SDI 3.0 – Transforming Government

by
Mark Sorensen, Joseph Abdo, Unni Krishnan,
The GPC Group

The term "spatial data infrastructure (SDI)" has been around for nearly two decades now, and many of the underlying principles have been around for even longer. While the formal definitions have not changed substantially with time, there is a growing number of converging forces that suggest we are approaching a new era that could fundamentally reposition SDI from a framework for sharing information and applications services, to a new way of looking at governance and public engagement. These trends are happening worldwide in both developed and developing countries, and today there are more opportunities than ever to configure emerging technologies and respond to perspectives about democracy, societal sustainability and resilience in ways that matter most, if we have the institutional awareness, leadership, and foresight to do so. This talk will present a summary of "on the ground" experiences in implementing SDI 1.0 and 2.0 in the Middle East and beyond, and thoughts about the trends, opportunities and innovations that are pointing towards SDI 3.0 and possible new dimensions of "GeoMaturity" and "GeoDesign" in society.

Geographic Information System (GIS) technology is commonly described as a computerized system for the compilation, access, retrieval, analysis and display of geographic and geographic-related data. Modern GIS is much more than computerized mapping – with the right technical and institutional frameworks it can provide a multi-sector, interdisciplinary, regional information infrastructure for bringing all manner of data together geographically to support integrated and multi-sector decision-making, strengthen the ability of diverse interests to better understand complex natural and socioeconomic systems and the interactions among them. This infrastructure will ultimately help to develop more sustainable and resilient communities, support wise management of resources and aid in the conservation of cultural and natural heritage.

A Spatial Data Infrastructure (SDI) incorporates GIS and further facilitates the development of a multi-scale, shared information environment that is analogous to other public-benefit infrastructure such as roads, utility networks and other physical infrastructure. While GIS is a technology and a science, an SDI adds the institutional and governance elements that are necessary for effective and reliable information sharing and coordination across traditional administrative and political boundaries. Technology provides the technical framework for information sharing, but much of that is often already under development for other more generic purposes such as the computerization of government organizations and the expansion of telecommunications networks in support of economic development and security. SDI leverages

those investments to reduce redundancy, reduce costs of GIS adoption, leverage the investment in geospatial and related data sources, and build channels of coordination laterally across sectors in ways that might otherwise not exist. It also introduces policy and regulatory mechanisms to encourage transparency and community participation while also protecting sovereign prerogative, security, privacy, and intellectual property rights. With the virtual explosion of mechanisms for the collection and proliferation of information from a wide and diverse field of connected and potentially connected sources from location aware mobile phones, smart infrastructure and buildings, information collecting vehicles, fixed monitoring stations, security apparatus and all manner of "sense networks", many of which are not governed or controlled by any central authority, the field is wide open in terms of how these networks may impact governments and vice versus.

The GPC Group has been involved in a wide variety of SDI and "federated GIS" development efforts over the past 17 years. These have involved communities of interest that have been either geographically based (communities, countries, regions), topical (water resources, biodiversity), or institutional (World Bank, World Health Organisation). Where once these communities measured the success of an SDI development effort in terms of the number of stakeholders served and the amount and quality of authoritative and well-documented data available, we have seen a shift in more recent years towards additional demand for application services and ultimately for proof of demonstrable, measurable and compelling impact on policies, decision making and operations on the groundThese "demand side" expectations bring with them a need to address institutional issues, opportunities and constraints that if not addressed can seriously constrain successful outcomes of an SDI initiative, even when the most elegant technical solution has been implemented. Resolving these institutional factors requires significantly different techniques and skillsets from "supply side" technical infrastructure matters, where much of the legacy SDI attention has been focused in the past.

Most of our SDI work at GPC has been in supporting governments to initiate, plan and develop their programs. We have always looked to leverage SDI international sound practices as experienced through our own practice with different nations or experiences shared by others through the Global Spatial Data Infrastructure Association (GSDI), the Open Geospatial Consortium (OGC), Group on Earth Observations (GEO), the Eye On Earth Summit Gobal Network of Networks Special Initiative, and other such venues. We have found it necessary to shape principles learned from international experience to fit the special circumstances and priorities of each new context. Both in our practice and more generally in the field, the scope and profile of programs has evolved significantly. Major drivers for this evolution include adaptation in response to new technology opportunities and trends, as well as increased access that has resulted from greater awareness among government leaders and managers of the potential application of SDI to substantively improving government services andeffectiveness. In parallel there has been a maturing of institutional mechanisms for more effectively leveraging SDI to address major societal issues. This has coincided with a growing recognition that most if not all societal and environmental problems that we face are symptoms of underlying dynamics that cannot be isolated nor treated effectively as separate "sectors", and that more holistic and systemic policies and coordinated interventions are required to achieve effective and sustainable solutions. This latter issue is a very major challenge, given that most of our educational and

professional systems are built around sector specializations and there are precious few mechanisms for interdisciplinary engagement at the technical level in most governments.

In our own practice we have experienced directly or observed through our engagement with others in the international GIS and SDI communities, two major cycles of SDI evolution, and we see clear signs of a third in front of us now. We have started calling these SDI 1.0, 2.0 and 3.0, with a nod to the equivalent evolutionary stages that have been used to characterize the development of the world wide web. In many cases the development of SDI for a particular context often follows a similar sequence. The major distinctions and events that we have noticed among these cycles is detailed in Attachment A to this document, and summarized as follows:

> ***SDI 1.0 - Foundation***. Official recognition of SDI as a formal mechanism for sharing information across government is established in the form of a decree or official charter. Emphasis is on data sharing and metadata, with an initial focus primarily on national, large scale information and the needs of national agencies. Selected groups of federal or primary stakeholders are required to participate, while others may have an option to follow or participate as a second tier "observer". The essential governance structure of executive and technical committees are put into place, and working groups may be formulated from these bodies from time to time to address particular issues, such as data standards. A basic GeoPortal and supporting data clearinghouse environment is established as an initial common repository for use by the community inclusive of some level of metadata documentation, but not all fundamental data requirements are covered and there are ongoing projects that need to be aligned to ensure government investment can fill the gaps in an efficient and coordinated manner. During this stage, data custodians begin the process of periodically updating the clearinghouse data with "snapshots" of their information which may or may not be updated transactionally.
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> ***SDI 2.0 - Institutionalization***. In the second generation of SDI, enterprise GIS at the entity level is optimized in all the key stakeholder organizations and additional emphasis is placed on the provision of application services within the community (SDI Convergence Research, Emerging Trends, and Critical Assessment, van Loenen, B., Besemer, J.W.J., Zevenbergen, J.A., Eds.). The Data clearinghouse and associated Service Level Agreements (SLA's) and licensing governing the dissemination and use restrictions on all data topics is in place, along with all the appropriate security measures. The breadth of the stakeholder community is widened to include users who are not primary data providers, and there is often more official engagement with government stakeholders beyond federal agencies and including institutional, private and civil society sector actors. Working groups continue to be formulated as needed to address particular subjects as they arise, and Special Interest Groups (SIG's) are initiated as sub-communities of practice for ongoing coordination within particular sectors such as "Utilities", "Environment", or "Safety and Security". All fundamental geospatial data sets are being maintained through business transactions within the custodian agencies, thus the data is as accurate and up to date as needed to support community needs. In this stage application services are added to provide the stakeholder community with common functional modules that can be used directly or embedded within a stakeholder's own application software. At this point, at a minimum there is at least passive improvement in coordination across government entities because each agency

becomes aware of what others are doing through their data. Ideally in this stage agencies are starting to take more active advantage of the coordination potential.

SDI 3.0 - Transformation. The third stage of evolution is largely hypothetical at this time, based on a projection of current trends into the future. In this stage, enterprise GIS is fully developed within all the key stakeholder organization, all fundamental data is being updated on a regular basis, and a central facility has been developed and stabilized at a level that is sufficient to continue to facilitate, promote and support the SDI program. With comprehensive and authoritative data now available, advanced decision support systems can be developed in a manner that supports more systemic issue and trend analysis, policy making and coordinated interventions in all sectors, however doing so requires parallel development of "spatial thinking" in the perspective, methods and tools by which decisions and policies are made. Special Interest Groups in key sectors would have their mandate broadened to provide a mechanism for better general coordination within and across sectors. Convergence of telecommunications, location based services, mobile computing, , sensing networks, volunteered geographic information from citizens and a growing field of intelligent infrastructure technologies all provide a rich and diverse information environment that can be tapped into with new tools and techniques for deriving useful results. This environment also provides a basis for establishing and multiple channels of two-way engagement with the public, private sector enterprises, institutional and civil society sectors in a manner that will likely transform how government actually functions. Through such a massively connected and dynamic information environment it should be possible to identify environmental and socioeconomic trends and their multiple causative factors and interdependent issues far enough in advance to initiate the coordinated interventions needed to avoid problems and take advantage of opportunities, thus strengthening the basis for the elusive community sustainability and resilience characteristics.

What Does This Look Like On the Ground? The above is an abstraction of the actual conditions we have been experiencing on the ground in our SDI implementation practice. The following provides a more concrete characterization of each phase that is an amalgamation of our actual experience, much of which has been in the Middle East and North Africa (MENA) region. These examples are a montage of our experience and not based on any single situation, but specific references are provided where these help to substantiate a principle.

<u>SDI 1.0 – Foundation</u>. The diagram below represents the starting point we have experienced with most SDI implementation programs. This assumes a mandate for SDI development has been issued from above, and that selected government entities have been selected to participate in the inaugural activity. This may be preceded by another stage whereby such mandate is actually established, but this is another paper in itself.

