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A Geographic Conceptual and Logical Data Model for Project Monitoring and Control based on PMI Project Management Standards: Caminosca S.A. Case

Wilson Gustavo Rueda Salazar

Richard Resl, Ph.Dc., Director de Tesis

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Wilson Gustavo Rueda Salazar

Richard Resl, Ph.Dc. ..…….……………………………

Director de Tesis

Pablo Cabrera, Ms. …………………………………..

Miembro del Comité de Tesis

Richard Resl, Ph.Dc. …………………………………..

Director de la Maestría en Sistemas

de Información Geográfica

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Decano del Colegio de Posgrados

Quito, enero de 2014

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RESUMEN

El uso eficiente de herramientas y técnicas para monitoreo y control de proyectos permite ejercer una adecuada evaluación periódica de los recursos asignados a los mismos, con el afán de cumplir con los productos objeto del proyecto dentro del tiempo establecido y sin incurrir en costos adicionales a los presupuestados. Hoy en día, el estándar de gestión de proyectos propuesto por el Project Management Institute PMI, es la primera referencia en buenas prácticas sectoriales a nivel mundial. Esta tesis, en primera instancia, tiene por objeto analizar los procedimientos recomendados por el PMI y contraponerlos con los procedimientos de monitoreo y control de proyectos con los que cuenta la compañía consultora ecuatoriana de diseños de ingeniería civil Caminosca S.A. En vista que Caminosca S.A. es una compañía con un catálogo importante de proyectos ejecutados en el Ecuador y regionalmente, aprovechando el potencial de las tecnologías actuales geo espaciales, y con el afán de inteligenciar a la compañía con respecto a valiosas estadísticas históricas-espaciales sobre desempeño de sus proyectos que en la actualidad no está siendo adecuadamente capturada, el presente estudio pretende proponer el diseño de un modelo geográfico lógico-conceptual a ser utilizado para el monitoreo y control de todos sus proyectos, significando una optimización y adición de una variable espacial con respecto al estándar original.

ABSTRACT

An efficient use of the adequate tools and techniques for project monitoring and control allows periodical evaluation of time and cost resources assigned to any such project. On a global scale, the best practices on project management are given by the Project Management Institute PMI standards. This thesis starts by analyzing the PMI standardized procedures for project management and compares them with the already implemented procedures by Caminosca S.A. Caminosca S.A. is an Ecuadorian consulting company for civil engineering with a significant list of projects executed nationally and regionally. This research aims at providing the company with a method of capturing new valuable knowledge about their history of project performance using spatial indicators structures, modeled and analyzed by GIS. Towards the end of this document a conceptual and logical spatial data model for project monitoring and control is proposed and evaluated as far such a spatial point of view would serve as a valuable addition to the common PMI standard.

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CHAPTER I: INTRODUCTION

1.1 Points of Departure

Within this section, basic information will be given about the reasons for choosing this research topic: background information of the project management information situation in Caminosca S.A.; rationale and statement of the problem; research purpose, objectives; and finally a general outline of the thesis document.

1.2 Background of the Problem

Caminosca S.A. is the most representative consulting company in Ecuador, providing civil engineering services since 1976, not only inside the country but regionally. The main activities for which the company provides its services are: hydropower, hydrocarbon, mining and environment, roads and transportation, water supply and sewerage, urban development and airports, irrigation, drainage and other multipurpose projects. The company's three main activities are: *Studies and Designs:* basic investigations, conceptual engineering designs, environmental impact assessments, feasibility studies, basic and detailed engineering, detailed designs and bidding-process documentation and technical assistance; *Construction Supervision and Project Management Services*; and, *Technical Consultancy.*

By means of the intense business activity and heterogeneous spatial location of its different services, one of the main challenges Caminosca S.A. has, is to efficiently manage a complex catalogue of projects, being simultaneously executed by the company in a diverse spatial context.

As a practical approach to handle this issue, since 2005 Caminosca S.A. has implemented a special unit for project monitoring and control with its own developed procedures, nevertheless the company has lately considered the possibility of aligning its practices with project management guidelines defined by the Project Management Institute

PMI, which is a worldwide organization vastly known for its leading standards on project management.

The purpose of this thesis will be the introduction of a link between the use of Geographic Information Systems GIS and the PMI's project management standards. Accomplished through the proposal of a conceptual and logical model of a spatial database, of how monitoring and controlling tasks should be carried out according to the business necessities of Caminosca S.A.

1.3 Statement of the Problem

Beginning from the definition given by the PMI of what a project is: "*A project is a temporary endeavor undertaken to create a unique product, service or result*" (Project Management Institute, 2008), it is easy to infer that in the temporal gap where the project is active, a considerable amount of resources must be invested in order to accomplish project milestones on schedule without any extra cost.

Depending on the complexity of the project and the specific skills that the project manager would have, those resources (*e.g.* budget, procurement, time, etc.) could be misspent if an adequate project management method is not implemented.

Project management procedures generate a considerable amount of information about the status of those resources in different stages of the project (project performance). In the case of Caminosca S.A, a preliminary qualitative assessment of the current project monitoring and controlling situation indicates that:

a. Not all relevant project performance data are being captured;

b. A standardized and mostly detailed procedure of project monitoring and controlling has not been implemented;

c. Existing active and ended project performance data is not approachable nor integrated in the implemented company database;

d. There is no awareness of the spatial characteristics of neither project performance data nor possible correlations or patterns.

The research problem is to study possible solutions to these issues through the following question: *Is it possible to integrate spatial technologies such as Geographic Information Systems with PMI project management standards into a functional geographic conceptual and logical data model for monitoring and controlling Caminosca S.A. projects?*

1.4 Problem Rationale

The broad spectrum of possibilities that the implementation of a GIS for project monitoring and controlling within Caminosca S.A. is worth considering. A company that has being providing its intellectual services for more than 30 years all over the country, and even internationally, undoubtedly has a valuable baggage of accumulated experiences dealing with different clients, budgets and deadlines, in different geographical contexts. The development of such tool could increase the currently incipient level of spatial awareness of possible relationships and patterns of project performance data within the rather extensive catalogue of the company executed projects, enhancing the business intelligence of the company and providing approachable access through data spatial allocation visualization.

The relevance of this research relies on the possibilities of complementing such a solid project management methodology PMI offers from a spatial point of view given by the proposal of a custom geographic information system data model.

1.5 Purpose and Objectives

The aim of this thesis research is to provide Caminosca S.A. with a preliminary conceptual and logical spatial data model for a project monitoring and control oriented GIS, suitable for Caminosca S.A. information requirements and, most importantly, based on PMI project monitoring and control standard. In order to accomplish this, the following objectives must be pursued:

1. Identifying and analyzing current monitoring and control processes implemented in Caminosca S.A.;
2. Identifying PMI monitoring and control guidelines for project management and defining which are suitable for Caminosca S.A. execution;
3. Designing a preliminary conceptual and logical model for a project monitoring and control oriented GIS;
4. Documenting spatial model design (*i.e.* geodatabase structures; feature classes and attributes; domains; and, relationship classes) through a data dictionary.

1.6 Assumptions

- Unrestricted access to Caminosca S.A. Quality Assurance Management System and particularly to monitoring and control process documentation;
- Access to Caminosca S.A. ArcGIS for Desktop existing license.

1.7 Restrictions

- Thesis research deadline;
- Partial restricted-use financial raw data;
- No standardized nor systematic capture of project performance data;
- No research funding;
- No ArcGIS for Server license.

1.8 Thesis Outline

In the present chapter, the motivations for choosing a project management methodology and a spatial data model are discussed.

Chapter II situates this thesis into PMI project management conceptual framework and evokes the main concepts of Geographic Information Systems. Chapter III presents background information on Caminosca S.A. structure, its quality assurance system, and as part of it, an appraisal of the company main monitoring and control documentation. The conceptual considerations on how the data model was planned and structurally defined are also discussed. For this part, Earned Value Management technique was considered as the main provider of project performance metrics. Details about data modeling process using CASE tools and a complete data dictionary of the resulting model are also provided in Chapter III.

A brief summary of the research and its results are presented in Chapter IV, to proceed later to present in Chapter V, recommendations and further complementary activities that should be held by the company –or any other interested company– upon implementation.

CHAPTER II: LITERATURE REVIEW AND CONCEPTUAL FRAMEWORK

2.1 Project Management Institute PMI Approach on Project Management

As stated above, in terms of project management guidelines, the Project Management Institute PMI has one of the most solid bodies of knowledge in this area as it has become the standard model to be followed in both governmental and business sector. It has been evolving since 1983 and today has a worldwide presence; it is formed by more than 650.000 members in 185 countries (Project Management Institute, 2012).

According to the depth of the knowledge, PMI has refined a set of different foundational standards, practice standards and standard extensions, which comprehend an extensive knowledge of common usage terminology, best practices and guidelines for project management. Its core standard is the PMBOK® Guide "*A Guide to the Project Management Body of Knowledge*". As a core or foundational standard, the PMBOK Guide does not define a specific methodology on project management rather than a set of guidelines or recommendations. Indeed, PMBOK Guide encourages the development of different *ad hoc* methodologies and tools to implement the suggested general guiding principles (Project Management Institute, 2008).

Conforming to PMI (2008), the definition of project management is: "*the application of knowledge, skills, tools, and techniques to project activities to meet the project requirements*". As most management standards, PMBOK Guide has a process approach to it. It conceives project management comprehended in different process groups, which typically tend to: identify project requirements, address expectations from the different stakeholders related to the project, and balancing the different project restrictions (*i.e.:* scope, budget, schedule, etc.). The five project management process groups defined by PMI in its standard, PMBOK Guide, are:

1. **Initiating:** Procedures needed to begin a project or a project phase;

2. **Planning:** Procedures needed to establish the scope of the project and the steps to take in order to conquer the project objectives;

3. **Executing:** Procedures needed to accomplish the project management plan;

4. **Monitoring and Controlling:** Regular procedures needed to maintain track on project schedule progress, scopes, cost, risk, etc.; thus identifying possible variations on the project original management plan;

5. **Closing:** Procedures necessary to finish all activities unleashed by all management group processes, in order to give formal closure to the project.

Processes are also grouped in Knowledge Areas, which are nine different discipline areas where the activities are executed and, with different importance levels, are recurrent in every project; those knowledge areas are:

1. Project Integration Management;
2. Project Scope Management;
3. Project Time Management;
4. Project Cost Management;
5. Project Quality Management;
6. Project Human Resource Management;
7. Project Communications Management;
8. Project Risk Management;
9. Project Procurement Management.

The logical and practical approach of the PMI project management standard, allows conforming a matrix between the nine knowledge areas (x) and the five process groups (y), in order to easily identify every process that could be performed in the project for its adequate execution. The expected interaction between knowledge areas and processes groups depends on the project management objective pursued. That interaction leads to 42 processes that can be observed in Table 1:

Table 1 *Project Management Knowledge Areas and Process Groups*

Knowledge areas	Project Management Process Group				
	1. Initiating process group	2. Planning process group	3. Executing Process group	4. Monitoring and controlling process group	5. Closing process group
Project Integration Management	-Develop project charter	-Develop project management plan	-Direct and manage project execution	-Monitor and control project work -Perform integrated change control	-Close project or phase
Project Scope Management		-Collect requirements -Define scope -Create WBS		-Verify scope -Control scope	
Project Time Management		-Define activities -Sequence activities -Estimate activities resources -Estimate activity durations -Develop schedule		-Control schedule	
Project Cost Management		-Estimate costs -Determine budget		-Cost control	
Project Quality Management		-Plan quality	-Perform quality assurance	-Perform quality control	
Project Human Resource Management		-Develop human resources plan	-Acquire project team -Develop project team -Manage project team		

Knowledge areas	Project Management Process Group				
	1. Initiating process group	2. Planning process group	3. Executing Process group	4. Monitoring and controlling process group	5. Closing process group
Project Communications Management	-Identify stakeholders	-Plan communications	-Distribute information -Manage stakeholders expectations	-Report performance	
Project Risk Management		-Plan risk management -Identify risks -Perform qualitative risk analysis -Perform quantitative risk analysis -Plan risk responses		-Monitor and control risks	
Project Procurement Management		-Plan procurements	-Conduct procurements	-Administer procurements	-Close procurements

Source: Project Management Institute (2008)

The processes stated before could be fully or partially executed during the project, depending on the project complexity and specific requirements. Either way, process groups should not be taken as project phases but as iterative tasks in each project stage (*i.e.* prefeasibility, feasibility, tender design, construction design, construction, etc.).

Due to PMI project management integrative approach, even at the very initial and final stage of the project, all process groups interact with others and particularly with monitoring and controlling processes as can be seen in Figure 1 and Figure 2, which are the main focus of this research:

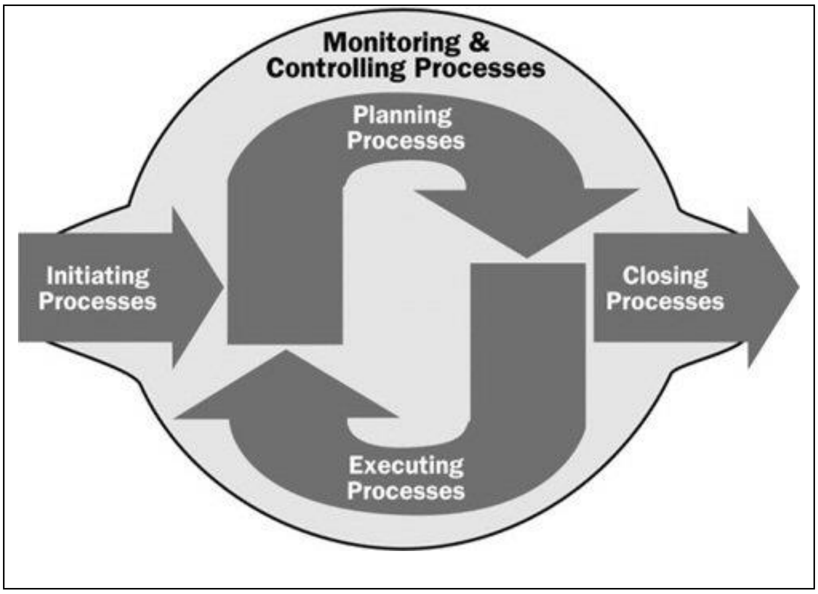

Figure 1 Project management process groups.

