & Benefits	Weight	Weighted Score	Risk Adj Wgt Score
2.5	Extra-Governmental Coordination	5.74%	3.3	2.9
3	**Government Foundation/Operational**	**24.40%**	**14.9**	**13.0**
3.1	Intra-governmental collaboration	4.15%	3.1	2.7
3.2	Mainstreaming of GIS technology	2.68%	2.2	1.9
3.3	Interagency Collaboration	3.42%	2.4	2.1
3.4	Reuse, Adaptation, and Consolidation	3.42%	3.0	2.6
3.5	Public Participation and Accountability	3.66%	1.6	1.4
3.6	Ease of Integration	5.61%	2.2	2.0
3.7	IT performance	1.46%	0.3	0.3
4	**Strategic/Political Value**	**8.80%**	**4.3**	**3.7**
4.1	Supports improved decision making	2.64%	1.3	1.1
4.2	Supports NSDI	2.46%	1.7	1.5
4.3	Close Working Relationships	2.64%	0.7	0.6
4.4	e-Gov Support	1.06%	0.5	0.5
5	**Government Financial**	**11.60%**	**4.9**	**4.3**
5.1	Total Cost Savings	7.19%	3.6	3.1
5.2	Total Cost Avoided	4.41%	1.3	1.2
	Total		**53.5**	**46.5**

Table 9 depicts the cost results (both estimated and risk-adjusted costs) for the project case studies.

Table 9. Cost Results

Estimated Case 1	2004	2005	2006	2007	2008	2009	Total
1.0 System Planning & Development	$119,708	$125,694	$42,272	$44,386	$46,605	$48,935	$427,601
2.0 System Acquisition & Implementation	$1,780,036	$1,869,038	$410,396	$430,915	$452,461	$475,084	$5,417,930
3.0 System Maintenance & Operation	$374,368	$393,086	$163,219	$171,380	$179,949	$188,947	$1,470,949
Total	**$2,274,112**	**$2,387,818**	**$615,887**	**$646,681**	**$679,016**	**$712,966**	**$7,316,480**

Estimated Case 2	2004	2005	2006	2007	2008	2009	Total
1.0 System Planning & Development	$46,075	$48,379	$50,798	$53,338	$56,004	$58,805	$313,398

2.0 System Acquisition & Implementation	$68,400	$71,820	$75,411	$79,182	$83,141	$87,298	$465,251
3.0 System Maintenance & Operation	$965,808	$1,014,098	$1,064,803	$1,118,043	$1,173,946	$1,232,643	$6,569,342
Total	**$1,080,283**	**$1,134,297**	**$1,191,012**	**$1,250,563**	**$1,313,091**	**$1,378,745**	**$7,347,991**

Risk Adjusted Case 1	2004	2005	2006	2007	2008	2009	Total
1.0 System Planning & Development	$131,701	$141,190	$48,542	$52,065	$55,714	$59,493	$488,704
2.0 System Acquisition & Implementation	$2,138,999	$2,290,127	$515,086	$553,582	$593,467	$634,784	$6,726,045
3.0 System Maintenance & Operation	$465,114	$497,229	$211,054	$227,134	$241,814	$259,035	$1,901,380
Total	**$2,735,814**	**$2,928,546**	**$774,682**	**$832,781**	**$890,995**	**$953,312**	**$9,116,129**

Risk Adjusted Case 2	2004	2005	2006	2007	2008	2009	Total
1.0 System Planning & Development	$55,514	$59,379	$63,775	$68,330	$73,458	$78,772	$399,227
2.0 System Acquisition & Implementation	$86,174	$92,173	$98,998	$106,068	$114,029	$122,277	$619,718
3.0 System Maintenance & Operation	$1,458,197	$1,559,715	$1,675,195	$1,794,837	$1,929,545	$2,069,119	$10,486,607
Total	**$1,599,884**	**$1,711,267**	**$1,837,967**	**$1,969,234**	**$2,117,031**	**$2,270,167**	**$11,505,551**

For additional VMM results by Value Factor, see Appendix D.

6.1.2 Cost and Risk-Adjusted Cost Results

Both case studies provided fiscal year (FY) 2004 cost estimates, as well as general guidelines on how these costs would change over the next few years. The costs presented in Table 9 are estimates derived for this analysis only, and do not necessarily reflect the planned expenditures by the two projects. Note that these results were in part derived from the evaluation of the risk of the two project case studies. Risk always increases cost, and costs also increase over time due to inflation. Combining these two elements generates the "risk-adjusted costs" shown in Table 9.

The results shown in Table 9 for Case Study 2 indicate a significant increase in costs due to risk as compared to Case Study 1. Looking at the total costs, Case Study 2 Planning & Development costs increase 27.4% over the base year, Acquisition & Implementation increase 33.2%, and Maintenance & Operation (M&O) increases 59.6%. Most notable is the increase in M&O costs, which suggests that not implementing open standards limits the flexibility and adaptability of the program over time. As M&O is the largest single contributor, this risk is the primary driver in the program's 56.6% total increase in cost. Table 9 also shows that Case Study 1 displays similar trends in cost increase; however, they are not as drastic as Case Study 2. The total cost increase due to risk is only 24.6%, which is significantly lower than Case Study 2. More important to Case Study 1 is the fact that M&O costs are a lower percentage of total costs than in Case Study 2.

As previously mentioned, risk adds what could be considered a price premium to any project. This premium can be measured by the percentage increase in risk-adjusted costs. Table 10 illustrates these increases.

Table 10. Percentage Increase in Risk-Adjusted Costs

Cost Element	Case Study 1	Case Study 2
1.0 Planning	14.3%	27.4%
2.0 Implementation	24.1%	33.2%
3.0 O&M	29.3%	59.6%
Total	**24.6%**	**56.6%**

According to Table 10, Case Study 2 had almost double the risk premium in Planning and Development costs. Moreover, Case Study 2 had a roughly 50% increase in risk in Acquisition and Implementation costs than did Case Study 1. Case Study 2 also had almost double the risk premium in M&O. Part of this increase in risk was due to the original cost structure developed by Case Study 2, where the majority of its costs (89%) were M&O costs. Because Case Study 2 had most of its costs in this category, and this category is exposed to the greatest risk over time, Case Study 2 had the largest increase in risk-adjusted M&O costs. Table 11 shows the pre- and post- cost and value results for both project case studies.

Table 11. Pre- and Post-Risk Cost and Value Results

FY 04-09 (Constant $Thousands)	Case 1	Case2
Cost, Pre-Risk	$7,316,480	$7,347,991
Cost, Post-Risk	$9,116,129	$11,505,551
Cost Risk Score	24.6%	56.6%
Value, Pre-Risk	84.0	53.5
Value, Post-Risk	72.3	46.5
Value Risk Score	-13.9%	-13.1%

Figure 3 - Figure 6 illustrate the different risk-adjusted spending estimates for both of the project case studies. Figure 3 illustrates the total risk-adjusted costs for both projects over the five-year period. The significant difference between the two project case studies is seen in the higher upfront spending by Case Study 1 versus the gradual increases in spending seen in Case Study 2.

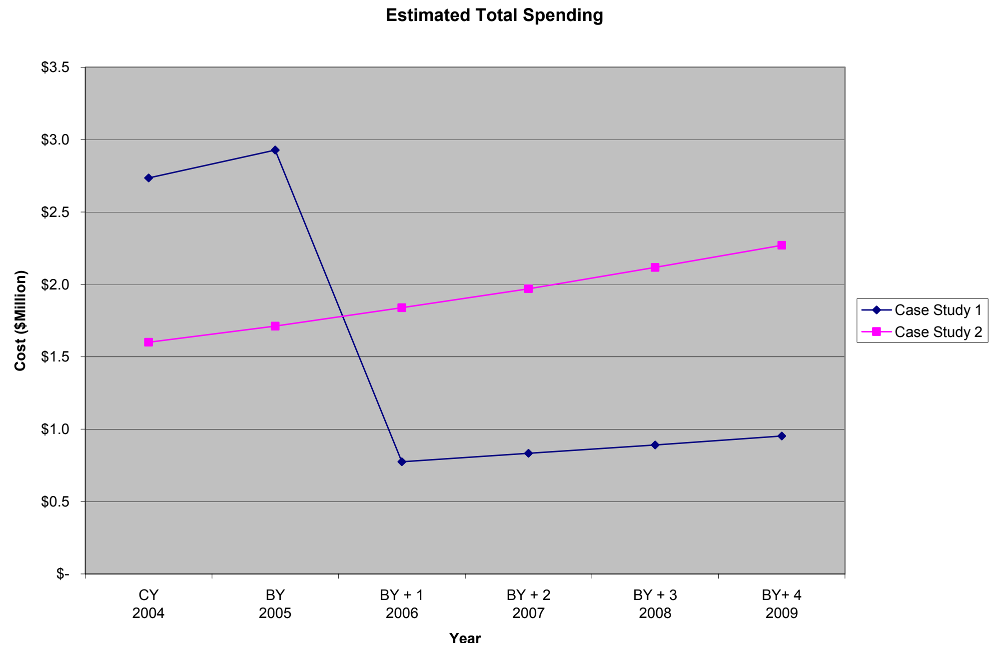

Figure 3. Total Costs

Figure 4 illustrates the 1.0 Planning and Design costs for both projects. Case Study 1 again shows higher upfront spending than Case Study 2; however, it significantly drops off once the project is up and running.

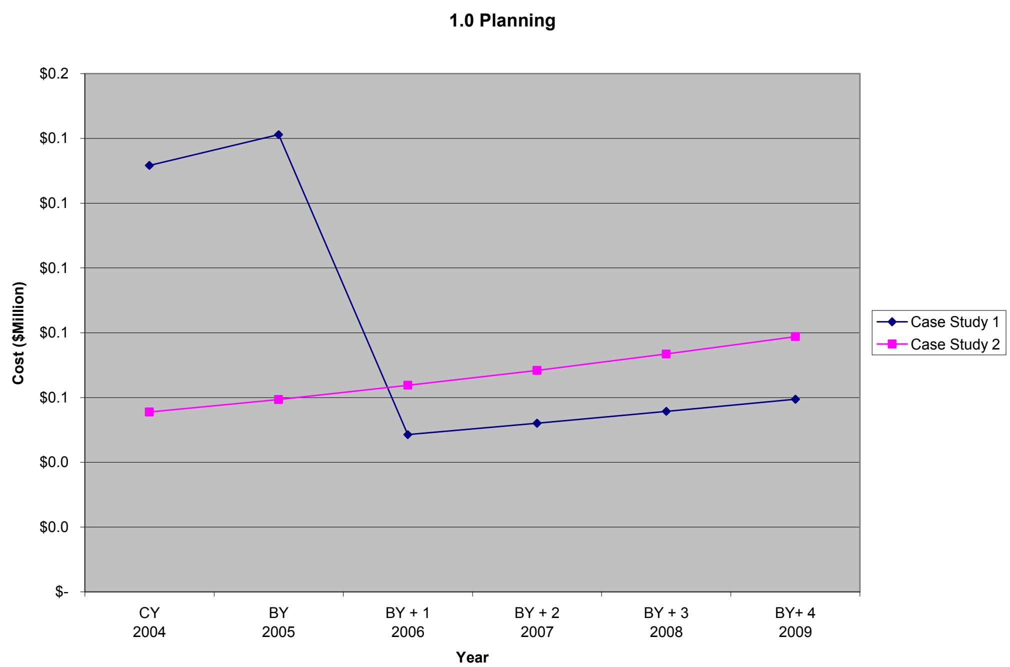

Figure 4. 1.0 Planning and Design Costs

Figure 5 illustrates the 2.0 Acquisition and Implementation costs. The trend of Case Study 2 focusing more of its budget on upfront cost continues in this figure. This cost includes the additional development resources required for implementing open standards.