In early 2005 the Abu Dhabi Executive Council (ADEC) ordered the formation of a Committee to oversee the development of a Spatial Data Management Centre (SDMC) to promote and support the development of an Abu Dhabi Spatial Data Infrastructure (ADSDI). The issue was then introduced as a charter within the eGovernment program mandate in 2006, under the administration of the Abu Dhabi Systems and Information Centre (ADSIC). Eight government

entities were chosen to participate directly in the first phase of SDI development starting in 2007. The first 6 months were spent assessing the existing situation and in the development of a comprehensive AD-SDI master plan, GeoPortal, and prototype data clearinghouse. This project, and especially the GeoPortal, attracted the attention and imagination of the Emirate's executive leadership, and support for the 2nd phase of program development.

In Libya, a 2005 project initiated by the General Post and Telecommunications Company (GPTC) engaged 17 agencies and institutions in the development of a Libya Spatial Data Infrastructure (LSDI) master plan, inclusive of an initial GeoPortal, a demonstration data clearinghouse, and a proposed national charter. The new Libyan Interim Government is now exploring the renewal of that initiative as a component of a more broadly define "eLibya" program.

In Afghanistan, the President issued a decree establishing the Afghanistan Spatial Data Infrastructure (ASDI) in 2009. This was the culmination of preparatory work by the Afghanistan Geodesy and Cartographic Head Office (AGCHO – the Afghan National Mapping Organization) supported by USAID and the USGS that involved workshops and meetings with high officials to both gain the support of the community and to establish the executive sponsorship that eventually led to the decree. While the decree has been in place, establishing the funding for initial SDI development has been a challenge due. This can partly be attributed to the manner in which most internal and external funding and technical assistance sources are focused on specific sectors, as well as continued security issues.

In Iraq, the significance of SDI was recognized in 2010 as an issue worthy of national attention and a program was initiated within the Prime Minister's office to explore the development of an Iraq SDI. Orientation workshops supported by the USGS were held in Erbil in 2011, and the Ministry of Planning has been assigned to develop an initial GIS Center to support the initiative.

Figure 1 – Initial stakeholder community

All of the above examples represent top-down initiatives that were instigated by aware, influential individuals. Each included processes by which building community awareness and support was a prerequisite for recognition and support by national leadership. In many cases, although the participants have agreed to play their part, there is usually no existing mechanism for multi-agency participation in a coordinated effort, so a great deal of effort must be expended to establish and sustain a working relationship and a common sense of ownership of the initiative among these disparate groups. There is usually a lack of trust among the participants who often must be convinced that participation does not mean giving up any of their administrative territory

or control of their information. The level of computing infrastructure, GIS, and SDI awareness among the participants has beenquite varied, representing a challenge in allowing progressive and more developed entities to excel, while supporting lesser developed agencies in starting along the path towards enterprise computing and GIS.

The above issues are overcome by establishing a program governance structure from the beginning that has top-down endorsement, is coordinated by a special entity with full time staff that is set up to facilitate, promote and support the initiative, and executive and technical representative committees to ensure entity participation, buy-in and support. This group works together over a year or two to assess the current situation, plan and build an initial foundation program. A master plan may be developed covering all these issues, inclusive but not limited to the following major elements:

- Orientation Seminar. Introduces all the key stakeholders to what is GIS, what is SDI, and how can they all benefit individually and collectively through this program. Who participates in what committee activities, and what level of involvement expected in each step of the work plan?
- Stakeholder Situation Survey. Involves stakeholder interviews and literature research to inventory and characterize the current situation in each participating entity. This covers the entire range of subjects from business processes, data used and generated, existing computing and human technical infrastructure capacities, administrative or other issues, opportunities and constraints, among other factors.
- SME Assessment. In some cases we have been asked to engage subject matter experts (SME's) in each of the government sectors involved (municipal, planning, national mapping, cadastral, etc.) to not only assess GIS requirements, but to look more generally at the level of development within each sector compared to sound practices internationally. This is often the case in situations where the economy is in transition such as a developing country looking to make rapid advancements or post-conflict situation where systems are being re-built from the ground up. In such cases, an integrated approach is taken to evaluate sectors individually as well as the interplay among them as the basis for sector development planning that then incorporates the SDI as an enabling environment to support institutional development and coordination.
- Data Inventory and Assessment. What existing data sources are currently available to support the information needs of the community? This is logically an element of the Requirements Analysis listed next, but is often broken out because it can be such a voluminous subject.
- Requirements Analysis. This addresses all the other requirements beyond basic data needs, including implications for existing business processes, common application functionality needs, policy and regulatory matters, financial implications, and other issues.
- Strategic Plan. The Strategic Plan considers the above matters and synthesizes a high level response, outlining the vision, mission, objectives and implementation approach for the nascent SDI program. This is important to get multi-level signoff on the basic guiding principles and priorities before expending substantial time and resources on more detailed planning and implementation activities.
- Program Alignment Strategy. Inevitably, there will be multiple projects already ongoing that have data redundancies, lack of standardization and otherwise represent government

investment that is not being optimized. Even if there is the authority to stop those projects to consider standardization, it usually more effective to find a way to nudge these initiatives to some practical level of alignment through a plan that seeks to minimize disruption while maximizing advantage to the government.

- Program Design. This document outlines all the business, technical and institutional framework components of the foundation program, thus articulating programmatic targets to be accomplished within the first 2-3 years of implementation. The plan may have a longer horizon up to 5 years, but anecdotal experience suggests this is a useful exercise in getting participants to think longer term, but the reality is almost always quite different based on events that were not anticipated.
- Implementation Plan. This plan lays out a well defined and practical approach for the implementation of the Program Design, including the definition of internal activities across the community along with associated interdependencies, specialized short term activities to be contracted out, tasks, outputs and resource requirements and budgetary figures.
- GeoPortal and Data Clearinghouse. A GeoPortal infrastructure may be introduced during the Data Inventory and Assessment activity as a mechanism for multiple stakeholders to be able to participate directly in the assessment. Beyond this initial purpose, the GeoPortal and initial data clearinghouse also provide a basis for demonstrating the significance of multiple data layers from multiple sources all available on the same platform, to management, leadership and others who can benefit from such exposure. Despite likely deficiencies in data accuracy, currency, standardization and other issues, this demonstration can be very effective in raising awareness and showing early progress beyond paper reports.
- Operations Plan. An Operations Plan lays out the structure, staffing, technical infrastructure and standard operating procedures to be followed in the establishment and initial operations of a technical coordination unit within the Initiative's secretariat function. Such unit provides a basic operational capacity to administer the data clearinghouse and to provide technical support and guidance to stakeholder entities planning to build or increase their own GIS capabilities for enterprise purposes.

During this phase, it is important to understand and reflect the dynamics and priorities of the government at large, beyond the most immediate requirements for GIS. This can provide valuable insights into how to best position the SDI to align with and be directly relevant to, and supportive of government priorities, especially in the framing of the Strategic Plan. In some cases, the SDI Stakeholder Assessment may be the first time that anybody has conducted a systematic evaluation of information flow through government, and this usually highlights current deficiencies and opportunities for improvement. It also helps to establish the SDI as an essential building block in accomplishing the government's vision and aspirations, thus further reinforcing the broader relevance of the initiative.

Beyond the strategic positioning of a first phase SDI, it is also important to demonstrate compelling benefits and "quick wins" along the way. A web-connected GeoPortal and initial data clearinghouse are a good start. In Abu Dhabi, the initial GeoPortal and data repository that were developed to support the Data Inventory and Assessment effort quickly became a powerful tool for illustrating the significance of the SDI to the Emirate's leadership. This repository

included over 140 layers of information from the 8 founding entities. None of this data was particularly up to date, standardized or highly accurate, but it was the first time the community and the leadership had seen all of this information together at one time. Demonstration of the GeoPortal ultimately had much more impact on the impression and understanding of key executives than all the strategic planning documents combined, and was thus key to gaining initial support for subsequent phases of development. However, it was also then critical to manage expectations, because the result of the data assessment indicated that there was a lot of work to be done before the information could be relied upon.

The publishing of basic common applications services for such things as mobile GIS can be implemented with out of the box functionality with good visibility and impact. Early on, in Abu Dhabi ADSIC provided mobile mapping services that could be consumed by any of the participating agencies and is now feeding several field inspection applications. Even basic web map services were an important early capability that was quickly picked up by the Education Council and the Health Department to support facility locator and operations center applications respectively.

It is also very important to maintain a proactive, responsive and interactive relationship with the community, agency managers and national leadership. The establishment and active maintenance of a website and online request for information hotline are often effective in this regard, as are holding regular meetings with the Executive and Technical committees. Likewise, providing immediate and helpful response to special VIP requests helps to gain and sustain executive leadership support. Provision for this sort of outreach and support needs to be built into the workplan, resource allocations and budgets of the foundation building phase to ensure that proactive response to the inevitable ad hoc requests does not compromise planned activities.

