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GIS Project Management

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1.31 GIS Project Management

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Glossary

Budgeted Costs of Work Scheduled/Performed Respectively, the detailed cost estimates for each activity in the project, or the sum of those activity costs that have been delivered so far.

Earned Value Analysis The intermediate sum of all costs expended minus the values already earned.

Earned Value Management Periodically compares the budgeted costs with the actual costs during the project.

Myers-Briggs (Type Indicator) A large world-wide administered survey of personality traits that helps human resource managers to create teams that work with less interpersonal friction.

Project Business Case The project proposal that describes what problem or opportunity will be addressed by the project.

QA/QC Is the acronym for the twin concepts of quality assurance/quality control. QC embodies the set of methods to test for adherence to quality standards at each step of the project. QA is the larger framework, within which the QC tests are designed and implemented.

Schedule Variance The costs accrued by a project because of the amount of time it is behind schedule.

SCRUM A project management methodology that allows a manager to start by building on empirical data, and then replan and iterate from there.

SMART Goals Goals that are specific, measurable, agreed-upon, realistic, and time-framed.

Stakeholders Are individuals who either care about or have a vested interest in the project.

1.31.1 Project Management Overview

There is a big gulf between GIScience as an academic endeavor and its application in the form of GIS project management in the real world. Project activities are complex because they rarely involve routine repetitive acts, but often require specific knowledge and skills to be used in their design, execution, and management. This article explains what project management is, its objectives, and the required ingredients from personnel to budgets, and the integration of the GIS project into the larger context of an organization's and even societal culture.

1.31.1.1 Project Attributes

Projects are temporary in nature. They are not an everyday business process and have definitive start dates and end dates. This characteristic is important because a large part of the project effort is dedicated to ensuring that the project is completed at the appointed time. To do this, schedules are created showing when tasks should begin and end. Projects can last minutes, hours, days, weeks, months, or years.

Each project is unique: they exist to produce a product or service that hasn't existed before. This is in contrast to operations (which a project may consist of), as they are typically ongoing and repetitive. The purpose of operations is to keep the organization functioning while the purpose of a project is to meet its goals and conclude. Therefore, operations are ongoing while projects are unique and temporary.

1.31.1.1.1 Definition of a project

There are many definitions of a project. Wysocki et al. (2003, p. 38), for example, define a project as "*a sequence of unique, complex and connected activities having one goal or purpose that must be completed by a specific time, within budget, and according to specification*". Central to this definition is a logical sequence of activities that must be completed within a specific time frame.

The Project Management Institute (PMI) (2013a, p. 8) defines project management "*the application of knowledge, skills, tools, and techniques to project activities to meet the project requirement*". This definition is supplemented by five Project Management Process Groups (PMPG) that describe the lifecycle of typical projects, and 10 knowledge areas in which project managers must be competent. The five PMPG are initiating processes, planning processes, executing processes, monitoring and controlling processes, and closing processes. The 10 knowledge areas, on the other hand, focus on management expertise in project integration management, project scope management, time management, cost management, quality management, human resources management, communications management, risk management, procurement management, and stakeholder management.

Project management has also been defined in many other ways in the related literature. However, it is apparent that many authors have accepted the PMI proposition that project management is a special branch of management characterized by the application of management principles and best practices that seek to steer the initiation, planning, implementation, monitoring, and closing of projects toward their ultimate success. It is also apparent that many authors have adopted the PMI's approach to group all project management activities into five sequential phases or levels, commonly called the project management lifecycle (PMLC).

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1.31.1.2 Project Characteristics

Projects have several characteristics:

- Projects are unique.
- Projects are temporary in nature and have a definite beginning and ending date.
- Projects are completed when the project goals are achieved or it's determined the project is no longer viable.

A successful project is one that meets or exceeds the expectations of the stakeholders.

1.31.1.2.1 Projects versus programs versus portfolios

Every organization that has multiple GIS users has de facto a GIS Program (Peters, 2008). If the users get their work done and are not aware of the business unit that allows them to do their work, then this means that the program manager does her job well. If on the other hand every GIS project starts from scratch and the only institutional memory is buried in the heads of those who did other GIS projects before, then the tool that constitutes GIS is clearly not used to its highest potential.

The PMI defines program management as "the application of knowledge, skills, tools, and techniques to a program to meet the program requirements and to obtain benefits and control not available by managing projects individually", (PMI, 2013b, p. 6). The scope of programs is hence beyond the sum of individual projects and includes training, operations, and maintenance activities. All this applies to GIS Programs as well. Two dimensions are useful to keep in mind when there is confusion about the differences between projects and programs:

- Uncertainty; well-managed projects generally have a low level of uncertainty associated with them. This starts with project specification and improves as a project moves toward its goal. Programs, on the other hand, do not start out with a well-defined scope and require continuous adjustment. In extreme cases, a successful project may still be abandoned because its program context has changed.
- Change management of projects is usually in the form of fixes when the original outcomes seem to become unattainable. Program management, however, anticipates changes and aims to adapt the program to changing contexts.

The practice of GIS Programs would be categorized in management science as a portfolio, a higher level management structure that has temporal bounds and combines multiple programs to achieve an organization's strategic objectives (PMI, 2013c). In addition, portfolio projects do not need to be related to each other. Both of these characteristics (no temporal bounds and possible nonrelatedness of the projects) are characteristic for GIS Programs. It follows that GIS Programs then combine the components of traditional programs and portfolios, namely strategic planning, governance, benefits management, and stakeholder engagement. GIS Programs, like portfolios, manage recurring activities (producing values) as well as projectized activities that are aimed at increasing value production capability.

Projects come at a wide range of scopes from single-purpose projects that serve one-time objectives to departmental projects that typically are handled within a dedicated GIS department, enterprise-wide projects that may be line-managed by a GIS department, which may then play a strategic role within an organization, and finally consortial GIS projects, where the costs are shared by a large number of stakeholders.

A project must have a well-defined goal with respect to the mission or mandate of an organization. In many instances, a project may be too complicated to be carried out as a single undertaking. Hence, it is necessary to divide it into several sub- or part-projects according to the prevailing organization structure (e.g., by departments or business functions) or geographical divisions (e.g., by regions, sales territories, or watersheds). Under such circumstances, each subproject is considered as a separate but interdependent undertaking in its own right. All subprojects have their specific goals but when added together these goals collectively constitute the specific goal of the parent project.

Every project or subproject is generally subject to three constraints regardless of its objective and scale. As depicted in Fig. 1, these are:

- Time. Projects have definitive milestones that specify when particular components (e.g., progress reports, prototypes) must be delivered, and a completion date when the database system being developed will become fully functional and operational.

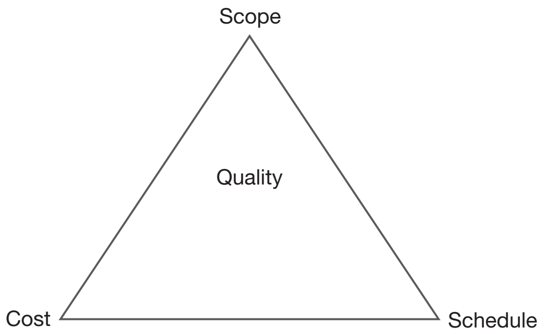

Fig. 1 The triple constraint of scope, schedule, and budget.

- Cost. Projects have cost or budgetary limits, which will impact the availability of human and technical resources.
- Specification. Deliverables of a project are required to meet a specific level of functionality and quality both independently and when working as a whole.

It is important to understand that the constraints of time, cost, and specification are interdependent and, as a result, changes in one constraint always cause changes in the others. For example, a change in the specification will inevitably lead to changes in the time and cost requirements. Similarly, delays in the delivery of intermediate and final products inevitably necessitate an extension of the project time frame, which will, in turn, increase the cost and resource requirements of the project. Clearly, the dynamic nature of the interplay among the constraints requires that projects must be properly managed in order to succeed. The principles and practice of management are often deployed in the context of managing tangible entities such as people, physical and financial assets, and the business operations of an organization. These same principles, however, can be equally applied to the management of tangible resources and nontangible activities that are required to complete a project.

1.31.1.3 The Process of Project Management

In spite of a long history of project management research, the application of that knowledge is lacking in both the GIS world as well as more generally in the realms of information technology or business administration. According to the CHAOS Report, published by the Standish Group (2016) that tracks over 50,000 projects around the world, some 20% of all projects fail and over 52% of all projects face major challenges, with only 22% considered to be successful. The vast majority of these challenges ad failures are avoidable by making sure that the business needs are understood early on and assuring that project management techniques are applied and followed. Having good project management skills does not completely eliminate problems, risks, or surprises. The value of good project management is to have standard processes in place to deal with all contingencies.

Project management is the application of knowledge, skills, tools, and techniques applied to project activities in order to meet the project requirements. Project management is a process that includes planning, putting the project plan into action, and measuring progress and performance.

1.31.2 Project Management and GIS Implementation Concepts

The design, development, and implementation of a GIS task are complex tasks which should not be underestimated. They require leadership, adequate planning, and a project-wise approach. This section, therefore, provides a generic organizational framework which is meant to support the design, development, and installation of a GIS.

1.31.2.1 The Triple Constraint of Scope, Schedule, and Budget

On any project, there are a number of project constraints that are competing for the project manager's attention. They are cost, scope, quality, risk, resources, and time. These six points are often abbreviated as the "triple constraint" of time, cost, and scope, illustrated in the form of a triangle to visualize the project work and see the relationship between the scope/quality, schedule/time, and cost/resource.

In this triangle, each side represents one of the constraints (or related constraints) wherein any changes to any one side cause a change in the other sides. The best projects have a perfectly balanced triangle. Maintaining this balance is difficult because projects are prone to change.

1.31.2.1.1 Cost

The definition of project success often includes completing the project within budget. Developing and controlling a project budget that will accomplish the project objectives is a critical project management skill. Although clients expect the project to be executed efficiently, cost pressures vary on projects. On some projects, the project completion or end date is the largest contributor to the project complexity. The development of a new drug to address a critical health issue, the production of a new product that will generate critical cash flow for a company, and the competitive advantage for a company to be first in the marketplace with a new technology are examples of projects with schedule pressures that override project costs.

The accuracy of the project budget is related to the amount of information known by the project team. In the early stages of the project, the amount of information needed to develop a detailed budget is often missing. To address the lack of information, the project team develops different levels of project budget estimates. The conceptual estimate (or "ballpark estimate") is developed with the least amount of knowledge. The major input into the conceptual estimate is expert knowledge or past experience. A project manager who has executed a similar project in the past can use those costs to estimate the costs of the current project.

When more information is known, the project team can develop a rough order of magnitude (ROM) estimate. Additional information such as the approximate square feet of a building, the production capacity of a plant, and the approximate number of hours needed to develop a software program can provide a basis for providing a ROM estimate. After a project design is more complete, a detailed project estimate can be developed.

The cost of the project is tracked relative to the progress of the work and the estimate for accomplishing that work. Based on the cost estimate, the cost of the work performed is compared against the cost budgeted for that work. If the cost is significantly higher or lower, the project team explores reasons for the difference between expected costs and actual costs.

Project costs may deviate from the budget because the prices in the marketplace were different from what was expected. Project costs may also deviate based on project performance. For example, a GIS manager estimated that a particular survey would take 750 labor hours, but 792 hours were actually expended. The project team captures the deviation between costs budgeted for work and the actual cost for work, revises the estimate as needed, and takes corrective action if the deviation appears to reflect a trend.

The project manager is responsible for assuring that the project team develops cost estimates based on the best information available and revises those estimates as new or better information becomes available. The project manager is also responsible for tracking costs against the budget and conducting an analysis when project costs deviate significantly from the project estimate. The project manager then takes appropriate corrective action to ensure that project performance matches the revised project plan.

More detail on aspects of project quality can be found in section "**Budget planning**".

1.31.2.1.2 Scope

The scope is a document that defines the parameters—factors that define a system and determine its behavior—of the project, what work is done within the boundaries of the project, and the work that is outside the project boundaries. The scope of work (SOW) is typically a written document that defines what work will be accomplished by the end of the project—the deliverables of the project. The project scope defines what will be done, and the project execution plan defines how the work will be accomplished.

No template works for all projects. Some projects have a very detailed scope of work, and some have a short summary document. The quality of the scope is measured by the ability of the project manager and project stakeholders to develop and maintain a common understanding of what products or services the project will deliver. The size and detail of the project scope are related to the complexity profile of the project. A more complex project often requires a more detailed and comprehensive scope document.

According to Burek (2011), the scope statement should include the following:

- Description of the scope.
- Product acceptance criteria.
- Project deliverables.
- Project exclusions.
- Project constraints.
- Project assumptions.

The scope document is the basis for agreement by all parties. A clear project scope document is also critical to managing change on a project. Since the project scope reflects what work will be accomplished on the project, any change in expectations that is not captured and documented creates opportunity for confusion. One of the most common trends in projects is the incremental expansion in the project scope. This trend is labeled "scope creep." Scope creep threatens the success of a project because the small increases in scope require additional resources that were not in the plan. Increasing the scope of the project is a common occurrence, and adjustments are made to the project budget and schedule to account for these changes. Scope creep occurs when these changes are not recognized or not managed. The ability of a project manager to identify potential changes is often related to the quality of the scope documents.

Virtually all GIS project scopes include background/context, research on goal, objectives, information categories, and the actual information products depicted in **Fig. 2**.

Events do occur that require the scope of the project to change. Changes in the marketplace may require a change in a product design or the timing of the product delivery. Changes in the client's management team or the financial health of the client may also result in changes in the project scope. Changes in the project schedule, budget, or product quality will have an effect on the project plan. Generally, the later in the project the change occurs, the greater the increase in the project costs. Establishing a change management system for the project that captures changes to the project scope and assures that these changes are authorized by the appropriate level of management in the client's organization is the responsibility of the project manager. The project manager also analyzes the cost and schedule impact of these changes and adjusts the project plan to reflect the changes authorized by the client. Changes to the scope can cause costs to increase or decrease.

More detail on aspects of project scope management can be found in section "**Defining the project scope**"

1.31.2.1.3 Quality

Quality is a combination of the standards and criteria to which the project's products must be delivered for them to perform effectively. The product must perform to provide the functionality expected, solve the identified problem, and deliver the benefit and value expected. It must also meet other performance requirements, or service levels, such as availability, reliability, and maintainability, and have acceptable finish and polish. Quality in a project is controlled through quality assurance (QA), which is the process of evaluating overall project performance on a regular basis to provide confidence that the project will satisfy the relevant quality standards.