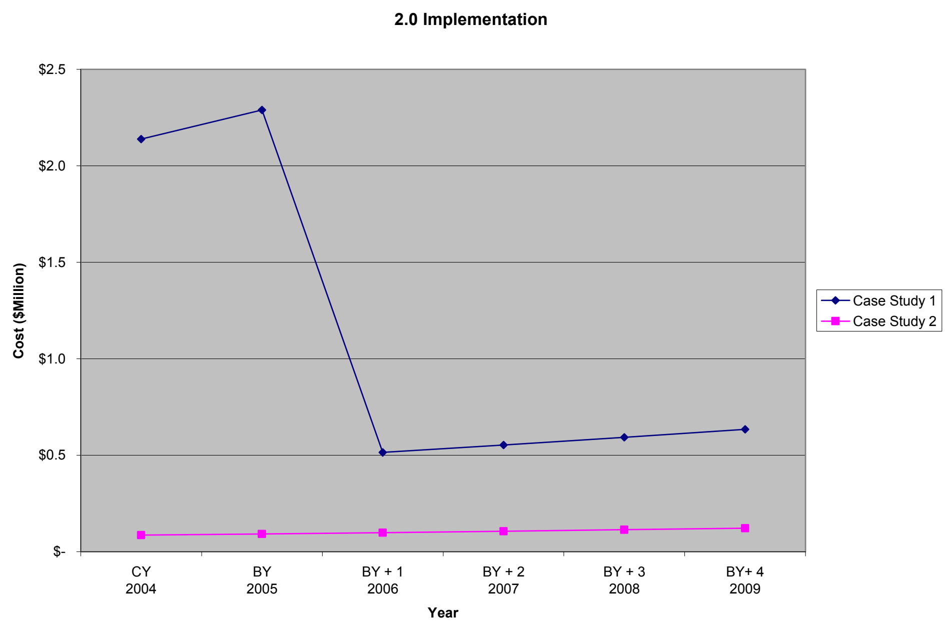

Figure 5. 2.0 Acquisition and Implementation Costs

Figure 6 illustrates the 3.0 Operations and Maintenance costs. This figure clearly shows that the investment Case Study 1 made in planning and implementation results in a long-term savings in M&O. As M&O was the category with the highest risks, this cost difference exposes Case Study 1 to lower future risks.

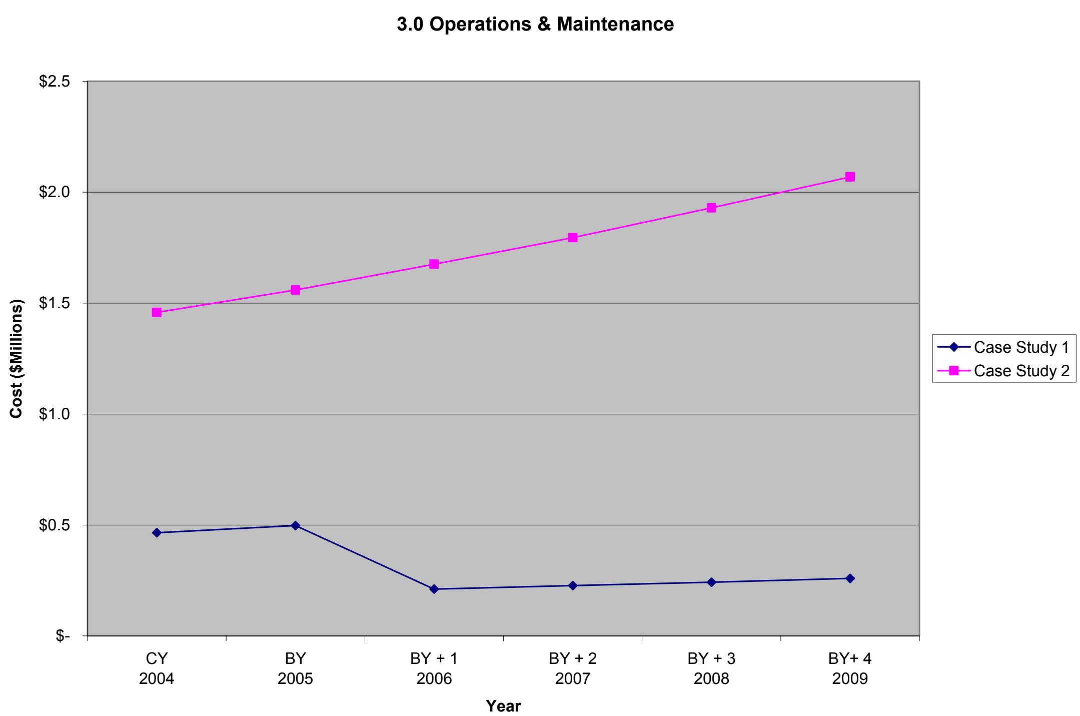

Figure 6. 3.0 Operations and Maintenance Costs

6.1.3 ROI Metric Results

The return on investment metric used in this study is the "savings to investment" ratio (SIR). Here, the savings refer to the Operations & Maintenance savings of Case Study 1 over Case Study 2 in terms of present value risk-adjusted costs. To calculate the savings, the difference in risk-adjusted O&M costs is calculated as $10,486,601 - $1,901,380, or $8,585,227. This difference is then divided by the Planning and Implementation costs in Case Study 1 ($7,214,749), which yields a SIR of 119.0%. (Note: Neither "net present value" nor "payback period" were calculated for this analysis. Both of these measures are indicators of future cash flows, and this analysis did not place a specific dollar figure on future benefits.)

6.2 Implications for Federal, State, Tribal, and Local Government

This section discusses Task A: "Qualitatively and quantitatively demonstrate through analysis, the ROI for Federal, State, Tribal and Local government who implement geospatial interoperable standards solutions. Use the GIRM v1.1 as the reference model. Assume an evaluation period of 5 years."

Governments at all levels have spent significant resources to acquire geospatial data to fulfill their various missions. One of the characteristics of digital data is that it can be shared between different systems with relative ease. Given the relatively large expense of collecting digital geospatial data, government agencies have a strong incentive to reuse and share geospatial data resources where practicable and where the data can meet multiple and overlapping mission objectives.

The value of standards and specifications to government is driven largely by the need to share resources. The motivations for sharing are varied, but research indicates that the most frequently cited motivations include the common mission/goals and saving resources.[17] In Case Study 1, standards are seen as a vehicle to maximize scarce resources to achieve multiple objectives. Standards are a way to centralize the design of the information architecture, allowing data production, data maintenance, and supporting software development to remain decentralized. In contrast, Case Study 2 developed a standard for data exchange and data content only. In Case Study 2, the bulk of the users have standardized on one software platform and data are published in a popular file format. This format is open, in the sense that it is published, but proprietary in the sense that the file syntax is not subject to the standards criteria set forth in Circular A-119. This file format functions as a *de facto* standard. Users are only required to format their data for upload and inclusion to the main data repository. In both instances, the use of standards is driven by the common need to save resources, specifically resources to reformat data into a compatible format.

The results of this study show that there is a significant improvement when using open standards over proprietary standards. The risk-adjusted ROI for using open standards over proprietary standards is 119.0%. This should be interpreted as spending $1 in planning and implementation to receive $1.19 in long-term savings. Additionally, Case Study 1 saved 26.2% overall compared to Case Study 2. One way to interpret this result is that for every $4 spent on a proprietary standard, the same value can be achieved through an open standard for $3. In this study, the project with open standards saved over $2.4M over the five-year life of the project. The implications for this result are significant for all levels of the government. For state, local, and tribal organizations with limited budgets, the potential savings

[17] Zorica Nedovic-Budic, Jeffrey K. Pinto, and Lisa Warnecke, "GIS Database Development and Exchange: Interaction Mechanisms and Motivations" *URISA Journal*, vol. 16, no. 1 (2004): 15-29, available at http://www.urisa.org/Journal/Vol16No1/Budic.pdf.

to be achieved with open standards may mean the difference between being able to implement (or not implement) geospatial applications for their organization.

At the federal agency level, the ROI captured by Case Study 1 should be attainable; however, the risks associated with increased connectivity between organizations, privacy and security concerns, and increased cost also amplify in this scenario. Case Study 1 was a national-level project with high levels of interaction; yet, this was one project within a larger organization.

Another important fact uncovered in this study was the *value* generated by the open standards solution. Even if both project case studies ultimately had the same risk-adjusted cost, the open solution returned higher value and benefits to its stakeholders. In fact, the open solution returned 55% more value to its stakeholders than did the proprietary solution. With increases in benefits such as this, the open solution would be preferable, even if its costs had been higher than the proprietary solution.

For this reason, standards make investment decisions clear.[18] Standards help to form an information culture and information economy that is content-rich and diverse in viewpoint. In Case Study 2, for example, the government partnered with industry to participate in standards setting activities so that early agreement was reached on requirements and so that both sides understood the path forward for implementation. By clarifying functions, service invocations, and data definitions, standards make the distribution of geospatial information understandable, not just for government technologists, managers, and administrators, but for all stakeholders, including industry partners.

It is important to note that neither of the two project case studies used the GIRM in system planning or deployment. However, Case Study 1 has made significant contributions to the development of many of the specifications referenced in the GIRM. The GIRM presents the standards and specifications from multiple perspectives, in such a way to make the standards more accessible for new users. The GIRM organizes the family of standards in five unique ways:

1. **Geospatial Topics:** data and data access, metadata, maps, coordinate reference systems, and geoprocessing services
2. **Viewpoints:** service invocation or information transfer
3. **Levels of Abstraction:** abstract standard or implementation specification
4. **Evaluation Criteria:** level of maturity of the standard or specification
5. **The Interoperability Stack:** the linkages between various components of a distributed system [GIRM]

By organizing the standards in to a "stack", or suite of services, the GIRM makes sense out of the complexity of individual standards.

[18] Martin Libicki, James Schneider, Dave R. Frelinger, and Anna Slomovic, *Scaffolding the New Web: Standards and Standards Policy for the Digital Economy*, MR-1215-OSTP (Santa Monica, CA: RAND Corporation, 2000), available at http://www.rand.org/publications/MR/MR1215/.

6.3 Impact of Geospatial Standards on Industry

This section discusses Task B: "Discuss the likely ROI for industry who implement geospatial interoperable, open standards-based solutions in the marketplace. Use the GIRM V1.1 as a reference model for related analysis and discussion."

As a preface to this section, it should be noted that no comparable cost figures were obtained for industry as they were for the project case studies. Consequently, this discussion is based on information gathered during case study research, as well as from supplemental materials, including interviews with industry representatives from several technology sectors.