Source: Project Management Institute (2008)

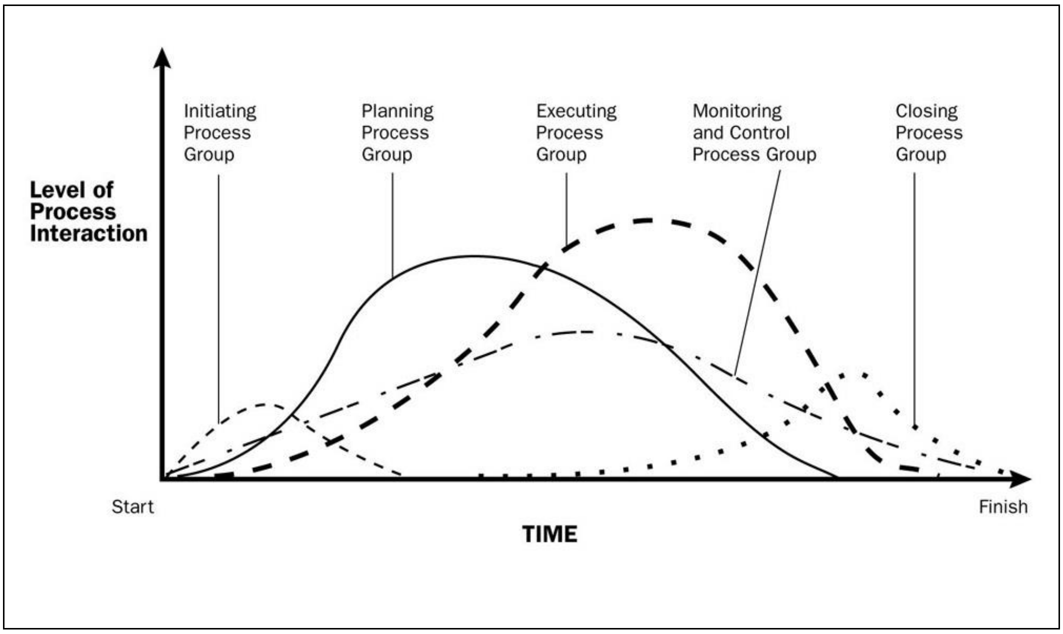

Figure 2 Project management process groups interaction.

Source: Project Management Institute (2008)

2.1.1 Monitoring and control process group: Monitoring and control is one of the most fundamental processes groups within the PMI standard due to the fact that it makes possible to collect, measure and distribute information about the state of the project regarding scope, schedule, budget, project team resources, quality and risk. Data generated through this process group allows the project manager or management team to evaluate accomplishment or forecasting any possible deviation in the original management plan.

According to PMI standard (Project Management Institute, 2008), among the different benefits of implementing monitoring and control processes are: "*...continuous monitoring provides the project team insight into the health of the project and identifies any areas requiring additional attention. The Monitoring and Controlling Process Group not only monitors and controls the work being done within a Process Group, but also monitors and controls the entire project effort... This review can result in recommended and approved updates to the project management plan".*

In the following lists there is a description of each monitoring and control process and its materials, methods and results:

1. **Monitor and Control Project Work:** This process is part of the Project Integration Management knowledge area and it is designed to consolidate the entire project tracking information obtained mainly from performance reports. If the project progress is not compatible with the defined project management plan, corrective actions must be taken.

Table 2 *Monitor and Control Project Work Process Inputs & Outputs*

Inputs	Outputs
- Project management plan - Performance reports - Enterprise environmental factors - Organizational process assets	- Change requests - Project management plan updates - Project document updates

Source: Project Management Institute (2008)

2. **Perform Integrated Change Control:** This process is part of the Project Integration Management knowledge area and its purpose is to evaluate change requests on the project management plan, deliverables and project documents.

Table 3 *Perform Integrated Change Control Process Inputs & Outputs*

Inputs	Outputs
- Project management plan - Work performance information - Change requests - Enterprise environmental factors - Organization process assets	- Change requests status updates - Project management plan updates - Project document updates

Source: Project Management Institute (2008)

3. **Verify Scope:** This process is part of the Scope knowledge area and it is intended to formalize acceptance on the project deliverables at the end of a phase or project. The main input is the deliverables validation obtained by inspection of the project finished products according to their predefined scope.

Table 4 *Verify Scope Process Inputs & Outputs*

Inputs	Outputs
- Project management plan - Requirements documentation - Requirements traceability matrix - Validated deliverables	- Accepted deliverables - Change request - Project document updates

Source: Project Management Institute (2008)

4. **Control Scope:** This process is part of the Scope knowledge area and its purpose is monitoring deliverables and project scope, as well as reflecting those changes in the scope baseline.

Table 5 *Control Scope Process Inputs & Outputs*

Inputs	Outputs
- Project management plan - Work performance information - Requirements documentation - Requirements traceability matrix - Organizational process	- Work performance measurements - Organizational process assets updates - Change requests - Project management plan updates - Project document updates

Source: Project Management Institute (2008)

5. **Control Schedule:** Control Schedule is a process of the Time knowledge area and it is used to update and manage any change in the project schedule, determined by performance reviews and or any schedule tool.

Table 6 *Control Schedule Process Inputs & Outputs*

Inputs	Outputs
- Project management plan - Project schedule - Work performance information - Organizational process assets	- Work performance measurements - Organizational process assets updates - Change requests - Project management plan updates - Project document updates

Source: Project Management Institute (2008)

6. **Cost Control:** This process is part of the Cost knowledge area and it is designed to monitor budget and register any changes in the cost baseline, based on performance reviews. Earned Value Management technique – to be presented on next chapters – is one of the most relevant tools to provide project cost and also schedule performance metrics (Padilla, 2012).

Table 7 *Cost Control Process Inputs & Outputs*

Inputs	Outputs
- Project management plan - Project funding requirements - Work performance information - Organizational process assets	- Work performance measurements - Budget forecasts - Organizational process assets updates - Change requests - Project management plan updates - Project document updates

Source: Project Management Institute (2008)

7. **Perform Quality Control:** This process is part of the Quality knowledge area and its purpose is to monitor quality performance measurements in order to address any possible quality change request.

Table 8 *Perform Quality Control Inputs & Outputs*

Inputs	Outputs
- Project management plan - Quality metrics - Quality checklists - Work performance measurements - Approved change requests - Deliverables - Organizational process assets	- Quality control measurements - Validated changes - Validated deliverables - Organizational process assets updates - Change requests - Project management plan updates - Project document updates

Source: Project Management Institute (2008)

8. **Report Performance:** Report Performance is a process of the Communications knowledge area and it is used to centralize and distribute the project performance information and forecasts.

Table 9 *Report Performance Inputs & Outputs*

Inputs	Outputs
- Project management plan - Work performance information - Work performance measurements - Budget forecasts -Organizational process assets	-Performance reports -Organizational process assets updates -Change requests

Source: Project Management Institute (2008)

9. **Monitor and Control Risks:** This process is part of the Risk knowledge area and its purpose is to implement risk plans and monitoring already identified risks.

Table 10 *Monitor and Control Risks Process Inputs & Outputs*

Inputs	Outputs
- Risk register - Project management plan - Work performance information - Performance reports	- Risk register updates - Organizational process assets updates - Change requests - Project management plan updates - Project document updates

Source: Project Management Institute (2008)

10. **Administer Procurements:** Administer Procurements is a process part of the Procurement knowledge area and its purpose is to monitor procurement relationships and observe contract performance.

Table 11 *Administer Procurements Process Inputs and Outputs*

Inputs	Outputs
- Procurement documents - Project management plan - Contract - Performance reports - Approved change requests -Work performance information	- Procurement documentation - Organizational process assets updates - Change requests - Project management plan updates

Source: Project Management Institute (2008)

2.2 Geographic Information Systems

According to Longley P., Goodchild M., Maguire D., and Rhind D. in their 2005 publication, Geographic Information Systems and Science, "*almost everything that happen, happens somewhere*". In light of the current state of art of geographic studies, it is impossible not to acknowledge the spatial nature of most information generated in the real world and its importance.

Various researchers argue that data is a commodity due to the cost and effort needed for its acquisition and register (Dueker, 1987; John Senior, 1998), and because information is basically infinite in volume, it is only valuable and cost-benefit worthy if a specific set of data can be selected from a vast pool of information and captured in order to achieve any particular research/application interest. Although its value, as Dueker said in his publication, "*The benefits of compatible or spatially registered land data are difficult to identify and to measure*" (Dueker, 1987).

Amongst the multiple concepts of what a Geographic Information System (GIS) is, one of the first concepts ever made was the one given in 1987 by Chorley in his report under the supervision of the Committee of Enquiry into the Handling of Geographic Information: "*A system for capturing, storing, checking, integrating, manipulating, analyzing and displaying data which are spatially referenced to the Earth*".

Another classical but more complete definition of a Geographic Information System is: "*System of hardware, software and procedures designed for the capture, storage, manipulation, analysis, and presentation of spatially referenced data for solving problems and management*" (NCGIA, 1990).

Important scholars in geography conceptually define Geographic Information Systems as composed by the six following parts (Longley, Goodchild, Maguire, and Rhind, 2005):

- Network;
- Hardware;
- Software;
- Data;
- Procedures;
- People.

2.2.1 Geographic data models: In a Geographic Information System context, real world digital information can be represented according different data models (Longley, Goodchild, Maguire, and Rhind, 2005): Computer-Aided Design CAD, graphical (non-topological), image, raster, vector (georelational-topological), network, Triangulated Irregular Network TIN and objects.

Between the different possibilities of data modeling, as for convenience in the efficiency and simplicity of data representation, Vector Data Models are one of the best available solutions (Longley, Goodchild, Maguire, and Rhind, 2005). Vector Data Models represent spatial objects codified explicitly through geometric shapes and boundaries (Bosque, 2000); typically polygons, lines and points.

2.2.2 Geodatabases: Within geographic information systems, spatial databases provide the possibility of managing an extensive array of spatial data using Relational Database Management Systems RDBMS.

Geodatabase is the name that ESRI has adopted for its primary spatial databases. According to ESRI (2013), a geodatabase is a: *"database or file structure used primarily to store, query, and manipulate spatial data. Geodatabases store geometry, a spatial reference system, attributes, and behavioral rules for data. Various types of geographic datasets can be collected within a geodatabase, including feature classes, attribute tables, raster datasets, network datasets, topologies, and many others. Geodatabases can be stored in IBM DB2, IBM Informix, Oracle, Microsoft Access, Microsoft SQL Server, and PostgreSQL relational database management systems, or in a system of files, such as a file geodatabase".*

Geodatabases allow incorporating special data types to optimize modeling of some aspects of geographical reality that could not be obtained with other simpler data structures.

CHAPTER III: MATERIALS AND METHODS

3.1 Case Study: Caminosca S.A.

3.1.1 Company history: Two hydraulic engineers, Eduardo Jácome Merino and Carlos Diego Jácome, started in 1976 a new enterprise named Caminos y Canales Cía. Ltda., to manage 1970's increasing market of engineering consulting in Ecuador.

This company located in Quito-Ecuador began its activities designing small country roads for Ministerio de Obras Públicas, topographic surveys for Instituto Ecuatoriano de Recursos Hídricos and sanitary sewage systems for Instituto Ecuatoriano de Obras Sanitarias.

After more than 20 years on the engineering consulting market, the company associates decided to change its name to Caminosca Caminos y Canales Cía Ltda; and in 2009, to Caminosca S.A. This latest change, not only in the company name but in its constitution, permitted to open business to an international territory, as a public limited company. International projects had been previously executed in: Argentina, Peru, Colombia, Panama and The Bahamas. An up-to-date infographic of Caminosca S.A. most significant projects, is presented in Appendix A.

Nowadays, Caminosca S.A. is the pioneer in hydropower project development in Ecuador, which remains its main strength. Because of Caminosca S.A. professional staff includes specialists from the different fields of engineering; the company has also developed many projects in the areas of: hydrocarbons, roads and transportation, urban development, and, water supply and sewerage (Caminosca S.A., 2013).

On December 2012, Caminosca S.A. signed an acquisition agreement with Cardno Limited, an Australian professional infrastructure and environmental services company, with business operations around the globe. Caminosca S.A. is intended to be completely fused with Cardno Limited on 2013 (Cardno Limited, 2013).

3.1.2 Quality assurance management system: Caminosca S.A. organization is mainly formed by: a shareholders board, a board of directors, an executive presidency, an executive committee, an administrative council and three vice presidencies, including:

- **Business vice presidency:** Responsible for providing business opportunities to the company.
- **Technical vice presidency:** Executes projects through cost, quality, services and time management.
- **Management vice presidency:** Manages the company resources and supports personnel requirements.

Caminosca S.A. organizational chart can be seen in Appendix B.

Caminosca S.A. engineering services are conducted under an extensively defined Quality Assurance Management System and ISO 9001:2008 standards regulations. According to the International Standard Organization ISO, ISO 9001:2008 standards define specific requirements for any quality management system, where any organization required to:

1. *"Demonstrate its ability to consistently provide product that meets customer and applicable statutory and regulatory requirements";*
2. *"...enhance customer satisfaction through the effective application of the system, including processes for continual improvement of the system and the assurance of conformity to customer and applicable statutory and regulatory requirements" (ISO, 2013).*

Caminosca S.A. Quality Assurance Management System is compiled on an extensive Quality Handbook (Caminosca S.A., 2005). It describes the three key productive processes for the company:

- Engineering Design;
- Construction Supervision and Project Management Services;
- Technical Consultancy.