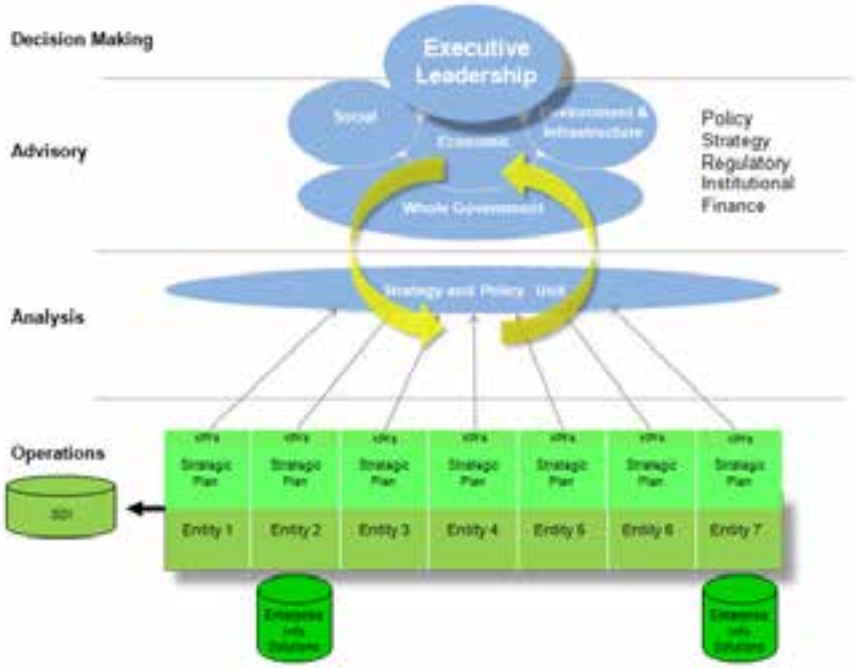

Figure 2 – Understanding the Broader Government Context

In Abu Dhabi, a stakeholder service desk was established early in the process to ensure that all inquiries and requests for information could be handled in a responsive manner. Regular meetings of the AD-SDI Technical Committee, comprising representatives from nearly 60 stakeholder entities, were held to both disseminate information and collect feedback. Over 20 Working Groups have been initiated over the past 5 years to address issues such as data standards and policies. A program website has been continuously maintained over the life of the program (http://sdi.abudhabi.ae/Sites/SDI/Navigation/EN/root.html), and members of the community have participated in several key international conferences and events, including three years attendance at the ESRI International User Conference, Global Spatial Data Infrastructure (GSDI) annual meetings and other such venues.

In Libya, representatives from 17 government organizations participated directly over a two year period in the development of a requirements analysis and master plan for the LSDI, including the development of an initial GeoPortal and website. Shortly before the 2011 revolution these resources disappeared from the web. Efforts are being undertaken now by the Deputy Prime Minister's Office and the Ministry of Telecommunications and Informatics to explore the re-establishment of the initiative, in recognition that an SDI and broader eLibya initiative can play a vital role in the reformulation of the government and national development planning efforts.

SDI 2.0 – Institutionalization. The first foundation stage has a limited shelf life, because there are many issues not yet resolved that will start to come to light when the aura of the new wears off and people begin to actually rely on the SDI information resources to do real work and make real decisions. Some SDI initiatives that had a strong initial push and attained the outward appearance of an intact initiative, then failed to follow through on the hard work of ingraining the principles and operational practices into the institutional fabric of the government. Some of these have not survived, or at best entered a state of functional stasis kept alive by some level of financial and political largesse.

Institutionalization is hard work, and not much of it has the kind of high visibility value that some ambitious pioneering adopters or the politically motivated crave. In acknowledgement of both the desire for immediate satisfaction and the need to strengthen foundations through what might appear to be a slow and cumbersome process, the initiatives that have made it to the second phase of evolution have addressed both. Care is taken to ensure that visible and compelling results are highlighted at every opportunity in the press, official reports, effective promotion of achievements among the community, visible participation in high profile events, awards, and membership and active participation in international forums and professional societies. However, the effects of such visibility campaigns are short lived if the SDI custodians and indeed all key members of the stakeholder community do not take care to build the core of standards, service level agreements, data licensing, geo-legal frameworks, active participation in working groups and special interest groups, and other community and core technical infrastructure strengthening activities that will strengthen and solidify the institutional base as a permanent fixture in government.

In Abu Dhabi, a major issue was the completion and standardization of geospatial data resources across the community. Several legacy projections and datums had been used by members of the

community, and there were no standard large scale base maps available. In addition, it was found that over 70 projects were already ongoing that involved the utilization and/or development of geospatial data, and none of these were coordinated with the others. Data and Program Alignment Strategies were developed in response to these issues, and a permanent function was established within the ADSIC Spatial Data Center (SDC) to work with the Secretariat of the Executive Council to ensure that all projects requesting budget through the Council that would either use or generate geospatial data would both take advantage of what is existing as well as develop new data according to standards that would allow this information to be used in the future beyond its original purpose. The SDC also worked with all three of Abu Dhabi's Municipalities to establish basemapping standards and a project monitoring program to ensure that highly accurate and standardized basemaps and high resolution orthophotography would be available to the community as soon as possible.

In Libya, the initial situation assessment identified major gaps in the area of national mapping, cadastre, development project tracking, land use planning, utility mapping and other activities, much of which were ongoing but with little or no coordination among them. Programs were defined to build databases and capacity in each key sector, and these were to be monitored by a Program Coordination Office (PCO). The PCO was only partially established prior to the revolution, and is now being re-explored.

Also critical in this phase is the development of enterprise GIS capabilities within all the key participating organizations, and especially those that are the custodians for data used by many others. For the institutionalization of SDI to be permanent, and for the government to gain maximum advantage from its GIS investments, it is critical that each of the participants achieves a level of enterprise GIS development that provides the best support possible in achieving the organization's own mission and purpose. Benefits from participation in the SDI will vary with each organization, but that benefit must be a close second to each organization being able to meet its own immediate needs. If SDI participation somehow compromises the ability to meet internal needs, participation is likely to be short-lived. In recognition of this, Abu Dhabi established a unique "GeoMaturity" program to measure and monitor the development of GIS capacity in each of the participation entities. The measurement index was developed in collaboration with international experts including a team from K.U. Leuven University in Belgium and other consultants from the U.S. and Canada. As part of the GeoMaturity program, the Abu Dhabi Executive Council issued a requirement for all Emirate government entities to develop a "GIS Roadmap" that would lay out a practical strategy and implementation plan for the optimization of GIS within each sector.

Deep institutionalization is more than just strong adoption program and use of GIS technology to do the same job better more efficiently. Ideally, it involves the development of a more intimate understanding of the mechanisms of government, and an incremental weaving of new perspectives, methods, tools and data into the system in a way that starts to transform those mechanisms. Sometimes technological advancements and proliferation result in "disruptive" change, as has been claimed in the contribution of internet, email and Facebook to what became known as the "Arab Spring". However, progressive governments around the world are learning to stay abreast of technological progress, and to take active steps to leverage new capabilities and

the increased connectivity and interactive nature of our global community towards solving pressing challenges facing us today.

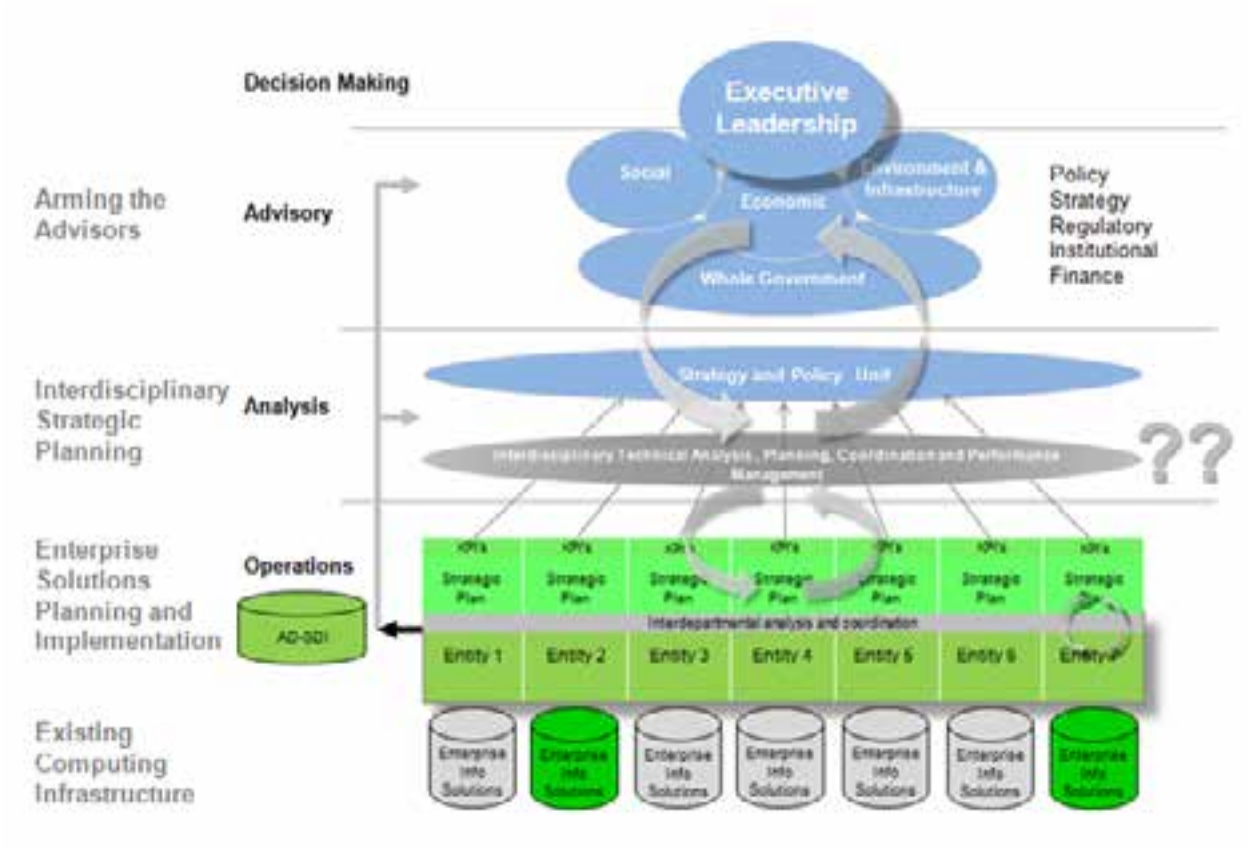

Figure 3 – Finding the Grey Areas - Governance Gap Analysis

Updating an SDI strategic plan in this second phase of evolution involves a more in-depth and holistic assessment of governance at its core, and the principles, practices and processes that result in changes to communities and ecosystems as a result. Such assessment needs to identify "grey areas" in government structure and operations that can be positively improved through the expansion, refinement and further evolution of the SDI, or through alignment with parallel process improvement actions that can be augmented with the SDI. This definition of SDI mandate may stray outside the bounds of classical definitions, but is important to acknowledge that if any initiative is to ultimately achieve the "demonstrable, measurable and compelling impact on policies, decision making and operations on the ground", these issues must be addressed. This approach to institutional structural matters also helps to position the initiative for true transformative impact in the third evolutionary phase discussed later.