Like government, industry is a broad category that comprises several technology sectors. These sectors include data conversion vendors and value-added resellers, geospatial software vendors, geospatial enabling technologies (e.g., GPS and Radio Frequency Identification [RFID]), remotely sensed imagery providers, and other ancillary commercial enterprises. Some sectors of the industry are completely indifferent to standards (e.g., data conversion vendors), and for the purposes of this study, discussion is restricted to those industry sectors for whom the standards and specifications have direct impact on their products and services.

Some geospatial technology companies view product support for GI standards and specifications as a market differentiator. Many of these vendors were partners with the government in Case Study 1 to implement early versions of the standards and build expertise early on with the technologies. These vendors claim they offer a service superior to proprietary products at a lower cost. For example, one vendor who has built its reputation on implementing the OGC stack has the goal of trying to implement the stack better and faster than anyone else on the market. In addition, Case Study 1 has had partnered with vendors who combine geospatial interoperable standards with open source code. These vendors see their edge in the market as being able to offer their clients some transparency as part of their suite of services.

Companies that stake their claim on geospatial standards are betting that they will catch on and that their product will become an indispensable piece of IT operating infrastructure. For these companies, building awareness, credibility, product loyalty, and intellectual capital is the path to ubiquity, and therefore, market share. This stance represents a marked difference from the more traditional stance of competing in the marketplace by offering proprietary data models, application interfaces, and associated services.

Since 1990, the growth in information technologies, including image processing, GIS, GPS, and location-based services, -has accelerated the need for, and the development of, standards. This need has been driven by the blurring of the lines between communication and computation.[19] The need for interfaces between these technologies is facilitated by standards and specifications. Attempts to standardize have followed two tracks. Track 1 is characterized by the Open Systems Interconnection (OSI) initiative, which is a reference model of data communication standards. The intent was to provide a detailed reference model for telecommunications and computing industries that could in turn be developed into standards and implementation specifications. However, none of these implementations materialized. This track has been referred to elsewhere as the structuralist approach.

[19] Martin Libicki, "The Role of Standards in Today's Society and in the Future," testimony given to the Subcommittee on Technology, Committee on Science, U.S. House of Representatives, 13 September 2000, available at http://www.house.gov/science/libicki_091300.htm.

Track 2 is characterized by the Internet Engineering Task Force (IETF). The IETF began as a loosely organized group of Department of Defense (DoD) contractors and engineers working on Advanced Research Projects Agency Network (ARPANET) and other DoD projects that began by developing simple, lightweight standards that were easily implemented. This track has been referred to elsewhere in this study as the minimalist approach. Case Study 1 has shown that industry finds it easier to get behind incremental (or minimalist) initiatives such as the IETF rather than more comprehensive (or structuralist) approaches such as OSI. A central reason for this is that the incremental approach reduces the risk for industry players by minimizing exposure to failures, while enabling industry to build intellectual capital with the specifications and the technologies as they evolve. The appeal of Track 2 to industry is that minimal standards that are "good enough" allow them to enhance their competitive position by being first to market with products that conform to the standards.

There are some risks to industry in participating in standards development activities, which all parties must act to minimize. Participating in standards activities without disclosing a proprietary intent (patentable interest or intent) has been considered fraudulent and can result in an unenforceable patent, as it did with the case of Dell. Both OGC and ANSI anti-trust rules require disclosure of material interests in patentable specifications prior to voting on technical measures. There are instances, however, where patent holders agree to no or very low royalties for use of proprietary methods and technologies, known as "reasonable and non-discriminatory" or RAND terms. In each instance, it depends on the market position of the company or technology sector.

Another issue that has arisen is that private financing of public goods. In contrast to SDOs (e.g., ANSI and ISO), membership in industry consortia is relatively expensive, open only to those who can afford it. This limited membership has the effect of developing privately financed standards that become club goods. Many companies view consortium membership as "pay-to-play" with the hope of an inside edge or a competitive advantage. Perhaps because the geospatial technology sector is relatively small as compared to the larger information technology industry, geospatial standards development is driven as much by small industry players as it is large ones. Moreover, the OGC has several categories of associate memberships and small company commercial memberships that allow for increased participation by smaller companies, nonprofit organizations, and academic organizations. A majority of the companies that contributed to Case Study 1 were small companies and academic researchers.

It is worth noting that support for geospatial standards by GIS software vendors is growing. ESRI, Intergraph, and MapInfo all support a mixture of OGC specifications. The reasons for their support are beyond the scope of this report, but their support has clear benefits for both projects. It means that these projects have an added measure of resilience and flexibility where these software platforms are already in use.

Calculating a specific ROI for individual companies within the geospatial software field is beyond the scope of this analysis. However, if results from the project case studies are any indication, widespread use of open standards in the geospatial community would have an impact on all companies in this sector. The organizations that would be most affected are the providers of GIS software. Currently, the majority of these vendors support open standards as part of their product suite. The demand for standards-based solutions in both the domestic and international market implies that for the market leaders in the various GIS categories, there are two solutions: block the adoption of open standards or provide solutions that meet and exceed the standards. Currently, none of the industry leaders has openly denounced the geospatial standards movement within the GIS community. Moreover, all of the market leaders are members of the OGC and some are members of INCITS L1.

At this stage of the standards development process, if companies competing for market share believe that the market will be dominated by solutions that support standards, they have two basic options:

- **Option 1:** Compete over different variations of open standard (e.g., ActiveX vs. Java)
- **Option 2:** Agree at the outset to define the open standard collectively.

If companies select Option 1, they will ultimately consume part of the market in the battle to determine the market leader. Eventually, a standard will emerge; however, it will be an expensive battle in terms of its cost and duration. This outcome is essentially a prisoner's dilemma (see Appendix E).

If companies select Option 2, they will be choosing to define a standard early and collectively, but they will eventually be competing on superior technology and service. Consumers will gain, as these companies are forced to begin competing on price, technology, and service versus competing between standards (see Appendix F).

6.4 Benefits to Public Access to Government Geographic Information

To understand the benefits of data sharing, it is necessary to look at the motivations for sharing data. Motivations for sharing data are rooted in the need for additional information to supplement existing information and to create new combinations of information that will presumably factor into better decision making.

The significance of access to geographic information is that combinations and re-combinations of the data can yield spatially driven insights to understanding, and hence, managing a wide variety of social, environmental, economic, and political processes. Open access to geospatial data is an inexpensive means to provide social and public goods (e.g., informed citizenry and government stewardship of resources), which are either very costly to provide or for which markets do not supply in sufficient quantity. Access to data also lowers the transaction costs between government agencies and private sector. The premise of open access is extracting increased value from existing data resources. The ratio of eyes-to-information increases as the data are used and reused. (This process could be extended to allow users to correct errors in the map data, much as access to credit reports allows users to correct errors in those records.)

There are some risks associated with unrestricted access to some data sets. Misuse of data is a continual concern, especially for certain data sets dealing with critical infrastructure, such as bridges, tunnels, or water supply.[20] There is also a potential for misuse of personal data, the more extreme example of which is identity theft. This study did not undertake a historical analysis, but an analysis of court rulings through history, as well as comparisons with other countries, could yield important insights for balancing the individual's right to know with public security. It is worth noting that Case Study 2 deals extensively with a key public infrastructure and due to the sensitive nature of that information, it was not released publicly.

As geospatial technologies become ubiquitous at all levels of government, a growing challenge is reaching semantic agreement. Simply put, semantic agreement in the context of geospatial data means that two or more parties agree on how real world features are to be defined and the terminology to reference these features. Case Study 1 has shown that success is often achieved when a minimalist

[20] Martin Libicki, James Schneider, Dave R. Frelinger, and Anna Slomovic, *Scaffolding the New Web: Standards and Standards Policy for the Digital Economy*, MR-1215-OSTP (Santa Monica, CA: RAND Corporation, 2000), available at http://www.rand.org/publications/MR/MR1215/.

approach is taken and the simpler solution is adopted. The evidence suggests that parties should define standards broadly and scope them narrowly with minimal feature sets and classes. It is incumbent on users of geospatial data to be mindful of the normative references and definitions in geospatial standards, particularly data content standards which concern themselves with how the world is modeled.

An interesting spin regarding access to data comes as governments, particularly at the local level, are attempting to recover some of the costs associated with creating geospatial databases.[21] A growing number of local and county governments are asserting copyright over their geospatial data, in spite of the fact that the individual records are a matter of public record and therefore not copyrightable. Copyright is insufficient protection of ownership and control insofar as it is used as a cost recovery mechanism.[22] Contracts and licenses are also used as a means to protect ownership and recover costs. These contracts may be difficult, if not impossible, to enforce. Liability on the part of government is the biggest disincentive to cost recovery policies. Most local governments use disclaimers when sharing data, releasing them from liability for incorrect data. However, attempts to assert copyright and enforce contracts could increase liability exposure by reducing the ability for government to claim sovereign immunity protections. If governments engage in essentially proprietary activities (i.e., charging above and beyond the normal and reasonable costs of reproducing data), agencies run a higher risk of liability than they would encounter with an open access policy.

The Internet has introduced a new dynamic by altering the cost of providing information. The Internet provides the ability to essentially limit the cost to transmitting data to zero, as long as the recipient is capable of making use of the data. The marginal costs, that is, the cost of providing the next copy of data, consists of the time and media required to transmit the data. Many governments, in contrast to those implementing cost recovery methods, have opted to charge only for the cost of reproduction, whether it be to upload data to an FTP site or burn it to a CD or other similar methods.

Digital data also confers a benefit in the form of economic efficiency, where the economic efficiency is defined as a state where there are no opportunities to make one group better off while at the same time making another group worse off.[23] For example, if Agency A creates an accurate base map of say, the State of Utah, and Agency B is capable of using this information, there is a significant savings since, in theory, Agency A can simply give Agency B the data. Agency A is no worse off, and Agency B is much better off.

6.5 Recommendations for Fostering Geospatial Interoperability

This section discusses Task D: "Develop recommendations regarding Geospatial interoperability that are balanced between the technological and budget realities by conducting a trade's analysis of associated pros and cons."

Be clear about the business drivers for implementing GIS/geospatial technologies. The length of time it takes between planning, implementation, and deployment is often a critical factor in project

[21] Jeff P. Johnson and Harlan J. Onsrud, "Is Cost Recovery Worthwhile?," National Center for Geographic Information Analysis, available at http://www.spatial.maine.edu/~onsrud/pubs/Cost_Recovery_Worthwhile.html; Peter Weiss, *Borders in Cyberspace: Conflicting Public Sector Information Policies and Their Economic Impacts Summary Report* (Washington, DC: U.S. Department oof Commerce, National Oceanic and Atmospheric Administration, National Weather Service, February 2002).

[22] Ibid., Johnson and Onsrud.

[23] "Licensing Geographic Data and Services," The National Academy of Sciences, 2004.

management. This time factor is sometimes due to business imperatives and other times to the political need to quickly show results. For the agencies where this is the situation, there have been some compelling arguments to be made for proprietary solutions. One reason has to do with the ease with which data can be readily and expeditiously imported. Both project case studies utilize proprietary software. Five years ago, it was considered more prudent to select software platforms based on market share, especially since OGC-compliant software and solutions were in their infancy. This is less the case at the writing of this report because the OGC specifications and the tools that implement them have matured considerably.