Beside those key productive processes, the following support processes are defined:

- Marketing;
- Strategic planning;
- Scheduling and control;
- Budget control;
- Acquisitions ;
- Administration and logistics;
- Finances;
- IT;
- Occupational safety and health;
- Corrective and preventive actions;
- Auditing;
- Human resources.

The three vice presidencies have its own set of quality assurance management documents (*i.e.* templates, instructives, procedures, plans); accessible through an internal document management system, according to ISO 9001:2008 standard recommendations.

3.1.3 Monitoring and control: Caminosca S.A. Scheduling and Control Division is part of the technical vice presidency and also has become one of the company's main support processes, since its recent establishment in 2005 due to the company implementation of a Quality Assurance Management System. Caminosca S.A. Scheduling and Control is the equivalent to PMI Monitoring and Control process group, as it will be compared further on this thesis, and for referral simplification purposes, it will be called as such.

Its primary responsibilities are to program personnel participation, budget control; and give advice to the technical vice president, design projects and construction supervision management, and project manager on project performance by providing opportune reports of project management metrics. According to the Project Execution Regulation instructive (2012), these responsibilities are:

- Monitoring and controlling of the progress of Caminosca S.A. projects;
- Register project progress;
- Efficiency control human resources assigned to projects;
- Cost-benefit analysis (approximate) of projects;
- Internal budget checking and collecting project management performance metrics;
- Provide support on billing;
- Generation of a statistical data base time and cost referral data of projects and its activities.

Aiming to provide a vision of the company's business movement, after inspecting Caminosca S.A. digital archive, at the time of writing this research, it was found that 460 projects had been executed by the company since 1990 and 578 bidding proposals were prepared (see *Figure 3*) . Under those 460 executed projects, 80 endeavors are currently active for the company, 365 are finished and 15 are filed under a suspended status (see *Figure 4*). An up-to-date infographic of Caminosca S.A. most significant projects, is presented in Appendix A.

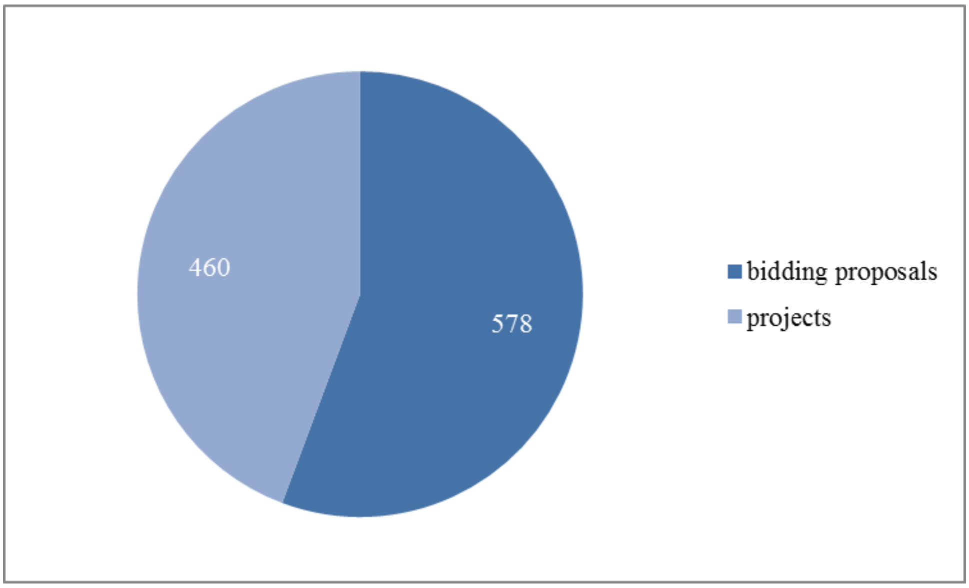

Figure 3 Business movement since 1990.

Source: Compiled by author (2013)

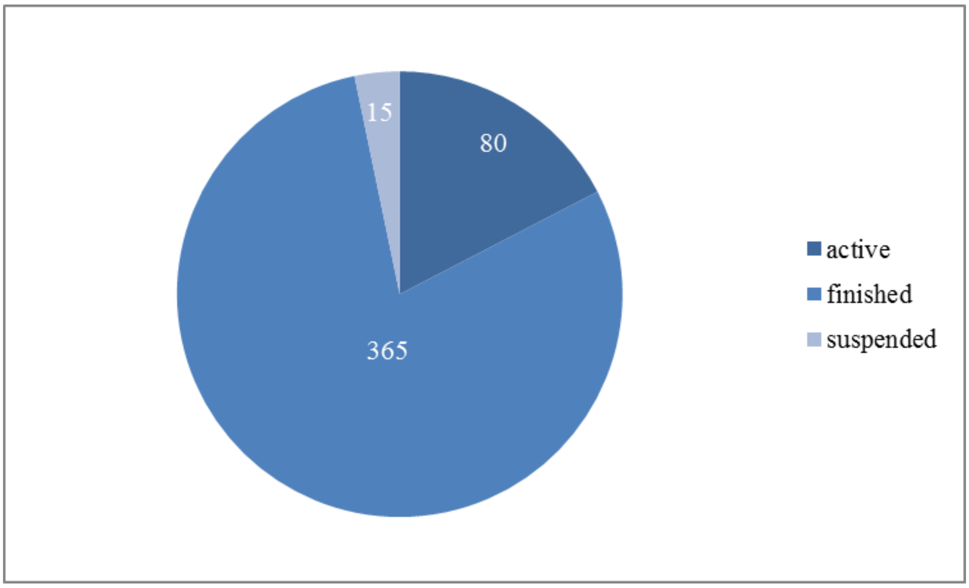

Figure 4 Caminosca S.A. current project status since 1990.

Source: Compiled by author (2013)

Caminosca S.A. engineering design and technical consultancy projects, due to its intellectual and intangible nature, independently from its location, are normally carried out and monitored from Quito headquarters and occasionally from Cuenca branch office. The rest of Caminosca S.A. projects (*i.e.* construction supervision and project management services) are executed from different temporal camp sites Caminosca S.A. has implemented while the project is active. On construction supervision and project management services projects, on-site monitoring and controlling is done and reported to headquarters on required basis.

In practice, main conducted monitoring and control activities are related to schedule control and reprogramming, and client billing support. Additionally, general project information is uploaded periodically into the company database, which is based on a Microsoft SQL server, and billing information is also uploaded when billing updates occur. Regarding cost control, project contractual and planned man-months are registered on the company database to forecast expenses curve deviation. Even that most of this information is extremely useful for monitoring and control effects and, as it will be shown further on chapter 3.2.1 Conceptual Modeling, company monitoring and control procedures are properly documented, this is neither sufficient to portrait an adequate report of project status nor to contribute approachable information of performance statistics for ended projects.

In order to evaluate the abundance and scope of quality assurance management documents that explicitly prescribe monitoring and controlling activities in Caminosca S.A., all the documents filed in the internal document management system were assessed. These monitoring and controlling documents are described and later summarized on Table 12. Also Table 12 shows which monitoring a controlling documentation it is considered it can be used within a spatial context/application.

Commercial Vice presidency>Commercial Management

- **Project Proposal Elaboration Instructive:** Assist Design and Construction Supervision Manager in biddings preparation (required man-hours information); assist Budget Division in internal budget preparation; advise to technical area on important items to be considered during contract negotiation.
- **Project Certificates Instructive:** Prepare and obtain project participation certificates.

Management Vice presidency>Human Talent Management

- **Timesheet Management Instructive:** Report personnel activities and time consumption to each head of division, Design and Construction Supervision Managers and Technical Vice President.

Management Vice presidency>Financial Management

- **Guarantee Management Procedure:** Report on a monthly basis to the Financial Manager all contracts signed or its modifications, in order to follow up on guarantees assured quantities.
- **Portfolio and Billing Management Procedure:** Create billing presentation format for standard and adjustment bills according to project contract; elaborate project billing; submit project billing to the Client; register billing on the financial company system database; report billing to technical vice president, construction supervision and design managers.

Management Vice presidency>IT Management

- **Database Information Entry Instructive:** Register new projects according to a predefined project creation form on the company database system[1]; registration of project billing information; personnel activities assignments.
- **New User Registration Instructive:** Assign projects to personnel in the company database system.

Technical Vice presidency>International Business

- **International Projects Information Reception Process:** Register new international projects on the company database system according to a predefined project creation form.

Technical Vice presidency>Monitoring and Control

- **Internal Budgets and Schedule Template**

Technical Vice presidency>General Projects

- **Project Execution Regulation Instructive:**

- **During Project Start:**
- Support project managers on: schedule elaboration and project personnel assignment.
- **During Project Execution:**
- Program schedule activities in collaboration with head of divisions and project managers.
- Monitor project performance.
- Billing under project manager supervision.

[1] The company database is implemented on a Microsoft SQL server which holds information about contacts; correspondence; invoicing; billing; procurement and project performance and general data.

- Producing project financial state reports in coordination with Financial Management.
- Evaluate project activity performance at project closure stage.

- **Association Projects Managed by Caminosca Procedure:** Report personnel activities and time consumption to project manager.
- **Project Initiation Template:** Collect project start information such as: project ID number, project short name, client name, technical director, project start date, etc.
- **Project Management:** Capture and record project performance indicators (man-hours consumption, progress); communicate performance indicators to managers; analysis of performance indicators.
- **Design Projects:** ***Planning:*** Create project constitution charter; register new projects on the company database system; communicate internally project start; ***Execution:*** Register project billing information; ***Closure:*** obtain project participation certificates, execute internal actions to project closure; handle guarantee reimbursement; register projects closure information on the company database; constitute project archive.
- **Construction Supervision Projects:** ***Planning:*** Create project constitution charter; register new projects on the company database system; communicate internally project start; ***Execution:*** Register project billing information;

  Closure: obtain project participation certificates, execute internal actions to project closure; handle guarantee reimbursement; register projects closure on the company database; constitute a project archive.
- **Procurement:** Constitute a subcontract archive.

Table 12 *Caminosca S.A. Monitoring and Controlling Documentation*

Dependency			Quality Documentation				Monitoring and Controlling Influence: Direct Influence				Monitoring and Controlling Influence: Indirect Influence				Quality Documentation Description
			Tm	Inst	Proc	Plan	Tm	Inst	Proc	Plan	Tm	Inst	Proc	Plan	
Commercial vice presidency	Commercial management		7	3	4	-	-	1	-	-	-	1	-	-	Project Bidding Elaboration Project Certificates
Management vice presidency	Administrative management		26	11	6	-	-	-	-	-	-	-	-	-	
	Human talent management		8	11	6	-	-	1	-	-	-	-	-	-	Timesheet Management
	Business dev. management		12	4	6	1	-	-	-	-	-	-	-	-	
	Financial management		4	7	9	-	-	-	1	-	-	-	1	-	Guarantee Management Portfolio and Billing Management
	IT management		3	8	4	1	-	2	-	-	-	-	-	-	Database Information Entry New User Registration
Technical vice presidency	Technical consultancy		-	-	1	-	-	-	-	-	-	-	-	-	
	Design management	Environ.	-	4	2	-	-	-	-	-	-	-	-	-	
		Budget	-	-	1	-	-	-	-	-	-	-	-	-	
		Drawing	-	1	9	-	-	-	-	-	-	-	-	-	
		Electrical	-	-	8	-	-	-	-	-	-	-	-	-	
		Structural	-	-	1	-	-	-	-	-	-	-	-	-	
		Geological	-	-	7	-	-	-	-	-	-	-	-	-	
		Hydraulics	-	-	7	-	-	-	-	-	-	-	-	-	
		Hydrocarbon	-	-	12	-	-	-	-	-	-	-	-	-	
		Mechanical	-	-	1	-	-	-	-	-	-	-	-	-	
		Survey	-	4	5	-	-	-	-	-	-	-	-	-	
		Transport	-	-	2	-	-	-	-	-	-	-	-	-	
	Construction sup. management		9	-	-	-	-	-	-	-	-	-	-	-	

	International business	-	-	1	-	-	-	1	-	-	-	-	-	Intl. Projects Information Reception
	Monitoring and controlling	1	-	-	-	1	-	-	-	-	-	-	-	Internal Budgets and Sch. Form
	General projects	9	3	9	-	1	1	4	-	-	-	1	-	Project Execution Regulation Association Projects Managed by Caminosca Project Initiation Form Project Management Design Projects Construction Supervision Projects Procurement
		79	56	101	2	2	5	6	-	-	1	2	-	

Source: Compiled by author (2013)

Note: Tm = Template; Inst = Instructive; Proc = Procedure; Plan = Plan; Underlined: Monitoring and Controlling documentation with spatial potential usage

3.2 Spatial Data Modeling

According to Worboys *et al* (1990), one of the most important steps in database design is to give a proper representation of the problem by developing a data model. A data model is a "*description of the rules by which data is defined, organized, queried, and updated within an information system (usually a database management system)*" (ESRI, 2013). As for ESRI GIS applications, Brennan (2005) defines a data model as a practical working template for starting a GIS project. Within an enterprise, the use of a data model template provides the possibility of better interoperability and efficiency in data usage and collection.

For the purpose of this research, the followed data modeling methodological approach is the one reviewed by Breman (2005), which comprehends:

- **Conceptual modeling:** consists on data base architecture planning and definition of the GIS scope (information products, key thematic layers, etc.);
- **Logical modeling:** implements the conceptual design developed on the previous stage, typically through a UML diagram (Unified Modeling Language) using CASE tools (Computer Aided Software Engineering). A tabular structure of the database and the behavior of the descriptive attributes are defined;
- **Physical modeling:** consists on the process of creating a prototype database and uploading data for the first time in order to, if necessary, go iteratively through the previous modeling stages to improve the design.

