[KE-04-012] GIS&T Project Planning and Management

Abstract

GIS&T project planning and management falls under the broader category of project management (PM) in general and information technology (IT) PM in particular, providing a rich background and guidelines that are stewarded by associations and their certifications. The lifecycle of a project or its component phases involves a number of process groups involving a series of actions leading to a result that are sequenced in the following manner: initiating, planning, executing and controlling, and closing. Effective project planning and management requires understanding of its knowledge areas in the project management body of knowledge (PM BoK), which include integration, scope, time, cost, quality, human resource, communications, risk, procurement, and stakeholder management. Numerous tools and techniques are available to assist the project manager in planning, executing, and controlling these efforts, some of which are specific to GIS&T projects. The distinctiveness of GIS&T project planning and management lies in an understanding of the uniqueness, overlap and connections that exist between the PM BoK and the GIS&T BoK, both of which have achieved new levels of maturity in recent decades.

Keywords: knowledge areas, process groups, project management, project planning

Author & citation

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Explanation

1. Definitions

Critical Path. The longest path through a project or to a defined milestone. The critical path is made up of a set of related linked tasks that lead to the conclusion of the project or milestone.

Gantt Chart. One view of a project plan or status report in which horizontally arranged linear bars depict start and end points of project tasks.

GIS Program. An ongoing effort or initiative established by an organization using GIS&T to support its mission and business requirements.

GIS Project. A temporary endeavor undertaken using GIS&T to create a unique product or service.

Pilot Project. A planned, limited activity that includes many attributes of a full project, which is designed as a demonstration or a trial of a project scope, specifications, or methodology. The pilot project is undertaken to answer questions and provide an opportunity to adjust the plan and specifications before proceeding with the full project.

Process Group. Related and mutually supporting sets of activities that help ensure a successful project. Defined by the Project Management Institute as an overall structure for project planning and management.

Project Charter. A document that officially authorizes a project, and it includes statements of project objectives, participation, and approval and commitment of resources by managers of stakeholder departments.

Project Management. The application of knowledge, skills, tools, and techniques to project activities to meet requirements.

Project Manager. An individual who has formal responsibility for directing and executing a project, its team and stakeholders, and the project deliverables and results.

Project Management Knowledge Areas. A framework that addresses critical concerns and practices that must be taken into account in project planning and execution.

Project Portfolio Management. A management approach based on a set of practices that view multiple projects as being interrelated and contributing together to overall program and organizational goals.

Resources. Tangible commodities that enable project work to be carried out. Resources include people, money, equipment, materials, and the organizations that are the sources of these commodities.

Stakeholder. Individuals, groups, or organizational entities that have some interest, participation, or role in a project or program, or which may be affected by its development and operation.

Task Predecessor: A defined attribute of a task that indicates the timing relationship of the task with another task. Also referred to as task "linkages," predecessors describe how the timing of one task is influenced by or related to another.

Work Breakdown Structure (WBS): A hierarchical format for presenting tasks in a project.

2. Introduction to Projects

2.1 Project and Project Management Definition and Context

The Project Management Institute (PMI) defines a project as a “temporary endeavor undertaken to create a unique product or service” (PMI 2017b). The operative phrases in this definition are “temporary” and “unique product or service”. Many projects fail because of poorly defined deliverables and loose schedules. Projects are successful when they focus on a clearly defined scope, leading to defined end results, in a planned time period. The PMI explains project management as “the application of knowledge, skills, tools, and techniques to project activities to meet requirements.” Project management is accomplished through the application and integration of project management process groups: initiating, planning, executing, monitoring, controlling, and closing.

Many researchers and practitioners emphasize the need for sound project planning and management. This is the fundamental thesis and mission of the Project Management Institute (PMI), which develops standards and best practices to improve the way projects are managed and how they can more effectively deliver results (see PMI, 2016; PMI, 2017c; PMI, 2017f). They confirm that the time spent in planning and tightly monitoring and controlling projects saves time and resources.

2.2 Project Context, Organizational Environment, and Foundation

2.2.1 Organizational Environment

Croswell (2018) and Croswell (2019) give a description of the types of organizations and groups that use GIS technology—including a range of public sector, private sector, not-for-profit, and academic organizations, companies, and agencies. GIS projects are planned and executed by these organizations to support their mission, business processes, and individuals (internal and external) that they serve.

Many organizations that use GIS technology have well-established GIS programs. A GIS program, for the purposes of this BoK, is defined as, “an ongoing effort or initiative established by an organization using GIS technology to support its mission and business requirements”. GIS programs normally have a well-defined organizational identity and are set up to provide a sustained, ongoing services for a user community—in contrast to the time-limited and focused scope of a GIS project. GIS programs range in size from very small (with limited staff and user community) to extremely expansive. In the last 20 years, it has been typical, in public sector and utility organizations to establish large, “enterprise GIS programs” with substantial staff and user communities in multiple offices inside and external to the organization. In many cases, a GIS program may have its basis in a major GIS development project that puts in place the technical and organizational pieces for sustained program operations. An ongoing GIS program usually initiates, directs, or supports multiple projects (e.g., database development or enhancement, software migration, application development and deployment, and a variety of special services).

2.2.2 "GIS Projects" within a Broader GIS Program Context

GIS programs normally have a well-defined organizational identity and are set up to provide a sustained level of services to a user community. In contrast, a GIS project has a time-limited scope and is focused on specific deliverables. In many cases, a GIS program may have its basis in a major development project that puts in place the technical and organizational pieces for sustained program operations. An ongoing GIS program usually initiates, directs, or supports multiple projects (e.g., database development or enhancement, software migration, application development and deployment, and a variety of special services).

This relationship between programs and projects is important, because it impacts the way in which projects are resourced and managed. GIS managers can balance the requirements for staff resource assignments and for coordinating work on multiple related projects that are in progress simultaneously. The Project Management Institute (PMI, 2016; PMI, 2017b; PMI, 2017c) describes the concept of "project portfolio management," which embraces a set of practices that view multiple projects as being interrelated and contributing together to overall program and organizational goals.

2.2.3 Foundation and Starting Points for Projects

Before detailed project planning and execution, it is important to confirm or establish key foundational elements and starting points which provide a solid basis for the project. These foundational components are part of the Initiating Process Group described in Section 2. In summary, these components include:

- Well-defined organizational mission and business processes
- Situation assessment providing a current-state baseline
- Assessment of requirements for the GIS project results which support the organization's mission and business processes
- High-level description of the project and project stakeholders
- Internal support and a Project Charter

There is a considerable body of literature and knowledge basis describing the purpose and approach for establishing and presenting these foundational components including Bennett (1990), Emoghene et al. (2017), Hitt (2017), Holdstock (2017), Pham et al. (2016), PMI (2017e), Somers (2000), and Tomlinson (2013).