Project quality focuses on the end product or service deliverables that reflect the purpose of the project. The project manager is responsible for developing a project execution approach that provides for a clear understanding of the expected project deliverables and the quality specifications. Developing a good understanding of the project deliverables through documenting specifications and

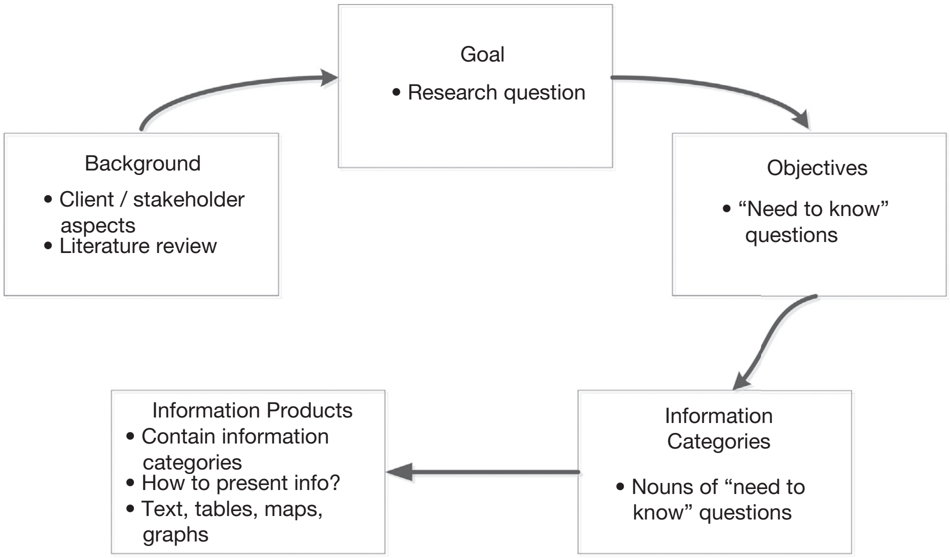

Fig. 2 Components of a GIS project scope document.

expectations is critical to a good quality plan. The processes for ensuring that the specifications and expectations are met are integrated into the project execution plan. Just as the project budget and completion dates may change over the life of a project, the project specifications may also change. Changes in quality specifications are typically managed in the same process as cost or schedule changes. The impact of the changes is analyzed for impact on cost and schedule, and with appropriate approvals, changes are made to the project execution plan (see also section "Project execution and control").

Although any of the quality management techniques designed to make incremental improvement to work processes can be applied to a project work process, the character of a project (unique and relatively short in duration) makes small improvements less attractive on projects. Rework on projects, as with manufacturing operations, increases the cost of the product or service and often increases the time needed to complete the reworked activities. Because of the duration constraints of a project, the development of the appropriate skills, materials, and work processes early in the project is critical to project success. In more complex projects, time is allocated to developing a plan to understand and develop the appropriate levels of skills and work processes.

Project management organizations that execute several similar types of projects may find process improvement tools useful in identifying and improving the baseline processes used on their projects. Process improvement tools may also be helpful in identifying cost and schedule improvement opportunities. Opportunities for improvement must be found quickly to influence project performance. The investment in time and resources to find improvements is greatest during the early stages of the project when the project is in the planning stages. During later project stages, as pressures to meet project schedule goals increase, the culture of the project is less conducive to making changes in work processes.

More detail on aspects of project quality can be found in section "Monitoring and control".

1.31.2.1.4 Risk

Risk is defined by potential external events that will have a negative impact on the project if they occur. Risk refers to the combination of the probability the event will occur and the impact on the project if the event occurs. If the combination of the probability of the occurrence and the impact on the project is too high, it is identified as a potential risk, which in turn should prompt the project manager to develop a proactive plan to manage that risk.

More detail on aspects of project risk can be found in section "Project risk and opportunity analysis".

1.31.2.1.5 Resources

Resources are required to carry out the project tasks. They can be people, equipment, facilities, funding, or anything else required for the completion of a project activity.

More detail on aspects of project quality can be found in section "Resource planning".

1.31.2.1.6 Time

Time is defined as the time to complete the project. Time is often the most frequent project oversight in developing projects. This is reflected in missed deadlines and incomplete deliverables. Proper control of the schedule requires the careful identification of tasks to be performed and accurate estimations of their durations, the sequence in which they are going to be done, and how people and other resources are to be allocated. Any schedule should take into account vacations and holidays.

The definition of project success often includes completing the project on time. The development and management of a project schedule that will complete the project on time is a primary responsibility of the project manager, and completing the project on time requires the development of a realistic plan and the effective management of the plan. On smaller projects, project managers may lead the development of the project plan and build a schedule to meet that plan. In larger and more complex projects, a project controls team that focuses on both costs and schedule planning and controlling functions will assist the project management team in developing the plan and tracking progress against the plan.

To develop the project schedule, the project team does an analysis of the project scope, contract, and other information that helps the team define the project deliverables. Based on this information, the project team develops a milestone schedule. The milestone schedule establishes key dates throughout the life of a project that must be met for the project to finish on time. The key dates are often established to meet contractual obligations or established intervals that will reflect appropriate progress of the project. For less complex projects, a milestone schedule may be sufficient for tracking the progress of the project. For more complex projects, a more detailed schedule is required.

To develop a more detailed schedule, the project team first develops a work breakdown structure (WBS)—a description of tasks arranged in layers of detail. Although the project scope is the primary document for developing the WBS, the WBS incorporates all project deliverables and reflects any documents or information that clarifies the project deliverables. From the WBS, a project plan is developed. The project plan lists the activities that are needed to accomplish the work identified in the WBS. The more detailed the WBS, the more activities that are identified to accomplish the work.

After the project team identifies the activities, the team sequences the activities according to the order in which the activities are to be accomplished. An outcome of the work process is the project logic diagram. The logic diagram represents the logical sequence of the activities needed to complete the project. The next step in the planning process is to develop an estimation of the time it will take to accomplish each activity or the activity duration. Some activities must be done sequentially, and some activities can be done concurrently. The planning process creates a project schedule by scheduling activities in a way that effectively and efficiently uses project resources and completes the project in the shortest time.

In larger projects, several paths are created that represent a sequence of activities from the beginning to the end of the project. The longest path to the completion of the project is the critical path. If the critical path takes less time than is allowed by the client to complete the project, the project has a positive total float or project slack. If the client's project completion date precedes the calculated critical path end date, the project has a negative float. Understanding and managing activities on the critical path are an important project management skill.

To successfully manage a project, the project manager must also know how to accelerate a schedule to compensate for unanticipated events that delay critical activities. Compressing—crashing—the schedule is a term used to describe the techniques used to shorten the project schedule. During the life of the project, scheduling conflicts often occur, and the project manager is responsible for reducing these conflicts while maintaining project quality and meeting cost goals.

More detail on aspects of project scheduling can be found in sections "Project schedule planning" and "Scheduling tools".

1.31.2.2 GIS Project Team Roles and Responsibilities

Staffing the project with the right skills, at the right place, and at the right time is an important responsibility of the project management team. The project usually has two types of team members: functional managers and process managers. The functional managers and team focus on the technology of the project. On a construction project, the functional managers would include the engineering manager and construction superintendents. On a training project, the functional manager would include the professional trainers; on an information technology project, the software development managers would be functional managers. The project management team also includes project process managers. The project controls team would include process managers who have expertise in estimating, cost tracking, planning, and scheduling. The project manager needs functional and process expertise to plan and execute a successful project.

Because projects are temporary, the staffing plan for a project typically reflects both the long-term goals of skilled team members needed for the project and short-term commitment that reflects the nature of the project. Exact start and end dates for team members are often negotiated to best meet the needs of individuals and the project. The staffing plan is also determined by the different phases of the project. Team members needed in the early or conceptual phases of the project are often not needed during the later phases or project closeout phases. Team members needed during the implementation phase are often not needed during the conceptual or closeout phases. Each phase has staffing requirements, and the staffing of a complex project requires detailed planning to have the right skills, at the right place, at the right time.

Typically a core project management team is dedicated to the project from start-up to closeout. This core team would include members of the project management team: project manager, project controls, project procurement, and key members of the function management or experts in the technology of the project. Although longer projects may experience more team turnover than shorter projects, it is important in all projects to have team members who can provide continuity through the project phases.

Project team members can be assigned to the project from a number of different sources. The organization that charters the project can assign talented managers and staff from functional units within the organization, contract with individuals or agencies to staff positions on the project, temporarily hire staff for the project or use any combination of these staffing options. This staffing approach allows the project manager to create the project organizational culture. Some project cultures are more structured and detail oriented, and some are less structured with less formal roles and communication requirements. The type of culture the project manager creates depends greatly on the type of project.

1.31.2.3 Communications

Completing a complex project successfully requires teamwork, and teamwork requires good communication among team members. If those team members work in the same building, they can arrange regular meetings, simply stop by each other's office space to get a quick answer, or even discuss a project informally at other office functions. Increasingly, however, team members hail from widely separated locations, and face-to-face meetings are replaced by electronic methods of communicating resulting in so-called virtual teams who may work synchronously and asynchronously. Communications technologies require a variety of compatible devices, software, and service providers, and communication with a global virtual team can involve many different time zones. Establishing effective communications, therefore, requires a communications plan.

1.31.2.4 Project Management and System Development Lifecycles

The Project Management Lifecycle (PMLC) defines how a project is managed effectively and efficiently from its conceptualization through implementation to its operationalization. A further term, namely the project lifecycle (PLC) is also used to describe this process. The terms PMLC and PLC are always used in conjunction with project management but they actually refer to two relatively distinct sets of concepts and processes. The purpose of a PLC is to describe the activities that must be completed in order to create a product or a service. The PLC of individual projects varies from one to another because of the uniqueness of the nature of each project. The Systems Development Lifecycle (SDLC) and Database Development Lifecycle (DDLC) are examples of the PLC for GIS implementation projects.

The PLC focuses on the tasks that are necessary for a project. In contrast, the focus of the PMLC is on how these tasks can be managed. In this regard, the PMLC is more of a conceptual framework for the systematic application of managerial principles and best practices, rather than the actual steps of building a product or service. As such, the PMLC remains the same for all projects regardless of the PLC being employed. This means that while the PLC of a GIS project is markedly different from that of, for example, a project to build a new highway, the PMLC for both projects is essentially the same, in terms of the project management cycle or phases. Throughout the course of every project, the PLC and PMLC work in conjunction with one another. It is the project manager's responsibility to ensure all PLC activities use the conceptual framework of the PMLC.

The Project Management Institute (2013a) groups project activities generally into the five phases depicted in **Fig. 3**.

This diagram is adapted from the PMBOK Guide (Project Management Institute, 2013a). The five PMLC phases are essentially sequential in nature. However, there is a feedback loop from the monitoring and control phase to the planning phase, as noted in **Fig. 3**. This loop can be followed as many times as is required until the project manager is satisfied that the project is sufficiently complete for it to be closed out and for the evaluation process to commence.

The duration of each phase and the amount of overlap between sequential phases may vary considerably depending on the nature of the project, the complexity of the activities in, and hence the efforts and resources required by individual phases.

The full PMLC starts with the initiation phase that aims to scope the project. The deliverable of the initiation phase is a document called the project proposal or business case that describes what problem or opportunity will be addressed by the project, the project goal, and objectives, the costs incurred and the resulting benefits, how success will be measured, and potential risks and obstacles that may be encountered.

Once the project proposal has received approval from the management of the organization, the planning phase commences. The major deliverables and the participating work groups are identified, and the project team begins to take shape. While most of the activities in this phase are undertaken by one or a few individuals that will form the core of the project team, it is common practice to hold a formal planning session for all stakeholders who will affect or be affected by the project. The deliverable of the planning activities is a detailed project plan that provides a description of each project activity, the resources required to complete the activities, the project schedule, different milestones for the delivery of intermediate results, as well as the dates for acceptance tests and final delivery of the project products.

The project execution phase, also commonly called the project implementation phase, is probably the most labor- and resource-intensive phase of the PMLC. This phase usually starts with the organization of the project team. Members of a typical project team include people transferred internally from other departments within the organization, new staff hired specifically for the project, and contract staff from external consulting firms. The actual people assigned to work on each activity of the project are identified, and detailed descriptions of the activities are developed, reviewed, and signed off. This signifies the actual design, building, and testing of the GIS to be delivered by the project.

The monitoring and control phase begins as soon as the implementation activities have commenced. It runs in parallel with the project execution phase as a way of quality assurance and quality control. Generally speaking, change management is the most critical component of this particular phase, and very clear protocols and procedures must be established to ensure that when conflicts arise (between users and developers as well as between different users), the problem(s) can be addressed expediently and effectively. As change requests always have some impact on the initial time, cost and resource allocation, adjustment to the original project plan is necessary, and the feedback loop is then activated.

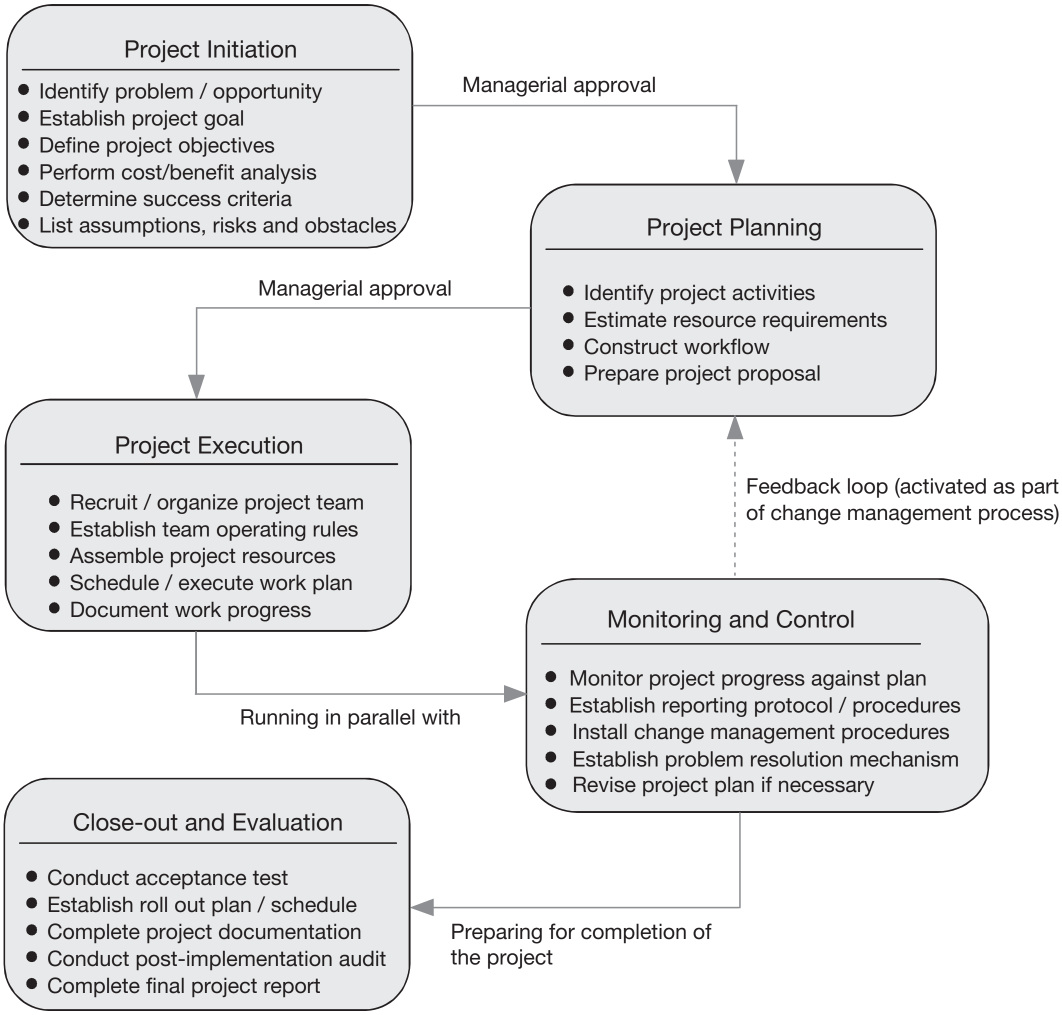

Fig. 3 The five phases of the project management lifecycle.