It is worth noting that, as previously stated on Chapter I: Introduction, the scope of this research is to conceptually analyze Caminosca S.A. monitoring and controlling situation in order to propose a logical model for the company, based on PMI standards for project management; therefore, and because of Caminosca S.A. restriction on disclosure and use of data, historical project performance data necessary to feed the designed database, had not been used in this research. Nevertheless, a complete preliminary and fully operative database prototype will be developed and documented at end of this study.

The specific methodological outline for this research, based and complemented by considering the recommendation of Brennan (2005) is presented in *Figure 5* and comprehends:

A. **Conceptual Modeling:**
   a. Review PMI standard for project monitoring and controlling;
   b. Review Caminosca S.A. monitoring and control procedures;
   c. Define which of Caminosca S.A. existing monitoring and control procedures are compatible with PMI;
   d. Identify key thematic layers to be spatially modeled.

B. **Logical Modeling:**
   a. Propose database tabular structure, to be further detailed on Data Dictionary Chapter;
   b. Define an entity – relationship diagram;
   c. Use CASE TOOLS to propose an XML schema of the model.

C. **Physical Modeling:**
   a. Create a geodatabase prototype and refine its structure if needed;
   b. Consolidate a pilot geodatabase using project management data and refine if needed.

D. **Data Dictionary:**
   a. Summarize object definition, attribute descriptions, domains, and relationships between objects designed in the data base.

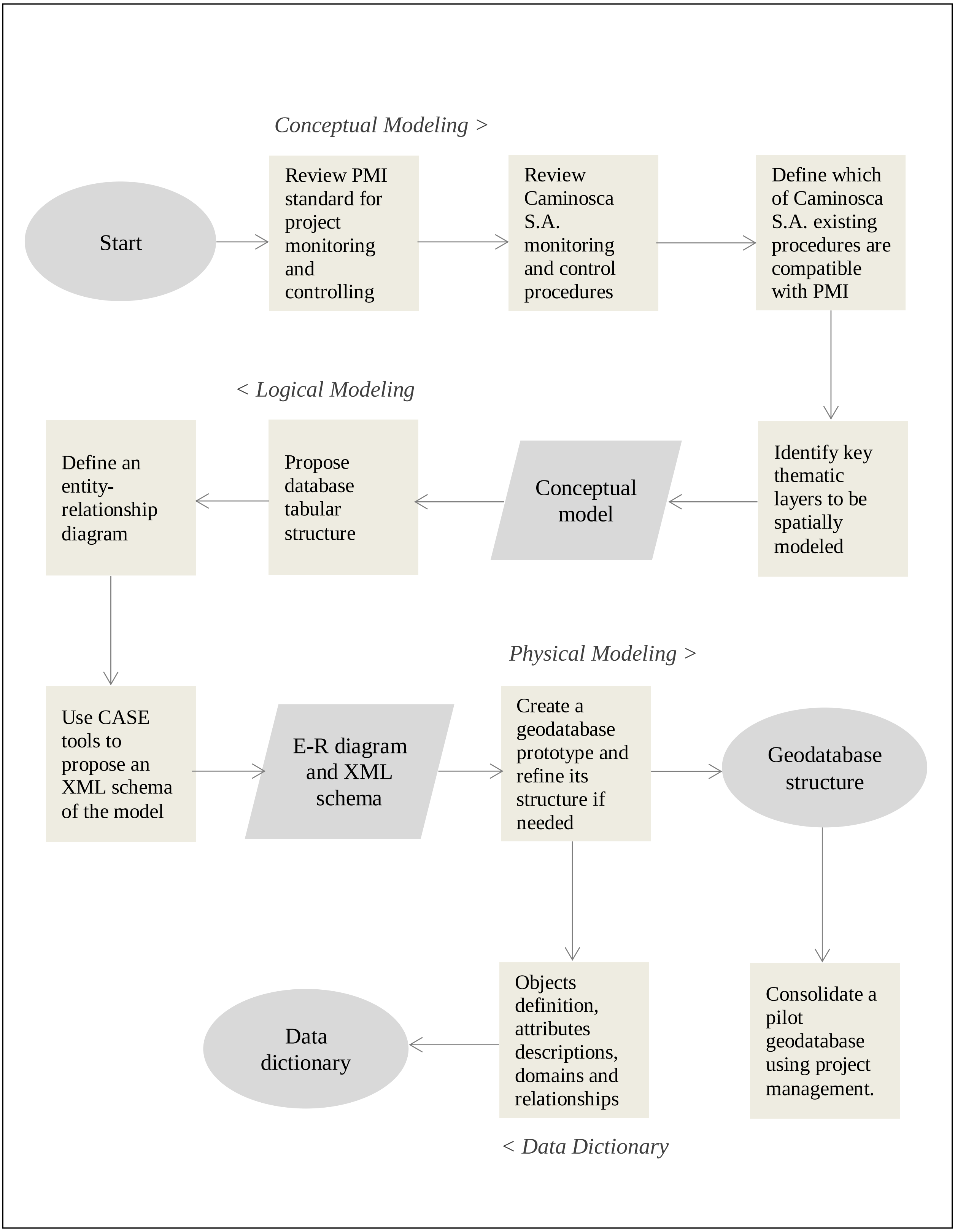

Figure 5 Research steps flow diagram.

Source: Compiled by author (2013)

3.2.1 Conceptual modeling: The activities related to developing a conceptual model began with the identification of which Caminosca S.A. monitoring and control responsibilities are actually related with PMI project management standards and can be used within a spatial context. For this thesis, the initial part of that identification was covered on the previous section of this chapter: Case Study, as it can be seen on Table 12. According to the results of a comparison between the two sources, most of Caminosca S.A. monitoring and control procedures are aligned with PMI standard monitoring and control process group. Additionally to that, Caminosca S.A. monitoring and control procedures cover some of the PMI Initiation process group standard through the activities concerned with project start. Table 13 shows the result of that comparison and the equivalence between the two.

It is important to notice that plenty of the most important Caminosca S.A. monitoring and control procedures are contained in PMI standard recommendation and that will be the base for the immediate data model development.

Table 13 *Caminosca S.A. Monitoring and Controlling Procedures and PMI Standard Equivalence*

Knowledge Area	PMI M&C Process Group	Caminosca S.A. Monitoring and Controlling Procedures Equivalence	
Project Integration Management	Monitor and Control Project Work Perform Integrated Change Control		
Project Scope Management	Verify Scope Control Scope		Project Execution Regulation
Project Time Management	Control Schedule	Internal Budgets and Schedules Form	Association Projects

Knowledge Area	PMI M&C Process Group	Caminosca S.A. Monitoring and Controlling Procedures Equivalence	
Project Cost Management	Cost Control	Guarantee Management Portfolio and Billing Management Timesheet Management Internal Budgets and Schedules Form	Managed by Caminosca S.A. Project Management Design Projects Construction Supervision Projects
Project Quality Management	Perform Quality Control		
Project Communications Management	Report Performance		
Project Risk Management	Monitor and Control Risks		
Project Procurement Management	Administer Procurements	Procurement	
(Other)		Project Proposal Elaboration Project Certificates	
Project Integration Management	*Initiation Process Group*	Project Initiation Form Database Information Entry New User Registration International Projects Information Reception	

Source: Compiled by author (2013)

As presented on Chapter 3.1.3, Caminosca S.A. monitoring and control main responsibilities, and most emphasized procedures, are concerned with budget and time handling. However though, those topics are not exhaustively quantified through the use of indicators and are diluted in broader and general regulations, such as Project Execution Regulation, which contains the most extensive information about monitoring and control within Caminosca S.A.

Through the assessed available information, it can be concluded that Caminosca S.A. monitoring and control procedures do not provide exhaustive and detailed indications about project performance metrics capture and analysis during project execution, neither performance communicational products nor budget and schedule specific control methods.

Pointing to cover this deficiency on the collected project management data, the conceived data model was implemented with a group of attributes fields to periodically fill in Earned Value Management data, which is one the most commonly used – and one of the most complete – methods for monitoring project performance (PMI, 2008; Padilla, 2012), not implemented in Caminosca S.A. yet. At the end of this thesis, Earned Value Management will be recommended as the main method to capture project performance indicators.

3.2.1.1 Earned value management: Earned Value Management EVM technique for measuring project performance consists on integrating project scope, schedule and cost metrics in order to assess project performance and forecasting (PMI, 2008).

EVM parameterizes project performance according the following metrics: (PMI, 2008).

- **Planned Value PV:** "*Planned value (PV) is the authorized budget to the work to be accomplished for an activity or work breakdown structure component.*"
- **Earned Value EV:** *"Earned Value (EV) is the value of work performed expressed in terms of the approved budget assigned to that work breakdown structure component… The term EV is often used to describe the percentage completion of a project."*
- **Actual Cost AC:** *"Actual cost (AC) is the total cost actually incurred and recorded in accomplishing work performed for an activity or work breakdown structure component. It is the total cost incurred in accomplishing the work that the EV measured"*

Variances metrics include:

- **Schedule Variance SV:** SV = *EV – PV*
- **Cost Variance:** CV = *EV – AC*

Performance Indexes:

- **Schedule Performance Index:** SPI = *EV/PV*
- **Cost Performance Index:** CPI = *EV/AC*

Forecasting metrics:

- **Estimate at Completion:** EAC = *AC – (PV – EV)*
- **Estimate to Completion:** ETC = *EAC – AC*
- **To Complete Performance Index:** $TCPI_{PV} = \frac{PV - EV}{PV - AC}$

3.2.1.2 Data model definition: As reviewed in previous chapters, Caminosca S.A. projects can be divided according to the nature of its business line: engineering design; construction supervision and project management services; and technical consultancy.

Caminosca S.A. operates from three main offices: Quito headquarters and Cuenca branch office, Ecuador; and Lima branch office, Peru.

The spatial characteristics of Caminosca S.A. projects conveniently allow using a vector data model, given the projects precise location and multiple monitoring and control attributes management capabilities required; for this reason, an ESRI ArcGIS personal geodatabase was developed to materialize the proposed logical model. The rationale for using an ESRI product is based on Caminosca S.A. previous acquisition of three ArcGIS for Desktop software licenses: one ArcGIS 9.1 and two ArcGIS 10.0; which are currently used for environmental assessments projects purposes.

The data modeling approach consisted on defining one geographical point feature class which will contain the spatial characteristics and projects general information, in order to link it to several attribute tables; each table for hosting project monitoring and control data, segregated according to different customized PMI knowledge areas and Caminosca S.A. actual data production and future monitoring needs.

The convenience of having different attribute tables for the diverse monitoring and controlling parameters relies on the possibility of updating each parameter table independently from the rest and subsequently link it to its spatial location. Apart from that, except from a geodatabase administrator, monitoring and control personnel will not be required to be GIS proficient to maintain the tables thus it can be done in a spreadsheet application, such as Microsoft Excel, and transparently imported into the geodatabase in any given data update frequency. Attribute tables were designed to reflect accumulated monitoring and control metrics through overall project execution, for which it requires periodical data updates.

To spatially contextualize the location of project performance data, two polygon feature classes for holding Ecuadorian political division were created. For purposes of overviewing spatially contextualized project management data from a high managerial point of view, macro political division such as provinces and cantons were selected as spatial reference features.

As for international projects, currently there are no important active projects from abroad although the geodatabase structure permits to add complementary feature classes, if required.

An entity – relationship entity diagram was made and it is presented in Appendix C.

3.2.1.3 Modeled entities: Activities related to the conceptual design of the GIS, started from the identification of monitoring and control data requirements according to the PMI standard recommendation but also Caminosca S.A. actual needs and possibilities for implementation. For this step, characterizing and outlining Caminosca S.A. monitoring and control procedures within the company Quality Assurance Management System played an important role, which was previously described in subchapter 3.1 of this document.

Not all PMI's knowledge areas were chosen for effects of data model implementation. Upon not considered knowledge areas, Procurement and Quality features are specifically monitored in Caminosca S.A. by other divisions using different management methodologies and tools and also cannot be spatially represented properly. Due management complexity, Cost knowledge area was subdivided in personnel usage, earned value and project financial traits.

Amongst the different possibilities for entity modeling, will be further described in chapter 3.3 - Data Dictionary, the set of objects and its geometry, that participate in the designed database model and its geometry.

3.2.2 Logical modeling: In order to carry out this activity, key thematic layer attributes and data field types were listed. Within the definition of attributes, there were included also: domains, relationships and subtypes fields. According to ESRI, subtype fields are a subset of features in a feature class, or objects in a table, that share the same attributes. The defined subtypes are based on the company current project status classification: active, pending and finished.

To proceed developing a UML diagram of the geodatabase components structure (*i.e.* feature classes, feature data sets, attributes architecture, domains and relationship classes definition), ArcGIS Diagrammer application was used.

3.2.2.1 Geodatabase design: Once the UML diagram was completed, an XML schema was exported to Arccatalog into an empty geodatabase. After performing a complete assessment of the geodatabase functionality and chosen data field types, this process was repeated iteratively on three instances until a refined geodatabase was produced, as it can be seen in Figure 6.

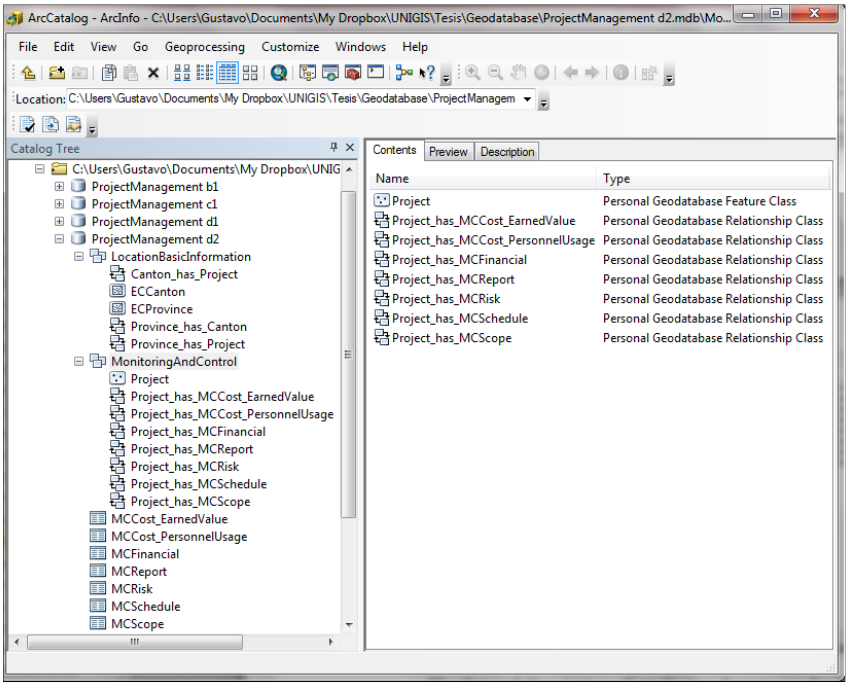

Figure 6 Resulting geodatabase after final XML import process.