2.3 Types of GIS Projects and Deliverables

For sound project planning and execution, GIS managers should first have a clear picture of the overall project objectives. The definition of "project" above encompasses a range of types and sizes. A GIS project may be of very limited scope and time period (a couple of weeks) or very large with extensive scope and involving a large team and stakeholder community, substantial budget, and extended time period (a year or more). Below is a general characterization of typical types of GIS projects:

- New or expanded GIS program development: Major project with the objective of designing and putting in place a new GIS program or a major expansion of an existing program to serve additional users and application requirements. This type of project is complex and multifaceted in nature typically involving aspects of software and hardware acquisition, database development, application deployment, and organizational development.
- Preparation of GIS standards or policies: Includes research and often review and consensus building with users and management to prepare written standards and policies that guide GIS operations. For example, standards may address technical

issues (e.g., data formats, application development methods), and policies may address any operational or administrative topic that impacts a GIS program.
- GIS database development or enhancement: Includes database design and all work associated with data collection, conversion, and compilation to build and deploy a new database or to enhance or augment an existing database. These projects include all aspects of team and contract management, source material management, quality control, and loading to a master GIS database for user access. The work often involves competitive procurement of database services and execution of work by a private contractor.
- Custom GIS application development: Involves using tools and functions of the GIS software to create and deploy custom applications that suit the needs of a specific group of users for generation of a particular product (map display, report, data file). The project includes an assessment of user needs, design, development, and deployment for user access.
- Computer or network hardware acquisition or upgrade: May include any acquisition of new computer hardware or upgrades of existing hardware necessary to support GIS operations. This may affect servers, desktop computers, network cabling or devices, peripheral devices, etc. The project includes analysis, design, research into available products, and very often, preparation of specifications and solicitation of bids from vendors. The project includes all installation, configuration, and testing, as well as the establishment of appropriate hardware maintenance procedures.
- Outreach or educational product development: Includes research, consultation supporting the compilation and production of materials and tools that support GIS program outreach, training, or education. Depending on the nature of the project, the end results could be training manuals, briefing guides, brochures, or presentation materials.
- Software acquisition or migration: Includes any acquisition of new software or migration to a new software package (installation of a new release of existing software or move to a new software package from another vendor). The scope will vary depending on the particular software environment and may include a formal competitive review and selection. Work includes installation and configuration and may include redesign or reformatting of data or applications so that they will work properly with the new software.
- GIS integration with external systems: Includes technical design and development to establish system linkages between the GIS software and database and external systems. The level of sophistication can vary greatly. The work may use integration tools provided by the software package, but often includes special programming work followed by testing and culminating in deployment and user training.
- Special GIS service projects: GIS programs that serve a large user community often are organized to respond to requests by those users for a variety of special projects that might include such work as custom map design and production, spatial analysis to support a user program or decision, etc. These projects may be requested without much warning or time for response. The most successful GIS programs are able to quickly assign resources, evaluate requirements, complete a design, and execute the work on a tight schedule.

The PMI definition of project makes reference to “unique product or service”. This refers to the planned outcomes of a project which, in GIS projects, are often called “deliverables”. A deliverable, depending on the type and scope of the project, could include such things as a: a) written report or plan (strategic plan, business plan, needs assessment, conceptual design, etc.), b) conceptual or physical database design, c) technical design or use-case for a custom GIS application, d) technical software, system, or network design/specification, e) specifications for GIS data collection/acquisition, f) aerial data and derived products (e.g., orthoimagery, LiDAR, digital elevation model), g) GIS data (field-collected data or data conversion from other source), h) custom GIS application, i) GIS training materials and program, j) map or data products generated by GIS.

2.4 Project Structure

The structure of a project has a strong influence on project success, and should include a clear scope, a formally assigned manager and team, and an involved user or stakeholder community. A well define structure can support effective planning, project communications, and execution of the required work (Croswell, 2019). Structures may vary by project, and any project structure should account for establishing the roles and connections among all of its components.

Figure 1 shows one example of a GIS project organizational structure designed to support effective management. The GIS project is under the direction of a GIS management office. Projects are authorized and supported by formal written documents that include, at a minimum, an approved project plan and budget. In many cases, project initiating, planning and executing (as discussed in Section 3) are supported by a business case and a project charter (see subsections 2.7 and 2.11 for a more detailed description). The business case is a document or presentation that describes the project and its business value. It is submitted to senior management in order to obtain support and approval of the project. The project charter is a document that officially authorizes a project, and it includes statements of project objectives, participation, and approval and commitment of resources by managers of stakeholder departments (Schwalbe, 2019).

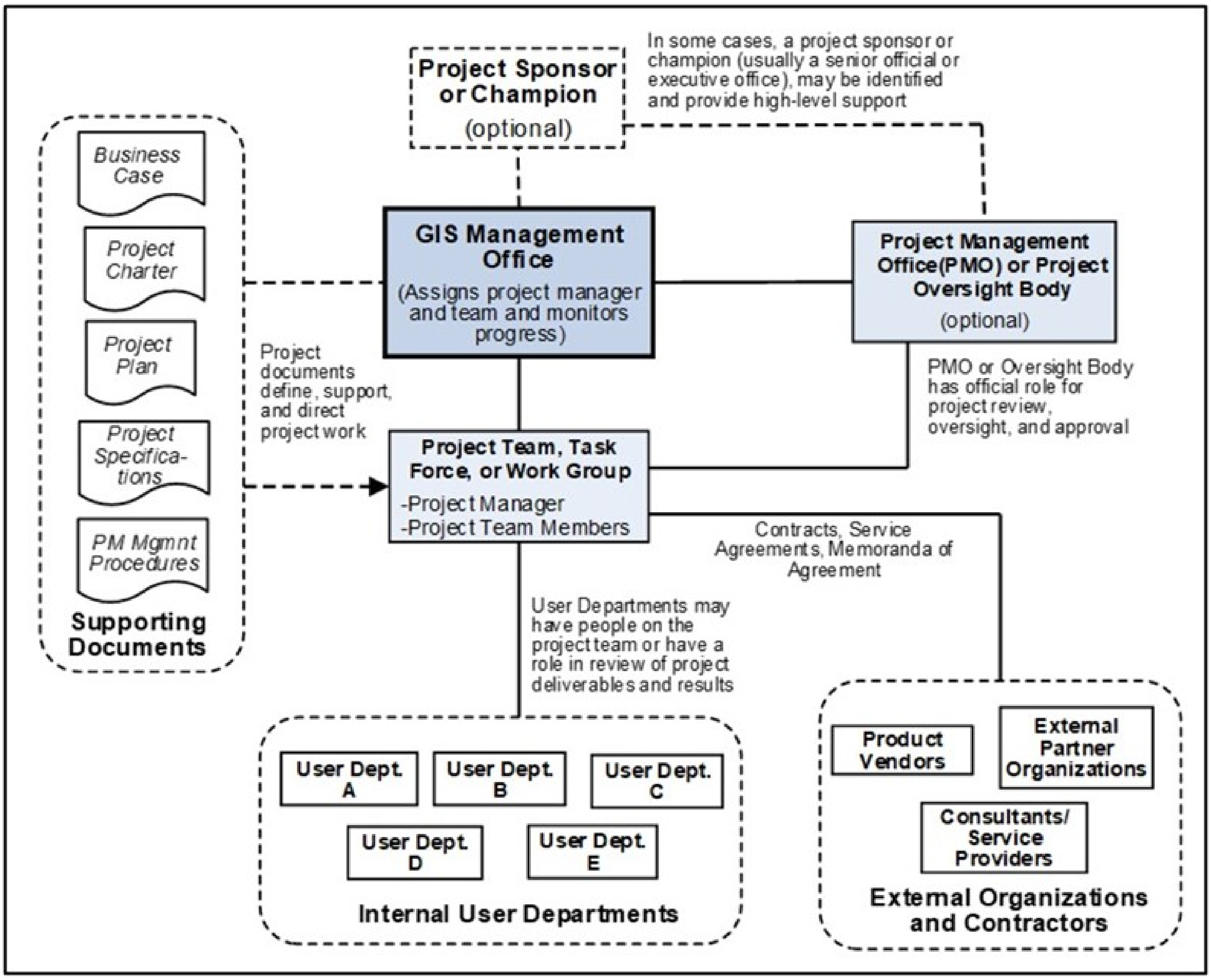


Figure 1. Model GIS Project Management Structure. Source: authors.

For large projects on which significant resources will be expended, it is good practice to establish an oversight body that is outside both the project and the GIS management office. In many cases, this oversight body is a committee composed of management-level personnel from stakeholder departments in the organization. The role of the oversight committee will vary depending on the nature of the project and the type of organization; but, at a minimum, the committee is responsible for the ultimate approval of project results. In most cases, the committee has a formal role in reviewing and commenting on project deliverables, approving budget and expenditures, and helping to resolve internal problems with resources and project participation.