Preparation for the final phase of the project usually starts well ahead of the conclusion of the execution phase. In this phase, the closeout activities include the installation and testing of the deliverables, post-implementation audit or evaluation, and the compilation of the final project report summarizing all project progress reports, acceptance of test results, and a brief description of the lessons learned. The final project report may also include recommendations to enhance and refine the GIS in response to anticipated changing user needs and advancements in the technological environment.

1.31.2.4.1 Project initiation

The start-up of a project is similar to the start-up of a new organization. The project leader develops the project infrastructure used to design and execute the project. The project management team must develop alignment among the major stakeholders on the project during the early phases or definition phases of the project. Logically, project initiation is the first phase of the PMLC. In practice, however, project managers actually start at the end and work backward mentally. Therefore, the discussion of project initiation starts first by defining the required outputs upon completion of the project, then makes preliminary estimates of the resources required, and finally develops the strategies required to construct and deliver the project output on time, within budget, and according to specification.

All projects are created for a reason. Someone identifies a need or an opportunity and devises a project to address that need. How well the project ultimately addresses that need defines the project's success or failure. Often, the pressure to get results encourages people to go right into identifying possible solutions without fully understanding the need or what the project is trying to accomplish. This strategy can create a lot of immediate activity, but it also creates significant chances for waste and mistakes if the wrong need is addressed. One of the best ways to gain approval for a project is to clearly identify the project's objectives and describe the need or opportunity for which the project will provide a solution.

Activities in the project initiation phase are conducted mostly by the project manager, possibly with the aid of one or more systems analysts and application specialists who are identified as potential members of the future project team. The very first task of project initiation is to define the goal of the project including the scope of the project in terms of what is included and what is excluded. Furthermore, the goal statements identify constraints of time, cost, and specification.

The plan for developing and tracking the detailed schedule, the procurement plan, and the plan for building the budget and estimating and tracking costs are developed during the start-up. The plans for information technology, communication, and tracking client satisfaction are also all developed during the start-up phase of the project. Flowcharts, diagrams, and responsibility matrices are tools to capture the work processes associated with executing the project plan. The first draft of the project procedures manual captures the historic and intuitional knowledge that team members bring to the project. The development and review of these procedures and work processes contribute to the development of the organizational structure of the project.

1.31.2.4.1.1 Writing a (request for) proposal

GIS projects can be implemented by internal staff or by external consultants either in total or in part (a process commonly referred to as outsourcing). There are three common approaches to outsourcing, namely sole source, invitation to tender (ITT), and request for a proposal (RFP). As the name implies, outsourcing by sole source means that the entire contract for a project is awarded to a single contractor without going through a competitive procurement process. When compared with the other two approaches, sole sourcing is less flexible and not as rigorous a procedure, although it takes much less time to pick a contractor from a list of contractors of record and start the project. For public organizations, sole sourcing can be seen as a form of favoritism, and the decision may be challenged by consultants or companies who feel that they have not been fairly treated. Hence, sole sourcing should be avoided except in the cases where the chosen consultant is the only possible candidate who can supply the material or service required.

An ITT and an RFP are competitive processes with different intents and purposes. An ITT is used when the organization is absolutely clear what it wants, and how it wants things to be done. Suppliers or vendors are openly invited to bid for the contract on the basis of factors such as price and ability to meet the specified requirements. An ITT is most suitable in situations where the supply of materials (e.g., computers and peripherals) and the type of services involved are relatively well-defined (e.g., facility maintenance and security services). An RFP, on the other hand, is used when the organization knows generally or exactly what it wants, but prefers to seek solutions from the consulting community. In GIS implementation projects, an RFP is a more prevalent approach than an ITT in terms of soliciting external consulting services.

An RFP is a relatively complex procurement process that demands considerable effort and expenditure on both the part of the requesting organization and the responding consultants. The complexity of an RFP is dependent on its objective and scope, which may cover all or a substantial part of the project execution activities.

There is no standard procedure for conducting an RFP but the workflow of a typical RFP exercise starts with the approval of the recommendation in a project proposal to elicit external work. The project team then prepares the RFP information package for approval. Since an RFP always ends up with a contract between the organization and the selected consultant, legal advice must be sought in advance so that the wording and general content can be reviewed from a legal standpoint, and a sample of the contract to be signed can be prepared. Any changes that are made to the RFP or the contract should, of course, be re-scrutinized by legal counsel before either document is issued and signed off on.

The extent to which individual components are included in the final RFP document and the steps that are followed in the process of compiling the RFP document is to some extent a function of the scale of the work that is being called for. Some tasks are relatively straightforward and have minimal risk associated with them. However, other tasks and indeed overall projects have considerable risks, especially where subcontractors may be involved or where the actual configuration of outputs is not clear at the time of developing the RFP document. In the latter case, care should be taken not to rush the preparation of the RFP document as errors or omissions that are made at the stage of the call for work will likely be compounded into the work that is produced. In the former case, the lines of responsibility for the completion of any subcontracted work must be made clear in the RFP document and all legal issues concerning subcontracting must be accounted for.

Writing a well-conceived goal statement requires considerable brainstorming and discussion with the project sponsor and representatives of potential users of the resulting GIS. It is sometimes also necessary to research the possible relationships between the project and legislated responsibilities and regulatory obligations of the organization, as well as safety and quality standards of the GIS that will result from the project. Goal statements should be SMART, i.e.:

- Specific, so that any individuals with basic knowledge of the project can understand the goal(s). The statement should be concise and clear, to avoid ambiguity or project creep within the context of the project's activities.
- Measurable, to determine clearly whether particular goal statements were achieved.
- Agreed upon, by the sponsor and representatives of potential stakeholders.
- Realistic or achievable; this is measured in terms of affordability and fiscal sustainability, acknowledging technical and political constraints.
- Time-framed, i.e., with a detailed schedule (see section "Project execution and control").

A project proposal, also referred to as a project overview statement or project definition form, is a document that summarizes the findings of the project initiation phase for approval by senior management of the organization. A Project Business Case (PBC) form can be developed for this purpose using a template. This approach is often preferred because a template is easy to create, edit, read, and standardize so that all projects within the same organization can be presented for management consideration in the same format.

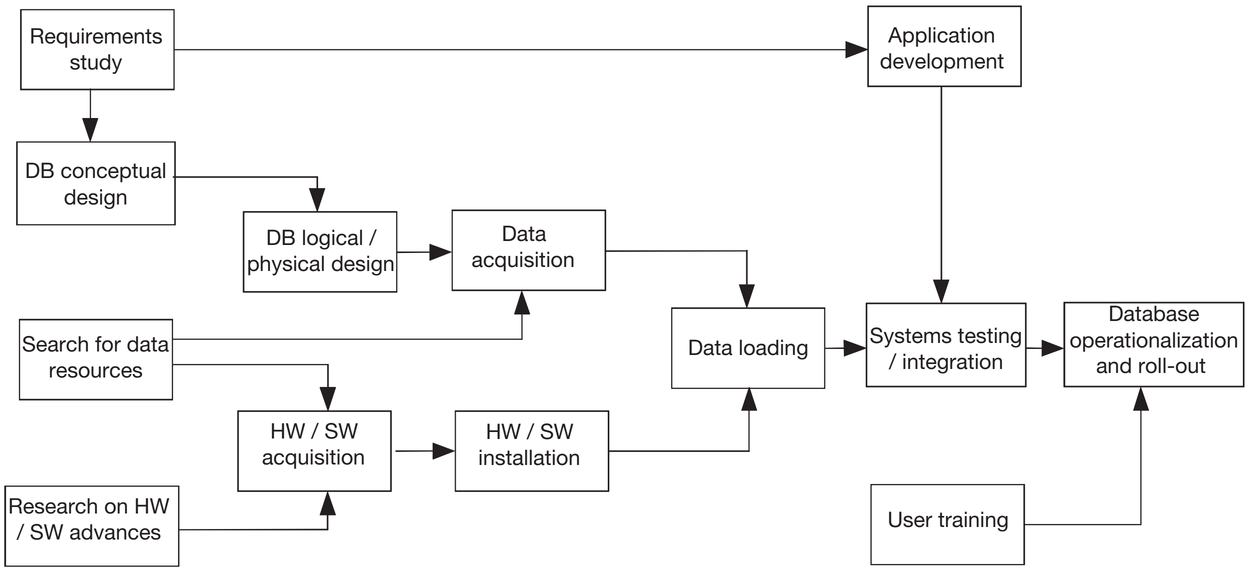

Fig. 4 Project planning flow chart.

Alternatively, a Proposed Solution (PS) form can be used for this purpose. The PBC form contains information that aims to help senior managers understand the justifications of the project. The information items in the form should be written in plain and concise business language. The PS form, on the other hand, provides a clear description of the proposed solutions. If alternative solutions are proposed to address a particular problem, a clear explanation of the pros and cons of different approaches as well as the reasons for picking the final choice must be given.

1.31.2.4.2 Project planning

The GIS project set-up entails defining the management structure within which the GIS project will be executed as depicted in Fig. 4. This includes:

1.31.2.4.2.1 Project steering group

The GIS project steering group represents the interest of the stakeholders for whom the system is designed. It should be chaired by the project sponsor and should include in particular those agents who are funding the system and those who provide the pertinent (local) data. The role of the GIS project steering group is to provide guidance to the GIS project team.

1.31.2.4.2.2 GIS project team

The GIS project team is in charge of executing the design, development, and installation activities under the guidance of the GIS project steering group. The GIS steering group selects the project team and receives its reports. The GIS project team includes at least:

1.31.2.4.2.2.1 Project manager A project manager is in charge of the overall coordination of the GIS design, development, and installation. The project manager is the key person in the project team. In many large organizations, such as government agencies or engineering consulting firms, there are professional project managers on the permanent staff whose job is to lead corporate projects. However, it is commonplace for organizations to appoint project managers from existing unit managers or senior IT personnel who have the training and experience to assume such a job function. All project managers are expected to be strategic in their thinking, tactful in dealing with people, and knowledgeable in the business area served by the project. The project manager serves as the chief executive officer of a project. He or she is the technical advisor to the project sponsor, mentor and supervisor of members of the project team, and representative of the project when dealing with internal and external stakeholders. The project manager usually has to work closely with members of the IT department to ensure adherence to corporate standards, protocols, and resource sharing policies.

It is the responsibility of the project manager to recruit members for the project team and organize them into a coherent working group. Team members can be co-opted from internal staff, or hired externally on a contractual or permanent basis if internal expertise is not available. The number of members of a project team varies according to the nature of a particular project. However, it is essential to recruit and choose team members with the understanding that they have collectively all of the necessary skills that are required to complete the project successfully. For large-scale GIS implementation projects, it is helpful to divide the team into small working groups, each headed by an experienced technical lead, such as map data conversion and acquisition, database design and system development, quality assurance and control, and end-user training. This makes the team more manageable and creates a clear sense of accountability and responsibility.

Experience has shown that while recruiting is seldom a problem, organizing members into a coherent high-performance team can be problematic. It is a real challenge for the project manager to use his or her people skills to ensure the commitment of the members to the project (i.e., their other competing duties or tasks will not negatively impact on the project). The project manager must also keep motivating team members continuously throughout the course of the project by mentoring team members, practicing open communication, giving mutual understanding and respect, recognizing achievements, as well as using disciplinary actions where and if necessary.

1.31.2.4.2.2.2 Other team members As such a project team has to fit into the larger organization context, an organizational chart as depicted in Fig. 5 is helpful for all stakeholders:

- Application specialists.
- A database architect.
- Software programmer(s).
- Independent validation team members.

1.31.2.4.2.3 Defining the project scope

The project scope is prepared by the GIS project team and describes all tasks to be carried out in relation to the design, development, and installation of the GIS. The scope has to be approved by the GIS project steering group during a kick-off meeting between the project team and the project steering group. See also section "Scope" for more on the project scope.

1.31.2.4.2.4 Sequencing of project tasks

The aim of the project work plan is to determine the most efficient order for the tasks by maximizing the use of resources. This is usually accomplished by having more than one task in progress at the same time and by preventing the delay of any given task from holding up the start of another task. The concept of "precedence relationships" between individual tasks is the governing principle for project scheduling. This concept identifies tasks either as "dependent" or "independent". Dependent tasks are those that cannot proceed until another task is completed, whereas independent tasks are those that can be carried out any time during the course of project execution. As noted earlier, an effective way of project scheduling is to consider the project from the end point and work backward to the starting point. In this way, it is relatively easy to identify those tasks that must be completed prior to the commencement of their respective predecessors. A complex project is made manageable by first breaking it down into individual components in a hierarchical structure, introduced as the work breakdown structure or the WBS in section "Time".

A commonly used tool to list out all the phases, activities, and tasks is the Gantt chart. It also illustrates estimates of how long each should take and the dates tasks should begin and end. A PERT chart displays the tasks in a project along with the dependencies between these tasks. Using a PERT chart is a great way to define and display the dependency relationships that exist between tasks. The PERT chart is used to document and track the critical path of the project; i.e., what essential tasks must get done in exactly what order to successfully complete the project. Section "Scheduling tools" provides further details on such scheduling tools.

Another essential component of the project plan is the identification of resources required for each task. The project team should first identify the type of resources needed, and then estimate the cost for that particular task. Cost can be estimated in one of two ways, namely a fixed cost (e.g., $5000 per year for a multiuser software license) or a variable cost (e.g., 50 hours of initial Java programming and 20 hours or less of additional programming work per year for maintenance and update). The project team should

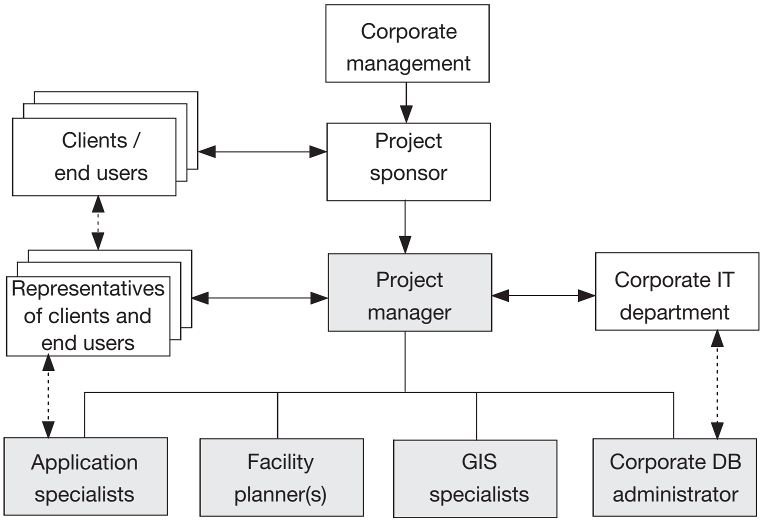

Fig. 5 Organigram of a GIS project and its setting in a larger organizational context.

carefully consider the matching of available resources and estimated resources. If for example, a particular task requires skills that are not found among project team members, then arrangements must be made for outside assistance. This may necessitate amendments to estimated time and costs, and the project plan must be adjusted accordingly.