Rely extensively on geospatial standards and specifications to guide planning. Standards clarify investment decisions by making each piece of the technology and its connection to other pieces of technology intelligible.[24] Because using georeferenced information from heterogeneous sources requires some level of data and application interoperability, geospatial standards and specifications provide a reference for making these connections. The GIRM provides a useful compliment to the standards and specifications by making them accessible. The GIRM groups standards and specifications into the following five broad categories to provide guidance to users and managers on which standards apply to what activities and technologies:

- Data and data access
- Metadata and catalog access
- Maps and visualization
- Geospatial reference systems
- Geoprocessing services (e.g., coordinate transformation and gazetteer)

Once users determine which specifications and standards apply to their situation, they can refer to the appropriate source documents for implementation. The GIRM and the standards should be used extensively in the process of implementing geospatial technologies to help make clear the technical growth trajectory.

The price point for geospatial software often matters in the choice of software platform. Rightly or wrongly, users will often make decisions about software based on what they can afford and not on what others are using. This scenario is especially the case for small organizations and agencies, such as nonprofit agencies or small local governments. Several free or very low cost Web mapping tools that support the OGC suite of specifications have recently been made available for download. These utilities minimize the risk of locking in to a vendor-specific technology, maximize the implementations of the OGC suite, and provide users on a limited budget with some of the benefits of geospatial technologies.

Where possible, use multi-year funding strategies. Standard, annual government budget cycles often work against the long-term investment in standards. At the federal level, government agencies, except for the DoD, do not budget beyond one year. Most federal agencies will find it difficult to justify investment in the long-term benefits of using standards because the exigencies of short-term budget priorities exceed and outweigh long-term interests. Standards typically require a longer lead time. Case Study I was budgeted as a five-year program, which allowed them sufficient time to invest in the development and implementation of several key specifications.

[24] Martin Libicki, James Schneider, Dave R. Frelinger, and Anna Slomovic, *Scaffolding the New Web: Standards and Standards Policy for the Digital Economy*, MR-1215-OSTP (Santa Monica, CA: RAND Corporation, 2000), available at http://www.rand.org/publications/MR/MR1215/.

The Internet is the delivery mechanism. Consumers of all stripes demand that everything work in a browser, and demand is rising for the support of very thin/mobile clients. The Internet is driving both technical convergence and the demand for standards. The Internet and related geospatial technologies facilitate the manifestation of latent spatial assets of an organization. Standards (or strong protocols) are needed to facilitate this growth. The growth in OGC and the maturity of the ISO 19100-series standards is paralleled by the growth in the consortia concerned with the operation of the Internet, for example, OASIS, the World Wide Web Consortium (W3C), and IETF.

Simple consensus-based voluntary standards have a better record of adoption than robust and complete standards. There are two basic approaches to standards development: the minimalist approach, as exemplified by Internet standards such as HTTP, and the structuralist approach, which is exemplified by OSI, ADA, and ANSI X12 standards.[25] The reasons for this are partly due to the challenges of achieving semantic agreement. When standards and specifications are defined broadly and narrowly scoped with minimal feature sets and classes, there are more opportunities for users to adopt the standard. As these simple standards are taken up by a wider group, the evidence shows is a better chance for users to become familiar with the associated technology and how the standard should evolve to deal with the technology.

6.6 Financial Metrics for Providing Geospatial Interoperability

This section discusses Task E: "Provide estimates of cost benefits, life-cycle costs and other financial metrics for implementing Geospatial Interoperability. Assume an evaluation period or life cycle of 5 years.

6.6.1 Cost/Benefit Information

Table 12 shows the pre- and post-risk adjusted costs and values for both project case studies. The cost risk score shows the percentage increase in cost due to risk, and the value risk score shows the percentage decrease in value due to risk. While there is a small difference in the value risk score between the two cases (-13.9% and -13.1%, respectively), there is a significant difference in the cost risk score.

Table 12. Value and Cost Information

FY 04-09 (Constant $Thousands)	Case 1	Case2
Cost, Pre-Risk	$7,316,480	$7,347,991
Cost, Post-Risk	$9,116,129	$11,505,551
Cost Risk Score	24.6%	56.6%
Value, Pre-Risk	84.0	53.5
Value, Post-Risk	72.3	46.5
Value Risk Score	-13.9%	-13.1%

The increase in risk-adjusted cost for Case Study 2 is governed by that project's high percentage of funding in O&M. Many of the significant risks impacted costs in the O&M area, and Case Study 2 had higher exposure to these risks. The risk-adjusted value scores imply that both cases will achieve

[25] Ibid.

their given level of value regardless of the risks involved. While these risks will reduce the overall value of each project by approximately 13.5%, this reduction in value is small compared to the increases in costs to the given projects.

Another way to interpret these results is by calculating how much each point of pre-risk-adjusted value costs. This calculation is carried out by dividing the pre-risk-adjusted cost by the pre-risk-adjusted value. For Case Study 1, this calculation amounts to $87,101 per value point, and for Case Study 2, $137,346, or more than twice as much for Case Study 2. This calculation shows that for Case Study 2 to achieve the value score seen in Case Study 1, almost twice as much money and time would need to be invested. If this is examined on a risk-adjusted basis, Case Study 1 will spend $126,088 and Case Study 2 will spend $247,431 per point of value.

6.6.2 Life Cycle Cost Information

Table 13 depicts the life cycle costs (constant, inflated, and discounted) for both projects.

Table 13. Life Cycle Costs

Risk Adjusted - Constant							
Case 1	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**Total**
1.0 System Planning & Development	$131,701	$141,190	$48,542	$52,065	$55,714	$59,493	$488,704
2.0 System Acquisition & Implementation	$2,138,999	$2,290,127	$515,086	$553,582	$593,467	$634,784	$6,726,045
3.0 System Maintenance & Operation	$465,114	$497,229	$211,054	$227,134	$241,814	$259,035	$1,901,380
Total	**$2,735,814**	**$2,928,546**	**$774,682**	**$832,781**	**$890,995**	**$953,312**	**$9,116,129**

Risk Adjusted - Constant							
Case 2	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**Total**
1.0 System Planning & Development	$55,514	$59,379	$63,775	$68,330	$73,458	$78,772	$399,227
2.0 System Acquisition & Implementation	$86,174	$92,173	$98,998	$106,068	$114,029	$122,277	$619,718
3.0 System Maintenance & Operation	$1,458,197	$1,559,715	$1,675,195	$1,794,837	$1,929,545	$2,069,119	$10,486,607
Total	**$1,599,884**	**$1,711,267**	**$1,837,967**	**$1,969,234**	**$2,117,031**	**$2,270,167**	**$11,505,551**

Risk Adjusted - Inflated							
Case 1	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**Total**

1.0 System Planning & Development	$131,701	$145,426	$51,498	$56,892	$62,706	$68,969	$517,192
2.0 System Acquisition & Implementation	$2,138,999	$2,358,830	$546,455	$604,914	$667,953	$735,889	$7,053,039
3.0 System Maintenance & Operation	$465,114	$512,146	$223,907	$248,196	$272,164	$300,292	$2,021,819
Total	**$2,735,814**	**$3,016,402**	**$821,860**	**$910,002**	**$1,002,823**	**$1,105,149**	**$9,592,050**

Risk Adjusted - Inflated							
Case 2	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**Total**
1.0 System Planning & Development	$57,179	$62,995	$69,689	$76,906	$85,158	$94,057	$445,984
2.0 System Acquisition & Implementation	$88,759	$97,786	$108,177	$119,380	$132,190	$146,005	$692,299
3.0 System Maintenance & Operation	$1,501,943	$1,654,702	$1,830,531	$2,020,105	$2,236,871	$2,470,636	$11,714,787
Total	**$1,647,881**	**$1,815,483**	**$2,008,396**	**$2,216,391**	**$2,454,219**	**$2,710,698**	**$12,853,069**

Risk Adjusted - Discounted							
Case 1	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**Total**
1.0 System Planning & Development	$131,701	$138,422	$46,657	$49,062	$51,471	$53,885	$471,197
2.0 System Acquisition & Implementation	$2,138,999	$2,245,222	$495,085	$521,653	$548,272	$574,943	$6,524,174
3.0 System Maintenance & Operation	$465,114	$487,479	$202,859	$214,034	$223,399	$234,616	$1,827,500
Total	**$2,735,814**	**$2,871,123**	**$744,600**	**$784,748**	**$823,142**	**$863,444**	**$8,822,871**

Risk Adjusted - Discounted							
Case 2	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**Total**
1.0 System Planning & Development	$55,514	$58,214	$61,298	$64,389	$67,864	$71,346	$378,625
2.0 System Acquisition & Implementation	$86,174	$90,366	$95,153	$99,950	$105,345	$110,750	$587,738

3.0 System Maintenance & Operation	$1,458,197	$1,529,132	$1,610,145	$1,691,315	$1,782,601	$1,874,064	$9,945,454
Total	**$1,599,884**	**$1,677,713**	**$1,766,597**	**$1,855,654**	**$1,955,810**	**$2,056,160**	**$10,911,817**

Note: A discount rate of 2.0% was used to calculated Discounted Values (from Appendix C of OMB A-94). These are risk-adjusted costs. An inflation rate of 3.0% (CPI from BLS.gov) was also used.

The return on investment metric used in this analysis is the Savings to Investment Ratio. Here, the savings represent the savings of Case Study 1 over Case Study 2 in terms of risk-adjusted costs. To calculate the savings, the difference in risk-adjusted Operations and Maintenance costs is calculated as $10,486,607 - $1,901,380 or $8,585,226. This difference is then divided by the investment made in Planning and Investment Case 1 ($7,214,749), which yields a SIR of 119.0%.

6.7 Lessons Learned in This Study

This section discusses Task F: "Provide a lessons learned and findings as a result of conducting the GI-ROI study."

The largest single factor impacting the VMM results was the impact of security and privacy on the cases. No one was able to foresee that Case Study 2 would be as constrained in its actions due to its concerns with national security issues. While accounting for this change would not have significantly impacted the results presented in this report, a more detailed approach would have enabled Case Study 2 to receive a higher value score.

On a broader scope, the impact of security and privacy on open standards within the geospatial user community is well understood. Policies and procedures are either in place or in development to ensure that geospatial data conforms with all of the necessary security and privacy concerns.

Ideally, the authors would like to see this study conducted again with a larger sampling of project case studies, namely one that canvasses three of the major stakeholders in geospatial standards-setting process: government, industry, and the standards development organizations. There are three groups of questions the survey should seek to determine. For government, the survey should ask the following:

- Are geospatial standards are being used?
- If so, what type of geospatial standards are being used (data or application interface)?
- What is the genesis of the standard (local or federal)?
- What other information is important (e.g., motivations, business rules, policy, and protocols)?

For industry, this survey should ask the following questions:

- What is the extent of support for geospatial standards?
- Is this company involved in standards setting activities?

And for standards development organizations, the survey should ask the following questions:

- What outreach efforts are being undertaken to broaden participation in standards setting activities?
- How can marketing and outreach efforts reach a broad cross-section of the geospatial community to educate them about standards setting processes?

This survey would yield much useful information that can be used to refine geospatial standards setting and be applied to important national initiatives such as the National Spatial Data Infrastructure (NSDI).