In our experience, there are at least four levels of "grey areas" that seem to be present in most governments and that tend to impact the form and effectiveness of any SDI initiative:

> Existing Computing Infrastructure. At the most basic level, organizations that are to benefit from SDI need to have some level of computing competence and infrastructure. In an ideal situation, computing infrastructure is fully developed and adopted to meet most

operational needs, even if GIS is not yet well developed within the organization. Achieving this level of development in all the most critical agencies is a prerequisite to optimizing an SDI within the second phase level.

Enterprise Solutions Planning and Implementation. In governments that are intent on modernization, entities that have not fully implemented enterprise computing and GIS may be required to develop a plan to do so, and are held accountable for implementing the plan over a reasonable timeframe. Besides providing a plan to fulfill an important capacity development need, the development of this sort of roadmap will usually identify internal communication and coordination deficiencies within an Agency, and make provision for filling such gaps in the enterprise GIS/IS program design. One of the key outcomes of this process is to ensure that all updating of fundamental geospatial information is being carried out on a transactional basis, through the day to day operations of the assigned custodian. This helps to ensure that available information is as accurate and current as practical.

Interdisciplinary Strategic Planning. In the more progressive government structures, entities are required to develop strategic plans that identify sector priorities, define strategic initiatives to address those priorities and provide key performance indicators (KPI's) that can be used to monitor the progress and impacts of those initiatives. Unfortunately, most government planning is carried out internally by each entity, with little substantive engagement with other organizations that may share interdependencies that only become apparent when more holistic and systemic analysis of societal and environmental issues are conducted. Even when there is a high level policy and strategy function in place at the higher level of government, it may be staffed by sector specialists who may not have recognized structural interdependencies nor have a method or information to support cross-sector, systemic analysis and planning. A Phase 2 SDI can be instrumental in highlighting this issue, and demonstrating how interdisciplinary information can be used to be understand underlying contributing factors and providing a sound foundation for the definition of multi-sector, coordinated intervention strategies, the sector components of which can then be reflected in the individual strategic plans of the agencies. This also surfaces the need for "common KPI's" that require acknowledgment of the responsibility and accountability of multiple agencies in different sectors to solving a particular issue.

Arming the Advisors. In most cases, executive leadership makes decisions following the input of trusted advisors. In practice, the trusted advisors are trusted because they have specialized knowledge, unique experience, information and track record in addressing issues within their area of specialization. In reality, the advisors are subject to the same lack of current and accurate information as the rest of us, and much of their advice is based on anecdotal and experiential foundations. Political and philosophical biases will never be removed from this process, but the provision of authoritative, accurate and current information can be a strong force in leveling the playing field, and ensuring that the political debate is at least informed with good and mutually defensible information on either side of any position.

SDI 3.0 – Transformation. Most mature SDI efforts in the world today have passed the first phase of SDI evolution as characterized in this paper, and many are well along in the

development of the second. Today there are a few that are pioneering new territory into what may eventually become accepted as a third phase of SDI evolution, where a high level of GeoMaturity pervades government, spatial thinking and "GeoDesign" in holistic and systemic terms is adopted in the physical, policy and institutional planning functions at multiple levels, and geospatial dimensions are built into a broad engagement of government with all manner of publics, including private sector, research and education institutions, civil society and the general public. Crowd-sourcing and citizen-based science also offers further opportunities for further community engagement as part of the design and decision making process, while also complementing traditional geospatial data information through citizen feedback and monitoring.

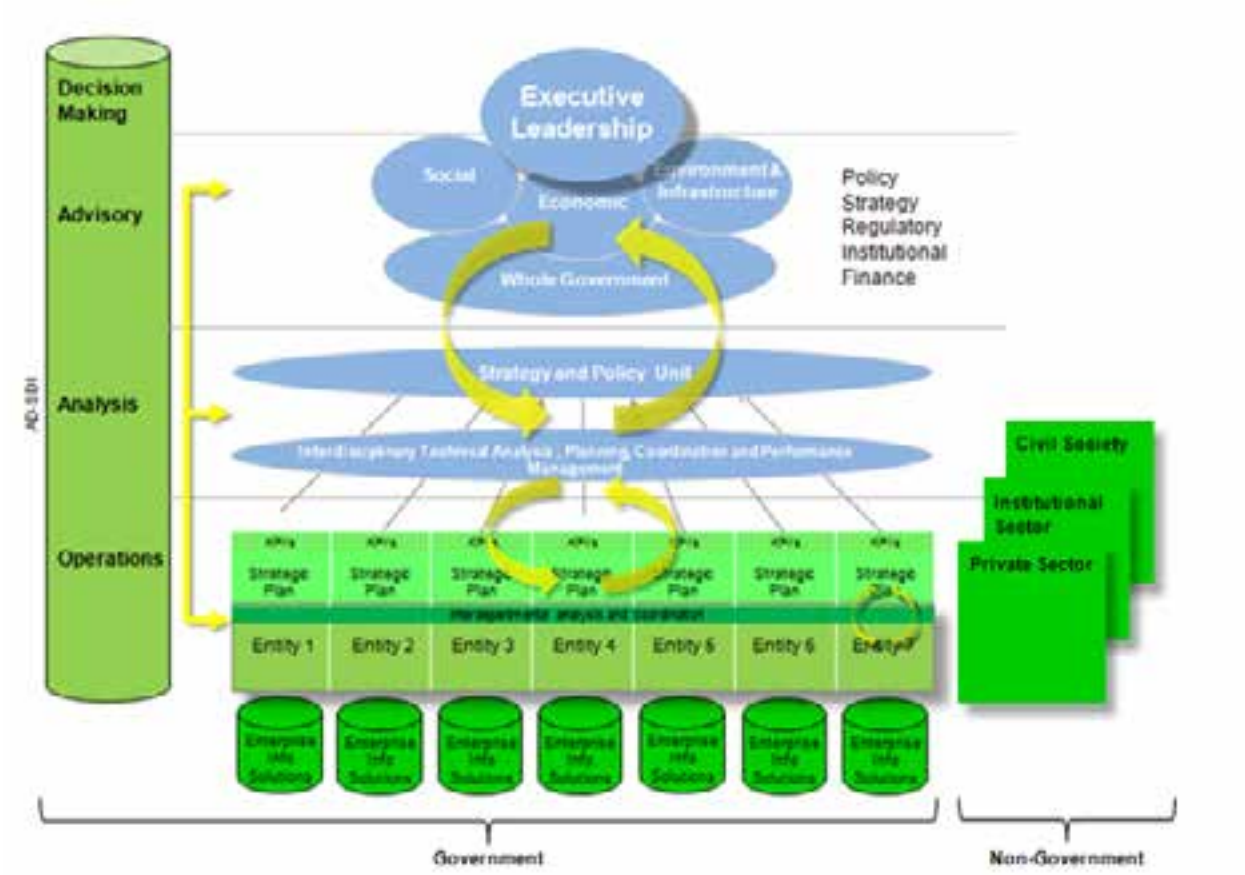

Figure 4 – Completing the Picture for Transformative SDI

The government of the Emirate of Abu Dhabi today is starting to explore this new horizon, including pursuing the implementation of an "Executive Dashboard" as one initial facet of a more broadly defined Decision Support System (DSS). ADSIC has been mandated by the Abu Dhabi Executive Council to promote and facilitate ICT development across Abu Dhabi society in and outside of government, and part of that has included the implementation of a new Public Call Center inclusive of a location based service for public reporting and complaint management. Discussions are ongoing with the Abu Dhabi Executive Council to explore how the SDI can be

leveraged to support the tracking and monitoring of the Emirate's substantial investments in infrastructure, and as a basis for performance assessment over time.

Although in its infancy, the interim government in Libya has promoted the notion of "eLibya" utilizing information technology, communications and SDI as key building blocks in a nation building process. The use of accurate and current information as the basis for prioritizing investment in social and physical infrastructure is seen as key to the success in moving the country forward.

Conclusions

Governments like Abu Dhabi that have the inspired leadership, resources and political will to explore new horizons to push the principles and practice of SDI beyond its traditional boundaries will likely provide some valuable lessons learned over the coming years. Others, like Libya, Afghanistan and Iraq have recognized the significance of SDI as an enabling environment for national development. Clearly the applications are broad and the implications are significant.

GIS, SDI and a wide range of emerging technologies are converging on new ways of thinking about government, its role, and its relationship with all segments of society, in different stages of development. However, there is no single discipline or profession that exists today that can claim it is the logical leader in determining how to best take advantage of these developments.

One may argue that the persons and organizations that have traditionally supported SDI development do not have the professional background and experience to guide such a transformative process, and should rather focus on establishing a solid infrastructure and let others tackle the macro societal and governance matters. This has some truth, but is must also be acknowledged that there are significant gaps and deficiencies in understanding geospatial information and thinking among the planning, strategy and policy making communities. Perhaps a new kind of organization that comprises an interdisciplinary team to facilitate engagement and integrated strategic planning across the government, inclusive of SDI is needed? There may be many viable models depending on the form and configuration of existing government and other factors, but it is clear we are on the cusp of a convergence of technologies and perspectives that are already changing the world around us, and it is up to us as "geospatial professionals" to help channel and shape that change towards solutions that matter.

"The best way to predict the future is to invent it." – Alan Curtis Kay.