Source: Compiled by author (2013)

The list and description of attributes, domains and relationships of the modeled objects is presented in Chapter 4 - Data Dictionary.

The geodatabase XML schema is included digitally in Appendix D.

3.2.2.2 Pilot geodatabase: Except from few exceptions –*i.e.* budget, schedule and billing progress– most monitoring and controlling indicators are not currently being captured systematically by the company and therefore cannot be used to immediate data base testing or nearby implementation. Aiming to try the proposed geodatabase design with project data but considering the current restriction of not counting yet on Earned Value Management project metrics proposed in this chapter, Ecuadorian project basic information was uploaded into the created prototype.

Data upload process began through the preparation of an Excel spreadsheet with project basic information, partly fed with a data checkout from the company database.

Project location was defined for each register on a 250:000 scale map. Data uploading process into its spatial vessel was accomplished through the simple data loader tool from ArcGIS Arccatalog, as it can be seen in *Figure 7*. Project general data was uploaded into the Project feature class while financial data was disposed into the MCCost_EarnedValue tabular information. Ecuadorian cantons and provinces were uploaded into its corresponding feature classes.

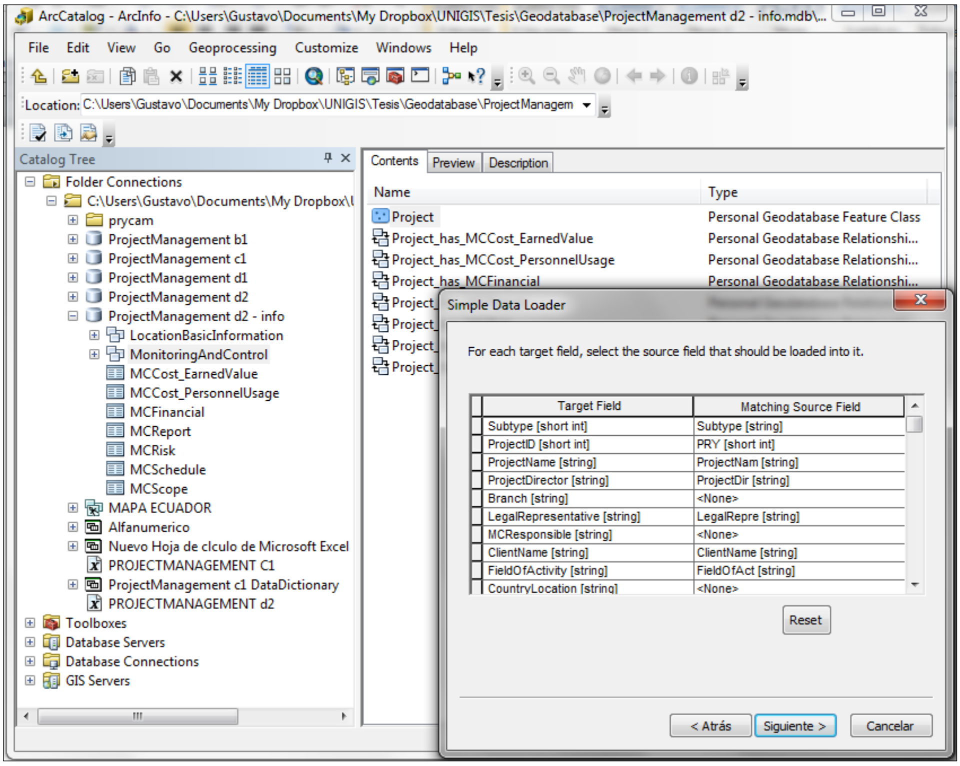

Figure 7 Data upload.

Source: Compiled by author (2013)

The designed geodatabase potential and flexibility was explored through different queries and spatial representation of project typology, status and budget, related to Ecuadorian macro political division (*i.e.* provinces and cantons). Those explored queries and its results are presented on the next figures.

How many active, pending and finished projects are located in each Ecuador province?

In order to answer this and most of the following test queries, ArcGIS Arc Map Report Wizard was used to summarize spatial records according any given attribute criteria, in this case: project subtypes and provinces. Map symbols were handled in order to represent adequately the queried information.

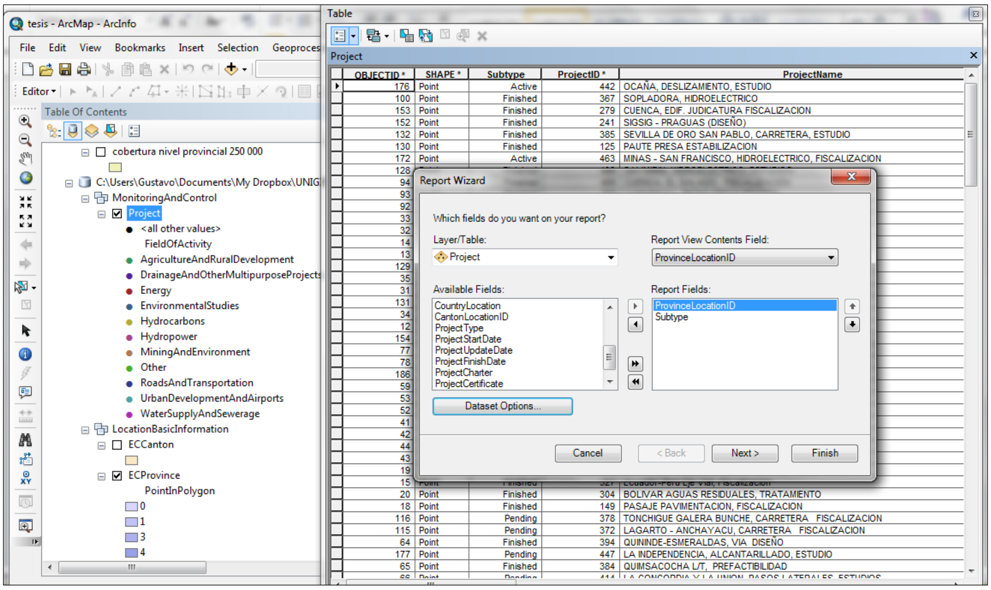

Figure 8 Usage of Report Wizard tool.

Source: Compiled by author (2013)

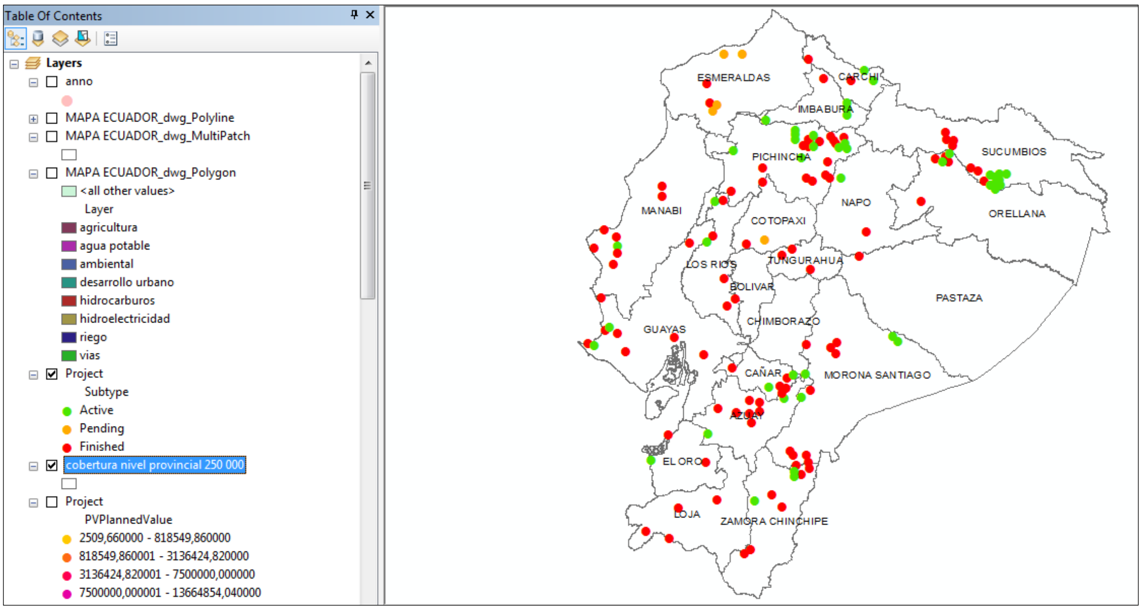

Figure 9 Project subtype spatial distribution – map.

Source: Compiled by author (2013)

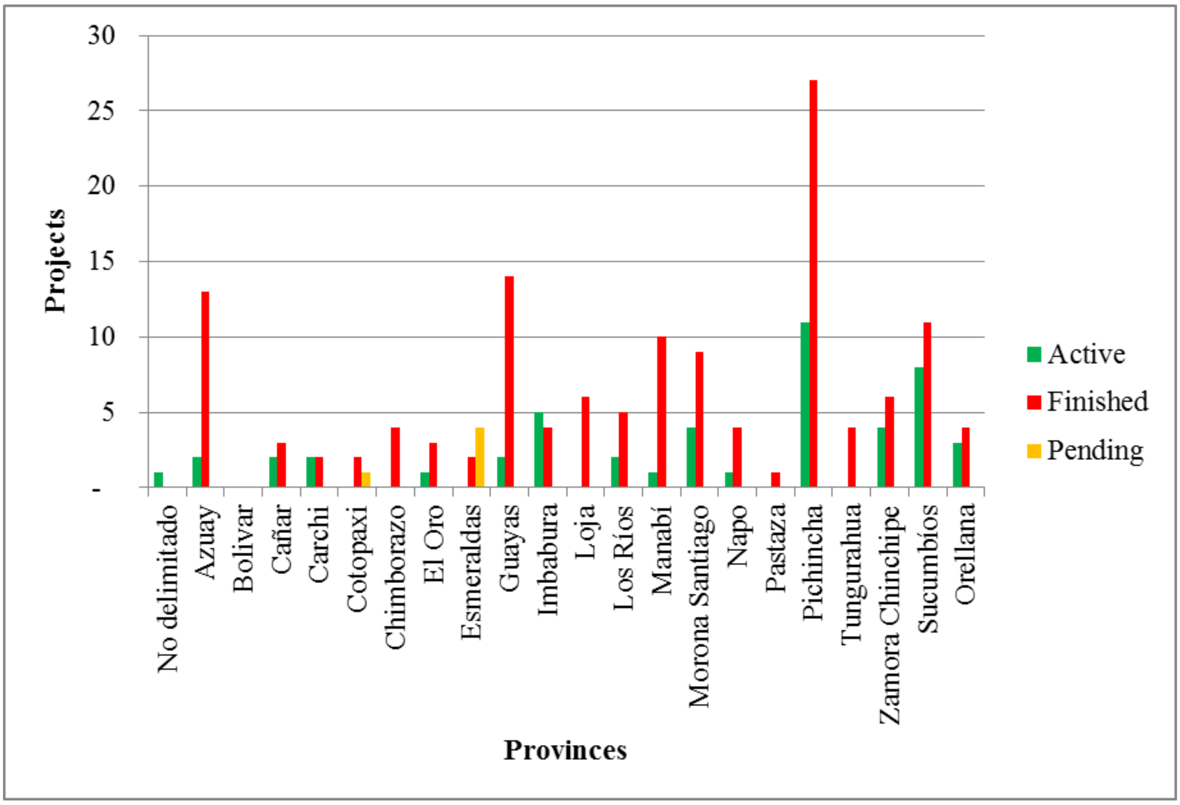

Figure 10 Project subtype spatial distribution – graph.

Source: Compiled by author (2013)

Where in Ecuador are the projects with the most expensive contractual budget?

Project budget information was uploaded into the MCCost_EarnedValue table and then joined into the Project feature class. Once budget project information was located, it was spatially joined and then summarized with the ECProvince feature class. The next figures present the result of that analysis, pointing that Azuay province is the location where Caminosca S.A. projects have accumulated historically the most expensive contractual budget.

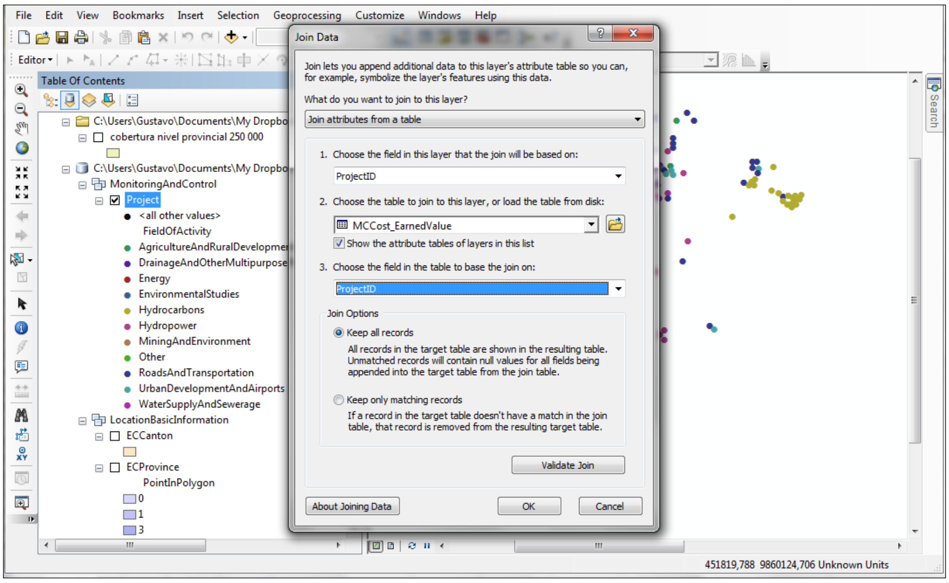

Figure 11 Usage of Join Data tool.