1.31.2.4.2.5 Project requirements

1.31.2.4.2.5.1 Requirement engineering The first step after defining the scope of the project is to conduct a needs assessment. During this task, the GIS project team reviews and details the user requirements provided in the preliminary analysis, and derives a consolidated set of products and system requirements, including functional needs, data needs, and processing needs. While these all flow into the technical specifications of the next section, it is important to integrate existing user practices. Because the incorporation of a new system may alter or conflict with existing systems and procedures at the level of user organizations, the linkage between the future GIS and existing systems and procedures at the level of the user organizations has been adequately examined. Recommendations to reengineer these existing systems and procedures are formulated on the basis of a detailed analysis of the current working procedures. The results of this task are reported in a document called Requirements Baseline (RB).

1.31.2.4.2.5.2 Technical specifications In response to the consolidated user requirements, the GIS project team provides a technical answer to the requirements baseline with a detailed and complete specification of the products information system expected. The results of this activity are reported in a Technical Specifications document and an associated Inventory of Existing Datasets, Design Justification Report, and Data Model Report.

The DJR assembles analyses performed by the GIS project team on all implementation choices for proposed GIS. It describes, in particular, all trade-offs, design choice justifications, feasibility analysis, make-or-buy decisions, and supporting technical assessments done during the software development.

Ideally, the data model report is developed in accordance with the requirements of the ISO 19000 series and here, in particular. This includes, in particular, the adoption of the ISO 19104 terminology, the development of data model using the Universal Modeling Language (UML), and the adoption of ISO 19115 requirements for metadata modeling.

1.31.2.4.2.5.3 System qualification planning This planning process is a response to the Requirements Baselines and includes a "scientifically sound" validation protocol for all products to be generated by the information system, including the description of all ground and ancillary data available. Problems, such as lack of insufficient validation data need to be investigated, the impact assessed, and the solutions identified. The results of this task are recorded in a System Qualification Plan (SQP).

1.31.2.4.2.6 Comparing options using a weighted decision matrix

Sometimes, there are multiple options to choose from when determining requirements and deciding which project to work on. One of the preferred tools to select the best option is a weighted decision matrix, which is a simple form of linear programming. A basic decision matrix consists of establishing a set of criteria for options that are scored and summed to gain a total score that can then be ranked. Importantly, it is not weighted to allow a quick selection process.

A weighted decision matrix operates in the same way as the basic decision matrix but introduces the concept of weighting the criteria in order of importance. The resultant scores reflect better the importance to the decision maker of the criteria involved. The more important a criterion, the higher the weighting it receives. Each of the potential options is scored and then multiplied by the weighting given to each of the criteria to produce a result.

The advantage of the weighted decision matrix is that subjective opinions about one alternative versus another can be made more objective. Another advantage of this method is that sensitivity studies can be performed.

1.31.2.4.2.7 Financial considerations

In many new project endeavors, it is important to find out if the project is financially feasible. Measures for such determination include the net present value (NPV), the rate of return (ROI), and payback analysis.

1.31.2.4.2.7.1 Net present value A dollar earned today is worth more than a dollar earned one or more years from now. The NPV of a time series of cash flows, both incoming and outgoing, is defined as the sum of the present values (PVs) of the individual cash flows of the same entity.

In the case when all future cash flows are incoming and the only outflow of cash is the purchase price, the NPV is simply the PV of future cash flows minus the purchase price (which is its own PV). NPV is a standard method for using the time value of money to appraise long-term projects. Used for capital budgeting and widely used throughout economics, finance, and accounting, it measures the excess or shortfall of cash flows, in present value terms, once financing charges are met. NPV can be described as the "difference amount" between the sums of discounted cash inflows and cash outflows. It compares the present value of money today to the present value of money in the future, taking inflation and returns into account. The NPV of a sequence of cash flows takes as input the cash flows and a discount rate or discount curve and outputs a price. Each cash inflow/outflow is discounted back to its present value (PV). Then they are summed. Therefore, NPV is the sum of all terms.

NPV is an indicator of how much value an investment or project adds to the firm. With a particular project, if NPV is a positive value, the project is in the status of positive cash inflow in the time t. If NPV is a negative value, the project is in the status of discounted cash outflow in the time t. Sometimes, risky projects with a positive NPV could be accepted. This does not necessarily mean that they should be undertaken since NPV at the cost of capital may not account for opportunity cost (i.e., comparison with other available investments).

1.31.2.4.2.7.2 Return on investment Return on Investment is a performance measure used to evaluate the efficiency of an investment or to compare the efficiency of a number of different investments. It is one way of considering profits in relation to capital invested. This is calculated by subtracting the project's costs from the benefits and then dividing by the costs. Return on investment studies of GIS projects are a relatively new field of academic research. The URISA Journal devoted an issue of its 2015 volume to this topic (URISA Journal, 2015).

1.31.2.4.2.7.3 Payback analysis Payback analysis is important in determining the amount of time it will take for a project to recoup its investments. This is the point at which the benefits start to outweigh the costs. The best way to see that is by charting the cumulative benefits and costs.

1.31.2.4.3 SCRUM development overview

"Scrum" is formal project management/product development methodology and part of agile project management. Scrum is a term from rugby (scrimmage) that means a way of restarting a game. It's like restarting the project efforts every X weeks. It is based on the idea that it is impossible to plan the whole project up front; therefore, a good program manager starts by building on empirical data, and then re-plans and iterates from there.

Scrum uses sequential sprints for development. Sprints are like small project phases (ideally 2 to 4 weeks). The idea is to take 1 day to plan for what can be done now, then develop what was planned for, and demonstrate it at the end of the sprint. Scrum uses a short daily meeting of the development team to check what was done yesterday, what is planned for the next day, and what if anything is impeding the team members from accomplishing what they have committed to. At the end of the sprint, what has been demonstrated can then be tested, and the next sprint cycle starts.

1.31.2.4.3.1 SCRUM roles

Scrum methodology defines several major roles. They are:

Product owners: essentially the business owner of the project who knows the industry, the market, the customers, and the business goals of the project. The product owner must be intimately involved with the Scrum process, especially the planning and the demonstration parts of the sprint.

Scrum Master: somewhat like a project manager, but not exactly. The Scrum Master's duties are essentially to remove barriers that impede the progress of the development team, teach the product owner how to maximize return on investment (ROI) in terms of development effort, facilitate creativity and empowerment of the team, improve the productivity of the team, improve engineering practices and tools, run daily standup meetings, track progress, and ensure the health of the team.

Development team: self-organizing (light-touch leadership), empowered group; they participate in planning and estimating for each sprint, do the development, and demonstrate the results at the end of the sprint. The development team can be broken into "teamlets" that "swarm" on user stories, which are created in the sprint planning session.

Planning meetings for each sprint require participation by the product owner, the Scrum Master, and the development team. In the planning meeting, they set the goals for the upcoming sprint and select a subset of the product backlog to work on. The development team decomposes these into tasks and estimates them. The development team and product owner do final negotiations to determine the backlog for the following sprint.

The Scrum methodology has its own set of metrics to help with future planning and tracking of progress.

1.31.2.4.4 System prototyping

The objective of this phase is to prototype the GIS project and to demonstrate a preliminary compliance with the consolidated user requirements by executing a representative set of the products to be routinely generated by the future system. The system prototype does not feature the entire range of requirements which have been identified in the requirement consolidation, but should be complete enough to allow a proper demonstration of the products to the GIS project steering group and to justify its authorization to proceed.

1.31.2.4.4.1 Software prototype design

During this task, the GIS project team documents all architectural software elements of the GIS following the instructions of the Design Justification Report (DJR) and the Data Model Report (DMR). Moreover, this design task also lists and details all verification test procedures for the validation of the different modules. The results of this task are reported in a Design Definition Report (DDR), a Data Model Implementation Report (DIR), and a Verification Test Procedures (VTP).

1.31.2.4.4.2 Software prototype development

This task encompasses the effective coding of the different software modules identified and their preliminary integration into a GIS software prototype. The output of this task is the GIS software prototype.

1.31.2.4.4.3 Sample data acquisition

In order to test the GIS prototype and to check its ability to generate products that conform to the requirements baseline and technical specifications, sample data needs to be acquired. These data are used for the execution of sample products (see next paragraph) and have to conform to the input data types required by the technical specifications.

1.31.2.4.4.4 Sample product execution

On the basis of the GIS software prototype, the project team implements a sample production. The outputs of this task are sample products generated by the GIS software prototype.

1.31.2.4.5 Project execution and control

Project implementation (or project execution) is the third phase of the project management lifecycle, where visions and plans become reality. This is the logical conclusion, after evaluating, deciding, visioning, planning, applying for funds, and finding the financial resources of a project. The implementation phase involves putting the project plan into action. It's here that the project manager will coordinate and direct project resources to meet the objectives of the project plan. As the GIS project unfolds, it's the project manager's job to direct and manage each activity, every step of the way. The better the original plan, the easier it will be for the project manager to handle any problems that come up (Tomlinson, 2005).

It is important to take into account that independently of the nature of the project, implementation takes time, usually more than it is planned and that many external constraints can appear, which should be considered when initiating the implementation step, for example, the seasonality in the availability of community engagement/resources).

> The basic requirement for starting the implementation process is to have the work plan ready and understood by all the actors involved. Technical and non-technical requirements have to be clearly defined and the financial, technical and institutional frameworks of the specific project have to be prepared considering the local conditions. The working team should identify their strengths and weaknesses (internal forces), opportunities and threats (external forces). The strengths and opportunities are positive forces that should be exploited to efficiently implement a project. The weaknesses and threats are hindrances that can hamper project implementation. The implementers should ensure that they devise means of overcoming them. Another basic requirement is that the financial, material and human resources are fully available for the implementation. (NETSSAF, 2008)

Other actions need to be taken before work can begin to implement the detailed action plan, including:

- Scheduling activities and identifying potential bottlenecks.
- Communicating with the members of the team and ensuring all the roles and responsibilities are distributed and understood.
- Providing for project management tools to coordinate the process.
- Ensuring that the financial resources are available and distributed accordingly.

The implementation phase is where the project team actually does the project work to produce the deliverables. The word "deliverable" means anything the project delivers, including all of the products or services, and last but not least the documentation of these deliverables. The steps undertaken to build each deliverable will vary depending on the type of project, and cannot, therefore, be described here in any real detail. For instance, engineering and telecommunications projects will focus on using equipment, resources, and materials to construct each project deliverable, whereas computer software projects may require the development and implementation of software code routines to produce each project deliverable. The activities required to build each deliverable will be clearly specified within the project requirements document and project plan.

Beyond mere direction of the work and delivery of results, it is the job of the project manager to also keep track of how the project team performs. The implementation phase keeps the project plan on track with careful monitoring and control processes to ensure the final deliverable meets the acceptance criteria set by the customer. This phase is typically where approved changes are implemented.

Most often, changes are identified by looking at performance and quality control data. Routine performance and quality control measurements should be evaluated on a regular basis throughout the implementation phase. Gathering reports on those measurements will help to determine where the problem is and recommend changes to fix it.

1.31.2.4.5.1 Project charter

A project charter, project definition, or project statement is a statement of the scope, objectives, and participants in a project. It provides a preliminary delineation of roles and responsibilities, outlines the project objectives, identifies the main stakeholders, and defines the authority of the project manager. It serves as a reference of authority for the future of the project. The purpose of a project charter is to:

- Provide an understanding of the project, the reason it is being conducted, and its justification.
- Establish early on in the project the general scope.
- Establish the project manager and his or her authority level. A note of who will review and approve the project charter must be included.

1.31.2.4.5.2 Project schedule planning

In order to develop our schedule, we first need to define the activities, sequence them in the right order, estimate the resources needed, and estimate the time it will take to complete the tasks.

The activity definition process is a breakdown of the project into work package elements. It documents the specific activities needed to fulfill the deliverables detailed in the project plan. These activities are not the deliverables themselves but the individual units of work that must be completed to fulfill the deliverables. Activity definition uses everything we already know about the project to divide the work into activities that can be estimated.

Expert judgment in the form of project team members with prior experience developing project scope statements can help to define activities. They may be employed to review an activity list created by the project manager, or they could be involved from the very beginning.

Once the activity definitions for the work packages have been completed, the next task is to complete the activity list. The project activity list is a list of everything that needs to be done to complete the project, including all the activities that must be accomplished to deliver each work package. The next step is to define the activity attributes starting with a description of each activity and determining the sequence of the work. Any predecessor activities, successor activities, or constraints should be listed in the attributes along with descriptions as well as any other information about resources or time.

All of the important checkpoints of the project are tracked as milestones. Some of them could be listed in a contract as requirements of successful completion; some could just be significant points in the project that the manager wants to keep track of. The milestone list needs to let everyone know which milestones are required and which are not.

1.31.2.4.5.3 Scheduling tools

For all but the smallest projects, it is useful to familiarize oneself with scheduling tools. The following paragraphs provide a brief introduction to four of them.

1.31.2.4.5.3.1 Gantt chart A Gantt chart is a type of bar chart that illustrates a project schedule. Gantt charts are easy to read and are commonly used to display schedule activities. These charts display the start and finish dates of the terminal elements and summary elements of a project. Terminal elements and summary elements comprise the work breakdown structure of the project. Some Gantt charts also show the dependency relationships (i.e., precedence network) between activities.

Gantt charts show all the key stages of a project and their duration as a bar chart, with the time scale across the top. The key stages are placed on the bar chart in sequence. A Gantt chart can be drawn quickly and easily and is often the first tool a project manager uses to provide a rough estimate of the time that it will take to complete the key tasks. Sometimes it is useful to start with the target deadline for completion of the whole project because it is soon apparent if the time scale is too short or unnecessarily long. The detailed Gantt chart is usually constructed after the main objectives have been determined.

1.31.2.4.5.3.2 Network diagrams Many project managers use network diagrams when scheduling a project. The network diagram is a way to visualize the interrelationships of project activities. Network diagrams provide a graphical view of the tasks and how they relate to one another. The tasks in the network are the work packages of the project. All tasks must be included in the network because they have to be accounted for in the schedule. Leaving even one task out of the network could change the overall schedule duration, estimated costs, and resource allocation commitments. The first step is to arrange the tasks into a sequence. Some tasks can be accomplished at any time throughout the project where other tasks depend on input from another task or are constrained by time or resources. The network diagram provides important information to the project team. It provides information about how the tasks are related, where the risk points are on the schedule, how long it will take as currently planned to finish the project, and when each task needs to begin and end.

1.31.2.4.5.3.3 PERT Another way to show how tasks relate is with the activity-on-arrow (AOA) diagram. Although AON is more commonly used and is supported by all project management programs, PERT is the best-known AOA-type diagram and is the historical basis of all network diagramming. The main difference is the AOA diagram is traditionally drawn using circles as the nodes, with nodes representing the beginning and ending points of the arrows or tasks. In the AOA network, the arrows represent the activities or tasks.

1.31.2.4.5.3.4 Critical path The critical path describes the sequence of tasks that would enable the project to be completed in the shortest possible time. It is based on the idea that some tasks must be completed before others can begin. A critical path diagram is a useful tool for scheduling dependencies and controlling a project. In order to identify the critical path, the length of time that each task will take must be calculated.

