# [KE-03-021] System Modelling for Effective GIS Management

## Abstract

A geographic information system in operation is highly complex, as the scope of the GIS&T Body of Knowledge demonstrates. Modern society relies on many complex systems, but most are self-contained mechanisms with limited and well defined interfaces. A GIS is a complex open system that extends across the realms of hardware, software, data, science, and human processes. A conceptual model of a GIS can be an effective tool to design, implement, operate, maintain, manage, and assessment tool.

*Keywords*: capability, Geospatial Management Competency, GIS Capability Maturity Model, GISCMM, management, managing the GI system operations and infrastructure, maturity, organizational assessment, organizational structure, Zachman Framework

## Author & citation

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## Explanation



### 1. Definitions

For a comprehensive list of definitions relevant for GIS Systems Modeling, consult the URISA GIS Management Institute Glossary (pdf), which was developed specifically to accompany the GIS Capability Maturity Model and the companion Geospatial Management Competency Model.

### 2. The Nature of Systems

Social utilization of geographic information science and technology typically depends on access to a geographic information system (GIS). The typical GIS is designed to meet the business needs of an organization, including government agencies, utilities, universities, business, commerce, and industry. GIS meets these needs by enabling new types of business functions, making existing business functions more effective, or by making business functions more efficient.

A system can be defined as a set of interacting or interdependent component parts designed for a specific purpose and forming a whole of varying complexity. System design should be driven by the specific functionality required for the GIS to meet the business needs identified, to justify the investment in the GIS. Society depends on many systems from the simple (a pair of shoes with laces) to the complex (a square-rigged sailing ship or a hybrid automobile). Systems can fail when critical components fail: a broken shoe lace, a jammed block on a sailing ship, or a faulty ignition switch on an auto.

Conceptually, a modern GIS comprises four major categories of architectural components: data, hardware, software, and people. Within each of these components, there are many sub-components, with significant variability driven by the purpose of the GIS and the nature of the sub-components available. Specific components and sub-components are chosen and configured when a GIS is first designed and then developed, implemented, and maintained. Advances in geospatial information science and related developments of commercial technology create an environment where the choice of components for an individual GIS presents continual architectural and operational challenges (Wellar 2012).

Models are useful tools to assess and manage complex systems. Several types of models have been proposed for assessing various aspects of GIS (IndraStar 2016; Karalopoulus and Kavouras 2015; Makela 2012; Mangan et al. 2009). The Zachman Framework is an enterprise ontology for viewing and understanding the elements of an enterprise, and it too has been proposed as a useful conceptual tool for the design of a GIS (Croswell 2009). It can be used to classify and describe the components of an information technology system around six questions (what, who, how, where, when, why) from the perspective of five stakeholder groups (planner, owner, designer, builder, and subcontractor) (Zachman Framework 2018).

Within the recent past modeling of geospatial system completeness and maturity has been developed at the national level. (Sparks et al. 2014; Bossler et al. 2015). System modeling has also been applied to other domain, for example municipal financial systems (Bailey et al. 2011).

## 3. Why GIS Succeeds as a System

As a system, the factors that contribute to the success of a GIS fall into two broad categories. First are the broad enabling components of a GIS: data, software, hardware, and people. These are the components that are acquired through purchase, development, access, hire, or other forms of acquisition. Second are the execution ability components related to the process maturity of the people and organization responsible to operate, maintain, and manage the GIS (GIS Management Institute 2013).

### 3.1 GIS Operations

The URISA GIS Capability Maturity Model (GISCMM) was developed to provide a manageable framework to assess a GIS operation throughout its development life-cycle. It provides a means to assess the data, software, hardware, and staff that comprise a GIS to a meaningful level without excess detail that would make its use too complex or costly. The GISCMM also allows a GIS operation to assess the core processes required for successful operation, without being excessively complex. This balance of adequate detail versus excess complexity within the GISCMM allows a GIS assessment that is meaningful, can be easily repeated over time, and that support comparison with other similar GIS operations.

### 3.2 Fitness-for-Use and Requirements

A GIS succeeds when its design, implementation, management, maintenance, and operation suit the purpose for which it was established. Continued success requires that each component is well maintained to ensure fitness for its intended purpose.

A GIS succeeds when it evolves to meet new requirements placed upon it. Many enterprise GIS operations are considered successful when they meet the needs of a small handful of core user groups. In municipal GIS, planning, public works, and permitting applications are often early adopters. These applications can represent less than five percent of a municipality’s total workforce. However, evidence suggests that for some municipalities, more than 40 percent of the workforce can use GIS effectively (Babinski 2017).