Source: Compiled by author (2013)

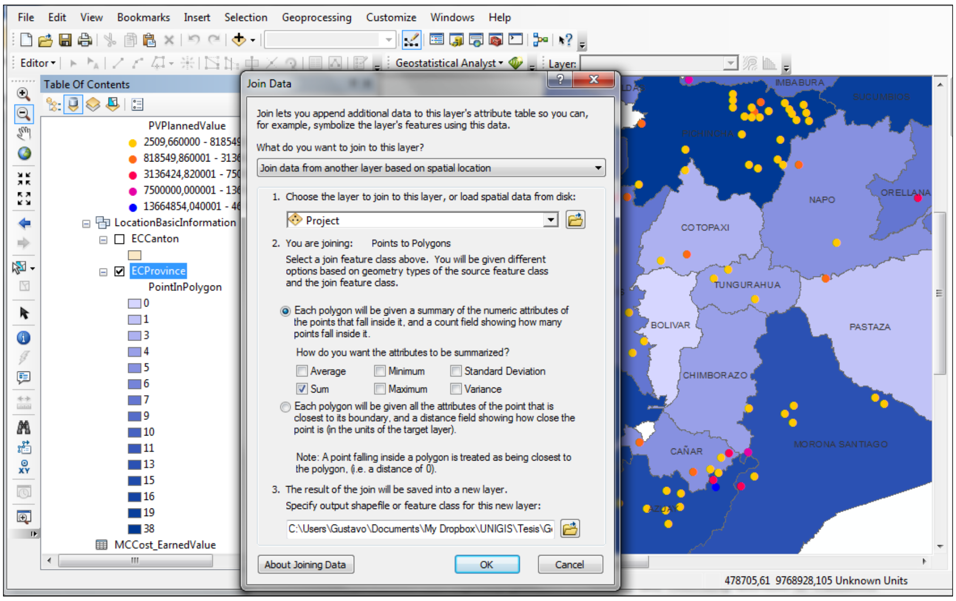

Figure 12 Usage of Spatial Join Data tool.

Source: Compiled by author (2013)

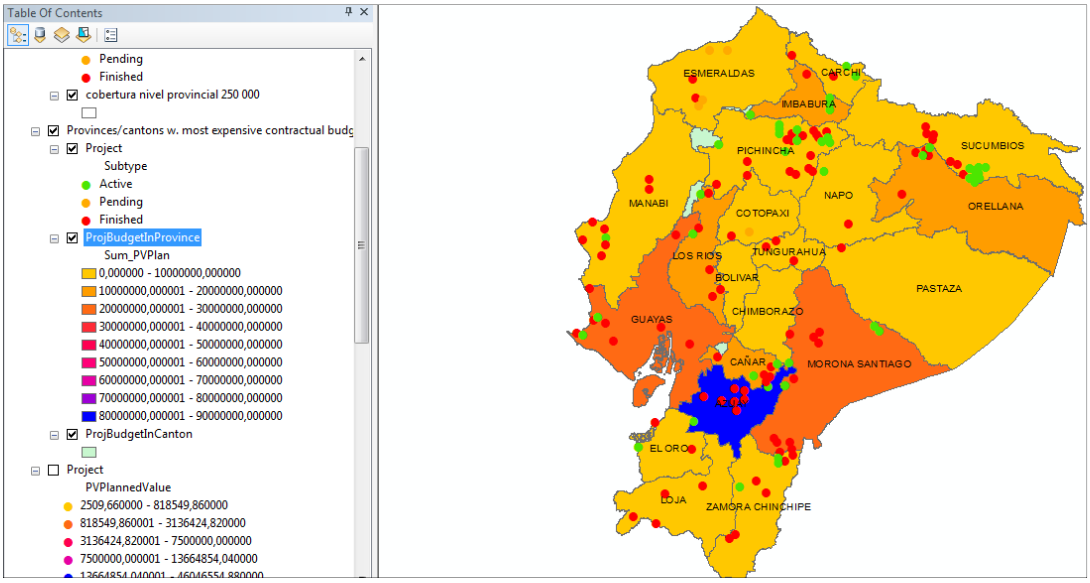

Figure 13 Project accumulated budget distribution by province – map.

Source: Compiled by author (2013)

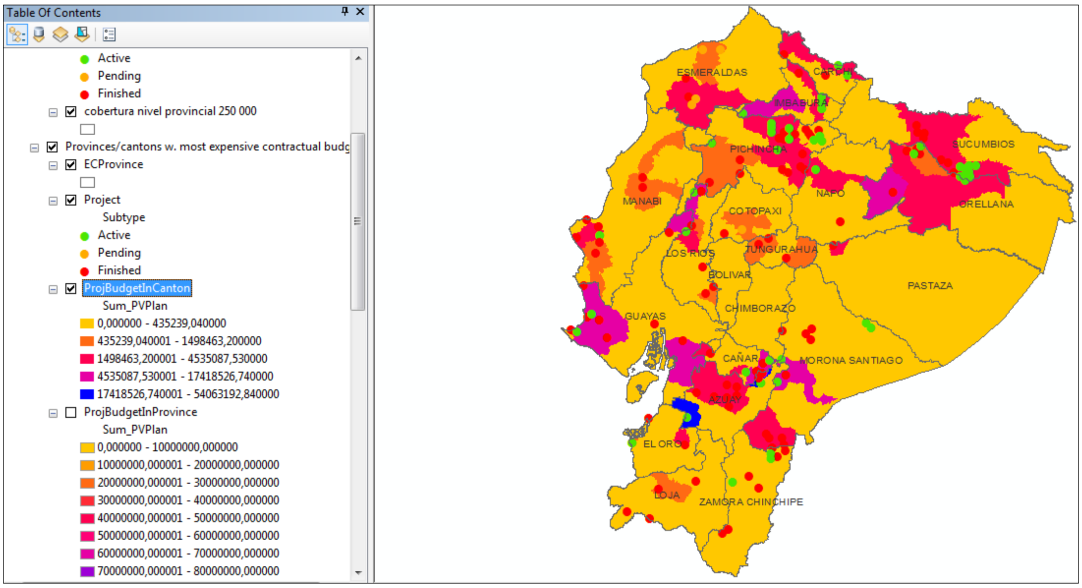

Figure 14 Project accumulated budget distribution by canton – map.

Source: Compiled by author (2013)

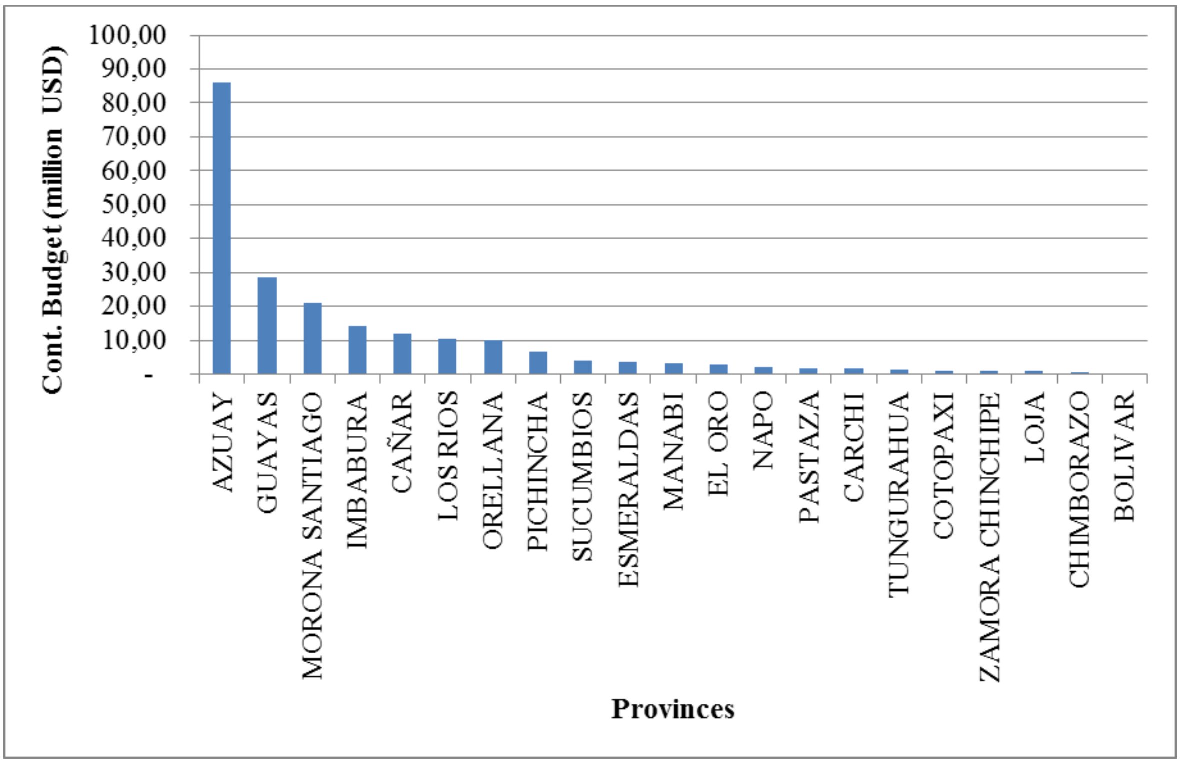

Figure 15 Project accumulated budget distribution by province – graph.

Source: Compiled by author (2013)

What is the project density by Ecuadorian province?

Project density by province was obtained through spatially joining projects and provinces, in order to obtain a project count attribute and then divided to province area. *Figure 16* shows that result pointing out that Azuay, Pichincha and Imbabura are the provinces with the highest project density. The lowest: Bolivar and Pastaza.

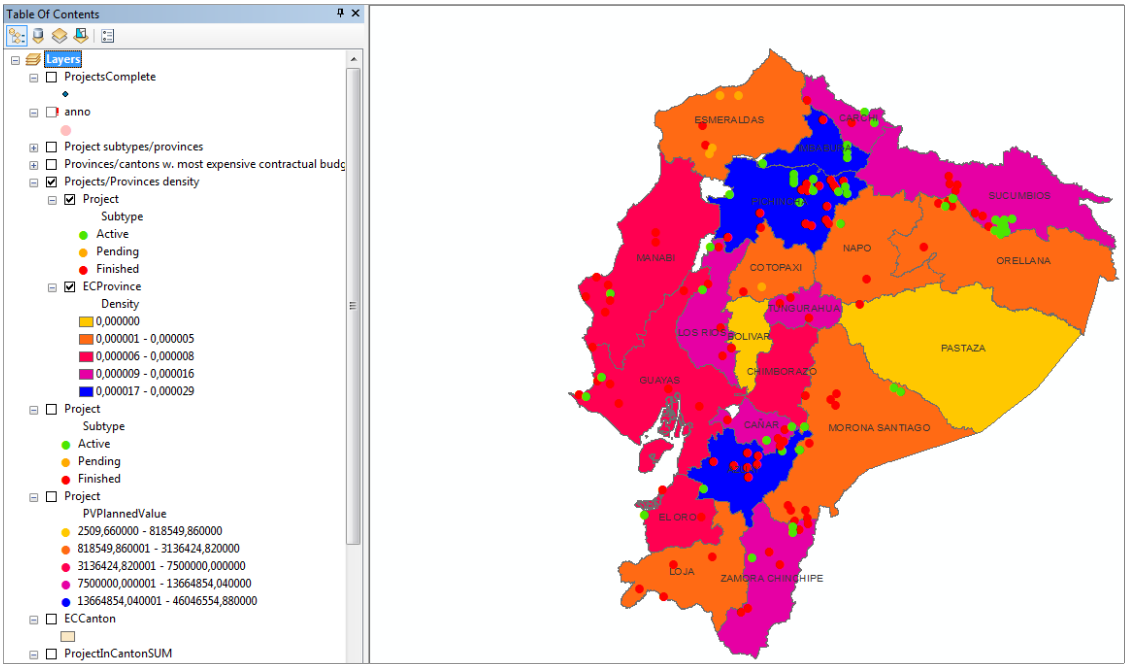

Figure 16 Project density by province – map.

Source: Compiled by author (2013)

What are the main project fields of activities in each Ecuadorian province?

Through querying and spatial joining, using the available information, for each province it was calculated the sum of contractual budget of each predefined project field of activity. That analysis permitted to identify province historical project vocation. It is important to remark that provinces with the highest historical accumulated budget –Azuay and Morona Santiago– are also identified with a hydropower vocation.