Project structure is likely to vary for each project, although some components may stay the same. For example, in Figure 1 a GIS Management Office (dark blue) may serve a similar role in all GIS projects. The project team and oversight body (light blue) may vary from project to project, depending on the nature of the deliverables and the project stakeholders. The components most likely to vary from project to project are outlined with dotted lines in Figure 1 and include internal departments, external organizations, supporting documents, and a project sponsor. In other cases, some components such as external contracts or organizations may not be a part of the project structure due to the nature of the work. It is often up to the project manager to carefully consider how each of these elements can be incorporated into the overall structure and contribute to a successful project.

2.5 GIS Project Management Competencies, Professional Associations and Certifications

2.5.1 Project Management Professional Associations and Certifications

There are a number of professional associations, some supporting professional certifications, which develop and promote best practices and standards for project management—all types including IT and GIS projects. The most prominent is the Project Management Institute (PMI) dedicated to sound practices and professionalism in project management. The PMI provides project management advocacy, standards, training and certification to project management professionals worldwide. PMI also provides educational and career-planning tools for students and practitioners. The premier information source is the Project Management Body of Knowledge (PMBoK) but there are numerous other publications prepared or provided by the PMI on project planning and management topics. The main professional certification supported by the PMI is the Project Management Professional (PMP) but other PMI certifications include: Program Management Professional (PgMP), Portfolio Management Professional (PfMP), Certified Associate in Project Management (CAPM), PMI Professional in Business Analysis (PMI-PBA), PMI Risk Management Professional (PMI-RMP), PMI Scheduling Professional (PMI-SP, and PMI Agile Certified Practitioner (PMI-ACP).

Other professional associations with a focus on management practices and certifications (applicable to IT and GIS projects) are:

- Academy of Management - www.aom.org
- American Management Association (AMA) - www.amanet.org
- American Society for Quality (ASQ) - www.asq.org
- Association for Project Management (APM) - www.apm.org.uk
- Axelos Ltd - www.axelos.com
- CompTIA (formerly known as the Association of Information Technology Professionals-AITP) - www.comptia.org
- International Project Management Association (IPMA) - www.ipma.world
- Urban and Regional Information Systems Association (URISA) - www.urisa.org

2.5.2 GIS Project Management Competency Models and Frameworks

This GIS&T Body of Knowledge includes a number of topics that directly relate to and support GIS project planning and management including:

- KE-01 The Process of GIS&T Design (expanded topic forthcoming)
- KE-03 Strategic Planning for GIS Design
- KE-19 Managing GIS Operations and Infrastructure (expanded topic forthcoming)

- KE-21 System Modelling for Effective GIS Management
- KE-33 Organizational Models for GIS Management

In addition to the GIS&T BoK and the PMI's "Project Management Body of Knowledge" discussed in Section 3, there are a number of other knowledge bases and models that are useful in describing and understanding GIS project management competencies and practices including:

- Geospatial Management Competency Model: The Geospatial Management Competency Model (GMCM), like the GTCM, was developed under the direction of the U.S. Department of Labor (Employment and Training Administration) in 2012, by a special work group organized by the Urban and Regional Information Systems Association (URISA, 2012). The GMCM specifies 74 essential competencies and 18 competency areas that characterize the work of most successful managers in the geospatial industry. (www.urisa.org/resources/geospatial-management-competency-model)
- The GIS Management Handbook: The Second Edition of this book, was published in 2019 by Kessey Dewitt Publications in association with URISA It is a comprehensive guide and reference to the field of GIS management—including project planning and management. It provides practical information on the development, implementation, and operation of GIS programs and projects—for a full range of public sector, not-for-profit, and private sector organizations and companies. See Croswell (2019).
- APM Competence Framework from the Association for Project Management (www.apm.org.uk/resources/find-a-resource/competence-framework). The APM Competence Framework sets out the competences required for effective project and program management. The framework consists of 27 competences based around outcomes that project professionals need to achieve. The APM Competence Framework provides a useful tool to evaluate current management competencies for individuals, project teams, and organizations to inform decisions on hiring, training, and adoption of best practices.

3. Project Management Process Groups

3.1 What is a Process Group?

As a project progresses from start to finish, it is useful to consider the process groups that are part of its lifecycle. Process groups (PMI, 2017c) are related and mutually supporting sets of activities that help ensure a successful project. Defined by the Project Management Institute as an overall structure for project planning and management, the process groups are initiating, planning, executing, controlling and closing (PMI 2017c). These process groups are discussed in more detail below and illustrated in Figure 2. It is important to understand that these process groups are not a project's phases, but rather the processes that all projects and their individual phases need to go through. The process groups span a project, and each of its phases, from initiating to closing.

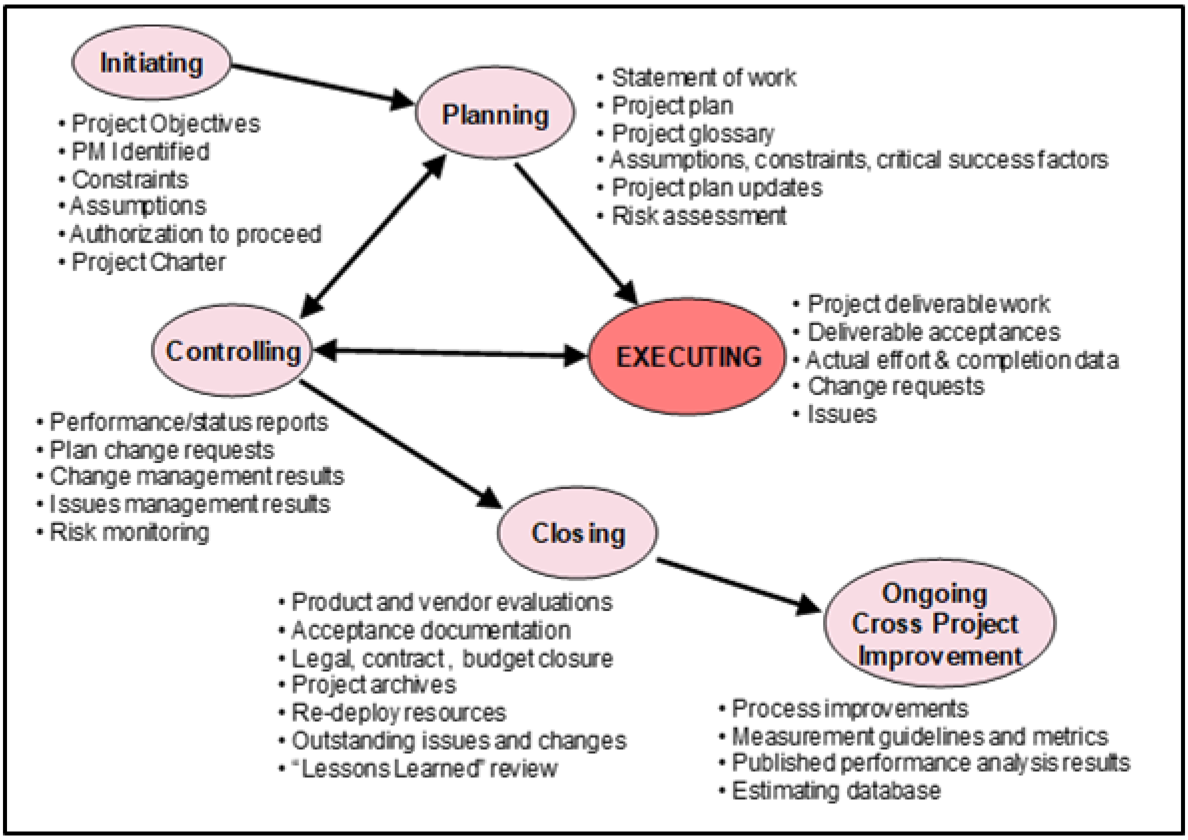


Figure 2. PMI process groups in a project lifecycle (from Croswell, (2019) and adapted from PMI (2017)). Source: authors.