Attachment A – Distinguishing Characteristics Between SDI Generations

Characteristic	***SDI 1.0***	***SDI 2.0***	***SDI 3.0***	***References and Current trends leading to SDI 3.0***
Period	1993 – 2002 decade	2003 – 2012 decade	2013 onwards	• GSDI Survey on the status of SDIs around the globe (Onsrud 1998) • GSDI cookbook (Nebert 2001) • INSPIRE directive entered into force on the 15 May 2007 On 16 September 2002, at the GSDI6 conference in Budapest, the GSDI working group on legal and economic aspects provided a global platform for the sharing of experiences and the discussion of the legal, economic, and organizational setting in which SDIs develop. The workshop discussed two country reports of SDIs that were well known for their advanced level of SDI development: the Netherlands and the United States.
Main goal	Reduce duplication of data	Spatially enable the government and provide applications services	Provide expanded location based services and expand to include interdisciplinary decision support systems, and broad information feeds to support eSociety	Location-based information supports a wide range of government, business, and public activities, and the use of this information has significant productivity-related benefits for the stakeholder organizations. Location-based information can be structured, stored or combined with other information resources in a variety of ways to answer many different questions related to "place." When location-based information is processed or integrated with other data to provide more descriptive spatial intelligence or analysis it becomes geospatial information and the data processed with it become geo-enabled. Location is often an important feature of many types of information that may not be considered as geospatial. For example: • Human resources systems capture, for each employee, the location of office buildings and rooms as well as home addresses, enabling optimal distribution of resources against a specific geography • Asset management systems generally identify where a piece of equipment is stored or used, enabling optimum utilization of assets from an enterprise perspective • Business performance reports often itemize results according to an organization's regions or jurisdictions, allowing for comparisons of performance between different organizational units and locations

				• Grants and funds to address specific community concerns are often distributed based on proximity to population centers or other relevant factors, maximizing the business utility of grants or funds to the population as a whole Geospatial information or geo-enabled data are used in a variety of business processes within any entity. This includes asset and personnel management, natural resources, environmental and health management, transportation, homeland security, intelligence, and defense. Some examples of geospatial information or geo-enabled data used for these business processes include property records, vehicle routes, species ranges, crime patterns, electronic health records, traffic congestion, utility networks, and hazardous waste management. A **spatially enabled eSociety** is an emerging concept to make spatial information accessible and available for the benefit of society. It is a concept where location, place, and other spatial information are available to government, companies, and citizens. It is the next evolution in the generational development and progression of SDI as it seeks to contribute to wider societal benefits and sustainable development objectives.
Infrastructure type	Centralised infra-structure	Decentralised infra-structure	Cloud-computing based infrastructure	Cloud computing may be new, but one thing hasn't changed: enterprise management's insistence on justifying IT investments by return on investment (ROI) and total cost of ownership (TCO). Therefore it is necessary to still weigh a solution's advantages and disadvantages as well as benefits and costs. In the geospatial arena, governments want their investments in spatial data to provide the greatest possible value to the citizens. Cloud computing efficiently leverages the investments that the government has made in the developments of service-oriented Spatial Data Infrastructure (SDI) and geospatial standards over the last decade. Governments of US, UK, Australia, Singapore as well as European Union have already established cloud computing strategies. Cloud spend in Europe is on the rise in 2011 and is anticipated to reach €5.9 billion by 2015 – and it's predicted that cloud computing could contribute over €760 billion to the major economies of the EU between 2010 and 2015. Cloud computing plays a key role in US President's initiative to modernize IT by identifying enterprise-wide common services and solutions and adopting a new cloud computing business model. The Federal CIO Council has established the Cloud Computing Initiative to fulfill the President's objectives for cloud computing. The Obama administration in December 2010 announced a "cloud first" policy, requiring

				agencies to use cloud services where possible for new IT requirements. The 2011 Federal Government Cloud Computing Survey shows lowering IT costs as the No. 1 business driver of cloud computing, mentioned by 62% of respondents. In the US the FGDC's redesigned **Geospatial Platform** (www.geoplatform.gov) provides shared and trusted geospatial data, services, and applications for use by government agencies, their partners, and the public. This platform is a managed portfolio of common geospatial data, services, and applications contributed to and administered by authoritative sources and hosted on a distributed, cloud-based infrastructure. ArcGIS Online (www.arcgis.com) portal deployed by Esri using the Portal for ArcGIS tool is a cloud based portal that offers geospatial data, applications, and services. The system is ready to use by anyone with no hardware or software to install or setup. All that is required to use ArcGIS Online is fast Internet connection and a web browser. A McKinsey & Company study estimates that carbon dioxide (CO2) emissions from data centers will quadruple to exceed emissions from the airline industry by 2020. Another study by Microsoft, Accenture, and WSP Environment & Energy shows significant potential for reducing energy and carbon emissions from Cloud Computing. The study finds that the smaller the organization the larger the benefit of switching to the cloud, with small organizations achieving 90 percent lower carbon emissions and large ones achieving 30 percent or more. Cloud computing may allow lesser developed communities to leapfrog the need for extensive local computing infrastructure by tapping into cloud based applications, information, communications and economic opportunities.

Data access	Clearinghouse helps users find information	Geoportal allows access to government and commercial data and services	Applications access data transparently. Diverse information feeds from multiple channels and sense networks, as well as volunteered information from the public.	The application systems developed using data from SDIs, instead of working in isolation, can be made to work with each other by integrating information across the systems to develop, what is called, a "system of systems" or "network of networks". The resulting solution can provide a unified view of events across systems and networks (i.e. agencies, departments, and services) enabling effective collaboration and communication to make smarter decisions. Adding sensors to systems allows for automation, where readings can trigger a series of events that allow the system to adapt to changing conditions. The adaptive and distributed nature of the sensor network ensures that the network will continue to collect and communicate information about a changing environment, regardless of sensor failures at individual locations. The fact that the sensors share and fuse information amongst them provides pre-validation for data so that it can be trusted and acted upon immediately. Sensor webs add real-time data into decision support systems, needed to meet the challenges of the future system of systems. Some indicators of the challenges ahead of us are (Source: IBM and Austin: Partners in a Smarter Planet, Brad McCredie, Vice President and IBM Fellow, April 2010): • 60 million people moving to cities each year • 59 cities with 5 million+ citizens by 2015 • 70% world population living in cities by 2050 • India's urbanization rate at 50% by 2030 • Equivalent of US population to join urban population in China by 2025 • $40+ trillion investment in urbanization in China (2005-2025) The next generation SDIs will have to rise to support such sophisticated applications of system of systems by accessing the required data through a whole new level of automation.

Nature of applications	Specialized desktop application s	Desktop, Mash-up, and web applications	Large no. of web and mobile applications enhanced with augmented reality	Just facilitating easy access to government data encourages development of innovative geospatial services and applications. Many governments are holding competitiond to bring the brightest software developers, engineers, designers, and technologists from around the world, who volunteer their time to apply their talents and work on issues of importance to the community. This has resulted in large number of innovative applications on web and smart phone platforms. Challenge.gov is an online challenge platform administered by the U.S. General Services Administration (GSA) that empowers the U.S. Government and the public to bring the best ideas and top talent to bear on the nation's most pressing challenges. This platform is the latest milestone in the Administration's commitment to use prizes and challenges to promote innovation. Challenge.gov facilitates the public and government together to solve problems by coming up with creative and innovative solutions. The public gets an opportunity help improve government by solving government's problems, as well as win prizes and recognition in the process. During the first quarter of 2010, Challenge.gov extended 57 challenges to the public from 27 executive agencies, resulting in novel solutions in the areas of childhood obesity, small business financing, preparing individuals for disasters, and management of type-one diabetes. In the United Kingdom, GeoVation is initiated, funded and managed by Ordnance Survey, Great Britain's national mapping agency. Through its GeoVation initiative Ordnance Survey encourages open collaboration in addressing communities' needs where geography is a key enabler. Through open innovation, data, tools and information can be combined to create new ventures which generate social and environmental value. As of 1 April 2011, through Ordnance Survey's Open Data License , the UK government is allowing all public bodies, free access even to the detailed MasterMap at 1:1,250 scale. From the OS OpenData site, anyone can download a wide range of Ordnance Survey mapping for free. NAVTEQ, through its Network for Developers (NN4D) empowers application developers with the knowledge, technical resources, support, and business development services to build and market location-aware apps for Web, mobile, automotive, GIS and enterprise markets worldwide. Every year Navteq asks the augmented reality (AR) community to vote across a selection of categories related to AR applications to find the best experiences of the year. There are literally hundreds of AR browsers available for the smart phones today.