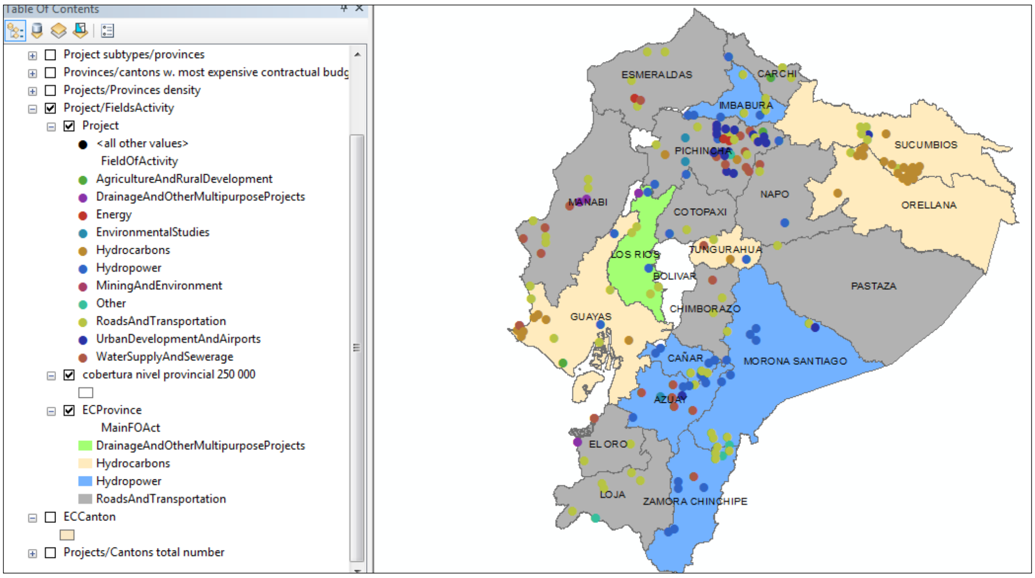

Figure 17 Project fields of activities by province – map.

Source: Compiled by author (2013)

3.3 Data Dictionary

To accurately document the geodatabase design and its components, ArcGIS Diagrammer schema report tool was used.

In the following section, design information will be presented on these subjects:

- Key feature classes and attributes description;
- Defined data domains;
- Relationship classes.

3.3.1 Feature classes and attributes description

Table 14 contains a list of the main defined feature classes, chosen modeled geometry and its possible subtypes. Two feature datasets were designed to hold the spatial information: *LocationBasicInformation* for the political administrative information; and, *MonitoringAndControl* for the project location. Tables that contain alphanumeric monitoring and control specific information were left as stand-alone object classes, whose names depend on the different PMI monitoring and control process groups they belong to.

3.3.1.1 Designed feature classes

Table 14 *Designed Feature Classes*

Feature Class Name	Type	Geometry	Subtype
LocationBasicInformation			
ECCanton	Simple FeatureClass	Polygon	-
ECProvince	Simple FeatureClass	Polygon	-
MonitoringAndControl			
Project	Simple FeatureClass	Point	Active Finished Pending
Stand Alone Object Classes			
MCCost_EarnedValue	Table	-	Active Finished Pending
MCCost_PersonnelUsage	Table	-	
MCFinancial	Table	-	
MCReport	Table	-	
MCRisk	Table	-	
MCSchedule	Table	-	
MCScope	Table	-	

Source: Compiled by author (2013)

3.3.1.2 Attribute description

Table 15 *Feature Class Description: ECCanton*

Field Name	Type	Description
OBJECTID	OID	ArcGIS auto generated object identifier
SHAPE	Geometry	Geographic data container
ECCantonID	String	Unique primary key
ECCantonName	String	Canton complete name
ECProvinceID	String	Province location. Foreign key
SHAPE_Length	Double	ArcGIS auto generated polygon attribute
SHAPE_Area	Double	ArcGIS auto generated polygon attribute

Source: Compiled by author (2013)

Table 16 *Feature Class Description: ECProvince*

Field Name	Type	Description
OBJECTID	OID	ArcGIS auto generated object identifier
SHAPE	Geometry	Geographic data container
ECProvinceID	String	Unique primary key
ECProvinceName	String	Province complete name
SHAPE_Length	Double	ArcGIS auto generated polygon attribute
SHAPE_Area	Double	ArcGIS auto generated polygon attribute

Source: Compiled by author (2013)

Table 17 *Table Description: MCCost_EarnedValue*

Field Name	Type	Description
OBJECTID	OID	ArcGIS auto generated object identifier
MCCost_EVParameterID	String	Unique primary key
ProjectID	Small Integer	Project ID. Foreign key
ContractualPersonnelProvision	Double	Up-to-date accumulated personnel provision ($) based on contract budget
PlannedPersonnelProvision	Double	Up-to-date accumulated personnel provision ($) based on internal budget
ActualPersonnelConsumption	Double	Up-to-date accumulated personnel consumption ($) based on real billing information
PVPlannedValue	Double	Planned Value
EVEarnedValue	Double	Earned Value
ACActualCost	Double	Actual Cost
CVCostVariance	Double	Cost Variance
CPICostPerformanceIndex	Double	Cost Performance Index
EACEstimateAtCompletion	Double	Estimate at Completion
ETCEstimateToCompletion	Double	Estimate to Completion
TCPIToCompletePerformanceIndex	Double	To Complete Performance Index, based on PV values
SVScheduleVariance	Double	Schedule Variance
SPISchedulePerformanceIndex	Double	Schedule Performance Index
Cost_EVUpdateDate	Date	Project Cost_EV table information last update
Subtype	Small Integer	Defined subtype

Source: Compiled by author (2013)

Table 18 *Table Description: MCCost_PersonnelUsage*

Field Name	Type	Description
OBJECTID	OID	ArcGIS auto generated object identifier
MCCost_PersonnelUsageParameterID	String	Unique primary key
ProjectID	Small Integer	Project ID. Foreign key
TotalContractualManMonths	Double	Total personnel provision for the project (man-months) based on contract budget
TotalPlannedManMonths	Double	Total personnel provision for the project (man-months) based on internal budget
ConsumedManMonths	Double	Up-to-date accumulated personnel consumption (man-months) based on real project billing information
ConsumedEnvironmentalManMonths	Double	Up-to-date accumulated Environmental Division personnel consumption (man-months) based on real project billing information
ConsumedRoadsManMonths	Double	Up-to-date accumulated Roads and Transportation Division personnel consumption (man-months) based on real project billing information
ConsumedStructuralManMonths	Double	Up-to-date accumulated Structural Division personnel consumption (man-months) based on real project billing information
ConsumedGeologyManMonths	Double	Up-to-date accumulated Geology Division personnel consumption (man-months) based on real project billing information
ConsumedElectromechanicalManMonths	Double	Up-to-date accumulated Electromechanical Division personnel consumption (man-months) based on real project billing information
ConsumedSurveyingManMonths	Double	Up-to-date accumulated Survey Division personnel consumption (man-months) based on real project billing information
Cost_PersonnelUsageUpdateDate	Date	Project Cost_Personnel table information last update
Subtype	Small Integer	Defined subtype

Source: Compiled by author (2013)

Table 19 *Table Description: MCFinancial*

Field Name	Type	Description
OBJECTID	OID	ArcGIS auto generated object identifier
MCCost_FinancialParameterID	String	Unique primary key
ProjectID	Small Integer	Project ID. Foreign key
PaymentBondGuaranteeExpiration	Date	Expiration date of payment bond guarantee last renovation
PerformanceBondGuaranteeExpiration	Date	Expiration date of performance bond guarantee last renovation
FixedCostBillingProgress	Double	Accumulated fixed cost billing progress
TotalFixedCostBilling	Double	Total contract fixed cost budget
TotalUnitaryPriceBilling	Double	Accumulated unitary price billing progress
Cost_FinancialUpdateDate	Date	Project MCFinancial table information last update
Subtype	Small Integer	Defined subtype

Source: Compiled by author (2013)

Table 20 *Table Description: MCReport*

Field Name	Type	Description
OBJECTID	OID	ArcGIS auto generated object identifier
MCReportParameterID	String	Unique primary key
ProjectID	Small Integer	Project ID. Foreign key
LastReceivedInternalReport	String	Date of last received internal report
LastSentInternalReport	String	Date of last sent internal report
ReportUpdateDate	Date	Project MC_Report table information last update
Subtype	Small Integer	Defined subtype

Source: Compiled by author (2013)

Table 21 *Table Description: MCRisk*

Field Name	Type	Description
OBJECTID	OID	ArcGIS auto generated object identifier
MCRiskParameterID	String	Unique primary key
ProjectID	Small Integer	Project ID. Foreign key
RiskManagementPlan	String	Link to Risk Management Plan document
RiskUpdateDate	Date	Project MCRisk table information last update
Subtype	Small Integer	Defined subtype

Source: Compiled by author (2013)

Table 22 *Table Description: MCSchedule*

Field Name	Type	Description
OBJECTID	OID	ArcGIS auto generated object identifier
MCScheduleParameterID	String	Unique primary key
ProjectID	Small Integer	Project ID. Foreign key
ContractualSchedule	String	Link to contractual schedule file
PlannedSchedule	String	Link to internal planned schedule file
PlannedScheduleProgress	Double	Percentage of planned schedule completion
ActualProgress	Double	Percentage of up-to-date actual progress
ScheduleUpdateDate	Date	Project MC_Schedule table information last update
Subtype	Small Integer	Defined subtype

Source: Compiled by author (2013)

Table 23 *Table Description: MCScope*

Field Name	Type	Description
OBJECTID	OID	ArcGIS auto generated object identifier
MCScopeParameterID	String	Unique primary key
ProjectID	Small Integer	Project ID. Foreign key
ContractualDeliverables	String	Link to project deliverables list
PlannedDeliverables	Small Integer	Total number of planned project deliverables
PlannedDeliverablesProgress	Small Integer	Number of completed planned project deliverables up-to-date
PlannedDeliverablesProgressPercentage	Double	Percentage of completed planned project deliverables
SOW	String	Link to Statement Of Work document
WBS	Small Integer	Project Work Breakdown Structure. True or False - Domain
ScopeUpdateDate	Date	Project MC_Scope table information last update
Subtype	Small Integer	Defined subtype

Source: Compiled by author (2013)

Table 24 *Feature Class Description: Project*

Field Name	Type	Description
OBJECTID	OID	ArcGIS auto generated object identifier
SHAPE	Geometry	Geographic data container
Subtype	Small Integer	Defined subtype
ProjectID	Small Integer	Unique primary key
ProjectName	String	Project name
ProjectDirector	String	Project Director name
Branch	String	Caminosca S.A. business branch project responsible - domain
LegalRepresentative	String	Caminosca S.A. contractual legal representative name

Field Name	Type	Description
MCResponsible	String	Caminosca S.A. Monitoring and Control responsible name
ClientName	String	Client name
FieldOfActivity	String	Caminosca S.A. field of activity - domain
CountryLocation	String	Country project location
ProvinceLocationID	String	Province project location. Foreign key
CantonLocationID	String	Canton project location. Foreign key
ProjectType	String	Project type - domain
ProjectStartDate	Date	Project start date
ProjectUpdateDate	Date	Project information last update
ProjectFinishDate	Date	Project finish date
ProjectCharter	String	Link to Project Charter document file
ProjectCertificate	String	Link to project certificate file

Source: Compiled by author (2013)

3.3.2 Domains: Domains are intended to protect the database integrity upon the implementation of coded values for predefined attributes. From Table 25 to Table 28, the currently implemented domains are presented:

Table 25 *Domain Description: DomainBranch*

Description	
Domain Type	Coded Value
Field Type	String
Merge Policy	Default Value
Split Policy	Duplicate
Domain Members	
Name	*Value*
ECQuitoHeadquarters	UIO
ECCuencaBranch	CUE
PELimaBranch	LIM
Associations	
Feature Class	*Field*
Project	Branch

Source: Compiled by author (2013)

Table 26 *Domain Description: DomainFieldOfActivity*

Description	
Domain Type	Coded Value
Field Type	String
Merge Policy	Default Value
Split Policy	Default Value
Domain Members	
Name	*Value*
AgricultureAndRuralDevelopment	ARD
DrainageAndOtherMultipurposeProjects	DRA
Energy	ENE
EnvironmentalStudies	ENV
Hydrocarbons	HDC
Hydropower	HDP
MiningAndEnvironment	MIN
RoadsAndTransportation	TRN
UrbanDevelopmentAndAirports	UDA
WaterSupplyAndSewerage	WSS
Other	OTH
Associations	
Feature Class	*Field*
Project	FieldOfActivity

Source: Compiled by author (2013)

Table 27 *Domain Description: DomainLogic*

Description	
Domain Type	Coded Value
Field Type	Small Integer
Merge Policy	Default Value
Split Policy	Duplicate
Domain Members	
Name	*Value*
False	0
True	1
Associations	
Feature Class	*Field*
MCScope	WBS

Source: Compiled by author (2013)

Table 28 *Domain Description: DomainProjectType*

Description	
Domain Type	Coded Value
Field Type	String
Merge Policy	Default Value
Split Policy	Default Value
Domain Members	
Name	*Value*
EngineeringDesign	DES
ConstructionSupervisionAndProjectManagementServices	SUP
TechnicalConsultancy	CON
Associations	
Feature Class	*Field*
Project	ProjectType

Source: Compiled by author (2013)

3.3.3 Relationship classes: For relationship class' definition purpose, it is a matter of importance to manage a unique ID system for each feature class element, which will serve as primary and auxiliary keys in any relationship class.

As for element coding, Caminosca S.A has established a project identification system which states that all projects adjudicated to the company –whether a contract is already signed or soon-to-be signed–, must be coded with a consecutive 3 digits unique code (*e.g.* 407, 408, etc.). For the geodatabase defined feature classes, Caminosca S.A. currently used coding system was maintained under the field ProjectID.