3.2 Initiating

Initiating processes are those that begin a project or one of its phases following the establishment of key foundational elements described in Section 1. Some of these actions may focus on identifying stakeholders and soliciting their input, or identifying key project personnel such as the project manager or the sponsors. Other items are concerned with the need for and merits of such work, including needs assessments, business cases, or alignment of the project with the organization. Other important items in this process group are contractual, such as signature of a formal contract or adoption of a project charter. At the end of the initiating process, the project or phase transitions into the planning process group.

3.3 Planning

Planning processes are used to formulate and maintain a blueprint that addresses the needs of the organization. This process may begin with a statement of work which is later refined into a comprehensive project plan. The plan should include elements to address any criteria that could have an impact on its success, including its scope, schedule, budget, quality, risk, and procurement needs. The plan addresses assumptions, constraints and critical factor for success, including any negative or positive eventualities. A plan for effective communication among team members, clients, sponsors, and stakeholders is also important to consider. Planning has a major influence on all subsequent process groups, but may also be updated or revised to account for the organizational needs as the project evolves. In moving out of planning, two new process groups, executing and controlling, begin simultaneously.

3.4 Executing and Controlling

Executing is the process group where work actually gets done--all of the other process groups support project execution activities. This requires careful coordination of people, technology, and other resources to deliver what the plan has promised.

In a well-executed project, the work will move along as planned and controlling efforts should be relatively stress-free. The controlling actions often include meeting, status reporting, and progress tracking with earned value methodology (EVM). EVM tracks what percentage of planned work was accomplished for the planned investment of resource, as discussed in Section 4. A project flawlessly executed will graph planned value, earned value (work accomplished), and actual cost on the same line. In a poorly executed project, however, controlling efforts can be substantial and stressful. EVM will reveal the actual cost rising above and the earned value dipping below the planned value. This result is not only bad, but difficult to correct given the constraints of the planned scope, time and cost. Any effort to get back on schedule will have additional cost, and any efforts to cut costs can further delay the schedule.

Resolving such cost and scheduling issues are one set of challenges a project manager faces, but there could be any number of additional issues requiring attention. Although some issues can be resolved in a simple manner, “change management” is a more structured approach focused on the transition from a current state to a desired future state (Aziz and Curlee (2017), Carr (2014), and Somers (1989)). Change control systems can be built on such approaches and try to both minimize negative changes and optimize positive changes.

As executing and controlling actions are completed, the project enters the final process group in its lifecycle.

3.5 Closure

Closing ends a phase or a project. Many of the activities during this time may be administrative, such as providing the deliverables and having the customer or stakeholder accept them. These actions may have legal or financial ramifications, so it is important to make closure official in whatever manners have been predetermined. Closing may also include efforts to document the work or ensure other projects can progress smoothly, such as archiving the project report or re-deploying team members to other projects.

The closing process groups can also include review of the project and efforts to understand what was learned from the project. These “lessons learned” can be especially helpful in planning future projects. Such knowledge can be critical input to ongoing cross-project improvement. Effective and efficient closing processes are critical to projects due to their limited planned lifecycle, unlike organizational management.

4. Project Management Frameworks

As described by the Project Management Institute (PMI, 2017c), project management knowledge areas address critical concerns and practices that must be taken into account in project planning and execution. Project managers that develop competencies in all 10 of these knowledge areas have an excellent perspective on the range of concerns addressed in effective project planning and management. Professional certification as a Project Management Professional (PMP) by the PMI as discussed in Section 1 has made this framework pervasive throughout the IT and other industries. Table 1 (Croswell 2019) lists the 10 project management knowledge areas, and provides a description of each, with the following Sections 4.1 – 4.7 highlighting planning and managing considerations important to GIS&T projects.

Table 1. Project Management Knowledge Areas

Knowledge Area	Description
Project Integration Management	Processes and activities needed to identify, define, combine, unify, and coordinate various aspects of project planning and management. In a practical sense, integration management includes making decisions about resource allocations, anticipating and formalizing changes to the overall project, and coordinating all elements of the project. Integration management encompasses preparation of a project charter and a preliminary scope that guides the project.
Project Scope Management	"Scope" is defined as the sum of the work, products, services, and results expected from the project. Scope management includes the processes required to ensure that all work required by the project is completed successfully. Scope management includes detailed planning for definition of work and deliverables, as well as activities for monitoring and verifying project execution and results.
Project Time Management	Planning for task and activity scheduling—the sequence, duration, and timing of tasks and controlling/adjusting changes to task timing or the overall schedule during project execution. Time management also includes managing the scheduling of resources assigned to project tasks.
Project Cost Management	Covers all processes involved in planning, estimating, budgeting, and controlling costs. Cost management also includes tracking costs and managing variances and changes to the original project budget.
Project Quality Management	Simply stated, quality is the degree to which a project result meets planned requirements and, depending on the nature of the project, reflects such characteristics as accuracy, reliability, functionality, etc. Quality management includes all activities that define quality parameters and policies, as well as the quality control and quality assurance processes during project execution.
Project Human Resource Management	Encompasses all activities that involve planning and assembling a project team and assignment of roles to each team member. Human resource management also includes ongoing team management with such activities as competency evaluation, training, assignment of work, performance monitoring, making changes to team composition and roles, etc. This also includes practices to build and maintain team member and project participant morale and productivity.
Project Communications Management	Processes that determine the information and communications needs of stakeholders and team members, as well as design of specific communication tools and products for use in the project.
Project Risk Management	Work in risk management planning that identifies risks and creates a management environment for responding to risks should they impact the project. Risk management includes all activities involved in monitoring risks and taking appropriate avoidance or mitigation steps.
Project Procurement Management	Processes that support the acquisition of products and services that are needed for the project or the sale of products or services that result from the project. This includes planning and specifying the products and services; evaluating and selecting suppliers or buyers; establishing purchase contracts or service-level agreements; managing acquisitions; monitoring performance of products or services; and terminating vendor/contract relationships.
Project Stakeholder Management	Stakeholders include organizations and people that have some role or interest in the project. Stakeholder management processes address stakeholder identification, planning for stakeholder engagement, and ongoing communications and work with stakeholders during project planning and execution.

4.1 Scope, Time, and Cost

Scope, time and cost are sometimes called the “triple constraints” of project planning and management, as one cannot be altered without having an effect on the other two. The scope refers to all work that will be done to complete the project and what processes will be followed to accomplish this work. As a result, timing and cost are inextricably woven into one composite fabric. The most common planning and management approach is to break the project down into hierarchical tasks that are sequenced and individually assigned durations and resources (including personnel). The resulting work breakdown structure (WBS) is used in the planning, executing, and controlling processes during the project’s lifecycle. The WBS can be used in conjunction with any number of PM tools and techniques such as Gantt charts, network diagrams, budgets, and earned value methodology, as discussed in Section 5.

4.2 Quality

PMI (2017c) defines quality as "the degree to which project deliverables meet requirements”. Although requirements may be customized in any number of manners, standards are often used to plan for and effectively manage quality. Numerous standards exist in the IT and other related industries. GIS&T related organizations and the industry specific standards with which they are concerned include:

- Open GIS Consortium (OGC) - www.ogc.org - standards for spatial data format, data classification, geospatial services and applications, and GIS operational practices.
- Federal Geographic Data Committee (FGDC) - www.fgdc.gov - standards for GIS data and metadata quality, format, content, and classification and related GIS data collection and maintenance practices.
- American Society of Photogrammetry and Remote Sensing - www.asprs.org - prepares and approves formal standards for aerial data imagery and LiDAR acquisition and processing and for map and orthoimage positional accuracy.
- International Association of Standardization (ISO) - www.iso.org - an independent international standards organization, which organized Technical Committee 211 (Geographic Information and Geomatics) to address GIS-related software, data, and services.
- Urban and Regional Information Systems Association (URISA)- www.urisa.org - standards and best practices for the management and use of GIS technology. URISA's GIS Management Institute (GMI) develops tools and best practices useful for GIS planning and management.