1.31.2.4.6 Resource planning

Another essential component of the project plan is the identification of resources required for each task. The project team first identifies the type of resources needed, and then estimates the cost for that particular task. Cost can be estimated in one of two ways, namely a fixed cost (e.g., $5000.00 per year for a multiuser software license) or a variable cost (e.g., 50 hours of initial Java programming and 20 hours or less of additional programming work per year for maintenance and update).

Resources are people, equipment, place, money, or anything else that is needed to perform all the planned activities. Every item on the activity list needs to have resources assigned to it. Before resources can be assigned to a project, one needs to determine their availability. Resource availability includes information about what resources are necessary, when they're available, and the conditions of their availability. If for example, a particular task requires skills that are not found among project team members, then arrangements must be made for outside assistance. This may necessitate amendments to estimated time and costs, and the project plan must be adjusted accordingly. It is important to schedule some resources such as consultants or training rooms way in advance, as they might be available only at certain times.

This resource estimation is the basis for determining how long each activity will take, a process known as activity duration estimation, where the project manager identifies how long it takes to perform each activity, starting with the information about that activity and the resources that are assigned to it, and then working with the project team to come up with an estimate.

1.31.2.4.7 Procurement management

The procurement effort in projects varies widely and depends on the type of project. Often the client organization will provide procurement services in less complex projects. In this case, the project team identifies the materials, equipment, and supplies needed by the project, and provides product specifications and a detailed delivery schedule. When the procurement department of the parent organization provides procurement services, a liaison from the project can help the procurement team better understand the unique requirements of the project and the time-sensitive or critical items of the project schedule.

On larger, more complex projects, personnel is dedicated to procuring and managing the equipment, supplies, and materials needed by the project. Because of the temporary nature of projects, equipment, supplies, and materials are procured as part of the product of the project or for the execution of the project. In GIS projects, we distinguish data, functional, and processing needs:

Data needs:

- Every GIS project requires a data inventory.
- This needs to be broken down into which maps or data are important for successful completion of each function in the unit.
- Data is rarely perfect; It is hence important to describe problems of current data and point out future needs as well.
- Although maps are usually the final output of a GIS project, creating a map inventory form will help clarify issues involved in map use down the road.

Functional needs:

Identify activities which an organization performs to carry out its mission.
Identify all of their organizational units.
List the functions that require maps or other geographic information. Huxhold (1996) has a nice overview list of functions requiring geographic information by department and function.

Processing needs:

- Define how the data are to be used to fulfill the functional needs of the organization.
- An application definition form contains data input requirements, processing requirements, and output products.

More complex projects will typically procure through different acquisition and management methods. Commodities are common products that are purchased based on the lowest bid. Commodities include items like concrete for building projects, office supplies, or even lab equipment for a research project. The second type of procurement includes products that are specified for the project. Vendors who can produce these products bid for a contract. The awarding of a contract can include price, ability to meet the project schedule, the fit for the purpose of the product, and other considerations important to the project. These vendors' performances become important parts of the project, and the project manager assigns resources to coordinate the work and schedule of the vendor. The third procurement approach is the development of one or more partners. A design firm that is awarded the design contract for a major part of an airport and a research firm that is conducting a study of passenger flows are examples of potential project partners. A partner contributes to and is integrated into the execution plan. Partners perform best when they share the project vision of success and are emotionally invested in the project. The project management team builds and implements a project procurement plan that recognizes the most efficient and effective procurement approach to support the project schedule and goals.

Procurement management follows a logical order starting with a plan for the whole project. Before doing anything else, it is important to identify all of the work that will be contracted out so that one can plan for any purchases and acquisitions. For each of these items, one then needs to set up the contract, identify the metrics that will be used to determine that the work is considered successful, pick a seller, and have a process in place to administer the contract once the work is happening.

The procurement management plan details how the procurement process will be managed. It includes the following information:

- The types of contracts and any metrics that will be used to measure the contractors' performance.
- The planned delivery dates for the work or products.
- The company's standard documents.

- The number of vendors or contractors involved, and how they will be managed.
- How purchasing may impact the constraints and assumptions of the project plan.
- The coordination of purchasing lead times with the development of the project schedule.
- The identification of prequalified sellers (if known).

The procurement management plan, like all other management plans, becomes a subsidiary of the project management plan. Some tools and techniques used during the procurement planning stage include make-or-buy analysis and definition of the contract type.

1.31.2.4.7.1 Spatial data acquisition and evaluation

During this task, the complete set of input data identified in the requirements baseline and technical specifications (see section "**Sample data acquisition**") is actually acquired. If data acquisition turns out to be a complex or long-term task (e.g. programming of aerial photograph or Lidar surveys), it is recommended to establish first a data acquisition plan. Data acquisition is often regarded as the most challenging and expensive part of a GIS project. However, maintaining data quality through the lifecycle of a database system can, in total, create greater challenges and be even more expensive. Spatial data are much more readily available now than ever before. With the construction of global and national geospatial data infrastructures, data warehouses, and Web-based information dissemination technologies, GIS projects now rely more on third-party data than on internal data conversion. New data collection technologies are now able to capture spatial data directly in digital form quickly and with a higher degree of accuracy than in the past. As a result, the focus of data in GIS projects has moved from acquisition to quality or usability. However, up to now greater data availability has not necessarily been translated into higher usability and, therefore, data and data quality remain mission-critical issues in GIS projects, and the compliance of all input data delivered with their technical specifications needs to be checked (see section "**Monitoring and control**" further down).

1.31.2.4.7.2 Technology acquisition and evaluation

Technology acquisition and evaluation is a relatively straightforward process when compared with data acquisition and evaluation. Technology, in this case, refers to computer hardware, software, and local and wide area networks, together with related peripherals and supplies. In many organizations, GIS must be implemented using corporate architectures and standards. Therefore, a GIS project team is often more concerned with the evaluation of the suitability of corporate resources specifically for spatial applications, than with their acquisition.

Developing a technology evaluation plan is a relatively complex task. It normally starts with a review of a user requirements study that seeks to identify both the hardware, software and network needs of the deliverables of the project. The project team then identifies the key features of these relative to the generation of the deliverables. These features are progressively broken down into further levels of detail and recorded in a software evaluation manual that is regularly updated during the process of development. The features to be evaluated are assigned either as a "must" or "should" requirement to indicate their relative significance in the evaluation process.

In the evaluation process, potential vendors are required to supply in detail specific information about each of the features of their products that are to be evaluated. The project team then reviews the completed product evaluations and shortlists the four or five best submissions that are deemed to meet the requirements of the project.

1.31.2.4.7.3 HR planning

The most important resource to a project is its people—the project team. Projects require specific expertise at specific moments in the schedule, depending on the milestones being delivered or the given phase of the project. An organization can host several strategic projects concurrently over the course of a budget year, which means that its employees can be working on more than one project at a time. Alternatively, an employee may be seconded away from his or her role within an organization to become part of a project team because of a particular expertise. Moreover, projects often require talent and resources that can only be acquired via contract work and third-party vendors. Procuring and coordinating these human resources, in tandem with managing the time aspect of the project, are critical to the overall success.

Through performance evaluation, the manager will get the information needed to ensure that the team has adequate knowledge, to establish a positive team environment and a healthy communication climate, to work properly, and to ensure accountability. Managing the project team includes an appraisal of employee performance and project performance. The performance reports provide the basis for managerial decisions on how to manage the project team.

Working with other people involves dealing with them both logically and emotionally. A successful working relationship between individuals begins with appreciating the importance of emotions and how they relate to personality types, leadership styles, negotiations, and setting goals. Emotions are both a mental and physiological response to environmental and internal stimuli. Leaders need to understand and value their emotions to appropriately respond to the client, project team, and project environment.

The Myers-Briggs Type Indicator (MBTI) is one of most widely used tools for exploring personal preference, with more than two million people taking the MBTI each year. The MBTI is often referred to as simply the Myers-Briggs. It is a tool that can be used in project management training to develop awareness of preferences for processing information and relationships with other people.

On larger, more complex projects, some project managers will use the Myers-Briggs as a team-building tool during project start-up. This is typically a facilitated work session where team members take the Myers-Briggs and share with the team how they process information, what communication approaches they prefer, and what decision-making preferences they have. This allows the team to identify potential areas of conflict, develop communication strategies, and build an appreciation for the diversity of the team.

No particular leadership approach is specifically appropriate for managing a project. Due to the unique circumstances inherent in each project, the leadership approach and the management skills required to be successful vary depending on the complexity profile of the project. However, the Project Management Institute published Shi and Chen's (2006) research that studied project management leadership traits and concluded that good communication skills and the ability to build harmonious relationships and motivate others are essential. Beyond this broad set of leadership skills, the successful leadership approach will depend on the profile of the project. For example, a transactional project manager with a strong command-and-control leadership approach may be very successful for a small software development project or a construction project, where tasks are clear, roles are well understood, and the project environment is cohesive. This same project manager is less likely to be successful on a larger, more complex project with a diverse project team and complicated work processes.

Matching the appropriate leadership style and approach to the complexity profile of the project is a critical element of project success. Even experienced project managers are less likely to be successful if their leadership approach does not match the complexity profile of the project.

1.31.2.4.8 Budget planning

Every project boils down to money. If there was a bigger budget, one could probably get more people to do the project more quickly and deliver more. That's why no project plan is complete without a budget. Regardless of the size of the project, and no matter how many resources and activities are in it, the process of figuring out the bottom line is always the same. It is important to come up with detailed estimates for all the project costs. Once this is compiled, all the cost estimates are combined into a budget plan.

1.31.2.4.8.1 Cost estimation techniques

It is now possible to track the project according to that budget while the work is ongoing. Here are some tools and techniques for estimating cost:

1.31.2.4.8.1.1 Resource cost rates People who will be working on the project all work at a specific rate. Any materials used to build the project (e.g., wood or wiring) will be charged at a rate too. Determining resource costs means figuring out what the rate for labor and materials will be.

1.31.2.4.8.1.2 Vendor bid analysis Sometimes, it is necessary to work with an external contractor to get the project done. One might even have more than one contractor bid on the job. This tool is about evaluating those bids and choosing the winner.

1.31.2.4.8.1.3 Reserve analysis Most projects have cost overruns. If the risk of something expensive happening is known ahead of time, it is better to have some cash available to deal with it. Reserve analysis means putting some cash away in the case of overruns.

1.31.2.4.8.1.4 Cost of quality Fig. 1 alluded to the balance between costs and quality. A good project manager will weigh the cost of all quality-related activities into the overall budget. As it is cheaper to find bugs earlier in the project than later, there are always quality costs associated with everything a project produces. The cost of quality is a way of tracking the cost of those activities.

1.31.2.4.8.2 Managing the budget

An activity can have costs from multiple vendors in addition to internal costs for labor and materials. Detailed estimates from all sources can be reorganized, so those costs associated with a particular activity can be grouped by adding the activity code to the detailed estimate. The detailed cost estimates can be sorted and then subtotaled by activity to determine the cost for each activity.

1.31.2.4.8.2.1 Managing the cash flow If the total amount spent on a project is equal to or less than the amount budgeted, the project can still be in trouble if the funding for the project is not available when it is needed. There is a natural tension between the financial people in an organization, who do not want to pay for the use of money that is just sitting in a checking account, and the project manager, who wants to be sure that there is enough money available to pay for project expenses. The financial people prefer to keep the company's money working in other investments until the last moment before transferring it to the project account. The contractors and vendors have similar concerns, and they want to get paid as soon as possible so they can put the money to work in their own organizations. The project manager would like to have as much cash available as possible to use if activities exceed budget expectations.

1.31.2.4.8.2.2 Contingency reserves Most projects have something unexpected occur that increases costs above the original estimates. If estimates are rarely exceeded, the estimating method should be reviewed because the estimates are too high. It is impossible to predict which activities will cost more than expected, but it is reasonable to assume that some of them will. Estimating the likelihood of such events is part of the risk analysis discussed above.

Instead of overestimating each cost, money is budgeted for dealing with unplanned but statistically predictable cost increases. Funds allocated for this purpose are called contingency reserves. Because it is likely that this money will be spent, it is part of the total budget for the project. If this fund is adequate to meet the unplanned expenses, then the project will complete within the budget.

1.31.2.4.8.2.3 Management reserves If something occurs during the project that requires a change in the project scope, money may be needed to deal with the situation before a change in scope can be negotiated with the project sponsor or client. It could be an opportunity as well as a challenge. For example, if a new technology were invented that would greatly enhance the completed project, there would be additional cost and a change to the scope, but it would be worth it. Money can be made available at the manager's discretion to meet needs that would change the scope of the project. These funds are called management reserves. Unlike contingency reserves, they are not likely to be spent and are not part of the project's budget baseline, but they can be included in the total project budget.

1.31.2.4.8.3 Evaluating the budget

A project manager must regularly compare the amount of money spent with the budgeted amount and report this information to managers and stakeholders. It is necessary to establish an understanding of how this progress will be measured and reported.

1.31.2.4.8.3.1 Earned value analysis A method that is widely used for medium- and high-complexity projects is the earned value management (EVM) method. EVM is a method of periodically comparing the budgeted costs with the actual costs during the project. It combines the scheduled activities with detailed cost estimates of each activity. It allows for partial completion of an activity if some of the detailed costs associated with the activity have been paid but others have not.

The budgeted cost of work scheduled (BCWS) comprises the detailed cost estimates for each activity in the project. The amount of work that should have been done by a particular date is the planned value (PV). These terms are used interchangeably by some sources, but the planned value term is used in formulas to refer to the sum of the budgeted cost of work up to a particular point in the project, so we will make that distinction in the definitions in this text for clarity.

The budgeted cost of work performed (BCWP) is the budgeted cost of work scheduled that has been done. The sum of BCWP values up to that point in the project schedule is the earned value (EV). The amount spent on an item is often more or less than the estimated amount that was budgeted for that item. The actual cost (AC) is the sum of the amounts actually spent on the items.

1.31.2.4.8.3.2 Schedule variance The project manager must know if the project is on schedule and within the budget. The difference between planned and actual progress is the variance. The schedule variance (SV) is the difference between the earned value (EV) and the planned value (PV). Expressed as a formula, $SV = EV - PV$. If less value has been earned than was planned, the schedule variance is negative, which means the project is behind schedule.

The schedule variance and the cost variance provide the amount by which the spending is behind (or ahead of) schedule and the amount by which a project is exceeding (or not fully using) its budget. They do not give an idea of how these amounts compare with the total budget.

The ratio of earned value to planned value gives an indication of how much of the project is completed. This ratio is the schedule performance index (SPI). The formula is $SPI = EV/PV$. An SPI value less than 1 indicates the project is behind schedule. The ratio of the earned value to the actual cost is the cost performance index (CPI). The formula is $CPI = EV/AC$.

1.31.2.4.8.4 Estimated cost to complete the project

Part way through the project, the manager evaluates the accuracy of the cost estimates for the activities that have taken place and uses that experience to predict how much money it will take to complete the unfinished activities—the estimate to complete (ETC).

To calculate the ETC, the manager must decide if the cost variance observed in the estimates to that point are representative of the future. For example, if unusually bad weather causes increased cost during the first part of the project, it is not likely to have the same effect on the rest of the project. If the manager decides that the cost variance up to this point in the project is atypical—not typical—then the estimate to complete is the difference between the original budget for the entire project—the budget at completion (BAC)—and the earned value (EV) up to that point. Expressed as a formula, $ETC = BAC - EV$.