Data content	Governme nt generated content	Government and industry generated content	• User generated content by crowd sourcing (e.g. Streetmap) • Real-time sensor inputs through automated sensor web systems	Volunteered Geographic Information (VGI), according to Goodchild , who coined the term, is the harnessing of tools to create, assemble, and disseminate geographic data provided voluntarily by individuals. Geospatial data provides such as Wikimapia, OpenStreetMap, Google Maps, Navteq, etc use this approach successfully to enhance their data. The idea of VGI or Crowd Sourcing centers on humans as sensors that voluntarily create, assemble, and disseminate geospatial data. There are wide variations in implementing crowd sourcing in a practical manner. On the one hand there are applications such as Ushahidi (http://ushahidi.com) that helps collect unstructured geo-referenced information about crisis and disasters. On the other hand the platform eBird (http://ebird.org/) helps in collecting highly structured geo-referenced information on bird sightings. Ushahidi is an open source platform that allows users to crowd-source crisis information using multiple channels, including SMS, email, Twitter and the web. It allows humans to record their observations of an event in real-time "as it is happening" rather than relying on scarce and possibly censored official reports. The Geospatial Cyber-infrastructure for Environmental Sensing (GeoCENS) project , costing nearly $1.1 million, is a user-driven platform that allows scientists to store and share geo-scientific and biological sensor data from anywhere in the world. The GeoCENS online platform enables simplified searching, storing and sharing of environmental and other geo-referenced data. GeoCENS follows OGC standard information models to achieve sensor/data interoperability. Through GeoCENS, researchers have access to data from more than 60,000 sensors, 1,750 real-time sensors and 2,800 Web Map Servers - and many more are being added each month. In SDI 1.0 and SDI 2.0 the lack of geospatial data was a barrier to SDI expansion and adoption. However, with the number of sensors and platforms growing exponentially, SDI's are facing another challenge - the need to manage a glut of data. To make sense of all of this data, the SDI 2.0 model of providing data and services by spatial analysis professionals at the hub of insight will have to change to new type of services and automated systems that feed more syntehesized data and infromation services. The China Earthquake Administration launched in February 2012 a new earth observation system to monitor the Earth's crust. The GNSS-based system has a network of 260 full-time observing stations, and 2,000 part-time stations that closely monitor their positions and communicate those throughout the network. The network joins similar systems, including the U.S.'s Plate Boundary Observation system and Japan's GEONE. The improved full-time monitoring with precision measurements

				greatly improves the quality of data regarding real-time conditions. With these added details, the government will be able to see and share warning signs, to improve human safety and reduce economic impacts.
Imagery support	Medium-resolution ortho-imagery	High-resolution ortho and oblique imagery	High-resolution 3D imagery and online access to 3D data sets	While 2D information dominates the spatial information industry the use of 3D information is emerging as a new trend in many disciplines. 3D modeling of virtual environments is a fast developing field and the need for virtual models is increasing rapidly. The use of 3D virtual models has expanded into many application fields. It has become popular to model city centers or other urban areas including buildings, roads, road structures like traffic lights and traffic signs, and vegetation. Recently, remarkably large urban areas are being modeled, like the city of Berlin. While 3D models are generally used for visualization of the built environment, they are also used in many sectors for sophisticated applications including urban planning, mapping of buildings and their heights, disaster management, simulation of new buildings, change detection, virtual reality, tourism, entertainment, etc. Supporting data models and standards such as CityGML, BIM (Building Information Model), BISDM (Building Interior Space Data Model), are IFC (Industry Foundation Classes) are becoming integral parts of SDIs today. 3-D geodata and 3-D analysis tools are revolutionising the geospatial sector, by causing us to think differently, react differently, and understand differently. While online access to high-resolution 3D imagery and 3D data sets is part of the exciting future, the development of new tools with enhanced capabilities to analyze the 3-D integrated spatial information, are contributing to the popularity of SDIs areound the world. A host of new 3D Business Intelligence solutions that more fully capitalize upon the 3D data are answering important and useful business questions ranging from flood modelling to telecommunications to aerospace and automotive applications with 3D driver assistance. High-resolution, uniform, and homogenous digital elevation data covering major portions of the earth with a vertical accuracy of 1m and Ground Sampling Distance of 5m are increasingly avaiable. This level of accuracy, resolution and uniformity provides value in an increasing number of geospatial solutions. In the aviation industry, airspace users today need high-resolution terrain and obstacle data in electronic format for distances up to 45 km from airports for increased airport capacity loading. Incorporating 3D stereoscopic visualisation or Virtual Reality (VR) are the norm in automotive and aerospace sectors.

Data update approach	New imagery and base mapping	Base mapping updated with selective mobile lidar data. Transaction-based data updating on operational basis	Data updating through multiple channels such as transactions, sense networks, VGI, data capture using UAS[1], compilation and smart synthesis of unstructured multi-media information	http://www.sensysmag.com/article/features/27244-discovering-the-next-dimension-how-lidar-data-is-changing-the-geospatial-workflow.html The unmanned aerial vehicle (UAV) or drone is the platform used for observations or to collect data. The term unmanned aerial system (UAS) includes a UAV and all of the ground control and communications infrastructure that is used to operate and receive data from the vehicle. Drones can be carried by men in the backpack or in their vehicle so when they encounter a situation that is on the other side of that hill, they can quickly pull them out of their backpack, assemble it and in a matter of minutes, and get live video of what is going on ahead of them. Sensors which are mounted on a UAV can range from digital imagery, gas particle sensors, radio frequency (RF) receiving and relay, but the most common sensor is a full-motion video sensor for either electro-optical (EO) or infrared (IR). In most UAS applications GIS plays a vital role in flight and mission planning, data collection, analysis, data visualization and distribution. In February 2012, Congress mandated US Federal Aviation Administration (FAA) to open airspace to drones, something that has never been done before. FAA has set the target of developing a plan for how UAS will integrate with the National Airspace System (NAS) by 2014. One basic premise which the FAA has accepted is that a small UAS, weighing less than 2 kg, which is operated below 120 meters, more than 8 km from an airport, and under the direct control of an operator, poses a very low risk to the aviation community. The first groups to gain FAA approval this year are expected to be law enforcement, search and rescue, disaster support, and scientific. The interest in security-related applications and disaster monitoring is growing considerably. During a crisis such as industrial accidents, natural disasters like forest fires, flooding, tsunamis, earthquakes etc, there is an urgent need for on-line and real-time information on the actual situation. UASs are excellent devices to be used for that. http://www.bakersfieldnow.com/news/local/Drones-Protecting-American-soil-or-an-invasion-of-privacy-152387275.html http://www.sensysmag.com/article/features/26474-first-civilian-photogrammetric-uav-flight-over-singapore.html

				This concept of Transaction-based updating is based on the premise that all built structures, such as buildings, roads, utilities, or even bill boards can be designed, constructed, altered, or demolished only with the knowledge and approval of relevant government departments. The approvals for these construction related activities are often granted by the departments through a permitting process that ensures that the proposed development and construction activities comply with the regulations and codes of the authorities. Such permits are required for Building Construction / Demolition, Road Works, Excavation Work, Plot Subdivisions, Geotechnical Investigation, Land Development, setting up of Advertisement Boards, etc. Within each department there are business processes associated with the receipt of permit requests, internal review of the requests, and approval of the permits. Many of the permits are directly related to land activity. These include, for example: • Zoning Permit • Building Permit • Code Enforcement • Licensing • Inspections • Subdivision Review • Rezoning • Plan Amendment • Address assignment • Site improvement Permit • Tree Removal Permit • Soil Exploration Permit The business transactions pertaining to the issuing of permits can be geo-enabled and enhanced with GIS tools to update the geospatial database and to keep it accurate and current reflecting the life-cycle changes (planned, as-built, demolished, etc) on all built structures, as and when such changes happen on the terrestrial landscape. Though everyone approves this concept in principle, its implementation by enhancing the departments' business processes is yet to be put into practice in any SDI environment.

Data Standards	Data content models created by each SDI	• Data content models created by each SDI • Data access standardized by OGC	Data content models to be standardized for interoperable SDIs	Many efforts have been put in to address different aspects of using geospatial data by improving its interoperability. For example, the specification for OGC catalog services defines a standard way for geospatial information discovery. However, only having the standard mechanisms for data discovery and access is not enough. The geospatial data content itself has to be organized in standard, easily understandable, and readily usable formats. That is, the geospatial data interoperability issue has to be addressed by standardizing the data content and feeding them into a SDI which provides interoperable mechanisms to advertise, visualize, and distribute the standardized geospatial data. Such standardized geospatial data should be fed into OGC Web Services to support on-demand data visualization and access. Presently, each SDI is developing data content models for data themes, such as building, transportation, utilitites, etc. to suit its local requirements. Coming up with standardized data content models for data themes, and solving these interoperability issues is critical to our ability to define and implement a national or global SDI.
Underlying web technology	Geoweb 1.0 • Static • Publishing • Producer centric • Centralised • Close coupling • Basic	Geoweb 2.0 • Dynamic • Participation • User centric • Decentralised • Loose coupling (mash ups) • Rich	Geoweb 3.0 and semantic web	Linked data is data in which real-world things are given addresses on the web (URIs), and data is published about them in machine-readable formats at those locations. Other datasets can then point to those things using their URIs, which means that people using the data can find out more about something without that information being copied into the original dataset. Ordnance Survey has released a number of their products as linked data, including postcode units and administrative areas. Linked Data is about using the Web to create typed links between data from different sources. These may be as diverse as databases maintained by two organizations in different geographical locations, or simply heterogeneous systems within one organization that, historically, have not easily interoperated at the data level. Technically, Linked Data refers to data published on the Web in such a way that it is machine-readable, its meaning is explicitly defined, it is linked to other external data sets, and can in turn be linked to from external data sets. According to Tim Berners-Lee “Linked Data is the Semantic Web done right”. Berners-Lee in 2006 outlined a set of 'rules' for publishing data on the Web in a way that all published data become part of a single global data space: 1. Use URIs as names for things 2. Use HTTP URIs so that people can look up those names 3. When someone looks up a URI, provide useful information, using the standards (RDF, SPARQL) 4. Include links to other URIs, so that they can discover more things