Standards or custom requirements are used in the planning and managing of projects to design and control quality deliverables. The terms “quality control” and “quality assurance” (QA/QC) are often associated with such processes that are inherent in all of the process groups from Section 2. QA can be distinguished from QC in that the former typically occurs after initial deliverable completion, and often is done by a separate group such as the client.

4.3 Risk

A risk is an uncertainty that can have a negative or, less frequently, a positive impact on meeting project objectives, and should be monitored and responded to should it arise. Although risks at an organizational level may be addressed in quantitative methods that include organizational, legal or political considerations, risk at the project level can often be more qualitative due to the limited duration and relative size, with respect to most organizations, of a typical project. Planning for and successfully controlling risk during execution should include the following considerations: identifying and describing the risk, assessing its probability and impact if it occurs, determining the potential triggers or indicators that could cause or harken its occurrence, classifying risks into summary categories (e.g. funding/resource allocation and staffing, organizational/legal/political, or technical/operational) and devising a response strategy should it occur.

One common qualitative approach is taking a risk register based on the information listed above and building a probability/impact matrix. The matrix is used to identify the most critical categories of risk (e.g. high impact and high probability) to prioritize the strategies for response. These responses can be part of the overall change management approach, as described in Section 3.4. The four overarching strategies are:

- Avoidance: adjusting a project plan (tasks, timing, resources, etc.) to protect objectives from negative impacts.
- Transference: the consequences or responsibility of a risk are shifted to a third party.
- Mitigation: reduction in the probability and/or impacts of an adverse risk event to an acceptable level.
- Acceptance: the risk event or threat is understood but not addressed by changes to the project plan or by the addition of resources to respond to the risk.

4.4 Human Resources

Assigning personnel to project roles and tasks as discussed in Section 4.1 is typically one of the responsibilities of the project manager (PM). The PM must manage personnel in a number of manners, including delegating responsibilities, assigning the proper personnel to appropriate roles, building a project organizational chart, and orchestrating the dynamics of the project team. Human resource considerations beyond the project include how individuals fit into the company's organizational chart, what other roles and responsibilities they have and how this might affect their availability, personal considerations such as leave time, communication styles, interpersonal skills, and any number of other qualities as unique as are individuals. At the project or program level, planning and managing requires effective resource loading so that a schedule considers the amount of personnel's time available during a specific period. Failure to do so within or among projects can result in overallocation of resources, requiring individuals to work for more hours than they have available. A common tool used to help in effective planning is resource leveling, which resolves such issues but can result in delaying tasks. Delayed tasks, however, do not always mean that the total duration of the project will be increased. This depends on whether the affected tasks fall on the "critical path", which is defined as the series of dependent tasks that defines the earliest time by which the project can be completed.

4.5 Stakeholders and Communication

Stakeholders can be thought of as anyone who is involved in or affected by a project, which is a broad grouping. Some categories of stakeholders include the project team, the organization(s), clients, sponsors, or anyone else affected - including the general public.

Identifying and engaging stakeholders, as well as planning and managing effective communication among stakeholders, is a big challenge. The project team may use some methods of communicating internally (e.g. email, meetings, shared documents, etc.) with other methods used to gain or distribute information, and specific to stakeholders external to the team (e.g. surveys; interviews; focus groups; forecasts; status progress, or final reports; training manual; lessons-learned documents; etc.). Planning and managing effective communications can be fraught with potential pitfalls, but some overarching guidelines such as formats, templates, procedures, and established frequency and channels of communication can help to set expectations and avoid mis-steps.

4.6 Procurement

If an organization lacks all of the resources (e.g. skilled staff, equipment, software) necessary for completing projects, they may turn to procuring these resources. For GIS&T projects and programs, procurements often involve consulting services, system infrastructure and software, or technical support. The vehicles to secure such support include: sole-source contracts; openly competitive contracts promoted with requests for proposals, qualifications or bids; an extension or amendment to an existing contract; and selecting resources from a pre-qualified pool of providers. Contracting formalizes these arrangements into documents that establishes terms for the provision of products or services from a contractor or vendor. Types of contracts include fixed-price, cost-reimbursable, time and expense, and unit price contracts. It is important to fully understand such contracts due to their legally binding nature.

4.7 Integration

Project integration management recognizes that dedicated efforts are required to coordinate all other knowledge areas throughout the lifecycle of a project. PMI (2017c) defines these as six processes which can appear similar to but differ from the process groups defined in Section 2. The processes are: developing the project charter, developing the project management plan, directing and managing project work, managing project knowledge, monitoring and controlling project work, performing integrated change control, and closing the project or a phase.

An explicit and implicit implication of project integration management is that the project manager has knowledge of the domain side (in addition to the management side) of the project that allows for its successful completion, which in this case would be knowledge areas from the GIS&T BoK. A study looking simultaneously at PM and GIS&T knowledge areas (Kennelly 2013) indicates that failure-prone projects are less influenced by lack of knowledge from the GIS&T BoK, and more detrimentally affected by issues in multiple PM knowledge areas (especially combinations of areas described in Section 4.1 and 4.2), underscoring importance of PM knowledge areas for GIS&T professionals in management positions.

5. Special Tools and Techniques for Project Planning and Evaluation

5.1 Automated Project Management and Visualization Tools

It is common practice for project managers to make use of automated tools to support project planning and the management of the project during execution. Project management software packages have tools that support critical parts of project planning and management, including the following:

- Setting up a project task hierarchy or work breakdown structure (WBS) and schedule, and automating the planning process to allow a project manager to apply and compare different project scenarios.
- Making necessary changes to the project during execution (as conditions warrant), and ensuring that any change to a task or resource automatically shows changes to related parts of the project (e.g., change in timing to one task is reflected in all other tasks linked to it). With project plans that capture relationships and dependencies among tasks (a.k.a. "predecessors"), adjustments to overall timing are largely automated.
- Assigning resources (people, money) to the project and establishing a link between resources and execution of work.
- Tracking of project status and calculation variances between planned and actual timing and resources.
- Showing information graphically in presentations and other communications.
- Reporting of project plan, status, and resource information.
- Linking and quickly accessing documents, Web sites, and other external information associated with the project or specific tasks.
- Linking separate plans from multiple, related projects for easy access to and exchange of task and resource information.

There are dozens of project management software packages on the market, but Microsoft ProjectTM is one example of a comprehensive project management package that has a large range of tools for project planning, scheduling, resource management, tracking and reporting with a wide array of project visualization capabilities (e.g., Gantt charting).

In the past, most project management software was designed for local desktop use but it is more common today to deploy these tools in a server environment with multi-user access and collaboration tools—at least for larger projects that involve a large team and group of stakeholders. In fact, there are a growing number of Web-based packages and Cloud-based platforms supporting project planning and tracking. These progressions mirror trends in GIS&T in moving toward Cloud-based platforms. The growing popularity of both hosting technology and management in the cloud relates to growing demand to create, share, collaborate in an online environment.

It is best to think of most project management software as a spreadsheet or database in which the rows are work plan tasks and the columns present information about the task (e.g., its number, name, timing, resources, etc.). Figure 3 is an example of a Gantt Chart view (from Microsoft ProjectTM software) of a hypothetical project work plan. a Microsoft ProjectTM view of a hypothetical project and conveys the overall spreadsheet concept. The most commonly used columns, as Figure 3 shows, are task number, task name, duration, start date, and finish date. Figure 3 shows how the tasks are organized into the WBS hierarchy with three levels.