If the manager decides that the cost variance is caused by factors that will affect the remaining activities, such as higher labor and material costs, then the estimate to complete (ETC) needs to be adjusted by dividing it by the cost performance index (CPI). For example, if labor costs on the first part of a project are estimated at $60,000 (EV) and they actually cost $63,000 (AC), the cost performance (CPI) will be 0.95. (Recall that the $CPI = EV/AC$).

To calculate the estimate to complete (ETC), assuming the cost variance on known activities is typical of future cost, the formula is $ETC = (BAC - EV)/CPI$. If the budget at completion (BAC) of the project is $600,000, the estimate to complete is ($600,000 – $60,000)/0.95 = $568,421.

1.31.2.4.8.5 Estimate final project cost

If the costs of the activities up to the present vary from the original estimates, this will affect the total estimate of the project cost. The new estimate of the project cost is the estimate at completion (EAC). To calculate the EAC, the estimate to complete (ETC) is added to the actual cost (AC) of the activities already performed. Expressed as a formula, $EAC = AC + ETC$.

1.31.2.4.9 Cost-benefit analysis

Many organizations require a cost-benefit analysis to be conducted as part of the project initiation process. Cost-benefit analysis, also called investment analysis, is based on the realization that justification for investments is best made when accompanied by some level of analysis of the associated costs and benefits both of the investment itself and its returns over a relevant time frame. In addition to providing a framework for planning, a cost-benefit analysis provides some assurance of the prudence of the initial capital expenditures on the project and the long-term support and maintenance costs of the resulting GIS.

However, as a project management instrument, cost-benefit analyses are often imprecise because they do not account for many of the non-monetarized subtleties and complexities that surround GIS projects. Cost-benefit analysis is particularly difficult in the case of larges-cale spatial data infrastructure projects that take several years to complete. Although the costs of information technology are relatively easy to measure and account for, the benefits side of the equation is difficult to formulate. This is because many significant benefits are intangible (e.g., improving the integrity of land tenure systems, better stewardship of the environment, and increasing public awareness of and interest in participatory democracy), and hence, cannot be quantified precisely in monetary terms.

Cost-benefit calculations are further complicated by three other factors. One of these includes what kinds of costs and benefits are measured and how they are measured, at what time the benefits are realized, and whether to include the values of external benefits or only those that relate directly to the project being undertaken. Further complicating matters is the principle of the time value of money, which stipulates that costs incurred today are "worth" more than the benefits of the same monetary values received in the future. The third factor is concerned with the variation and variability of the lifecycles of different project components (e.g., the relatively short, perhaps 3 to 5-year, technology lifecycle and the longer term, and often indefinite, data lifecycle).

Working within the above limitations, a typical cost-benefit analysis can be conducted as an "educated guess" to assist in project management decision making, using the following two steps:

Assumptions. There are four sets of assumed parameters or variables used for the calculation of cost and benefits. These include:

- The time frame for project lifecycle, payback period, initial investment period, and benefit accrual period.
- Costs for personnel (wages and benefits), facilities, equipment, and materials obtained from the Resource Requirements Form (see section "Culture of Stakeholders").
- Benefits from productivity gain, cost recovery (including royalty from the sale of data, potential revenues and user fees), value-added services, and economic spin-off internally and externally.
- Discount rates for use as differential weightings in the calculation of future costs and benefits.

Calculation. The cost-benefit analysis calculates annual benefits less annual costs relating to the creation and maintenance of the GIS resulting from the project. Two sets of values are normally calculated, namely:

- The sum of Flow of Net Benefit (SFNB), which simply calculates a sum of all the payments and income/benefits over the same assumed payback period.
- Net Present Value (NPV), also called "discounted net present value", which calculates the sum of future payments (negative values) and income/benefits (positive values) over an assumed payback period and reduces them to present value using an assumed discount rate.

1.31.2.4.10 Application development strategies and techniques

A GIS project involves a substantial amount of effort and resources to be focused on application development. This includes the design, programming, testing, and integration of software modules for the user interface, database connectivity, information retrieval and analysis, generation of reports, presentation of graphics, and multimedia information products.

GIS applications are now developed predominantly using software engineering methods (Pressman, 2005; Summerville, 2005).

1.31.2.4.11 Project risk and opportunity analysis

Despite the best of intentions and careful thought invested in the project initiation and planning processes, the possibility of unexpected problems and benefits occurring during the course of the project lifecycle is real. Risk and opportunity analysis are not always seen as integral and critical components of project planning; however, a prudent project manager should realize that there is no perfect approach to project planning, and if something can go wrong, it usually will. The idea of potential risk and opportunity analysis is based on the belief that an experienced project team does not and cannot know exactly what problems will occur and when they will occur, but they are able to anticipate the types of potential problems and have the capability of dealing with them if they materialize. In essence, potential risk analysis is a preventive measure rather than a regular element of a project. The idea of potential risk analysis is closely related to the notion of project quality above.

Risk analysis essentially aims to help the project team develop contingency plans so that it can respond quickly and correctly to problematic situations before irreparable damage is done. One of the most common problems is the resignation or reassignment of project team members to another project. This problem is particularly acute in the case of large-scale multiyear infrastructure projects, or for projects in organizations where staff resources are limited and priorities change within short time frames. Another very common problem is the late delivery or delays in the availability of source materials.

In addition to risks, the project manager should also look at the possibility of maximizing the opportunities of the project. They can do this by, for example, exploring the potential of extending the functionality of the GIS, providing value-added sales of the data to other users, and using their experience gained in the project being undertaken to offer consulting services to other organizations. All these will potentially bring additional revenue to the project, thus increasing its return on investment and long-term sustainability.

Risk exists for all projects. The role of the project management team is to understand the kinds and levels of risks in the project and then to develop and implement plans to mitigate these risks. Risk represents the likelihood that an event will happen during the life of the project that will negatively affect the achievement of project goals. The type and amount of risk vary by industry type, complexity, and phase of the project. The project risk plan will also reflect the risk profile of the project manager and key stakeholders. People have different comfort levels with risk, and some members of the project team will be more risk averse than others.

The first step in developing a risk management plan involves identifying potential project risks. Some risks are easy to identify, such as the potential for a damaging storm in the Caribbean, and some are less obvious. Many industries or companies have risk checklists developed from past experience. The Construction Industry Institute published a 100-item risk checklist that provides examples and areas of project risks. No risk checklist will include all potential risks. The value of a checklist is the stimulation of discussion and thought about the potential risks on a project.

The project team analyzes the identified risks and estimates the likelihood of the risks occurring. The team then estimates the potential impact on project goals if the event does occur. The outcome of this process is a prioritized list of estimated project risks with a value that represents the likelihood of occurrence and the potential impact on the project.

The project team then develops a risk mitigation plan that reduces the likelihood of an event occurring or reduces the impact on the project if the event does occur. The risk management plan is integrated into the project execution plan, and mitigation activities are assigned to the appropriate project team member. The likelihood that all the potential events identified in the risk analysis would occur is extremely rare. The likelihood that one or more events will happen is high.

The project risk plan reflects the risk profile of the project and balances the investment of the mitigation against the benefit for the project. One of the more common risk mitigation approaches is the use of contingency. Contingency is funds set aside by the project team to address unforeseen events. Projects with a high-risk profile will typically have a large contingency budget. If the team knows which activities have the highest risk, contingency can be allocated to activities with the highest risk. When risks are less identifiable to specific activities, contingency is identified in a separate line item. The plan includes periodic risk-plan reviews during the life of the project. The risk review evaluates the effectiveness of the current plan and explores possible risks not identified in earlier sessions.

1.31.2.4.11.1 Defining risk

Following Holton's (2004) essay, we define risk is the probability of an uncertain event or condition that, if it occurs, has a negative effect on a program's objectives. Both, the size of the effect and the probability combine to give the overall measure of risk. Damodaran (2007) offers a more expansive definition that sees risk as much as an opportunity that gets squashed if risk management is solely aimed at minimizing exposure to risk.

1.31.2.4.11.2 Risk management process

At a higher level, overall risk is defined as the exposure of stakeholders to the consequences of variation in individual risks. The high-level process starts with an initiation step that defines the scope and objectives of risk management. A key output from the initiation step is the risk management plan, which details how risk will be managed throughout the life cycle.

Risks should be identified and documented in the risk register. The relative significance of identified risks is assessed using qualitative techniques to enable them to be prioritized for further attention. Quantitative risk analysis may also be used to determine the combined effect of risks on objectives. The process continues with risk response planning, aiming to avoid, reduce, transfer or accept threats as well as exploit, enhance, share or reject opportunities, with contingency (time, cost, resources, and course of action) for risks which cannot be managed proactively. The final step is the implementation of agreed responses.

The whole process is iterative. For example, assessment or response planning can lead to the identification of further risks; planning and implementing responses can trigger a need for further analysis, and so on. It is important that risk management is not conducted in isolation. Risks at the project level, for instance, may have to be escalated to the program level or vice versa.

Risk management must contribute, as appropriate, to both business risk assessments and organizational governance requirements. The manager must be aware of risks that have an effect outside their scope of responsibility, e.g., those that could affect the organization's reputation. The management of general health and safety risks is usually excluded from program risk management, as the management of these risks is traditionally handled by a separate function within the organization.

1.31.2.4.11.2.1 Risk by phases Risk management consists of six steps or phases.

(1) We must identify what is the risk, and what is at risk. It could be timescales, the realization of a benefit, or the delivery of a capability.
(2) Although the program manager is ultimately responsible, each risk should be given an owner who is best positioned to perform mitigating actions on the risk and monitor the risk.
(3) The owner then evaluates and assigns the risk with an impact and probability score.
(4) Every risk has a standard set of mitigations which can be applied to it:

- Transfer: can the risk be transferred to another party, for example, could an insurance policy be taken out?
- Tolerate: this is frequently used for risks with very low impact, and is effectively the do-nothing option. Tolerate effectively means the risk is monitored but the program proceeds without proactive action being taken to address the risk.

- Terminate: this refers to adjusting the program so the risk is no longer applicable to the program, for example, a project may be removed entirely from the program so the risk can never materialize.
- Treat: this is where concrete actions are taken to reduce the probability of the risk materializing or impact of the risk should it materialize.

(5) The risk owner then takes concrete actions to ensure that the above mitigation measures are carried out.
(6) All risks and actions which have been created need to be reviewed regularly, so the risk impact and probability can be updated following any actions which have been performed to treat them.

1.31.2.4.11.3 Project risk and project complexity profile

Risk management can be understood as a complex system. It is affected by individuals, groups, stakeholders, host organizations, clients, and the broad external environment. Fundamental to understanding this system are the concepts of risk attitude and risk appetite. Risk attitude is an individual's or group's natural disposition toward uncertainty and is influenced by their perception of risk. Perception is itself influenced by many factors, including conscious and subconscious reactions to risk. Risk attitude will affect the way people develop responses to risk and the way they react if a risk event occurs.

The risk attitude of a group or individual is often described in one of three ways:

- Risk averse, where risk is avoided;
- Risk seeking, where risk is actively sought;
- Risk neutral, where risk is neither actively sought nor avoided.

A risk-averse attitude may be useful in some situations (e.g. local government) but detrimental in others (e.g. an entrepreneurial, technology start-up company). Conversely, risk seeking is a positive attribute in some situations but unsuitable in others.

Understanding risk attitude can help geospatial managers by giving insight into why some situations are considered more risky than others, and why individuals or groups behave in certain ways when confronted with risk.

Risk appetite is the amount of risk an individual, group, or organization is prepared to take in order to achieve their objectives to take risk in a given situation, influenced by their propensity to take risk and/or the organizational risk culture.

A manager needs to understand the risk appetite of the stakeholders. In the definition phase of a life cycle, the development of a solution to meet requirements will be heavily influenced by the stakeholders' risk appetite. Some ways of meeting requirements may be delivered quickly or produce high returns but also involve high levels of risk. These would be acceptable to risk-seeking stakeholders but not to those who are risk averse.

The manager also needs to understand the risk attitude of the team members and ensure that they are managed in a way that is compatible with the stakeholders' risk appetite.

1.31.2.4.12 Monitoring and control

Project monitoring and control should be done independently of project execution in order to prevent potential conflicts of interest from occurring when the individuals executing a project monitor and control their own activities.

1.31.2.4.12.1 Quality planning

Quality planning is a systematic process that translates the top management's expression of its intentions, direction, and aims regarding quality into measurable objectives and requirements, and lays down a sequence of steps for realizing them within a specified timeframe. Identification and characterization of quality as a basis for quality management procedures is helped by reference to accepted geospatial standards such as ISO, OGC, FGDC, or URISA (see section "**Standards**").

1.31.2.4.12.2 Quality planning tools

A preventative approach to data quality uses a four-tier Total Data Quality Management (TDQM) model to define, measure, analyze, and improve data quality (Wang, 1998). This approach differs from conventional methods in two ways. First is the emphasis on the use of pre-defined rules to validate the data before they are entered into the database. Second is the systematic capture and analysis of detected errors as well as the subsequent feedback of information to develop preventative measures at the data collection and supply end of the database construction process.

1.31.2.4.12.3 Contract management and control

Contract management requires considerable people skills. The project manager not only deals on a day-to-day basis with the contractor but also serves as the primary liaison between the contractor and the project team on various aspects of the project.

A common pitfall in contract management is the use of more than one contractor in the same project. Although it is not uncommon for a project contract to be awarded to more than one consultant (e.g., one for the database, the other for the application program development), awarding multiple contracts for a single project can be the project manager's worst nightmare and, therefore, should be avoided if possible. In the case of large-scale projects that are difficult for one contractor to complete alone, the usual solution is to allow the contractor to subcontract, subject to compliance with certain conditions (e.g., the principal contractor must be able to satisfy the project manager that the subcontractors have the capabilities and resources to complete the assigned components to the required performance standard, or the contractor takes full responsibility for delivery of subcontracted components). When this happens, the project manager typically only interacts directly with the principal contractor. He or she should avoid intervening in the working relationship between the principal contractor and any subcontractors (e.g., getting involved in dispute resolution between the principal contractor and subcontractors on any specific aspect of the project).

During the course of the project, disagreements between the project team and the contractor occur from time to time. In order to facilitate the resolution of potential conflicts, it is important for the project manager to specify the rules and protocols for communication between the two parties, and apply these rules strictly and consistently when problems occur. Typical rules and protocols often include communications channels (e.g., all communication must be done between the person designated by the principal contractor and the project manager only), the exclusive use of written communication, and the time limit for the contractor to respond when questions are raised, as well as the time limit for the project manager to indicate acceptance after a response is received from the contractor.

1.31.2.4.12.4 Change control

A commonly overlooked aspect of contract management is change management. Often, no matter how carefully a project manager plans a project and develops project specifications for hardware, software, and performance standards, unforeseen events may happen to necessitate a change in the plan and the specifications.

Change in project plans and project specifications can be generally classified into five categories. Whenever a change is required, the person (e.g., the contractor or a particular project team member) initiating the change will start the change request process. This is usually done by completing a project change request form.

When a problem occurs, one can't just make a change, because it may be too expensive or take too long to do. Instead, one should see how it affects the triple constraint of Fig. 1 and how it impacts project quality to determine whether it is worth making the change. If change impact evaluation does not show an impact on the project triple constraint, then it is alright to make the change without going through change control. In all other cases, change control is the set of procedures that enables the project manager to make changes in an organized way.