				These have become known as the 'Linked Data principles', and provide a basic recipe for publishing and connecting data using the infrastructure of the Web while adhering to its architecture and standards. (URIs: Uniform Resource Identifiers; RDF: Resource Description Framework; SPARQL: an RDF query language with its name a recursive acronym that stands for SPARQL Protocol and RDF Query Language. SPARQL allows [a] query to consist of triple patterns, conjunctions, disjunctions, and optional patterns.) RDF allows users to describe both Web documents and concepts from the real world—people, organizations, topics, things—in a computer-processable way. Publishing such descriptions on the Web creates the Semantic Web. URIs are very important, providing both the core of the framework itself and the link between RDF and the Web. Although RDF is recommended for implementing the Linked Data, as a single global model for all data sources, other structured formats such as GML can support semantic linking. Key interlinking hubs are sites such as DBpedia and Geonames. DBpedia extracts RDF triples from the "Infoboxes" commonly seen on the right hand side of Wikipedia articles, and makes these available on the Web in RDF to be crawled or queried with SPARQL. Geonames in turn provides RDF descriptions of millions of geographical locations worldwide.
Transition from *Product* to *Process*	**Product** model mainly aimed at creating metadata and core datasets	**Process** model based on SOA and web services aimed at sharing datasets	Social learning process aimed at enhanced data utilization	An SDI may be defined as a *framework* of policies, institutional arrangements, technologies, data, and people that enable the effective sharing and maximal utilization of spatial data. While SDI 1.0 followed a **product model** mainly aimed at creating metadata and core datasets, SDI 2.0 transitioned to a **process model** based on SOA and web services mainly aimed at creating large number of interoperable datasets and business datasets of stakeholders. The **process** is built upon relationships: personal, political, and institutional. This transition of SDI as a product to SDI as a process was largely driven by its users and its usage. An SDI facilitates access to the spatial data assets held by a wide range of stakeholders with a view to sharing and maximizing the overall utilization of the data. Sharing increases combined use of data sets created by different data producers; the more data sets that can be combined, the greater the potential number of end-user applications and the greater the Return on Investment of SDI. In SDI 3.0 the process

				trend is continuing with the development of standards to include more complex web services to support 3D data and sensor web data. In fact the newly emerging application areas are now becoming an integral component of SDI. However, the principal objective of SDI remains unchanged - to facilitate access to the geospatial data assets held by a wide range of stakeholders with a view to maximizing their overall utilization.
User group focus	Data producer centric	Professional user centric	Neo-geographic user centric	In the SDI community there is a shift away from spatially aware GIS professionals to location based services for the public as a whole, spearheaded by neogeographers. **Neogeography** is using new techniques and inventing new terms: mash-ups, crowdsourcing, geostack. A whole range of websites, communities, and applications from the commercial Google Maps to the grassroots OpenStreetMap have emerged. In their totality, these new communities and applications represent a step change in the evolution. The term neogeography refers to the combining of online mapping with data, incorporating classic cartography and GIS and exposed via Web 2.0 style mashups. It combines the complex techniques of cartography and GIS and places them within reach of users and developers. According to ***Introduction to Neogeography*** (by Andrew J. Turner, O'Reilly Media, Inc., 2006) "Neogeography means *new geography* and consists of a set of techniques and tools that fall outside the realm of traditional GIS. Where historically a professional cartographer might use ArcGIS, talk of Mercator versus Mollweide projections, and resolve land area disputes, a neogeographer uses a mapping API like Google Maps, talks about GPX versus KML, and geotags his photos to make a map of his summer vacation. Essentially, Neogeography is about people using and creating their own maps, on their own terms and by combining elements of an existing toolset. Neogeography is about sharing location information with friends and visitors, helping shape context, and conveying understanding through knowledge of place."

Database approach	Emphasis on spatial data creation	Emphasis on data sharing using relational databases	Emphasis on NoSQL and Columnr databases to support geo-business intelligence using Hadoop-based analytics	Increasing amount of data are being stored in the world in databases and it continues to grow. The world's stored digital data is measured in exabytes, with 1 exabyte equal to one billion gigabytes (GB) of data. In 2010, the amount of data stored was in excess of 1,000 ExaBytes, which is an increase of over 500% compared to four years back. According to IBM,every day, we create 2.5 quintillion bytes of data — so much that 90% of the data in the world today has been created in the last two years alone. This data comes from everywhere: sensors used to gather climate information, posts to social media sites, digital pictures and videos, purchase transaction records, and cell phone GPS signals to name a few. This data is **Big Data.** Big Data is any type of data - structured and unstructured data such as text, sensor data, audio, video, click streams, log files and more. New insights are found when analyzing these data types together. **NoSQL** is a term used to designate database systems that differ from classic relational systems in some way. The term NoSQL really means **Not Only SQL**. The idea is that both SQL and NoSQL technologies can coexist and each has its place. As the name indicates, NoSQL is not SQL and is not relational. Most of the Web 2.0 leaders have adopted the NoSQL technology to dea with huge volumes of data; companies such as Google, Facebook, Twitter, Digg, Amazon, and LinkedIn all use NoSQL in one way or another. This is because performance degrade in a traditional RDBMS as we store the massive amounts of data required in social networking applications and the semantic web. In order to handle hierarchical nested data structures easily in SQL, multiple relational tables with all kinds of keys would be required. This data complexity affects the performance. NoSQL can handle hierarchical nested data structures without degrading the perfomrnace of the database. These data stores may not require fixed table schemas, and usually avoid join operations and typically scale horizontally. NoSQL is designed for distributed data stores for very large scale data needs. In a NoSQL database, there is no fixed schema and no joins. A relational database "scales up" by using faster hardware and more memory. NoSQL, on the other hand, can scale up by spreading the load over many commodity systems. This is the component of NoSQL that makes it an inexpensive solution for large datasets. Organizations that have massive data storage needs are looking seriously at NoSQL. Business intelligence (BI) applications are moving from the traditional connection to an OLAP Data source based on relational database to the ability to link to and consume data from a variety of disparate sources including social networks. The ability for a modern BI application to be able to use mashups of data to provide agility when

				dealing with integrations of multiple types of data sources has led to NoSQL being promoted by many as the next big thing within BI. **Columnar Database:** Business intelligence typically calls for the ability to have business users perform ad-hoc analytics and reporting tasks over as much data as possible. Instead of querying the source relational database, the data is replicated into a columnar database that is designed specifically for ad-hoc analytics. Columnar simply means that the data is stored by column instead of by row. Even simple drag-and-drop operations of a business user within a desktop tool can turn into complex database operations (joining, grouping, aggregating) that would choke any relational database, yet are handled by a columnar database without any difficulty. Plenty of IBM customers are seeing tangible ROI by analysing big data (http://www-01.ibm.com/software/data/bigdata/industry.html): • **Healthcare**: 20% decrease in patient mortality by analyzing streaming patient data • **Telco**: 92% decrease in processing time by analyzing networking and call data • **Utilities**: 99% improved accuracy in placing power generation resources by analyzing 2.8 petabytes of untapped data
Decision Support	Anecdotal	Used as Spatial Decision Support System	Geo-business intelligence with real-time sensor inputs	There's a broad range of different sensors that can be deployed in a sensor web for various observations and purposes—from environmental monitoring, to hazard detection, to security observation. Sensors might include temperature, moisture, wind, noise, video, infrared, radio frequency, seismic activity, air quality, chemical and biological, etc. Individual sensor web pods might have specific sensors or a cluster of sensors that each inform one another. The web of sensors becomes an intelligent and adaptive network as data from individual sensors and groups of sensors become fused on the fly. Readings from individual sensor pods detecting anomalous events can trigger adaptive behavior in nearby pods or the entire sensor network. Adding sensors to systems allows for automation, where readings can trigger a series of events that allow the system to adapt to changing conditions. The adaptive and distributed nature of the sensor network ensures that the network will continue to collect and communicate information about a changing environment, regardless of sensor failures at individual locations.

				Sensor webs add real-time data into decision support systems. The fact that the sensors share and fuse information amongst themselves provides pre-validation for data so that it can be trusted and acted upon immediately. http://www.sensysmag.com/dialog/perspectives/27101-what-do-sensors-add-to-a-decision-support-system.html
Governance model	• Top down • Emphasis on coordinatio n	• Policy driven • Emphasis on regulated participation	• User driven • Emphasis on diverse combinations of regulated, incentivized, and voluntary participation	SDI 1.0 followed a top down government approach to the development of SDI by concentrating on administration and institutional arrangements, including clearinghouse, to ensure the smooth operation of SDI. In SDI 2.0 the emphasize was on creating an environment which facilitates coordination and cooperation among all stakeholders regarding access to spatial data; to eliminate duplication in the capturing of spatial data; and to promote universal access to such data. An SDI is usually government-sponsored mainly because of its nature of comprehensive data coverage, involvement of a number of stakeholders across multiple organizations, the need for large financial investments, and the consequent necessity of an administrative body with associated policies, laws, and regulations. That is, the SDI development was traditionally accomplished by government agencies. However, this is no longer the case, with all sectors of society increasingly becoming spatially aware and contributing to the development of SDI. The readily accessible and available spatial products such as Google Maps, hand-held navigation devices (GPS and smart phones), web 2.0 technology, and social media have opened the way for innovative geospatial applications used on a day-to-day basis by the common man and is contributing towards the next generation of SDI development and a spatially enabled society. The creation of economic wealth, social stability, and environmental protection can be facilitated through the development of products and services based on spatial information collected by all levels of society including governments, private sector, and the public. In SDI 1.0 and 2.0, the need for authority and some form of central control in the management of SDI was well recognized. However, with the active involvement and proactive participation of all levels of stakeholders including governments, private sector, and the public in the development and management of SDI initiatives, a more participatory governance structure is required for the effective functioning of SDI. The value of spatial data can be assessed realistically only when the interests, beliefs, and values of all stakeholders (individuals, groups, organizations) are taken into account. Now, the concept of more open and inclusive SDIs is emerging, where users play a vital