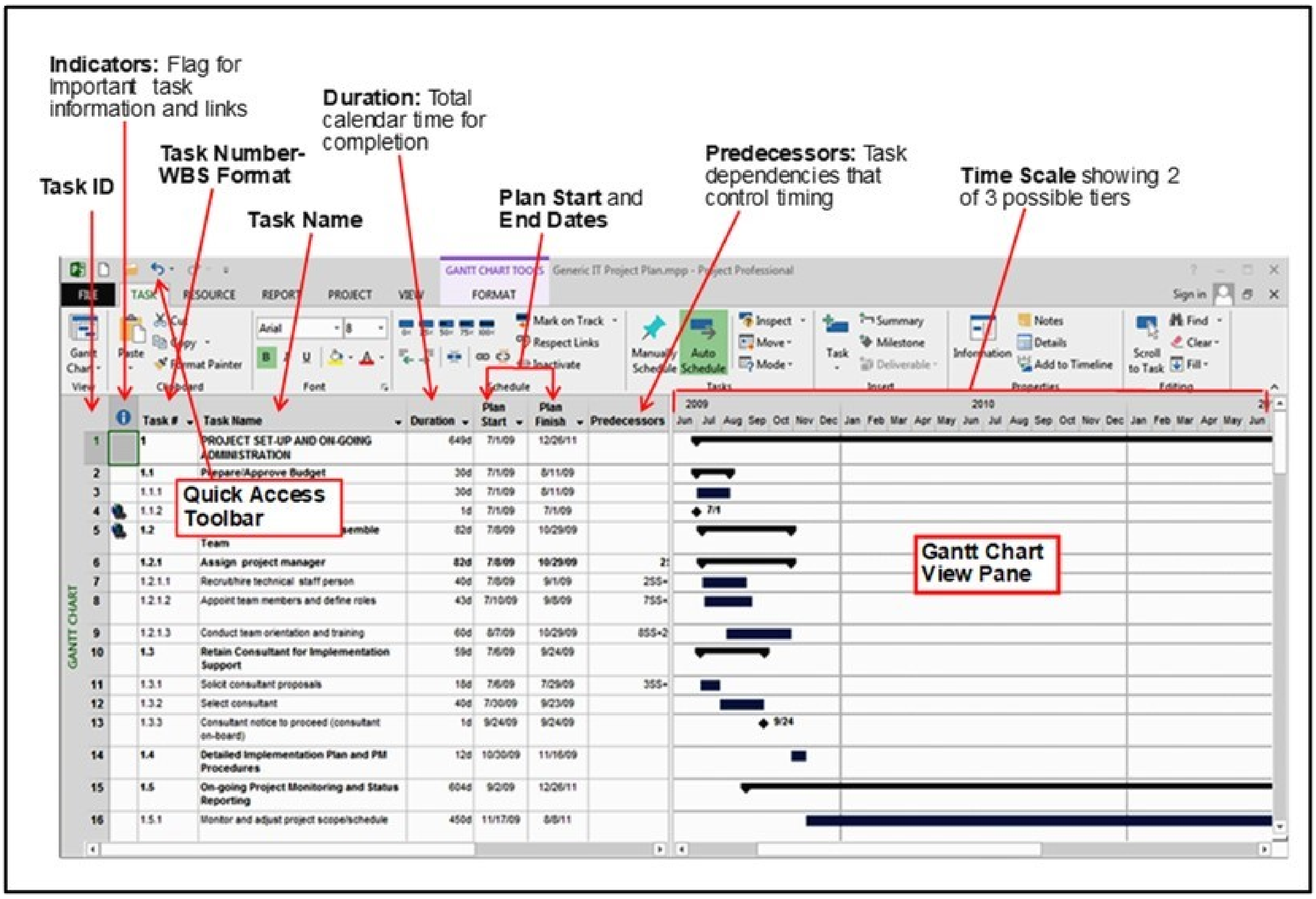


Figure 3. General "Spreadsheet" Concept of Project Management Software (example from Microsoft ProjectTM). Source: authors.

Project management software allows users to define a number of task types, as illustrated in Figure 4.

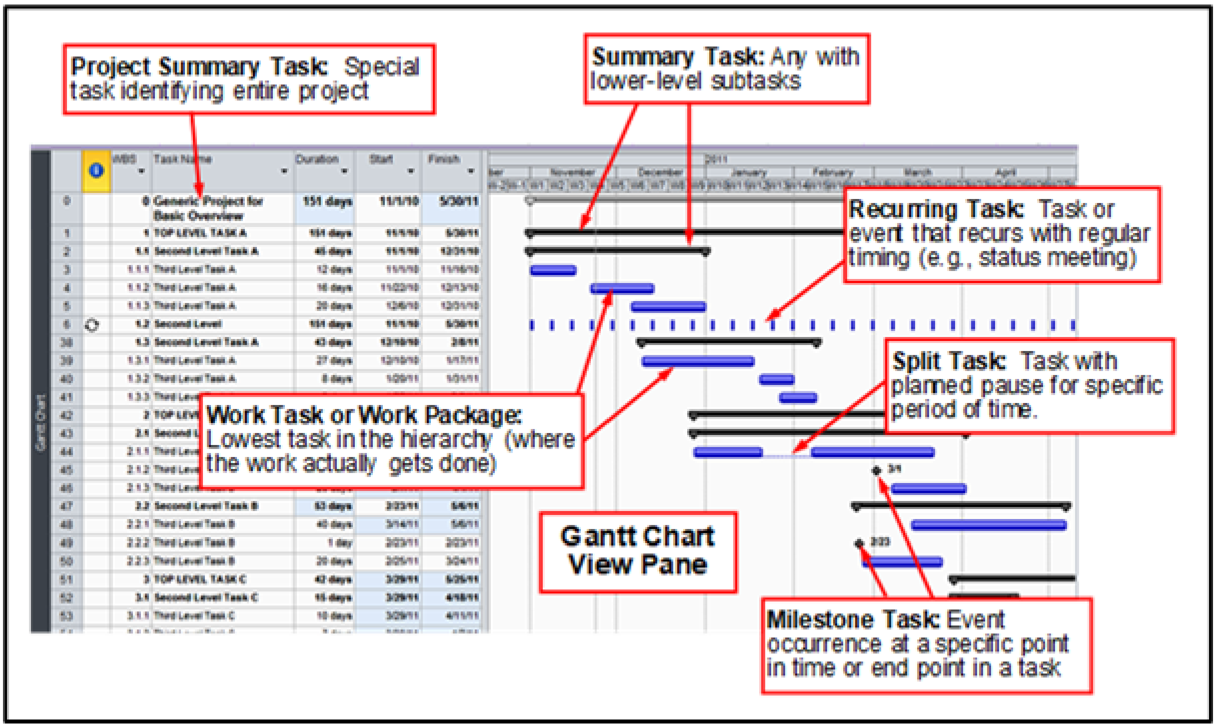


Figure 4. Types of Tasks in a GIS Project. Source: authors.

Project management software packages include features that allow users to define specific controls on the timing of tasks. This includes task linkages, also referred to as “predecessors” or “relationships” that often are defined by when another task finishes or starts.

Timing controls can be made very flexible with the assignment of “lags” or “leads” to any of the predecessor types. A lag or lead directs a linked task to start or finish at a specified time before or after the start or finish of a task to which it is linked.

A valuable feature of project management software is the ability to view project information in different ways, including graphic visualization, that help a project manager and team understand the project, test different scenarios, and communicate project information to others. The Gantt view is the most commonly used, but there are many other ways to view task and resource information including the calendar view and network diagram view shown in Figure 5.