Any such change to a project plan starts with a change request. Every change to the project must be documented so one can figure out what needs to be done, by when, and by whom, as well as to form a basis for learning from the management of past project to improve the management of new ones.

Once the change request is documented, it is submitted to a change control board. A change control board is a group of people who consider changes for approval. If there is no such agency, then the change request could also be submitted to the project sponsor or management for review and approval. Putting the recommended changes through change control will help to evaluate the impact and update all the necessary documents. Not all changes are approved, but if the changes are approved, they are returned to the team to put them in place.

The implementation phase uses the most project time and resources, and as a result, costs are usually the highest during this phase. Project managers also experience the greatest conflicts over schedules in this phase. When the project is running behind, one can sometimes find ways to do activities more quickly by adding more resources to critical path tasks; a process known as crashing. Crashing the schedule means adding resources or moving them around to bring the project back into line with the schedule. Crashing always costs more and doesn't always work. There's no way to crash a schedule without raising the overall cost of the project. Therefore, if the budget is fixed and there isn't any extra money to spend, this technique is not applicable.

Project fast tracking refers to a situation where two activities that were originally planned to occur in sequence are now implemented at the same time. An example from the GIS world would be the concurrent testing of user acceptance testing (UAT) and the functional performance. This is a pretty risky approach though as there is always a good chance one might need to redo some of the work that was done concurrently. Crashing and fast tracking are schedule compression tools. Managing a schedule change means keeping all of the schedule documents up to date. That way, one can always compare (and report to higher management) the results to the correct plan.

1.31.2.4.12.5 Project documentation and control

Project monitoring and control starts with proper project documentation and record keeping, and is among the greatest challenges for a project manager. Project documentation includes all documents resulting from the project initiation and planning phases as well as ongoing amendments to project schedules, memoranda distributed to project team members, minutes of project team meetings, communication with the contractor and representatives of stakeholders, progress reports from the contractors, expenditure reports, and progress reports from internal project team members.

Project documentation and record keeping serve several important purposes in project management. One of these is to help the project manager maintain control of the project and keep track of its progress. They also allow the project manager to track the resources used against the activities completed and in progress.

From the beginning of a project, its manager must ensure that all members of the project team keep detailed notes of their respective activities (e.g., where they store their data and application program files, and the methods used for as well as progress made in the development of a particular application software module). As discussed in section (g), standards are very important in this context. Even mid-sized organizations will eventually develop their own standards as part of their GIS program or portfolio management. If a particular member is reassigned to a new role in the project or leaves the project altogether, these notes will allow the project manager quickly to provide the replacement with sufficient information to continue seamlessly with the work in progress.

Project documentation and record keeping are tedious and time-consuming tasks. However, it is important to keep a balance between the time and cost of record keeping on the one hand, and the usefulness of the documentation on the other hand. Obsession with detailed documentation and record keeping may be a waste of valuable resources, but keeping a collection of unorganized documents and project notes will not help either. The project manager has to use his or her discretion to set up a project documentation and record keeping system that is both economically sustainable to maintain and easy enough to access and use.

1.31.2.4.12.6 Quality assurance

The terms quality assurance (QA) and quality control (QC) are often used in conjunction with one another (QA/QC). In reality, however, they refer to two relatively distinct but closely interrelated sets of concepts and practices. QA and QC have their origin in manufacturing and engineering. The purpose is to safeguard the quality of products against possible imperfection in design, craftsmanship, the material used, and production processes. Thus, QA/QC are preventive measures that are applied throughout the entire production or construction cycle of hardware manufacturing and engineering development projects. GIS projects, being a design and implementation undertaking, require stringent QA/QC measures to ensure that all activities, from design, development, production, installation, servicing, and documentation, are carried out according to accepted practices and standards, and will lead to the delivery of a system that is useful for its intended purposes.

The relationship between QA and QC in GIS projects is often confused. QA should be seen as the umbrella activities that provide the support infrastructure for the technical application of QC measures. The support infrastructure includes corporate information quality and standards, competencies of project staff, and performance standards of business procedures served by the GIS resulting from individual projects. Of particular interest here are the ISO and OGC standards that will be discussed in the next section.

At the technical level, QC is applied by conducting a sequential series of software tests that include:

- *Unit tests*. These tests target the smallest unit of software construction, namely the functional modules, and are carried out immediately after the source-level code is developed, reviewed, and checked for correct syntax.
- *Integration tests*. These tests aim at detecting potential errors associated with the interaction between individual functional modules. There are different approaches to integration testing. The most commonly used one is called regression testing, which is carried out incrementally each time a new module is completed and added to the software system.
- *Systems test*. This is the final stage of software testing conducted when the entire development process is complete. In practice, systems testing is actually a series of tests with different purposes that collectively seek to verify the functionality of the database system as a whole. The four commonly used tests are a recovery test (to verify the ability of the system to restore itself to the state before the failure), a security test (to verify the ability of the system to protect itself from unauthorized use), a stress test (to examine the response of the system to abnormal events such as excessive interruption, excessive number of users, and maximum memory use), and a performance test (to monitor the functioning of the system in run-time). As the systems test is carried out to determine whether the final system is functionally acceptable for implementation, it is also commonly called the acceptance test.

Once fully operational, the GIS has to be validated in accordance with the validation protocols agreed in the system qualification plan. Modular tests are conducted by team members who have not taken part in the coding operations. Tests have to conform to the verification test procedures. The results of this task are reported in a verification test report. On the basis of that report, a final tuning of the information system specifications is then carried by the GIS project team. This tuning may result in improved versions of the requirements baseline, technical specifications, the design justification report, data model report, and system qualification plan.

1.31.2.4.12.7 Standards

Identification and characterization of quality as a basis for quality management procedures is helped by reference to accepted standards such as:

The family of ISO technical specifications 191xx (as of 2016, some 68 different specifications have been passed; hence the "xx"). The International Organization for Standardization (ISO), is an independent, nongovernmental organization, the members of which are the standards organizations of the 162 member countries. Its technical committee 211 has been tasked with the development of technical specifications for digital geographic information, covering areas such as:

- Simple features access.
- Reference models.
- Spatial and temporal schemas.
- Location-based services.
- Metadata.
- Web feature and map services.
- Classification systems.

The Open Geospatial Consortium (OGC) is an independent standards organization with participation of industry and government organizations, and coordination with professional associations and other standards organizations. The OGC has established standards for spatial data format, data classification, geospatial services and applications, and GIS operational practices. The OGC standards have been adopted by many GIS software and database companies and by user organizations. As of 2016, the OGC has published some 49 standards including CityGML, GML, NetCDF, and the plethora of web services such as WCS, WFS, WMS, WPS that are now the foundation of all web-based geospatial applications.

The Federal Geographic Data Committee (FGDC) is a U.S. Federal government organization, which develops and approves standards for GIS data and metadata quality, format, content, and classification and related GIS data collection and maintenance practices. Similar organizations exist in Europe (INSPIRE), Canada (CGDI), Australia/ New Zealand (ANZLIC), and elsewhere.

The Urban and Regional Information Systems Association (URISA) is an international professional and educational association that promotes standards and best practices for the management and use of GIS technology. Of particular relevance to this article is their GIS Management Institute (GMI), which develops tools and best practices useful for GIS planning and management.

1.31.2.4.12.8 Ethical responsibility in publicly financed projects

While the topic of ethics will be discussed in more general terms in section "Ethics", this section here deals with the need for an extra layer of monitoring and control in publicly financed projects. This starts with the procurement process, where the bidding process may involve criteria that go beyond the scope of the GIS project itself, e.g., minimum wage requirements or a preference to women- and minority-owned enterprises. Lobbying rules and other conflict of interest declarations will put additional burden on the monitoring requirements, sometimes dismissively labeled as "red tape".

1.31.2.4.13 Deployment (technology roll-out activities)

After the deliverables have been physically constructed and accepted by the customer, a phase review is carried out to determine whether the project is complete and ready for closure.

1.31.2.4.13.1 System engineering

During this task, the GIS project team completes all developments in accordance with the refined technical specifications and data model report. This includes the final coding of software modules and their final integration into an operational GIS package. Besides the GIS package itself, it is the project manager's responsibility to also refine the design definition report and the data model implementation report.

Critical success factors for implementation of comprehensive GIS systems will require a large investment in staffing resources and its funding as an information technology project. The implementation process must be recognized as such, therefore being managed like any major IT project to achieve optimal benefits and results.

1.31.2.4.14 Closeout and evaluation

1.31.2.4.14.1 Development and testing

The objective of this phase is to complete the development of the geographical information system and to demonstrate the compliance with the consolidated user requirements refined during the prototyping phase.

1.31.2.4.14.2 Support (user documentation, training, technology transfer)

Prior to its installation at the users' premises, the information system has to be adequately documented. This documentation includes all the documents mentioned above, extended to the documents described hereafter.

1.31.2.4.14.2.1 Installation guide The installation guide describes all operations to install and configure the information system at the users' premises. It specifies, in particular, the minimum hardware requirements and versions of operating platforms. Another important item at this stage is the need to pay attention to the implementation of the data model into the GIS software.

1.31.2.4.14.2.2 Software user manual The software user manual describes all the functionalities of the software elements of the GIS package and has to be written in such a way that it is understandable by the users' organizations.

1.31.2.4.14.2.3 Manual of procedures The manual of procedures describes all procedures which support the operations routinely performed by the information system, especially those which require human intervention. These include:

- Overall system administration procedures including back-up and archiving procedures, maintenance operations, the configuration of new users, etc.
- Data diffusion policy and procedures (including pricing policy, if any).
- Quality control procedures.
- Financial procedures.
- Documentation procedures.
- Annual performance review procedures.

1.31.2.4.14.2.4 Training plan The training plan aims at specifying the human skills which are required to operate the information system properly and the training efforts to be undertaken so that the staff of the users' organizations matches these human skill requirements. The training plan describes the different training modules which are required and for each of them the number of hours which will be lectured, the list of staff members who will attend the module, and a preliminary investigation of potential training service providers.

1.31.2.4.14.3 Closing-out contracts

Contractual closeout includes identification and status of each project contract and subcontract, their values and their terms and conditions. The contract status should include any incomplete deliverables; terms, conditions, and dates for obtaining remaining deliverables; real and potential claims; pending and any ongoing legal actions; warranties made as part of the contract; and any other information that might prove useful to the user organization in relation to legal, contractual, warranty, or deliverables.

Before the contract is closed, any minor items that need to be repaired or completed are placed on a punch list of all the items that still remain to be done. The project team will then work on all of the items on the list, building a small schedule to complete the remaining work. Once the punch list becomes smaller, the project manager begins closing down the project, maintaining only enough staff and equipment to support the team that is working on the punch list.

In many public projects, a major component is regulatory compliance, which ascertains that no additional active management is needed.

The development and execution of closing-out contracts may take as much time as the project itself because once signed, it usually does not allow a client to request any changes or repairs, and it serves as protection against legal recourse once the project is finished. Signing of the closing-out contract usually coincides with the last payment as well.

1.31.2.4.14.4 Post-project evaluations

In many cases when a project is completed, it is time to start thinking about its upgrade and enhancement. The purpose of the post-implementation evaluation is to summarize the experiences gained in the project just completed so that the same mistakes will not be repeated in the next version of the database system and in other similar projects.

In essence, a post-implementation evaluation is a comparison between the predicted events and the events that actually occurred during the entire course of the project's lifecycle. Experience has shown that projects rarely run exactly as planned and scheduled. Variances between planned and actual events can often be generally traced to two primary causes, namely technical and personnel. Thus, a post-implementation evaluation report is best approached from these two perspectives. It is common practice for the project sponsor to analyze the performance of project personnel, while the project manager is responsible for the evaluation of the performance of equipment and applications. In conducting the technical portion of the evaluation, the project manager should pay special attention to the problems encountered and the solutions that were used to deal with the problems successfully.

Upon completion of the evaluation report, the project manager should submit copies to the project sponsor and senior management to signify the completion of the entire project. He or she should distribute copies of the report to all project staff.

1.31.2.4.14.5 Project archival

The documents associated with the project must be stored in a safe location where they can be retrieved for future reference. Signed contracts or other documents that might be used in tax reviews or lawsuits must be stored. Organizations will have legal document storage and retrieval policies that apply to project documents and must be followed. Some project documents can be stored electronically.

Care should be taken to store documents in a form that can be recovered easily. If the documents are stored electronically, standard naming conventions should be used so documents can be sorted and grouped by name. If documents are stored in paper form, the expiration date of the documents should be determined so they can be destroyed at some point in the future. The following are documents that are typically archived:

- Charter documents.
- Scope statement.
- Original budget.
- Change documents.
- Manager's summary—lessons learned.

1.31.3 Stakeholder Management

People and organizations can have many different relationships to the project. Most commonly, these relationships can be grouped into those who will be impacted by the project and those who can impact the project. A project is successful when it achieves its objectives and meets or exceeds the expectations of the stakeholders. This insight is fairly new: the Project Management Institute, for example, added stakeholder management to its core list of knowledge areas only in its latest (fifth) edition of the project management guidebook. Stakeholders are individuals who either care about or have a vested interest in the project. They are the people who are actively involved with the work of the project or have something to either gain or lose as a result of the project. In a project to add lanes to a highway, motorists are stakeholders who are positively affected. However, they negatively affect residents who live near the highway during the project (with construction noise) and after the project with far-reaching implications (increased traffic noise and pollution).

A successful project manager will identify stakeholders early in the project. For each stakeholder, it is important to identify what they want or need and what influence or power they have over the project. Based on this information, the need to communicate with the stakeholder or stakeholder group can be identified, followed by the creation of a stakeholder management plan. A stakeholder

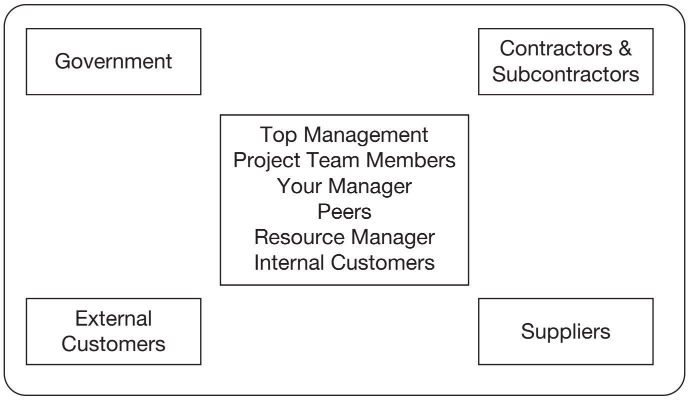

Fig. 6 Project stakeholders. Adopted from Barron M and Barron A (2011) Project management for scientists and engineers. Galway: Connexions.

register is used to identify and track the interactions between the project and each stakeholder. This register must be updated on a regular basis, as new stakeholders can arise at any time, and the needs and interest levels of a particular stakeholder may change through the course of the project.

Often there is more than one major stakeholder in the project. An increase in the number of stakeholders adds stress to the project and influences the project's complexity level. The business or emotional investment of the stakeholder in the project and the ability of the stakeholder to influence the project outcomes or execution approach will also influence the stakeholder complexity of the project. In addition to the number of stakeholders and their level of investment, the degree to which the project stakeholders agree or disagree influences the project's complexity.