Multiple levels of government engage the universe of geospatial standards in diverse ways. Government is at once a user, an advocate, and a resource provider, as Case Study 1 demonstrates. The government also steps in to address market failures and to protect basic public health and safety where there is no market incentive to do so. Governments therefore have an established role in financing the production of public goods and addressing shortcomings where commercial markets fail to provide those goods. However, governments at different levels have varying motivations for adopting standards, and the standards they adopt vary widely.[26] Federal government agencies are more likely to adopt and implement the ISO 19100-series standards and OGC specifications. But, county and municipal governments are more likely to develop and adopt a local standards specifically for data exchange. In fact, most are apt to adopt no standard at all as they are to adopt a federal standard. Case Study 2 implements a minimal set of standards, yet supports a wide variety of popular COTS file formats. These findings suggests a number of conclusions:

- That the family of standards central to this study are poorly suited to local use
- That the data content and exchange standards (both local and federal/international) are immature and will eventually need to be harmonized
- That there is a fundamental disagreement about the semantics associated with the application of the standards.

All of these conclusions may, to some extent, be true. While there is broad agreement that semantic and syntactical agreement is good for government operations, the cost of achieving semantic agreement is likely to be high.[27] Furthermore, geographic descriptions are often ambiguous and gaining agreement in one context may be unsuitable for another.

For added perspective, this study could benefit from interviewing or canvassing a broader, more representative sample of industry representatives from various geospatial technology sectors. This survey includes not just the obvious market leaders, but also the numerous small companies who are engaged in developing niche products or conducting research and development. Future studies should be aware that interviewing a small sample of vendors risks introducing the bias of a few vendors to the study. And, if the study team "hand-selects" these vendors, it would introduce the study team's bias to the study. For this study, the analysts relied on industry trade groups to supply an industry point of view.

This study has identified at least three stakeholder groups that have an active role in geospatial standards setting: government, industry, and the SDOs/SSOs. Successful standardization depends on all three parties coming together to make common cause to advance goals beneficial to all parties.

[26] Zorica Nedovic-Budic, Jeffrey K. Pinto, and Lisa Warnecke, "Articles Currently Under Peer Review by the *URISA Journal*," *URISA Journal I*, vol. 14 (2003).

[27] Martin Libicki, James Schneider, Dave R. Frelinger, and Anna Slomovic, *Scaffolding the New Web: Standards and Standards Policy for the Digital Economy*, MR-1215-OSTP (Santa Monica, CA: RAND Corporation, 2000), available at http://www.rand.org/publications/MR/MR1215/.

Failures of standardization can occur due policy failure, market failure, and failure in the standards development process.[28]

Like all information technologies, geospatial technologies are subject to economic forces, including economies of scale, network effects, switching costs, lock-in, and system effects that determine how revenues are distributed.[29] A closer study of these economic forces with specific reference to geospatial technologies would provide insight in to how standardization efforts can build resilience and minimize these costs and risks.

A weakness of the horizontal American method of standard setting is that there is very little high-level coordination brought to the process. This lack of high-level coordination leaves American industry competing over the domestic market, while at a disadvantage when compared to foreign competitors.[30] Fortunately, geospatial technologies fare somewhat better. Compared to the majority of 150 American standards consortia, the OGC has significant international participation. And, support for the OGC specifications is growing among U.S.-based geospatial software vendors.

In 2000, ANSI released the National Standards Strategy. This strategy was under revision at the time of this report, so the results and implications were not available for this study. However, the revision was going forward with broad cross-section of representation from all major stakeholder groups, including the geospatial industry. This study could benefit from the larger perspective of this strategy and implications for the future.

6.8 Recommendations for Leadership and Structure with Regard to Geospatial Interoperability Standards

This section discusses Task G: "Conduct business case studies from the two selected examples above and discuss results and recommendations – that is, the economic and other related benefits (including technology) rationale for the USG and Industry to implement geospatial interoperable open standards based solutions. Discuss rationale to not implement geospatial interoperable open standards based solutions, if applicable. Assume an evaluation period or life cycle of 5 years."

Adopt and implement standards early in the project life cycle. The results of this study suggest that projects that adopt and implement standards early on in the project life cycle build in a margin of business resilience and operational flexibility that can lower long-term costs for operations and maintenance. Case Study 1 demonstrates that even when standards are immature, developing and implementing a minimal standard confers some benefits. Similarly, with further research it would be possible to document the cost savings incurred by Case Study 2 as a result of implementing data submission standards and requiring descriptive metadata with data submissions. The cost savings for Case Study 2 have to do with pre-processing time saved, automatic file syntax recognition, as well as audit information about the data (e.g., currency, accuracy, and how the data were compiled).

Profiles (see Section 2) can increase the adoption of standards. Often, organizations reject the adoption of standards because they are perceived as not meeting the business needs of that organization. The tension between national standardization efforts and the complex, multiple-mission reality of locally

[28] Thomas Hemphill and Nicholas Vonortas, "U.S. Antitrust Policy, Interface Compatibility Standards, and Information Technology" (Washington, D.C.: The Center for International Science and Technology Policy, September 2003), available from http://www2.gwu.edu/~cistp/PAGES/antitrust.pdf.

[29] Ibid.

[30] Ibid.

developed data models is likely to prevail until serious efforts are made to harmonize local, state, and international standards. Likewise, SDOs and SSOs recognize that voluntary standards are frequently a compromise. Profiles allow these organizations to reference and comply with the standard while tailoring it for their specific needs. There are at least three examples of standards profiles:

- **Constraining profiles:** An agency's standards profile references the FGDC Content Standard for Digital Geospatial Metadata (CSDGM), has 11 sections, but implements only Section 1 dealing with Identification, Section 4 dealing with Spatial Data Organization, and Section 10 dealing with Contact Information.
- **Extending profiles:** An agency's standards profile references the FGDC CSDGM, but adopts the extensions for biological data.
- **Tailoring profile:** An agency's standards profile references the FGDC CSDGM, but makes the condition reporting of temporal elements mandatory [ISO/IEC 2002:N0312].

Profiles introduce some flexibility in to the standards setting process that helps an organization realize the benefits of the standards while at the same time meeting the specific business needs of their organization. A good example of this occurs in Case Study 2, which has created a metadata profile from the FGDC CSDGM. The agency benefits from having an audit trail for their data, while at the same time it has minimized the reporting burden on data providers.

A greater understanding of profiling practices could stimulate the uptake of standards in the geospatial community. SDOs and SSOs should increase outreach efforts to educate the geospatial community on profiling best practices. Government, as advocates and standard-enablers, should promote the development of simple standards to foster quick institutional uptake and integration in to the technical fabric.[31]

The role of government with regard to geospatial standards is indispensable. The U.S. government has traditionally set few standards, preferring to rely on private interests to develop standards, with government intervening periodically to correct market failures. American government has acted to enable the standards process, but mostly has relied on private sector to establish the content of specifications. The NTTAA legislation has shifted responsibility for standards development from the National Institute for Standards and Technology (NIST) to industry consortia (e.g., OGC) and independent SDOs (e.g., ANSI). This shift has made standards development more responsive to rapidly changing market conditions, while leaving the government free to participate in standards development in other roles such as brokering, enabling, correcting market failures, fostering collective action, enforce contracts, and maintaining the patent system. So, government should continue to play a role ensuring that standards are developed with due process and with equal protection for all parties.

Government must take an active role to protect intellectual property rights and foster the information commons. There are conflicting economic incentives for private industry to patent standards and capture the revenue streams associated with the use of the technology. There are also several concerns associated with patenting standards and specifications. The first concern is the effect of stifling collaboration. Industry is characterized by heterogeneous players who wield asymmetrical power. Those with a great deal of market share and market dominance are compelled to act opportunistically to enhance or protect their market position. This situation contributes to increased uncertainty and

[31] For more information on profiles, see ISO/IEC JTC1 SC36 N0312, 2002, *Frequently Asked Questions (FAQ) about Standards Profiles.*

risk for industry players in the standards development process and often leads to what Linda Graves calls a "prisoner's dilemma" outcomes. (See Appendix E for more information on the prisoner's dilemma.) These are suboptimal outcomes of a standards development process where rather than cooperate to attain a good compromise, one party will defect to from the process in order to reap all the benefits.

The second concern about patents is what constitutes patentable technology. In 1999, Amazon attempted to patent a single-click purchasing process, and in 2004, Microsoft was granted a patent on double-clicking to launch applications on 'limited resource computers" such as PDAs. On the face of it, it would seem that these patent claims stretch the limits of what constitutes "novel" and "non-obvious" uses of technology. But, it is not a trivial matter to those who challenge the patents, many of whom are small companies with limited resources and are burdened with demonstrating that the technology or method existed as "prior art." This can be a very expensive and time consuming process.[32]

There are several roles the government can play to help facilitate optimal standards setting processes and reduce the occurrence of social dilemmas. Among those outlined by Graves et. al are these actions that government geospatial professional parties can bring to the process:

- Establishing clear intellectual property policies for all participants
- Establishing and facilitating clear rules for access and availability to standards and standards-setting processes
- Facilitating access to information
- Reducing the information asymmetry between participants
- Adopting only open, collaboratively developed standards
- Participating and contributing to open standards development processes

Government must support SDOs and SSOs in fostering greater awareness of standards setting processes. Government agencies at all levels needs to partner with SDOs and SSOs to develop local profiles of minimal standards, which are more likely to be adopted and accepted by users and vendors. Case Study I began with a set of minimal standards, offering both a starting point for agreement as well as flexibility and extensibility to accommodate rapidly converging technologies. Case Study I also is engaged in efforts to harmonize local and regional data content standards to develop national standards. These small minimal standards give each stakeholder a voice in the immediate future of the standard and gives them a stake in the ongoing refinement and maintenance of the standard. The government role is in engaging the geospatial community in this process.

Only a fraction of local, regional, and states participate in federal geospatial standard setting activities. A federally funded survey of state, local, regional, and other sub-national standards and specifications could help align national geospatial practice across multiple levels of government. These standards have the weight of local buy-in and could form the building blocks for efforts to set national geospatial standards, especially for data content and exchange. A survey of local, state, and regional standards could be used to address the need to achieve semantic agreement between these communities. This issue is likely to be an ongoing challenge because the geospatial data were collected by numerous local, regional, and state agencies for a wide ranges of missions and end uses, and local conditions. A

[32] OASIS Intellectual Property Rights Policy, available at http://www.oasis-open.org/who/intellectualproperty.php.

taxonomy of standards and data content models would provide insight into how semantic agreement might address differences in many dimensions, for example, scale, identity, rules, and vocabulary.

A supplement, or companion volume, to the GIRM could be developed to educate the broader community on standards setting. This supplement could include an explanation of the institutional background, a brief overview of the role of standards, how to engage in the standards setting process, and reference materials. Such materials, effectively distributed, could increase state and local participation in national standards setting activities, and help federal agencies build relationships with local communities, and be more responsive to local concerns.

Support for international standards development is in the national interest. There is a national interest in actively participating in the international standards bodies and that interest is to maintain consistency with global standards. The U.S. is increasingly interlinked with the global economy and countries whose governments sponsor, if not mandate, compliance with international standards. Noncompliance costs the national economy in the form of technical barriers to trade (TBT). In 1998, TBT cost U.S.-based industry between $20 billion and $40 billion annually.[33] If U.S. industry is to compete effectively in these markets, a broad and active standards community is an asset in maintaining linkages to these vital trade structures. There is room for leadership on the government's side to contribute time to international SDOs and SSOs and to represent national interests in these forums.