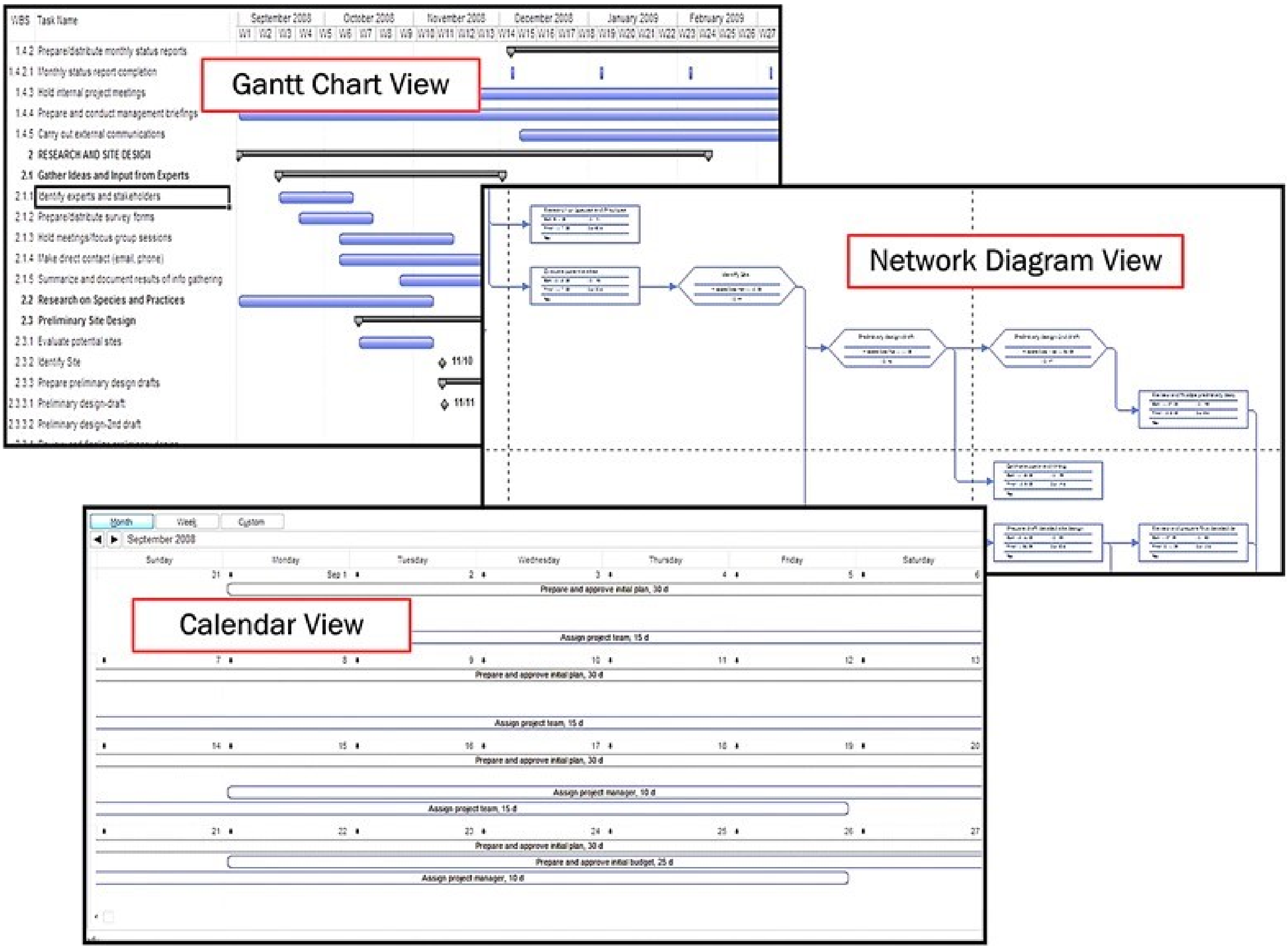


Figure 5. Common Views of GIS Project Tasks. Source: authors.

In addition to its use for project planning, project management software has very effective features for tracking and logging information about project status during execution. This includes the ability to enter and display information on actual status, calculating variances from the plan, and generating reports. One very effective way to use these tools is to establish a project "baseline" after the tasks and timing are set up. This stores the plan information in separate fields, which can be used in display and variance reporting.

Many project management software packages have sophisticated tools for assigning and managing project resources and tasks. These resource management tools can be used in a very simple way, for example to identify only budget projections and people or contractors assigned roles by tasks. But the software provides more sophisticated capabilities for resource-driven projects by supporting the following tasks:

- Tracking the status of resources and adjusting resource assignments by task to achieve full utilization of resources (i.e., fully utilize people but avoid overscheduling them).
- Automatically adjusting task timing based on the amount of resources assigned (e.g., assignment of more team members' hours will reduce the overall time for task completion).
- Load balancing (of workload).

- Managing work calendars and team members' timesheets.
- Budgeting and managing finances based on assignments of labor hours or resource usage by task.

5.2 Financial and Related Monitoring Tools/Techniques

Financial management for projects encompasses budget preparation and management of costs and expenditures during project execution. Croswell (2019, Chapter 5) provides detailed information about the type of costs associated with GIS programs and projects and the budgeting process. In a project context, the term "resource" is often used as a general term to refer to all people, money, equipment, and tangible assets that are used and expended to produce project deliverables. In practice, most of these types of resources can be expressed in monetary terms. Penn State Dutton e-Education Institute (2020) includes a thorough summary of GIS project costs and project financial management concerns https://www.e-education.psu.edu/geog871/l6_p3.html.

Project financial tracking requires the monitoring of two main expenditure categories: "direct costs" and "indirect costs". Most organizations have specific definitions for these terms and practices for managing them. Direct and indirect costs are related concepts explained below:

- The cost category list above presents typical "direct costs" which are expended for projects. The cost of workers (specifically their time applied to the project) is an example of a direct cost. If a project manager is to determine the cost of a day of an employee's efforts, it is important to not only account for his salary, but also the cost of all of the employee's benefits for that month. For longer projects, it may also be necessary to include costs or estimates of salary increases for team members during the project's life cycle. Cost for contracted staff would be defined by applying a contracted rate (e.g., dollars per hour, day, or month). Direct costs also include all monetary expenditures for products (e.g., software, equipment) and services (e.g., travel costs, training services) that must be accounted for in the project budget.
- "Indirect costs" represent costs that are incurred by an organization carrying out a project but which are not specifically accounted for or tracked as part of a project. As such, indirect costs are often tallied for the entire organization, and then prorated to individual projects by the organization. Indirect costs are sometimes called overhead, and include a range of things such as: building rent and operational costs (utilities, maintenance, custodial services); insurance fees; tax payments; employee training not attributable to a specific project; and costs for office furniture, equipment, and computer hardware which is not accounted for through specific projects. In private companies, staff time which is not billed to a specific project, and therefore does not bring in revenue (marketing and sales staff), is also considered overhead. Individual organizations have considerable discretion on how to categorize indirect costs vs direct costs that are directly attributable to one or more projects. Many government agencies and private companies account for overhead costs as a "multiplier" applied to employee costs. For instance, private GIS consulting companies typically establish hourly or daily monetary rates that take into account the employee's base salary and benefits along with physical overhead and the company's non-billable employee costs. A company that pays a GIS Analyst a salary of $85,000 per year plus benefits (roughly equivalent to $50/hour), may establish a multiplier of 2.4 to cover overhead as well as expected profit, resulting in a billable rate of $120/hour. In projects, it is important to

establish clear "billable rates" for project team members because this is the basis for tracking project labor costs.

As described by a number of authors, including Fournier (2008), Marchewka (2015), and Schwalbe (2019), financial tracking at the project level uses a number of standard financial metrics. These metrics reflect budgets and actual costs in monetary terms, which include direct project expenses and may also include labor time, material consumption, equipment costs, etc. Metrics are attached to specific tasks and deliverables. These metrics are normally aggregated for summary reporting at the project or phase level and are used in a performance tracking approach called "Earned Value Methodology," or EVM. EVM is an effective technique for tracking costs and examining expenditures on a project, initiative, or other budgeted expenditure relative to completed work. Its strength is that it looks at cost, time, and task completion within the scope of the project simultaneously. It uses a WBS and budget created during the development stage, but tracks these metrics during the implementation stage of a project life cycle. In EVM, the term "value" means planned or accomplished "work" based on planned tasks and costs—expressed in dollars or other monetary units (actual monetary expenditure or labor time converted to a monetary amount). The main EVM measures are documented at https://www.e-education.psu.edu/geog871/l6_p6.html and in table 9.8 of Croswell (2019).