A small commercial construction project will typically have several stakeholders. All the building permitting agencies, environmental agencies, and labor and safety agencies have an interest in the project and can influence the execution plan of the project. The neighbors will have an interest in the architectural appeal, the noise, and the purpose of the building.

The following section details the functions and relationships of the stakeholders depicted in Fig. 6.

1.31.3.1 Stakeholders

1.31.3.1.1 Top management

Top management may include the chief executives, directors, division managers, and others. These people direct the strategy and development of the organization. If one has top management support, it will be easier to recruit the best staff to carry out the project, and acquire needed material and resources; also visibility can enhance a project manager's professional standing in the company. That comes with the risk though that failure can be quite dramatic and visible to all, and if the project is large and expensive (most are), the cost of failure will be more substantial than for a smaller, less visible project.

1.31.3.1.2 Project team

The project team is made up of those people dedicated to the project or borrowed on a part-time basis. A project manager has to provide leadership, direction, and above all, the support to team members as they go about accomplishing their tasks. Working closely with the team to solve problems helps to build rapport. Team management is not an easy task; some of the difficulties that many projects run into include:

- If project team members are borrowed and they don't report to the project manager, their priorities may be elsewhere.
- They may be juggling many projects as well as their full-time job and have difficulty meeting deadlines.
- Personality conflicts may arise. These may be caused by differences in social style or values, or they may be the result of some bad experience when people worked together in the past.
- If communication breaks down, one may learn about missed deadlines only when it is too late to recover.

1.31.3.1.3 Internal customers

Internal customers are individuals within the organization who are customers for projects that meet the needs of internal demands. The customer holds the power to accept or reject the project outcomes. Early in the relationship, the project manager will need to negotiate, clarify, and document project specifications and deliverables. After the project begins, the project manager must stay tuned into the customer's concerns and issues and keep the customer informed. Common stumbling blocks when dealing with internal customers include:

- A lack of clarity about precisely what the customer wants.
- A lack of documentation for what is wanted.
- A lack of knowledge of the customer's organization and operating characteristics.

- Unrealistic deadlines, budgets, or specifications requested by the customer.
- Hesitancy of the customer to sign off on the project or accept responsibility for decisions.
- Changes in project scope.

1.31.3.1.4 Contractors and suppliers

There are times when organizations don't have the expertise or resources available in-house, and work is farmed out to contractors or subcontractors. This can be a construction management foreman, network consultant, electrician, carpenter, architect, or anyone who is not an employee. Managing contractors or suppliers requires many of the skills needed to manage full-time project team members.

Any number of problems can arise with contractors or subcontractors:

- Quality of the work.
- Cost overruns.
- Schedule slippage.

Many projects depend on goods provided by outside suppliers. This is true for example of construction projects where lumber, nails, bricks, and mortar come from outside suppliers. If the supplied goods are delivered late or are in short supply or of poor quality, or if the price is greater than originally quoted, the project may suffer.

Depending on the project, managing contractor and supplier relationships can consume more than half of the project manager's time. It is not purely intuitive; it involves a sophisticated skill set that includes managing conflicts, negotiating, and other interpersonal skills.

1.31.3.2 Politics of Projects

Many times, project stakeholders have conflicting interests. It's the project manager's responsibility to understand these conflicts and try to resolve them. It's also the project manager's responsibility to manage stakeholder expectations. Be certain to identify and meet with all key stakeholders early in the project to understand all their needs and constraints.

Project managers are somewhat like politicians. Typically, they are not inherently powerful or capable of imposing their will directly on coworkers, subcontractors, and suppliers. Like politicians, if they are to get their way, they have to exercise influence effectively over others. On projects, project managers have direct control over very few things; therefore, their ability to influence others—to be a good politician—may be very important.

Here are a few steps a good project politician should follow. However, a good rule is that when in doubt, stakeholder conflicts should always be resolved in favor of the customer.

1.31.3.3 Culture of Stakeholders

When project stakeholders do not share a common culture, project management must adapt its organizations and work processes to cope with cultural differences. Communication is perhaps the most visible manifestation of culture. Project managers encounter cultural differences in communication in language, context, and candor. Language is clearly the greatest barrier to communication. When project stakeholders do not share the same language, communication slows down and is often filtered to share only information that is deemed critical. The barrier to communication can influence project execution where the quick and accurate exchange of ideas and information is critical. The interpretation of information reflects the extent that context and candor influence cultural expressions of ideas and understanding of information. In some cultures, an affirmative answer to a question does not always mean yes. The cultural influence can create confusion on a project where project stakeholders represent more than one culture.

1.31.3.4 Strategies for Stakeholder Management

Securing stakeholders' support is absolutely critical to the success of a project. Even if all the deliverables are met and the objectives are satisfied, if the key stakeholders aren't happy, the project will be deemed a failure. The first step, therefore, is to identify who the stakeholders are. Just because someone is important in the organization does not necessarily mean she is important to the project. The typical suspects are the manager, her boss, the client, the client's manager, any subject matter expert whose involvement is necessary, and the board reviewing and approving the project. In some situations, there are people who think they are stakeholders. From the manager's perspective, they may not be, but these need to be handled carefully. They could be influential with those who have the power to impact the project and should not be dismissed out of hand.

Second, a project manager needs to determine what power they have and what their intentions toward the project are. Do they have the power to have an impact on the project? Are they in support or opposition to the project?

Third, what's the relationship among stakeholders? Can the project's chances be improved by working with those who support the project by co-opting them to improve the views of those who oppose it? A key piece of stakeholder management efforts is constant communication to her stakeholders.

1.31.4 Project Management Expertise

1.31.4.1 Application Knowledge

Application-specific knowledge and skills pertaining to a particular GIS project are not particularly important at the management level. The project manager can usually pick up relevant knowledge and skills through interaction with application specialists and user representatives as the project unfolds. Technical competencies and skills, on the other hand, are essential throughout the entire project lifecycle, and especially so in the project execution phase. Such competencies and skills are project-specific because different types of projects require different technical skill sets. A project manager is not normally expected to be a technical expert. However, it is essential for the project manager to have, as a minimum, a good understanding of the basic principles of GIS. It is useful to consider application knowledge from another perspective by taking technical competencies and skills into consideration.

Fig. 7 shows the role of technical competencies and skills in project management. Project management competencies and skills are classified into three categories according to their respective nature, namely strategic, tactical, and technical. Strategic competencies and skills cover mainly the two areas of "organizational culture" and "communication", which are both described in the following sections. These two areas of competencies and skills are applied mainly in the initiation and closing phases of the project lifecycle. The tactical competencies and skills discussed in section "Stakeholder Management" are needed most for the planning and monitoring and control phases of the PMLC.

1.31.4.2 Understanding the Project Environment

There are many factors that need to be acknowledged in the project environment. At one level, it is important to think in terms of cultural and social environments such as people, demographics, and education. Many GIS projects take place in an international context where projects are doomed to fail if they do not heed political and cultural influences.

Of all the factors, the physical ones are the easiest to understand, and it is the cultural and international factors that are often misunderstood or ignored. How we deal with clients, customers, or project members from other countries can be critical to the success of the project. For example, the culture of the United States values accomplishments and individualism. Americans tend to be informal and call each other by first names, even if having just met. Europeans tend to be more formal, using surnames instead of first names in a business setting, even if they know each other well. In addition, their communication style is more formal than in the United States, and while they tend to value individualism, they also value history, hierarchy, and loyalty. Harvey (1997) did a fascinating study on the differences in the culture of GIS implementation between Münster, Germany, and Seattle, WA (United States).

Cultural differences of a very different kind occur also within (larger) organizations. All projects inevitably involve changes in the organizational culture, institutional structure, business processes, and people and it is the responsibility of the project manager to steer the organization through the transition with minimum disruption to the organization's business, the least anxiety of its staff, at the lowest possible cost, and within the shortest realistic time frame.

1.31.4.3 Management Knowledge and Skills

Project management is the responsibility of a project manager. This individual seldom participates directly in the activities that produce the GIS, but rather strives to maintain the progress and productive interaction of various parties in order to minimize the overall risk of failure. A project manager is expected to have a specific level of competency and skills in technical management,

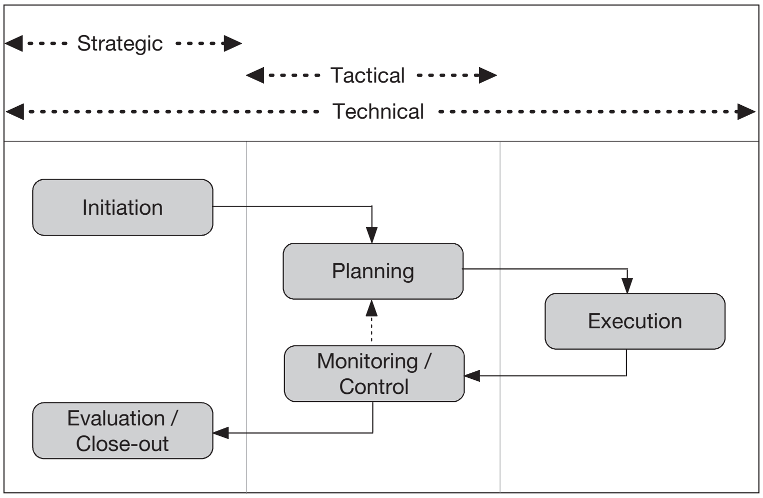

Fig. 7 Project management competencies and skills.

financial management, and people management in order to accomplish this objective. In many organizations, the project manager is required to possess a professional designation from an accreditation body, such as the PMI noted above. Although a professional designation for a manager is by no means a panacea for the success of a project, such a requirement at least reflects the general realization that a set of managerial competencies and skills is essential for the practice of effective project management. Typical project manager job functions include:

- Define scope of project
- Identify stakeholders, decision-makers, and escalation procedures
- Develop detailed task list (work breakdown structures)
- Estimate time requirements
- Identify required resources and budget
- Evaluate project requirements
- Identify and evaluate risks Prepare contingency plan
- Identify interdependencies
- Identify and track critical milestones
- Participate in project phase review
- Secure needed resources
- Manage the change control process
- Report project status

The New York State Project Management Guidebook (Mulholland, 2003) identifies five core sets of competencies and skills for project managers. These include:

1.31.4.3.1 Communication

Good communication skills are a critical requirement for project managers. Project managers spend 90% of their time communicating. Communication in project management is bidirectional in the sense that talking and listening are equally important. The project manager must be able to convey his or her messages clearly both verbally and in writing. At the same time, he or she must be willing to listen to suggestions and ideas put forth by project sponsors, project team members, and other stakeholders of the project both within and outside of the organization. Project communication can thus be summed up as knowing "who needs what information and when" and making sure they have it.

1.31.4.3.2 Trust building

Project management can be a very difficult task if the project manager is unable to gain the trust of the project sponsor, project staff, and other stakeholders. Trust and credibility cannot be built overnight. They must be developed over time and can be inspired only if the project manager exhibits behaviors compatible with the competency and skill requirements described above, is willing to admit mistakes and accept responsibility for actions, values differences and diversity of opinions and cultures, and treats everyone equally and equitably.

1.31.4.3.3 Leadership

Leadership is the ability to motivate and inspire individuals to work toward expected results. Leaders inspire vision and rally people around common goals. A good project manager can motivate and inspire the project team to see the vision and value of the project. The project manager as a leader can inspire the project team to find a solution to overcome perceived obstacles to get the work done.

Experience has shown that project teams seldom become high performing immediately after their formation. It takes time and effort to build an effective and coherent project team. As the team leader, the project manager should continuously motivate members by letting them know the benefits and potential opportunities of the experience and skills to be gained in the project. He or she must provide team members the necessary training to perform their assigned tasks effectively, and recognize their efforts and accomplishments appropriately. Team leadership also means delegation and empowerment, where necessary, to increase the sense of belonging among team members. At the same time, team leadership never ignores accountability and discipline, which will be applied impartially, transparently, and promptly when and if the situation warrants them.

1.31.4.3.4 Problem solving

While a project manager has considerable responsibility for the success of a project, he or she does not always have absolute authority and control over human, financial, and technical resources allocated to the project. Therefore, it is essential for a project manager to be politically astute, and have good networking and negotiation skills to deal with senior managers and all stakeholders to ensure appropriate and sustainable support for the project. It is also important for a project manager to have good mediation skills to resolve disputes or conflicts among members of the project team as well as those between the project team and other stakeholders of the project.

1.31.4.4 Certification

Certification is a process designed to recognize individuals who have demonstrated a level of expertise in their profession. Although there are specialized certifications for a number of disciplines (e.g. intelligence, photogrammetry, surveying), the GIS Certification Institute's (GISCI) designation of GIS Professional (GISP) is the most widely accepted industry-wide, internationally recognized, software-agnostic certification available to geospatial professionals. There are, as of 2016, more than 8000 GISP-certified professionals in 25 countries. The GISP helps employers identify professionals who are committed to the skilled and ethical use of

GIS. GISPs have a unique set of skills and responsibilities that can enhance their workforce. In contrast to a degree, the GISP certification emphasizes regular renewal intervals that require a combination of work experience, education, and contributions to the GIS profession. The value of a GISP is acknowledged by the fact that they demand on average about 25% higher salaries, all other qualifications being equal.

1.31.4.5 Ethics

Good ethics is good business (Jakobs, 2017). In the United States, both the PMI and the GISCI require their members to sign a Code of Ethics and Professional Conduct. GIS professionals are expected to deliver quality work. Part of this is addressed by the certifications discussed in the previous section. This includes the need of the professional to keep updated in the field through readings and professional development. Each member of the project team is expected to identify risks and the potential to reduce them. Many of the characteristics of project management are mirrored in the expectations of the individuals working on the project. They include the identification of alternative strategies to reach employer/funder goals and the implications of each, as well as the requirement to document one's work so that others can use it (see also section "**Project documentation and control**").

Ethical behavior assumes GIS professionals to hold information confidential unless authorized to release it. Any conflict of interest ought to be avoided and when this is not possible to be disclosed.

1.31.5 Summary

GIS project management is somewhat of a neglected child in the academic treatment geospatial work. Management practices are seen as just that: applications that do not merit further investigation. The fact that business schools exist and thrive hints at the gaping hole that GIScientists have left uncovered. One of the main messages of this article is that we need to look beyond the immediate application of GIS and see GIS implementations in a larger enterprise context. Much can be derived from the body of traditional management literature. But even here, the bon mot "spatial is special" holds true. It starts with the characteristics of spatial data and continues with the unusual breadth of application areas that require generalists and specialists to collaborate even more than in standard information technology.

Most college-level GIS programs teach the technology and the science behind it, which serves the science community well, and the industry adequately—up to a point. GIS certificates, both academic and vendor-driven abound, addressing the needs for the bottom string of a hierarchy of GIS professionals. There is, or at least has not been, a corresponding body of knowledge for higher level GIS professionals or managers, which is surprising given that there are thousands of GIS departments in the United States alone. A systematic investigation of what makes a GIS program successful (the URISA Awards for Exemplary Systems in Government come to mind) requires analyzing and abstracting all the aspects of GIS project management discussed on the previous pages. A compendium of best practices and how they might even inform GIS use in more traditional academic settings has yet to be written. In the meantime, this article will hopefully shed some insight on the complexities that experienced GIS managers have learnt to deal with.

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