				role in spatial information management and SDI development, including the custodianship of spatial data, which is no longer totally controlled by government or industry. There is growing utilization of open models and social media for spatial information management and knowledge sharing at the community level. (Ref: Spatially Enablement of NRM Communities through Spatial Knowledge and Information Network Development, Dev Raj Paudyal, Kevin McDougall and Armando Apan, University of Southern Queensland, Australia, 2012)
Main use	**Strategic decision making** with national level data sets	**Operational decision making** with inter-operable urban level data sets	**Cross-sector decision making** using smart city, smart region, smart nation, inter-operable systems	In cities across the world, public services such as housing, transportation, water, waste, public safety, etc. are operating in isolation, with hardly any coordination / collaboration across the concerned agencies. Integration and interconnection of all these public services present many challenges along several dimensions. These include challenges of addressing the syntactic and semantic interoperability of interacting systems-of-systems, along with how the services are shared, provisioned (at rest or in motion), stored, co-registered, and secured. In order to support integrated city operations, a unifying platform that facilitates accessible, transparent, and accountable data / service sharing between public services and citizens of the city are required. Such a Smart City Operating System built on top of an open, standards based architecture can provide advanced capabilities around collaboration, sharing, mobility, multi lingual / translation, cyber security, and privacy. They also provide context sensitive visualization tools to increase citizen interaction and offer facilities for 3rd party software developers to create useful new applications that leverage the available data sets and services. Using data collected from sensors located across the city, the applications developed using Smart City OS can offer near-real-time KPIs to help managers monitor and optimize the performance of city services, personnel, programs, and others resources. For example, an application to respond to landslides, floods, and other natural disasters will draw on information collected from multiple sensors, such as traffic cameras and rain meters, and provide near-real-time situational awareness in a single view. The technical feasibility of such advanced operating systems is already proven and private enterprises have also made them commercially viable as shown by the following two examples. London shall test the 'smart city' **Urban Operating System** by using the Greenwich peninsula as a test bed for new technologies running on the system. Its aim is to connect key services such as water, transport, and energy to citizens. Greenwich is an

				area earmarked for restoration in London — especially with the upcoming Summer Olympics during July-August 2012.
Multi-SDI operation	Standalone SDIs	Collaborative SDIs	Interoperable SDIs	The INSPIRE report 'A Conceptual Model for Developing Interoperability Specifications in Spatial Data Infrastructures', was published on 25/04/2012. The report provides a comprehensive overview of the data components of spatial data infrastructures and describes how to achieve interoperability by developing interoperability targets for each theme according to which data then has to be transformed. The report explains the common principles and methodology for developing these interoperability targets. (See Row 10 above on *Data Standards*)
Data license agreement	Bilateral license agreements	Master License Agreement managed manually	Automated Digital Rights Management	DRM is a technology for describing, identifying, trading, protecting, monitoring and tracking all forms of rights usages over both tangible and intangible information assets including management of rights-holders relationships. Geospatial DRM manages all rights, not only the rights applicable to permissions over digital geographic data. The current inability to confidently control the flow of such information activities has been a barrier to broader adoption of Web-based geospatial technologies. The adoption of an open DRM capability that is acceptable to all parties in a Web services transaction environment will enhance the flow of geographic data and information. The approaches for managing and protecting geospatial content fall broadly into two categories: (i) technical measures to control access and (ii) legal measures to control usage. DRM aims to bridge those two worlds by enabling electronic licences for both access and usage of content. **Digital Rights Management: An Expert Paper**, Graham Vowles, The AGI Foresight Study - The UK Geospatial Industry in 2015 In 2007 OGC approved the Geospatial Digital Rights Management Reference Model (GeoDRM RM), an abstract specification for the management of digital rights in the area of geospatial data and services. The goal of OGC's GeoDRM effort is to make sure that a larger market has access to geospatial resources through a well understood and common mechanism that enables more than today's "all or nothing" protection. A major motivation for this effort is the need to manage the "ownership obstacle to data sharing" in spatial data infrastructure scenarios. The GeoDRM RM defines the framework for web service mechanisms and rights languages to articulate, manage and protect the rights of all participants in the geographic information marketplace, including the owners of intellectual property and the users who wish to use it.

Performance monitoring	Performance measurement systems with emphasis on activities	Performance management systems with emphasis on results	Performance culture with focus on operational management as well as policy decisions	Unlike performance measurement systems, the emphasis In performance management systems in governments, is on results, and not activities. This shift allows the entire organization to focus on how to improve results instead of just reading what the results were. Even departments that had only partial control over a result saw their responsibility not only in doing their part, but also in collaborating and coordinating with other departments and with stakeholders outside the organization to achieve the desired goals. Setting targets became an important part of the process that led to knowing where you were and giving a direction to where you wanted to be. The evolution from measuring to managing performance is attained by establishing a performance culture and this is not always easy. The following 8 steps provide a critical framework for establishing this type of culture: • Determine what results your organization is trying to achieve. • Communicate the goals you want to achieve – clearly and often. • Make learning your focus. • Encourage telling stories about the relationships between the measures. • Experiment and monitor the results. • Establish the line of sight between workers' activities and the results you desire. • Focus on goals and results to make yourself accountable for outcomes not totally under your control. • Do it all over again. To create and maintain a performance culture, it is essential to have a performance management system in place that utilizes measurement and focuses on operational management as well as policy decisions. This provides the framework for a performance culture and encourages the ongoing comparison of your results to the benchmarks and targets you establish. Periodic management review of the results establishes and maintains the performance culture as part of the organization.

New Technology Trends		• Internet of Things • Next-Generation Network (NGN) • Ubiquitous Sensor Network (USN) • WPAN (Wireless Personal Area Network)	The **Internet of Things (IoT)** could be defined as a dynamic global network infrastructure with self configuring capabilities based on standard and interoperable communication protocols where physical and virtual "things" have identities, physical attributes, and virtual personalities and use intelligent interfaces, and are seamlessly integrated into the information network. In simple terms, the Internet of Things refers to uniquely identifiable objects (things) and their virtual representations in an Internet-like structure. It offers specific object-identification, sensor and connection capability as the basis for the development of independent cooperative services and applications. If all objects of daily life were equipped with Radio-frequency identification (RFID) tags, they could be identified and inventoried by computers. However, unique identification of things may be achieved through other means such as barcodes or 2D-codes as well. A single numbering scheme, such as IPv6, can also make every single object identifiable and addressable. **Next Generation Networks (NGNs)** are the new network architecture that will unify today's fixed, mobile, internet, and broadcast networks. This emerging technology is a packet-based network able to make use of multiple broadband technologies, providing telecommunication services to users, with independence of service-related functions from transport technologies. This innovative technology is expected to bring about greater energy efficiency than legacy networks. The term "**Ubiquitous Sensor Networks" (USN)** is used to describe networks of intelligent sensor nodes that could be deployed "anywhere, anytime, by anyone and anything". The technology has huge potential as it could facilitate applications and services in a wide range of civilian and military fields, including ensuring safety and security, environment and habitat monitoring, real-time healthcare, landmine detection, intelligent transport systems (ITS), promoting personal productivity, and enhancing national competitiveness. A **wireless personal area network (WPAN)** is a personal, short distance area wireless network (typically extending up to 10 meters in all directions) for interconnecting devices centered on an individual person's workspace. WPANs address wireless networking and mobile computing devices such as PCs, PDAs, peripherals, cell phones, pagers and consumer electronics.

Data Policy	Driven by data clearing house requirements	Driven by the need to share spatial data and established through a consensus process	Driven by global **Open Government Data** movement	Many governments around the world are opening government data for use by the public by publishing their data on the Internet using portals (such as data.gov) to make it easy for the public to find and use this data. Sharing this data enables greater transparency; delivers more efficient public services; and encourages greater public and commercial use and re-use of government information. To help governments open and share their data, the W3C eGov Interest Group has developed a set of guidelines to emphasize standards and methodologies to encourage publication of government data, allowing the public to use this data in new and innovative ways. Starting with the US Government in May 2009, 31 countries have so far launched their own open and shared data sites with access to machine-readable data. These sites serve as key tools in the global open government movement. While www.data.gov is the US Government site, other countries follow a similar naming structure with www.data.gov.uk for United Kingdom, www.data.gov.au for Australia, www.data.gov.sg for Singapore, etc. Besides government data and metadata, these sites also offer large number of applications developed using government data, as well as resources for developers. The principles of Open Government Data are implemented by each nation in slightly different ways. The US government has formalized the policies regarding the data to be published through its **Data Policy** statements (www.data.gov/datapolicy). In July 2010 the Australian Government made a Declaration of Open Government that committed to "strengthening citizen's rights of access to information, establishing a pro-disclosure culture across Australian Government agencies including through online innovation, and making government information more accessible and usable".

User Communities Served	Government departments at national levels of rich countries	Plus: Government departments at sub-national levels and urban areas as well as businesses and industries	Plus: Rural communities in Developing Countries and Less Developed Countries	Using SDI in innovative ways can solve development challenges in under-served rural areas in Developing Countries (DC) and Less Developed Countries (LDC). SDI can deliver government services to the communities in the rural areas to enhance their economic productivity, health, education, and access to markets. ICT has already exploited "leap-frog" opportunities such as skipping landlines and adopting mobile phone technologies, and skipping wired Internet connectivity and going straight to wireless technologies. Solar power is increasingly used by communities to keep the mobile phones charged. Complemented with cloud computing technologies, these innovative channels can be used by SDI to deliver services directly to the end users in most rural areas in DCs and LDCs, where electricity supply is often limited and often unreliable even when present. Reaching end users directly can help avoid the middle men and corrupt politicians in supporting equitable distribution of available resources to all areas of the health and educations systems. The main technologies potentially useful in alleviating barriers to accessing rural communities are satellite technology, wireless Internet connectivity, and cellular networks. Many villages in India, where a sizable proportion of the population is without sustainable access to safe drinking water and basic sanitation, are empowered with these three technologies. In India satellite technology is quite advanced in the three principal areas of remote sensing, communication, and weather forecasting. The relevant global statistics regarding mobile phones states: • Mobile broadband subscriptions are expected to grow from nearly 1 billion in 2011 to over 5 billion globally in 2016 • In 2011, global smartphone shipments exceeded personal computer shipments for the first time in history • By 2011, over 85 percent of new handsets will be able to access the mobile Web Harnessing the full potential of SDIs to the benefit of the impoverished rural community will require different models and approaches with an intricate mix of old and new infrastructural elements.