Clearly, the effective employment of EVM depends upon regular monitoring and tracking of expenditures and the status work (relative to a plan). Table 2 is an illustration of EVM measures applied to a GIS application development project.

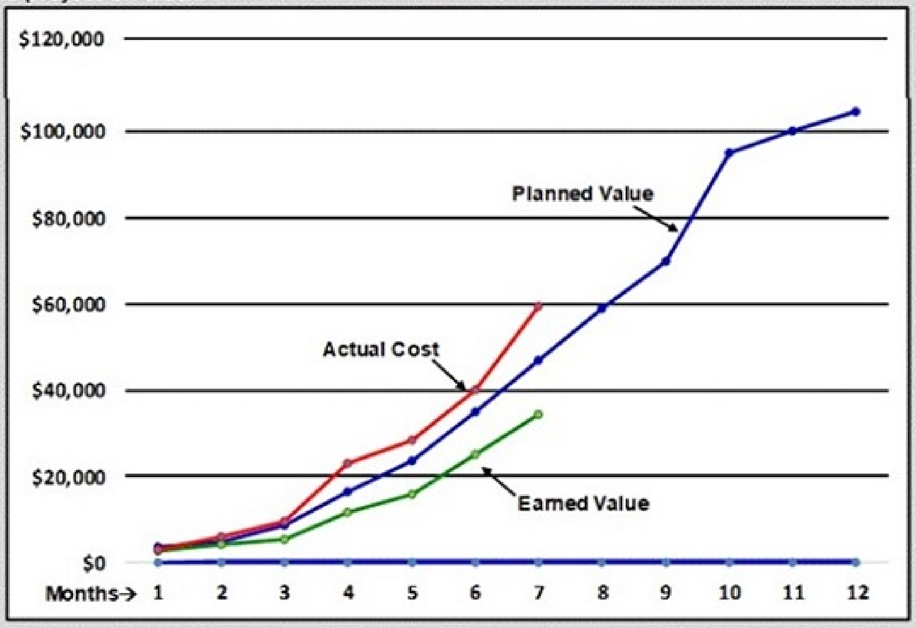
Table 2. Earned Value Measurement Project Example

GIS Project: Design, development, and deployment of a Web-based application allowing public users to access a GIS database, select specific map layers, interactively delineate a geographic area, and export/download data in a selected format. The application also calculates a cost for the data and allows users to pay via credit card. The project is scheduled to last for 12 months. The total budgeted cost (BAC) that takes into account the cost of contracted services and in-house staff time. The project manager monitors project costs (in-house labor and contractor costs) and the percent of work completed.

EVM TABLE: This table shows the main EVM measures with a focus on project status at Month 7. These measures show that the project is overbudget and that the performance of work significantly lags behind planned work.

Months:	1	2	3	4	5	6	7	8	9	10	11	12
Planned Value (PV):	$3,400	$4,700	$8,700	$16,500	$23,500	$35,000	$47,000	$59,000	$70,000	$95,000	$100,000	$104,500
Planned % Complete:	3%	4%	8%	16%	22%	33%	45%	56%	67%	91%	96%	100%
Actual % Completion:	1%	2%	5%	11%	15%	24%	33%					
Earned Value (EV):	$2,700	$4,200	$5,225	$11,495	$15,675	$25,080	$34,485					
Actual Cost (AC):	$2,800	$5,900	$9,400	$23,050	$28,400	$40,100	$59,500					
Schedule Variance (SV):	-$100	-$1,700	-$4,175	-$11,555	-$12,725	-$15,020	-$25,015					
Cost Variancen(CV):	$600	-$1,200	-$700	-$6,550	-$4,900	-$5,100	-$12,500					
Cost Performance Index (CPI):	0.96	0.71	0.56	0.50	0.55	0.63	0.58					
Schedule Performance Index (SPI):	0.79	0.89	0.60	0.70	0.67	0.72	0.73					
Estimate at Completion (EAC):	$108,370	$146,798	$188,000	$209,545	$189,333	$167,083	$180,303					
Estimated Cost to Complete (ETC):	$105,570	$140,898	$178,600	$186,495	$160,933	$126,983	$120,803					
Estimated Time to Complete (ETC) in months:	14.1	11.4	17.0	13.2	13.0	10.7	9.4					

EVM GRAPH: The graph below depicts the planned value (PV) of the project (blue line) over the projected 12 months and the actual cost (AC) and earned value (EV) relative to the PV line at Month 7. This graph visually shows that the AC (red line) is higher than and the EV (green line) is lower than the PV. This indicates that there are problems that should be rectified to keep the project on track.



5.3 Software/Application Development Methodologies

Many formal methodologies exist for application development. Methodologies such as the waterfall method, the spiral method, rapid prototyping, and others are well documented and tend to be complete and rigorous in the steps and requirements they impose. Ballard (2015) gives a useful overview of structured (waterfall) development methodologies requiring substantial upfront design in comparison with more adaptable agile methodologies.

In the last 15 years, many software and application development projects have adopted Agile approaches in place of more traditional, highly-structured methodologies (see Section 7.6). “Agile Development” is described by the Agile Alliance (www.agilealliance.org) as “a set of a set of methods and practices where solutions evolve through collaboration between self-organizing, cross-functional teams.” These agile or adaptive environments are often designed to have more frequent review or quality steps throughout the project (Schwalbe 2019). The intent is to identify the root cause of issues and to allow experimentation with new approaches to address these issues. Agile methodologies allow for greater flexibility in defining and verifying requirements and building these into the development and testing approach (Todaro, 2019). A key point is that a decision to adopt an Agile approach for application development does not eliminate a need to do up-front requirements assessment and design. But it does create a more flexible development environment—demanding more frequent team and customer interaction and allowing changes to requirements and design during the process.

The purpose of every formal methodology is developing an application that is technically sound and meets the users’ needs for functionality, security, and ease of use. Whether or not a formal application development methodology is used, it is vitally important to employ a logical process, such as the one generalized in Figure 6, which begins with solid design and proceeds through iterative development steps with considerable user review and comment prior to full deployment.

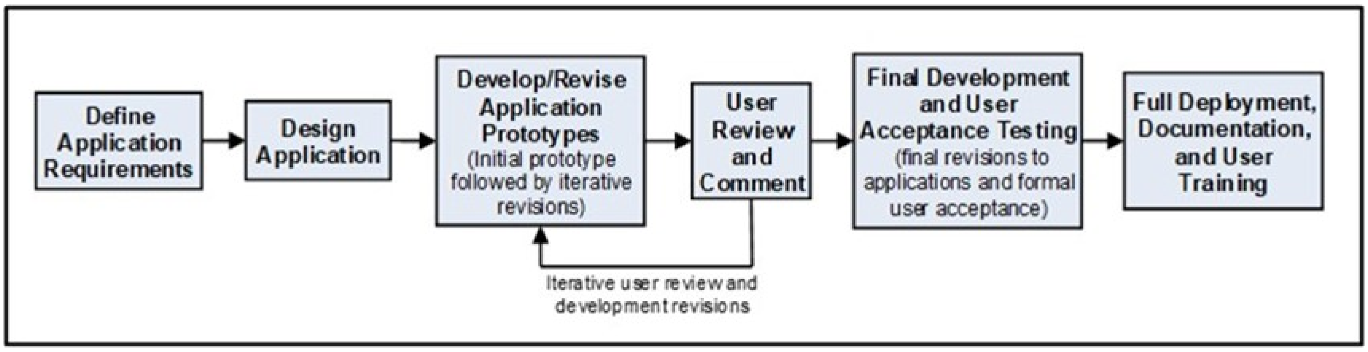


Figure 6. General Process for Application Design and Development. Source: authors.

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