[33] Richard E. Hebner, "Standards and Trade – Who Really Cares?," speech given at Fall 1998 Public Lecture Series: Technology Standards and Standardization Processes, Stanford University U.S.-Japan Technology Management Center.

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Appendix A Taxonomy of Standards

There is a continuum of institutions involved in setting standards that range from pure market to pure government sponsorship[34] as shown below:

- **Market:** The pure market setting produces proprietary, *de facto* standards through competitive market forces.
- **Market/Non-market:** Market-based *de jure* standards developed with minimal government involvement, usually in an advisory capacity.
- **Market & Non-market:** Public and private sectors share equal responsibility for developing *de jure* standards.
- **Non-market/Market:** The government assumes primary sponsorship and development of *de jure* standards, with private sector acting as technical advisors.
- **Non-market:** The government assumes responsibility for development of *de jure* standards mandated by law and regulation. Private sector involvement is limited to the public comment and review period.

Still another typology is defined by the Organization for Economic Cooperation and Development [OECD 1991] that supplement the above continuum as follow:

- **Vertical Model:** Top-down, centralized government system model best exemplified by China, Russia (and former USSR states), and Eastern Europe
- **Centralized Model:** Characterized by strong centralized national standards bodies, that may be a part of government or quasi-government agencies. Japan and Germany exemplify this model.
- **Decentralized Model:** A model in which the voluntary sector and the government sector are clearly separated, exemplified by Canada and somewhat less in the U.S.
- **Horizontal Model:** Coordination is either not as comprehensive or has co-equal private sector partners and government acting as enabler and sometimes technical advisor or sponsor. The U.S. is best characterized by this model [OECD 1991].

In addition, there are accredited SDOs and informal SDOs. The International Organisation for Standardization (ISO) and the American National Standards Institute (ANSI) are examples of accredited SDOs. ANSI is recognized by ISO as the accredited representative body in the international standards development process. In addition, the Information Technology Industry Council sponsors the International Committee for Information Technology Standards (INCITS) who has a committee, L1, dedicated to producing voluntary consensus standards for geographic information systems. Standards developed by these groups are the primary subjects of this study.

Informal standards are developed by consortia. For this study, the most significant of these consortia is the Open Geospatial Consortium (OGC). Consortia standards are referred to as specifications that focus on implementation, sometimes of abstract standards such as those developed by ISO or ANSI. However, there is often not a one-to-one correspondence between abstract standard and implementation specification, and OGC also sponsors the development of abstract specifications, as

[34] Thomas Hemphill and Nicholas Vonortas, "U.S. Antitrust Policy, Interface Compatibility Standards, and Information Technology" (Washington, D.C.: The Center for International Science and Technology Policy, September 2003), available from http://www2.gwu.edu/~cistp/PAGES/antitrust.pdf.

well. All of the specifications are voluntary and developed through consensus of the members. As of this writing, OGC is comprised of 109 commercial members, 58 government members (including international members), 10 nonprofit institutions, and 95 academic and research institutions. OGC has formal partnerships with ISO (specifically with ISO Technical Committee 211), and with INCITS L1. as well as relationships with the Organization for the Advancement of Structured Information Standards (OASIS). The specifications developed by OGC are also primary subjects of this study.

The Federal Geographic Data Committee (FGDC) also plays a significant role in standards development. The FGDC was established by OMB Circular A-16 and charges the FGDC with coordinated use, sharing, and dissemination of geospatial data on a national basis. FGDC has an established standards subcommittee whose objective is to support the development of the National Spatial Data Infrastructure (NSDI). The subcommittee also has an established Standards Working Group open to public participation (FGDC). The FGDC works closely with INCITS L1 to coordinate the development of geographic information standards on a national basis.

The world of standards is quite large and even a generalized subset of information technology (IT) standards encompasses a very diverse set of standards and specifications.

This study deals only with the costs and benefits of standards in the ISO 19100-series, FGDC, and OGC family of standards and specifications. Standards that belong to the IEEE, W3C, OASIS, and other families of standards may be referenced inasmuch as they play a supporting or related role. But because these standards have no explicit geospatial focus, they are not treated in this study. The geospatial standards in this study are developed on top of the lower elements in the pyramid. Just as a stable set of Internet standards enable the emergence of the World Wide Web, so common geospatial data formats and interfaces enable the emergence of a set of common geospatial standards.

Appendix B Cost Element Structure

A. Description of the Alternatives

B. Cost Analysis

C. Value/Benefit Analysis

D. Risk Analysis

E. ROI Calculation

F. Comparing The Alternatives

G. Recommended Alternative

H. System Development & Planning

I. System Implementation

J. System Operations And Maintenance

Appendix C VMM Categories, Risk Methodology, and Basis of Estimate

Direct User (Customer) Value

Benefits directly realized by users or multiple user groups. Users or customers will vary based on the type of initiative being assessed. Users may include, but are not limited to, government employees, other government organizations, and citizens.

Direct User		Normalized Scale										
Measure	**Description**	**0%**	**10%**	**20%**	**30%**	**40%**	**50%**	**60%**	**70%**	**80%**	**90%**	**100%**
Ease of Use	**Geospatial resources and systems are easy to translate, transform, and ingest**											
Metrics	Expertise required to support data transmission	Very High		High			Medium		Low		Very Low	None
	Level of Effort of the reconciliation process	Very High		High			Medium		Low		Very Low	None
	Complexity of data: number of changes in Field Length/Value/Types/etc	Very High		High			Medium		Low		Very Low	None
Broad Data-Sharing Capabilities	**Capabilities exist for broad GI data-sharing between communities of interest**											
Metrics	Level of Effort required to support data transmission	Very High		High			Medium		Low		Very Low	None
	Number of inquires for meta-data	None	Minimal-	Minimal	Minimal+	Some-	Some	Some+	Significant	Significant	Significant+	Significant++
	Number/Diversity of Clientele	One Client	Minimal-	Minimal	Minimal+	Some-	Some	Some+	Significant	Significant	Significant+	Many Diverse Clients
Data availability and accessibility	**Geospatial data and applications are readily available and accessible for communities of interest**											
Metrics	Is relevant data available in timely	No										Yes

Direct User		Normalized Scale										
Measure	**Description**	**0%**	**10%**	**20%**	**30%**	**40%**	**50%**	**60%**	**70%**	**80%**	**90%**	**100%**
	fashion?											
	Number of hits per hour/day/week	None	Minimal-	Minimal	Minimal+	Some-	Some	Some+	Significant	Significant	Significant+	Significant++
	Number of downloads (per day/hour)	None	Minimal-	Minimal	Minimal+	Some-	Some	Some+	Significant	Significant	Significant+	Significant++
	Are data available via inter- or intranet?	No										Yes

Social (Non-Direct User/Public) Value

Benefits not related to direct users (e.g., society as a whole)

Social		Normalized Scale										
Measure	**Description**	**0%**	**10%**	**20%**	**30%**	**40%**	**50%**	**60%**	**70%**	**80%**	**90%**	**100%**
Citizens and citizen services are able to make better decisions	**The data allow users to make better-informed judgments. Public access to the data encourages citizens to provide an extra measure of quality control to data.**	No										Yes
Metrics	Public web mapping available	None	Minimal-	Minimal	Minimal+	Some-	Some	Some+	Significant-	Significant	Significant+	Significant++
	Number of repeat Users	No										Yes
	Feedback exists between producers of data and consumers of data											
Coordination and Streamlining	**GI data are readily available for those who need them. Coordination with groups exists outside of your direct agency. Links exist with outside communities of interest.**	None	Minimal-	Minimal	Minimal+	Some-	Some	Some+	Significant-	Significant	Significant+	Significant++
Metrics	Number/Diversity of end users	None	Minimal-	Minimal	Minimal+	Some-	Some	Some+	Significant-	Significant	Significant+	Significant++
	Number and diversity of catalogs registered	No										Yes

Social		Normalized Scale										
Measure	**Description**	**0%**	**10%**	**20%**	**30%**	**40%**	**50%**	**60%**	**70%**	**80%**	**90%**	**100%**
	Partnership mechanisms are in place and are well defined	None	Minimal-	Minimal	Minimal+	Some-	Some	Some+	Significant-	Significant	Significant+	Significant++
	Number of MOUs/SLAs/Others with external agencies	None	Minimal-	Minimal	Minimal+	Some-	Some	Some+	Significant-	Significant	Significant+	Significant++
	Level of participation in state/local/tribal coordinating councils	None	Minimal-	Minimal	Minimal+	Some-	Some	Some+	Significant-	Significant	Significant+	Significant++
	Level of connectedness to data clearinghouses and spatial search catalogs											
Efficient use of taxpayer resources	**Financial as well as non-financial resources are used in the best interest of Society as a whole**	No										Yes
Metrics	Is there an accounting system in place to track requests for the data?	Unknown	Complete Duplication				Moderate Duplication		Very Little Duplication			No Duplication
	Are redundant data or applications being created?	Unknown	Completely Similar				Moderately Similar		Similar			No
	Are other organizations performing similar tasks?											
Minimal barriers exist to obtaining the data	**Data are accessible and available through well-defined processes.**	Significant		Significant		Significant -			Moderately Low	Low	Very Low	Free
Metrics	Cost of data to external users	Very High		High				Moderate		Low		Very low
	Number of steps to locate and retrieve data											

Social		Normalized Scale										
Measure	**Description**	**0%**	**10%**	**20%**	**30%**	**40%**	**50%**	**60%**	**70%**	**80%**	**90%**	**100%**
Institutional Effectiveness	**Increased access to spatial data across the enterprise leads to better decision-making and increased operational effectiveness.**	Not At All	Very Limited		Limited		Moderately			Partially		Completely
Metrics	Data is accessible to other organizations	Not At All	Minimal-	Minimal	Minimal+	Some-	Some	Some+	Significant-	Significant	Significant+	Significant++
	Decision making process is repeatable, transparent, and scalable	Not At All	Very Limited		Limited		Moderately			Partially		Completely

Government Operational/Foundational Value

Order of magnitude improvements realized in current government operations and processes and in laying the groundwork for future initiatives

Government Foundation/Operational		Normalized Scale										
Measure	**Description**	**0%**	**10%**	**20%**	**30%**	**40%**	**50%**	**60%**	**70%**	**80%**	**90%**	**100%**
Interagency Collaboration	**Current and future collaboration efforts among agencies are supported (buy/create once, use many times)**											
Metrics	Number of formal agreements in place with other agencies	None	Very Low		Low		Medium		High			Very High
	Communities of Interest and User Groups exist to promote the sharing of data	No										Yes
	Number of agencies participating in the dissemination of data	None	Very Low		Low		Medium		High			Very High