### 3.3 Sustainability

Most of the core components of a municipal GIS can support increased usage without significant increase in GIS cost. The costs for data maintenance, database infrastructure, server and application software, and associated labor costs for maintaining the database and core applications are by far the largest GIS budget items, but they do not typically increase with increased usage.

GIS end-user costs are small in comparison. Most municipal office staff and many field staff work with computer equipment that is suitable for GIS applications. GIS-based web mapping applications have no significant end-user cost. Some municipal staff may require access to commercial GIS software and to GIS end-user training and support. A key responsibility of GIS management is to increase business utilization of the GIS system within the enterprise to spread the cost of the system infrastructure to as many end-users as possible.

Another key role for GIS management is to evaluate new geospatial technology. As the science and technology of GIS evolves, new products provide potential efficiencies or enhanced end-user capabilities. Integrating new technology into a GIS system requires careful planning and implementation. Typically, the GIS cannot be taken out of operation while new components are integrated, tested, and put into operation.

A successful and sustainable GIS requires management that understands the maintenance requirements of the core components of the system. It requires a management focused on optimal performance of the system based on standardized procedures coupled with detailed performance metrics.

A geographic information system is a complex and expensive part of municipal government and many other agencies. Its big budget and staff are often prime targets for cost-cutting. It is natural that GIS operations be stressed by demand or resource allocation. However, a successful GIS requires a management that understands the core components of the system and their current and potential state of suitability to ensure a continued functioning and efficient GIS.

## 4. Identifying and Addressing GIS Under-performances or Failures via the GISCMM

A GIS can under-perform, struggle, or even fail if key components are lacking or underdeveloped. As is the case with other systems, when the components are out of alignment or uncoordinated, failures are more likely. A GIS differs from other complex systems, like a hybrid automobile or USGS Eagle, in that many of its components can be owned, managed, and maintained by another organization, but implemented and used in a separate GIS. For example, many GIS operations share geography with other discrete GIS operations. A county, large city, water utility, and regional transit agency might each share substantial common geography. Ideally, there is no reason that each agency must develop and maintain redundant framework spatial data layers. Within an operational framework of distributed responsibility and shared resources, many data sources can be maintained by one lead agency and utilized by many, saving cost. Core end-user desktop or online GIS applications can also be designed, implemented and maintained by one agency for use by other local agencies, reducing costs and accelerating GIS use by agency staff.

While all of these seem perfect approaches to having effective operations, these connections also represent potential locations of problems. An assessment of a GIS system will need to cover a wide range of system components to determine where the trouble spots may be.

As was described earlier, the GIS Capability Maturity Model (GISCMM) provides a framework for evaluating the completeness of the system and suitability for the designated business purpose. It can help identify weaknesses and help to prioritize investment or development efforts to achieve a balanced and complete enabling capability to meet designated business needs. The GISCMM also provides a framework for analyzing the process maturity of the staff that manages and operates the GIS. Deficiencies can negatively impact the effectiveness of the GIS. In this way it helps to identify execution ability deficiencies to help prioritize corrective actions to improve execution ability and achieve a balanced level process maturity to maximize ROI from the GIS investment and operational costs.

### 4.1 Using the GISCMM for Domains of Systems

Domains of systems are defined by the purpose for which they are designed. Financial systems, asset management systems, work-order management system, and others each have a designated business domain that they serve and benefit. The GIS Capability Maturity Model is designed to assess systems designed to store, maintain, analyze, and visualize data sets with business-focused spatial features.

### 4.2 Using the GISCMM for Design of Systems & Fitness-for-Purpose

The GISCMM provides a useful framework for assessing the architecture and detailed design of a GIS. Despite its general nature, it makes frequent reference to assessing "fitness for purpose" in assessing individual components.

### 4.3 Using the GISCMM for Completeness of Systems

The GISCMM is a high-level model. For mission-critical GIS-based applications, products, and services the GISCMM should be supplemented with life-cycle analysis. In most GIS organizations, individual processes are rarely evaluated as long as they work to keep the systems components functioning, to deliver expected GIS outputs, and achieve the hoped for organizational outcomes.

The GISCMM framework can be used through the GIS development life-cycle as a checklist to ensure completeness of the system to support its intended business purpose. It recognizes that some components may not be required for a GIS designed for a limited purpose but requires a rationale statement for excluding a component.

### 3.4 Using the GISCMM for Assessment of Enabling Capacity and Executing Ability

The GIS Capability Maturity Model assesses a GIS based on two broad categories of components: the enabling capability and the execution ability, each with its own metrics.