Government Foundation/Operational		Normalized Scale										
Measure	**Description**	**0%**	**10%**	**20%**	**30%**	**40%**	**50%**	**60%**	**70%**	**80%**	**90%**	**100%**
Reuse, Adaptation, and Consolidation	**Data and Applications from existing geospatial efforts can be efficiently reused and adapted. Initiative supports consolidation of currently fragmented Federal geospatial efforts**											
Metrics	Policies in place answers ensures no duplication of efforts	No										Yes
	Data and applications meet multiple mission objectives	No										Yes
IT performance	**Initiative facilitates IT performance within government agencies**											
Metrics	Number of hits (per hour/day/week)	None	Very Low		Low		Medium			High		Very High
	Time to get usable response	Very High			High		Moderate			Low		Very Low
Intra-governmental collaboration	**Collaboration between Fed/state/local/tribal organizations**											
Metrics	Number of formal agreements in place with other agencies	None	Very Low		Low		Medium		High			Very High
	Number of agencies involved	None	Very Low		Low		Medium		High			Very High
	Level of participation of external agencies	None	Very Low		Low		Medium		High			Very High
Public Participation and Accountability	**Level of awareness and use by non-governmental organizations and individuals**											
Metrics	Proportion of public information accessible online	0	10	20	30	40	50	60	70	80	90	100
	Percent of citizen transactions conducted via the Internet	0	10	20	30	40	50	60	70	80	90	100

Government Financial Value

Financial benefit (e.g., cost savings, cost avoidance) realized by the government, including financial benefits received by the managing or sponsor agency as well as other federal agencies

Government Financial Value		Normalized Scale										
Measure	**Description**	**0%**	**10%**	**20%**	**30%**	**40%**	**50%**	**60%**	**70%**	**80%**	**90%**	**100%**
Total Cost Savings	**This is the total savings the Government will achieve over current practices**											
Metrics	Total Cost Savings	0	10	20	30	40	50	60	70	80	90	100
Total Cost Avoidance	**This is the total cost avoided in the future.**											
Metrics	Total Cost Avoidance	0	10	20	30	40	50	60	70	80	90	100

Strategic/Political Value

Benefits that move an organization closer to achieving its strategic goals, the priorities established by the Executive Office of the President, and congressional mandates

Strategic/Political		Normalized Scale										
Measure	**Description**	**0%**	**10%**	**20%**	**30%**	**40%**	**50%**	**60%**	**70%**	**80%**	**90%**	**100%**
E-Gov support	**Initiative supports Federal (OMB) e-Gov Initiatives, President's e-Gov Strategy, and Quicksilver initiative. http://www.geo-one-stop.gov/ or similar initiative**											
Metrics	Supports e-Gov style initiative?	No										Yes
Close working relationships	**Initiative facilitates close working relationships between partnering departments and State/Local/Tribal governments**											

Strategic/Political							Normalized Scale					
Measure	**Description**	**0%**	**10%**	**20%**	**30%**	**40%**	**50%**	**60%**	**70%**	**80%**	**90%**	**100%**
Metrics	Data is able to be transmitted to other organizations without rework	Not Transmittable	Significant Rework				Moderate Rework					No Rework
	Number of active participants	None	Minimal-	Minimal	Minimal+	Some-	Some	Some+	Significant-	Significant	Significant+	Significant++
	Identifiable inter-agency initiatives or decisions	None	Very Low		Low		Medium			High		Very High
Supports NSDI	**Standards foster the development of NSDI**											
Metrics	Contributes to framework data	Not At All					Passively		Less Actively	Actively		Very Actively
	Consolidates/Aggregates framework data	Not At All					Passively		Less Actively	Actively		Very Actively
	Adheres to National Policies (FGDC)	Not At All					Passively		Less Actively	Actively		Very Actively
	Complies with Executive Orders, OMB reports, etc	Not At All					Passively		Less Actively	Actively		Very Actively
Supports improved decision making	**Initiative supports improved decision and policy making activities**											
Metrics	Supports internal mission decision making	Not At All	Marginally	Minimally-	Minimally	Minimally+	Somewhat-	Somewhat	Somewhat+	Less Effectively	Effectively	Very Effectively
	Responds to National decision making quickly and correctly	Not At All	Marginally	Minimally-	Minimally	Minimally+	Somewhat-	Somewhat	Somewhat+	Less Effectively	Effectively	Very Effectively
Mainstreaming of GIS technologies	**This is the "Map Quest effect": Standards enable GIS data/applications/technology to fit seamlessly into IT and other business tools.**											
Metrics	Facilitates use by non-GIS specialists	No										Yes

Strategic/Political		Normalized Scale										
Measure	**Description**	**0%**	**10%**	**20%**	**30%**	**40%**	**50%**	**60%**	**70%**	**80%**	**90%**	**100%**
	Takes "GIS Specialists" out of the workflow	No										Yes

Risks
Cost Overruns
Lost Information and Data
Hardware/Software Failure & Replacement
Project Size Over/under-estimated
Project Team and Oversight/Management Planning Not Structured Properly
Security Needs of Agencies May Not Be Fully Addressed by the GI Open Interface standards
Inadequate Allocation of PMO Staff & Time Requirements to Implement Standards
Inadequate Expertise of Agency Staff with Geospatial Interoperable Standards
Inadequate Estimation of Implementation Time
Poor Monitoring of Execution & Critical Path while implementing GI open standards
Absence of Federal Policy and Technological Standards for Artifacts and Registry/Repositories
Lack of Awareness of Geospatial Technologies Government-wide
Lack of Agency Executive Support and Long-term Leadership Due to Foundational/Fundamental Nature of Initiative
Agency Continuance of Stove-piped Individual GIS Efforts and Low Resultant Reuse of Data/Applications
Geospatial Data and GIS Applications in Use by Agencies Developed without Access to Geospatial Standards
Organizational Culture in Agencies is Resistant to Adoption of Federal Specifications, Standards and Wider Adoption of Geospatial Standards
Existing Standards May Not be Scalable to Support Future Interoperable Technologies
Efficiency Gains Realized Only if Data Standards are Accompanied by Application Standards
Uncertain Long-term Funding Needed for Upgrades and to Support Standardization and Coordination Efforts
Cross-Agency Nature of Efforts Will Complicate Consensus-Building on Technical Specifications and Overall Coordination of Registry Activities
Sustainable Configuration Management Methods not tied to Standards Update Cycle
Life Cycle Costs Risk Associated with Mis-estimating Life-Cycle Costs and Exceeding Forecasts;
Reliance on a Small Number of Vendors Without Sufficient Cost Controls.

Risks
Risk Associated with Choosing an Investment that Depends on Other Technologies or Applications that Require Future Procurements to be From a Particular Vendor or Supplier.
Risk associated with the immaturity of standards-based technology; risk of technical problems/failures with applications and their ability to provide planned and desired technical functionality
Risk that the proposed alternative fails to result in process efficiencies and streamlining; risk that business goals of the program or initiative will not be achieved; and risk that the program effectiveness targeted by the project will not be achieved.
Risk Associated with Strategic/Government-wide Goals (i.e., President's Management Agenda (PMA) and e-Gov Initiative Goals) and Risk that the Proposed Alternative Fails to Result in the Achievement of These Goals or in Making Contributions to Them.
Unanticipated Effects of Applications not Working Well Together
Unforeseen Lack of Interoperability Between Different Standards
Isolation if Standards Take Hold and the Organization Does not Adopt and Implement
Concern that a Given Technology Will not Achieve its Potential, and the Ramifications to Downstream Users if This Occurs

Appendix D VMM Results

Table D-1. Direct User Benefits Results

	Value Factors & Benefits	Weight	CASE STUDY 1 Weighted Score	CASE STUDY 1 Risk Adj Wgt Score	CASE STUDY 2 Weighted Score	CASE STUDY 2 Risk Adj Wgt Score
1	**Direct User**	**26.5%**	**22.7**	**19.6**	**11.8**	**10.3**
1.1	Ease of Use	9.8%	8.1	7.0	5.1	4.5
1.2	Broad Data Sharing Capabilities	6.6%	5.1	4.4	2.6	2.3
1.3	Data Availability and Accessibility	10.1%	9.6	8.2	4.0	3.5

Case 1 received 19.6 out of a possible 26.5 possible points for this category. The area of concern with this case was ease of use.

Table D-2. Social Value Results

	Value Factors & Benefits	Weight	CASE STUDY 1 Weighted Score	CASE STUDY 1 Risk Adj Wgt Score	CASE STUDY 2 Weighted Score	CASE STUDY 2 Risk Adj Wgt Score
2	**Social Value**	**28.7%**	**26.9**	**23.1**	**17.6**	**15.3**
2.1	Institutional Effectiveness	5.7%	5.1	4.4	4.0	3.5
2.2	Efficient Use of Tax Payer Resources	3.7%	3.7	3.2	3.4	3.0
2.3	Minimal Barriers Exist to Finding and Obtaining Data	5.7%	5.5	4.7	3.2	2.7
2.4	Citizens Are Able to Make Better Decisions	7.7%	7.5	6.4	3.6	3.1
2.5	Extra-Governmental Coordination	5.7%	5.2	4.4	3.3	2.9

Case 1 received 23.1 out of a possible 28.7 points. Case 1's initial design focused on serving both its direct user and the larger community as a whole. While interviewing Case 1, they expressly kept the larger community's long-term interest in mind.

Table D-3. Government Operational/Foundational Results

	Value Factors & Benefits	Weight	CASE STUDY 1 Weighted Score	CASE STUDY 1 Risk Adj Wgt Score	CASE STUDY 2 Weighted Score	CASE STUDY 2 Risk Adj Wgt Score
3	**Government Foundation/Operational**	**24.4%**	**19.6**	**16.8**	**14.9**	**13.0**
3.1	Intragovernmental Collaboration	4.1%	3.1	2.7	3.1	2.7
3.2	Mainstreaming of GIS Technology	2.7%	2.7	2.3	2.2	1.9
3.3	Interagency Collaboration	3.4%	2.8	2.4	2.4	2.1
3.4	Reuse, Adaptation, and Consolidation	3.4%	3.4	2.9	3.0	2.6
3.5	Public Participation and Accountability	3.7%	2.4	2.0	1.6	1.4
3.6	Ease of Integration	5.6%	4.0	3.5	2.2	2.0
3.7	IT Performance	1.5%	1.1	0.9	0.3	0.3

Table D-4. Strategic/Political Value Results

			CASE STUDY 1		CASE STUDY 2	
	Value Factors & Benefits	Weight	Weighted Score	Risk Adj Wgt Score	Weighted Score	Risk Adj Wgt Score
4	**Strategic/Political Value**	**8.8%**	**7.9**	**6.8**	**4.3**	**3.7**
4.1	Supports Improved Decision Making	2.6%	2.4	2.0	1.3	1.1
4.2	Supports NSDI	2.5%	2.1	1.8	1.7	1.5
4.3	Close Working Relationships	2.6%	2.3	2.0	0.7	0.6
4.4	e-Gov Support	1.1%	1.1	0.9	1.5	0.5

Table D-5. Government Financial Results

			CASE STUDY 1		CASE STUDY 2	
	Value Factors & Benefits	Weight	Weighted Score	Risk Adj Wgt Score	Weighted Score	Risk Adj Wgt Score
5	**Government Financial**	**11.6%**	**7.0**	**6.0**	**4.9**	**4.3**
5.1	Total Cost Savings	7.2%	4.3	3.7	3.6	3.1
5.2	Total Cost Avoided	4.4%	2.6	2.3	1.3	1.2
	Total		**84.0**	**72.3**	**53.5**	**46.5**

Appendix E Background on the Prisoner's Dilemma

Note: This material is taken from http://en.wikipedia.org/wiki/Prisoner's_dilemma and reproduced here under terms of the GNU Free Documentation License described here: http://en.wikipedia.org/wiki/Wikipedia:Text_of_the_GNU_Free_Documentation_License.

The classical prisoner's dilemma (PD) is as follows:

> Two suspects, you and another person, are arrested by the police. The police have insufficient evidence for a conviction, and having separated the both of you, visit each of you and offer the same deal: if you confess and your accomplice remains silent, he gets the full 10-year sentence and you go free. If he confesses and you remain silent, you get the full 10-year sentence and he goes free. If you both stay silent, all they can do is give you both 6 months for a minor charge. If you both confess, you each get 2 years.

It can be summarized thus:

	You Deny	You Confess
He Denies	Both serve six months	He serves ten years; you go free
He Confesses	He goes free; you serve ten years	Both serve two years

Let's assume both prisoners are completely selfish and their only goal is to minimize their own jail terms. As a prisoner you have two options: to cooperate with your accomplice and stay quiet, or to betray your accomplice and confess. The outcome of each choice depends on the choice of your accomplice; unfortunately, however, you don't know the choice of your accomplice. Even if you were able to talk to him, you couldn't be sure whether to trust him.

If you expect your accomplice will choose to cooperate and stay quiet, the optimal choice for you would be to confess, as this means you get to go free immediately, while your accomplice lingers in jail for 10 years. If you expect your accomplice will choose to confess, your best choice is to confess as well, since then at least you can be spared the full 10 years serving time and have to sit out 2 years, while your accomplice does the same. If however you both decide to cooperate and stay quiet, you would both be able to get out in 6 months.

Confessing is a dominant strategy for both players. No matter what the other player's choice is, you can always reduce your sentence by confessing. Unfortunately for the prisoners, this leads to a poor outcome where both confess and both get heavy jail sentences. This is the core of the dilemma.

If reasoned from the perspective of the optimal interest of the group (of two prisoners), the correct outcome would be for both prisoners to cooperate with each other, as this would reduce the total jail time served by the group to one year total. Any other decision would be worse for the two prisoners considered together. However by each following their selfish interests, the two prisoners each receive a lengthy sentence.

If you had an opportunity to punish the other player for confessing, then a cooperative outcome could be sustained. The iterated form of this game (discussed below) presents an opportunity for such punishment. In that game, if your accomplice cheats by confessing this time, you can punish him by cheating next time yourself. Thus, the iterated game builds in an opportunity for punishment absent in the classic one-period game.

Appendix F Background on the Economic Theoretical Basis for Technology Standards

GIS buyers and suppliers, at this stage of the standards adoption cycle, determine whether or not to adopt OGC or similar standards. Some of the questions they will need to ask themselves include the following:

- What is the cost to adopting at this time?
- What is the cost to not adopting at this time?
- If I adopt this standard, what will be the cost to me if a competing standard emerges?
- How many of the organizations that I coordinate with are going to adopt this standard?
- How is selecting the standard in question going to affect my legacy data/applications?
- What partnerships/alliances have formed outside of OGC/ISO/FGDC to promote standards?

A company that adopts a "losing" standard must either pay the cost to switch to the dominant standard, or limit their level of interconnectivity with others who chose the dominant standard.

Additionally, the "dominant" standard may in fact not be the technologically superior standard. At this point in the development of geospatial standards, the real question is whether to adopt either open, interoperable standards or to adopt proprietary *de facto* standard. De facto "standards" are not standards in the sense that a standards-making body sponsors them. Rather, these are conventions that either due to lack of official standard or through weight of software market penetration become a routine way of doing things because it is convenient for operators of like systems to do so.

One of the major reasons to compete to become a standard in a given industry is the dominant market position the "winning" standard will achieve. However, in competing for this dominate position, competing firms consume some part of the eventual gains. This situation occurs because potential consumers sit on the sidelines waiting for a dominant position to emerge. Each potential consumer is waiting to see what all of the other consumers are going to decide before making a purchase. If enough consumers postpone purchasing decisions, the dominant standard may take a considerable amount of time to emerge. Additionally, providers of the technology who have not committed to a given standard are likewise going to wait out the competition before developing products reliant on the given set of standards.

One way to avoid this prolonged competition over standards is for the firms in a given market to agree upon a given standard early in the process. This changes the arena where firms compete: instead of competing over standards, which negatively impacts both firms and consumers, the firms could compete on product features and functionality, service offerings, and ultimately on price.

To see why competing over differing standards has a negative impact on all firms playing, consider Game Theory's "dollar auction" example. The rules of a dollar auction are straight forward:

1. A $1 bill is being auctioned off, with opening bids starting at $0.00.
2. The winning bid gets the $1, and the 2nd highest bidder must pay their losing bid to the auctioneer and receives nothing in return.
3. There must be at least two "players" bidding on the dollar.

At first glance, this may seem to be an attractive offer. Suppose there are 2 players, Player A and Player B. Player A bids $0.01 initially, and Player B bids $0.05. At this point, if Player A doesn't counter-offer, he loses only $0.01, and Player B makes $0.95 profit. Therefore Player A will counter-offer. This offer/counter-offer arrangement will continue until Player A bids $0.99 after Player B has bid $0.98. At this point, Player A's profit would be only $0.01, and Player B is facing the loss of $0.98. Player B has little option but to bid $1.00 to receive $1.00. Player A is now in a poor position: without a counter offer, Player A is going to lose $0.99. Player A's options are to either lose the $0.99, or bid $1.01 and lose only $0.01. Once this occurs, both players face losses of varying magnitude. Two solutions to avoiding this outcome include not bidding at all (waiting for a standard to emerge externally) and creating a coalition to bid just once (have the firms in question decide between themselves what the standard should be).

The dollar auction represents the competition over standards in many ways. While firms do not "bid" on winning, they do invest resources to ensure their standard wins. The more resources different firms invest on becoming the dominant standard, the more they stand to lose if their standard doesn't become dominant. Organizations without the recourses to compete in a prolonged standards war would adopt an externally defined standard and invest its resources in ensure their selected standard became dominant. The fear of entering into a "dollar auction" over the dominant standard should entice firms to agree upon a standard early in the process.

The longer the market takes to determine a standard, the more expensive it will be for firms operating within that market. The more expensive this competition becomes, the greater the tendency for firms to cooperate at the beginning. The difficulty with this reasoning is that it is difficult for individual firms to determine how expensive or how long it will take the market to determine the dominant standard. Nor are companies willing to cede control of such an important aspect of their market early in a competition.

Factors that affect the emergence of a dominant standard include the following:

1. Control over and size of installed user base

Customers locked into the current technology are generally reluctant to switch to a competing technology. Markets with high levels of industry concentration are likely to be slow to switch to a new standard. In the GIS market, there is less industry concentration. While major firms such exist in the market, they do not control more than 50% of the market by individually.

2. Ownership of intellectual property rights

If an individual firm had complete control of a radical new technology, it would be in a good position to capitalize on that technology. In the GIS domain, however, the competition exists between multiple vendor-defined formats and an open standard. The open standard is loosely controlled, which lowers barriers to entry into this market for new software and application (and data) providers.

3. Capability to innovate

A firm with a reputation for innovative new technologies would be in a strong position to define a new standard. With respect to open standards, one draw back is the "design by committee" concerns end users may have. If the OGC develops a reputation for delaying decisions, consumers may defect to a proprietary solution that solves their immediate business problems sooner rather than later. One way for OGC to avoid this is to ensure that there are scheduled, marginal releases. It would be better for OGC to solve 80% of the solution quickly than 100% of the solution later on.

4. First mover advantages

While there is some debate about the true nature of "first mover advantages," firms or organizations that already are competing in a market do have some natural advantages. Organizations already in a market are both farther down the learning curve than new entrants, as well as having established sales and distribution methods.

5. Manufacturing capabilities

The manufacturing capabilities in question in the GIS software market include a company's ability to create, verify, and ship new software. Larger, more well established software providers will profit from having developers, quality assurance, and distribution in place.

6. Strength in complements

A unified, open, interoperable GIS standard would be a strong complement in the GIS software market. Essentially, if all software and data providers agreed upon this standard, everyone would become a complement for everyone else. This would increase the value of data, however it would potentially lower the value of individual software applications.

7. Brand name/reputation

Having a well-established brand name or a good reputation in a networked environment reassures consumers that the company in question will endure. When selecting between a known commodity with a proven track record and a start up organization, many consumers will value the assurance provided by the brand name over the potential benefits derived from advances promised by the start up. Brand names and reputations are a company's assets, and need to be supported and nurtured or they can quickly disappear.

8. Presence of large customers

Additionally, large customers play a role in the selection of standards. If the U.S. government could coordinate all purchasing decisions throughout the federal, state, and local levels, it would be a major force in the selection of a given standard. This activity would take a high level of coordinating, and there are costs involved in that coordination.

How does standardization benefit consumers?

There are a number of general reasons that standardization benefits consumers. The primary reason is the presence of network externalities, which occurs when a given consumer benefits when other consumers participate in the network by using the same set of standards. There is a "market mediated" effect, which occurs when complementary goods and services (add-on applications, data, etc) become cheaper because of the growth of the market. Ultimately, the consumer benefits from standardization by having a broader selection of applications and data, and the resulting price competition by software and data providers.

Why would consumers not want to jump on the bandwagon?

In any networked technology market, there will always exist some group of end users who opt out of using the dominant standard. One reason for this is the existence of a non-dominant standard that offers either a higher level of technology or a more appropriate level of technology. Examples of this can be seen in the Betamax/VHS rivalry. It was widely acknowledged that Betamax had a superior technology, however VHS became the dominant standard. In this market, Betamax was driven out of the market entirely. A more relevant example is the continued existence of Apple. Apple users feel that they have a technical edge on Windows-based operating systems. Additionally, the Unix environment still exists to server a very small, but resilient, market of high end scientists and researchers, as well as other "power users" such as computer graphics.

An example of the long-term presence of a non-dominant standard is the existence of Apple in the PC marke . Today, Apple users are confident that The Apple Company and third party Apple suppliers will exist into the future. If Apple users believed that they would run out of future options along the Apple path, such as if Apple were to go out of business, they would quickly jump ship to Windows to avoid exorbitant switching costs in the future. Additionally, companies may actively choose to remain outside of the dominant standard to protect their market share. (think about what would happen to Apple if it became compatible with Windows).

The downside of standardization includes the following:

- Reduction in the number of versions of a product/application
- Locked into a standard prevents switching to a superior technology
- Standards limit the possible scope of future innovation. Firms may be reluctant to pursue a given line of R&D if it is thought that this research may not be compatible with the dominant standard. This may be easily overcome by technology, but is one reason that some firms and consumers are reluctant to adopt standards.

Additional questions:

1. What happens to both firms and consumers switching costs over time?
2. What is the cost to switch for a given firm? For the whole industry?
3. Is switching permanent? Reversible? Exclusive?
4. If the standard doesn't "take hold," what are the costs to switching back to proprietary forms? What other impacts would there be?
5. Are there software companies that are going to actively avoid standardization?
6. Consumers already using shape files enjoy some measure of compatibility with other consumers. Assuming there is a consumer who is using 100% shape files, and has 100% compatibility with all of its direct suppliers and customers. What benefits will this consumer enjoy by switching to open standards?
7. Are there consumers sitting on the sidelines waiting for open, interoperable standards to be developed before they enter the GIS market?
8. Are there firms waiting for open standards to be developed in order to develop applications?

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