“Enabling capability can be thought of as the technology, data, resources, and related infrastructure that can be bought, developed, or otherwise acquired to support typical enterprise GIS operations. Enabling capability includes GIS management and professional staff” (GIS Management Institute 2013). The GISCMM includes brief descriptive characteristics of each enabling capability component, to aid in objective evaluation that will support future re-evaluation or comparison with peer agencies.

To use the model, a rating is determined for each of the 23 separate enabling capability components. The ratings are metrics designed to chart the development status of the component (Table 1).

**Table 1.Enabiling Capability Components Measured within the GISCMM**

| | Ratings for Enabling Capability Components | | | | | | |
|---|---|---|---|---|---|---|---|
| Enabling Capability Component | 0.00 Desired but not Planned | 0.20 Planned but with no resources available to achieve the capability | 0.40 Planned and with resources available to achieve the capability | 0.60 In progress but with only partial resources available to achieve the capability | 0.80 In progress with full resources available to achieve the capability | 1.00 Fully Implemented | NA |
| EC1. Framework GIS Data1 | | | | | | | |
| EC2. Framework GIS Maintenance1 | | | | | | | |
| EC3. Business GIS Data2 | | | | | | | |
| EC4. Business GIS Data Maintenance2 | | | | | | | |
| EC5. GIS Data Coordination | | | | | | | |
| EC6. Metadata | | | | | | | |
| EC7. Spatial Data Warehouse | | | | | | | |
| EC8. Architectural Design | | | | | | | |

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| EC9. Technical Infrastructure | | | | | | | |
| EC10. Replacement Plan | | | | | | | |
| EC11. GIS Software Maintenance | | | | | | | |
| EC12. Data Backup & Security | | | | | | | |
| EC13. GIS Application Portfolio | | | | | | | |
| EC14.GIS Application Portfolio Management | | | | | | | |
| EC15. GIS Application Portfolio O&M | | | | | | | |
| EC16. Professional GIS Management | | | | | | | |
| EC17. Professional GIS Operational Staff | | | | | | | |
| EC18. GIS Staff Training & Professional Development | | | | | | | |
| EC19. GIS Governance Structure | | | | | | | |
| EC20. GIS Linked to Agency Strategic Goals | | | | | | | |
| EC21. GIS Budget | | | | | | | |
| EC22. GIS Funding | | | | | | | |
| EC23. GIS Financial Plan | | | | | | | |

1 A rating is performed for each of the seven (7) NSDI framework data sets.

2 A rating is performed for up to 10 (10) agency designated critical non-framework geospatial data sets.

The GISCMM also evaluates the execution ability components of the GIS. “Execution ability can be thought of as the process maturity of the GIS management and staff responsible to operate the GIS. For the GISCMM, each execution ability component is assessed against a classic process metric that charts progression towards operational maturity” (GIS Management Institute 2013). As is the case with the Enabling Capacity model, each of the 22 execution ability components must be assigned its own rating (Table 2).

**Table 2. Execution Ability Components Measured within the GISCMM**

| | **Ratings for Execution Ability Components** | | | | |
|---|---|---|---|---|---|
| **Execution Ability Components** | Level One: Ad-hoc Processes | Level Two: Repeatable Processes | Level Three: Defined Processes | Level Four: Managed and Measured Processes | Level Five: Optimized Processes |
| EA1. New Client Services Evaluation and Development | | | | | |
| EA2. User Support, Help Desk, and End-User Training | | | | | |

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|---|---|---|---|---|---|
| EA3. Service Delivery Tracking and Oversight | | | | | |
| EA4. Service Quality Assurance | | | | | |
| EA5. Application Development or Procurement Methodology | | | | | |
| EA6. Project Management Methodology | | | | | |
| EA7. Quality Assurance & Quality Control | | | | | |
| EA8. GIS System Management | | | | | |
| EA9. Process Event Management | | | | | |
| EA10. Contract & Supplier Management | | | | | |
| EA11. Regional Collaboration | | | | | |
| EA12. Staff Development | | | | | |
| EA13. Operation Performance Management | | | | | |
| EA14. Individual GIS Staff Performance Management | | | | | |
| EA15. Client Satisfaction Monitoring & Assurance | | | | | |
| EA16. Resource Allocation Management | | | | | |
| EA17. GIS Data Sharing | | | | | |
| EA18. GIS Software License Sharing | | | | | |
| EA19. GIS Data Inter-operability | | | | | |
| EA20. Legal and Policy Affairs Management | | | | | |
| EA21. Balancing Minimal Privacy with Maximum Data Usage | | | | | |
| EA22. Service to Community and Profession | | | | | |

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