The direction and cardinality of the geodatabase conceived relationship classes are presented below:

Table 29 *Relationship Class Description: Canton_Has_Project*

Composite	No	
Cardinality	One To Many	
Notification	None	
Attributed	No	
	Origin	*Destination*
ObjectClass	ECCanton	Project
Key	ECCantonID (*Origin Primary Key*)	CantonLocationID (*Origin Foreign Key*)
Labels	ECCanton	Project

Source: Compiled by author (2013)

Table 30 *Relationship Class Description: Project_Has_MCCost_EarnedValue*

Composite	No	
Cardinality	One To One	
Notification	None	
Attributed	No	
	Origin	*Destination*
ObjectClass	Project	MCCost_EarnedValue
Key	ProjectID (*Origin Primary Key*)	ProjectID (*Origin Foreign Key*)
Labels	Project	MCCost_EarnedValue

Source: Compiled by author (2013)

Table 31 *Relationship Class Description: Project_Has_MCCost_PersonnelUsage*

Composite	No	
Cardinality	One To One	
Notification	None	
Attributed	No	
	Origin	*Destination*
ObjectClass	Project	MCCost_PersonnelUsage
Key	ProjectID (*Origin Primary Key*)	ProjectID (*Origin Foreign Key*)
Labels	Project	MCCost_PersonnelUsage

Source: Compiled by author (2013)

Table 32 *Relationship Class Description: Project_Has_MCFinancial*

Composite	No	
Cardinality	One To One	
Notification	None	
Attributed	No	
	Origin	*Destination*
ObjectClass	Project	MCFinancial
Key	ProjectID (*Origin Primary Key*)	ProjectID (*Origin Foreign Key*)
Labels	Project	MCFinancial

Source: Compiled by author (2013)

Table 33 *Relationship Class Description: Project_Has_MCReport*

Composite	No	
Cardinality	One To One	
Notification	None	
Attributed	No	
	Origin	*Destination*
ObjectClass	Project	MCReport
Key	ProjectID (*Origin Primary Key*)	ProjectID (*Origin Foreign Key*)
Labels	Project	MCReport

Source: Compiled by author (2013)

Table 34 *Relationship Class Description: Project_Has_MCRisk*

Composite	No	
Cardinality	One To One	
Notification	None	
Attributed	No	
	Origin	*Destination*
ObjectClass	Project	MCRisk
Key	ProjectID (*Origin Primary Key*)	ProjectID (*Origin Foreign Key*)
Labels	Project	MCRisk

Source: Compiled by author (2013)

Table 35 *Relationship Class Description: Project_Has_MCSchedule*

Composite	No	
Cardinality	One To One	
Notification	None	
Attributed	No	
	Origin	*Destination*
ObjectClass	Project	MCSchedule
Key	ProjectID (*Origin Primary Key*)	ProjectID (*Origin Foreign Key*)
Labels	Project	MCSchedule

Source: Compiled by author (2013)

Table 36 *Relationship Class Description: Project_Has_MCScope*

Composite	No	
Cardinality	One To One	
Notification	None	
Attributed	No	
	Origin	*Destination*
ObjectClass	Project	MCScope
Key	ProjectID (*Origin Primary Key*)	ProjectID (*Origin Foreign Key*)
Labels	Project	MCScope

Source: Compiled by author (2013)

Table 37 *Relationship Class Description: Province_Has_Canton*

Composite	No	
Cardinality	One To Many	
Notification	None	
Attributed	No	
	Origin	*Destination*
ObjectClass	ECProvince	ECCanton
Key	ECProvinceID (*Origin Primary Key*)	ECProvinceID (*Origin Foreign Key*)
Labels	ECProvince	ECCanton

Source: Compiled by author (2013)

Table 38 *Relationship Class Description: Province_Has_Project*

Composite	No	
Cardinality	One To Many	
Notification	None	
Attributed	No	
	Origin	*Destination*
ObjectClass	ECProvince	Project
Key	ECProvinceID (*Origin Primary Key*)	ProvinceLocationID (*Origin Foreign Key*)
Labels	ECProvince	Project

Source: Compiled by author (2013)

CHAPTER IV: RESULTS AND DISCUSSION OF FINDINGS

The main objective of this research was to propose a conceptual and logical model for project monitoring and control based on PMI project management standards, and link it to geo spatial technologies. The obtained model was created to fit Caminosca S.A. business logic necessities. As reviewed on previous chapters, Caminosca S.A. Quality Assurance System provides a wide and generous group of procedures intended for, among other things, standardizing project monitoring and control activities. Those procedures are very similar to PMI standard recommendation; nevertheless, Caminosca S.A. existing documentation do not contribute with an adequate level of methodological detail on how those tasks should be performed and what project performance metrics should be stored, leading, ultimately, to the loss of the company business intelligence. In agreement with the previous context, it is very valuable any effort to standardize Caminosca S.A. monitoring and control procedures and define specific project performance metrics to be collected on regular basis and its storage.

As a solution to these data capture and management issues, this thesis studied and demonstrated it is possible to integrate Geographic Information Systems with PMI project management standards into a functional geographic conceptual and logical data model for monitoring and controlling Caminosca S.A. projects. Functionality of the spatial database was explored by implementing a pilot with project basic information and through it responding a set of arbitrary geographic questions.

This thesis proposed a conceptual and logical spatial data model using an ESRI geodatabase for vector data (projects location) and tabular information (monitoring and control parameters). Due the discrete nature of monitoring and control project data Caminosca S.A. produces, a vector data model was the best-suited option to manage georeferenced project performance records in comparison to the possibility of using a raster data model. Furthermore, a vector data model with independent tables for the different monitoring and control attributes linked to a project spatial feature class provides a simple solution for an easy update process that will not require experienced GIS operators for this task. CASE tools – such as ArcGIS Diagrammer – were useful to create an initial UML model from which the geodatabase was further created in ArcGIS Arccatalog.

While PMI standard divides monitoring and control process group into nine knowledge areas, for this research and aiming to satisfy Caminosca S.A. information needs, the proposed geodatabase contains one feature class that holds the project general information and location, and seven monitoring and control parameters attribute tables, including:

- Cost: Earned Value;
- Cost: Personnel Usage;
- Financial;
- Incoming and outcoming reports;
- Risk;
- Schedule;
- Scope.

Due to the lack of definitions on what specific project performance metrics should be collected by the control and monitoring division, a specific Earned Value Management attribute table was implemented. Earned Value Management technique provides the opportunity to periodically obtain project health indicators on important parameters such as cost and schedule. However, PMI standard recommendations, such as Earned Value Management technique, can be subject to change upon project complexity and the company response capability.

PMI knowledge areas, including Quality and Procurement management, were not implemented as attribute tables in the geodatabase, because, Caminosca S.A. has special subunits and tools to control those fields. PMI Integration knowledge area is not explicitly modeled in the geodatabase, basically because the geodatabase itself plays an integrative role among other monitoring and control parameters. A spatial feature data set with political division location was created in the geodatabase with the purpose of give context to the spatial monitoring and control observations. Initially, there is only data from Ecuador but complementary political information data can be uploaded, if needed.

The use of geo spatial technologies to materialize PMI project monitoring and control standard is possible as demonstrated in this thesis and enriches PMI methodology adding a spatial analysis point of view not conceived in the original standard. This is particularly important in a company with multiple projects simultaneously held in diverse geographical locations.

Once upon the Earned Value Management method is implemented in the company and the financial information is uploaded into the geodatabase, in addition to having a complete archive of active, pending and finished projects performance and its financial indicators, multiple spatial queries can be done to the system, possibly including:

- How many active projects are currently delayed and who is the monitoring and control responsible for those projects?
- Where are the projects with the highest Cost Performance Index CPI?
- What kind of projects consume the most environmental personnel resources and where are located?
- Where are the hydropower projects more than 10% behind schedule?
- Where are the projects with the lowest Schedule Perform Index SPI?

Proposing a spatial conceptual and logical model for project monitoring and control helps achieving the goal of creating a useful statistical project database expressed on Caminosca S.A. Project Execution Regulation Instructive, but also spatially contextualized for easier geographic querying and analysis. Upon Caminosca S.A. implementation, the proposed geodatabase would permit, among other things, providing project performance data of ended projects that will serve to planning purposes.

Even though this research responds to Caminosca S.A. particular business logic, it can be concluded that, because of the world wide application of PMI project management standard, the proposed spatial data model is a valid tool for other public or private institutions with multiple and simultaneous projects on their responsibility, with slight customization required. Besides the data storage capability, this data model contributes with a tool for an easy project status reporting, and also with an eloquent communication mechanism for all-at-once quick and complete project status catalog visualization, mainly addressed to executive managers, allowing an early detection of projects possible deviation.

CHAPTER V: RECOMMENDATIONS

This research was pursued to elaborate the most complete investigation possible considering the stated research question and project assumptions and restrictions, in order to count on a fully functional conceptual and logical spatial data model for project monitoring and control, based on Caminosca S.A. case and, most importantly, considering PMI project management standards. However, the results of this thesis must be acknowledged as a preliminary – but important due to the originality of this contribution – step for GIS and project management integration. For further studies, it is suggested taking into account the following recommendations:

- Project performance data capture forms must be designed prior the geodatabase feeding process begins. Once designed, on site locations project performance forms should be filled in and submitted to Caminosca S.A. headquarters, so the data base feeding process can be done from there.
- The proposed spatial data model permits to store monitoring and control parameters in non-spatial attribute tables, allowing non proficient GIS users to feed the different tables independently and using regular spreadsheets. Before implementation, a proper data update workflow and a GIS database administrator must be defined.
- Nowadays, most spatial data consumers do not need to be proficient GIS users. Considering monitoring and control information is restricted to high-managerial profiles, geodatabase access permissions must be granted for those users and ArcReader (free) applications should be installed in their computers. Beneficiaries could possibly include: company vice-presidents; design and construction supervision managers; head of divisions and project managers.

- Symbology layer files, data subset queries or even further, Published Map Files PMF, can be created to maximize data access facilities among the users.
- While an ESRI geodatabase could provide adequate support to Caminosca S.A. monitoring and control needs, if the geodatabase is going to be used in other company with no ArcGIS license, open source geodatabase alternatives shall be considered.
- Before geodatabase operation and maintenance is engaged, a referential budget should be prepared, at least considering the following items:
    - Geodatabase administrator and map publisher fee;
    - Monitoring and control personnel fees;
    - ArcGIS license annual cost;
    - User and developer training.
- With the purpose of suggesting an initial conceptual and logical model that takes advantage of PMI standards, and taking into consideration data access restriction and limited ArcGIS license availability for this thesis, a standalone personal geodatabase was designed, accomplishing the intended research goals. If later on an ArcSDE geodatabase is considered for implementation, further complementary studies should include direct connection to the Microsoft SQL company database in order to easy access to financial and existing project information. An ESRI ArcGIS geodatabase type comparison is presented in Appendix E.

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Appendix A

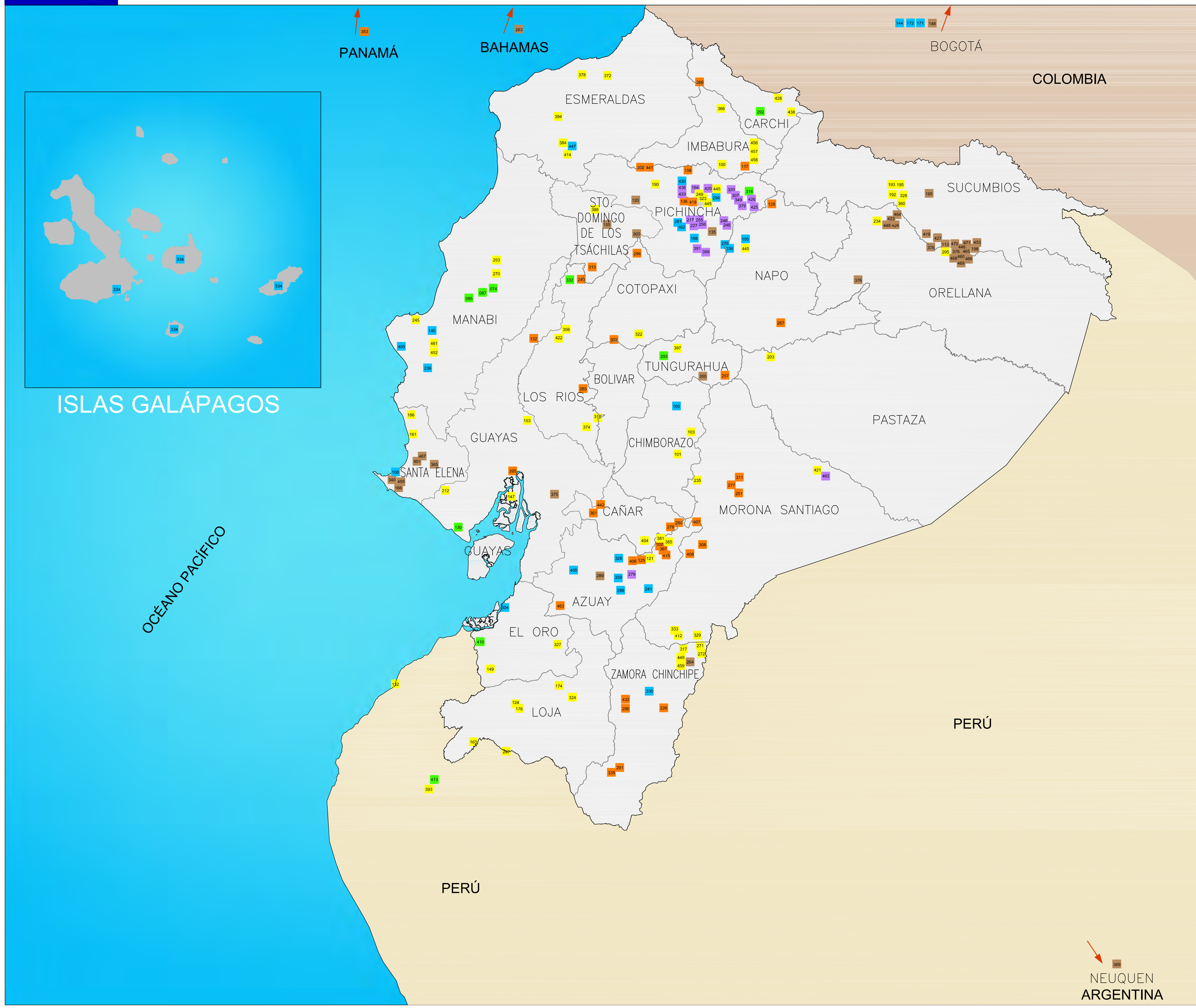
Caminosca S.A. Projects Location Infographic

desde 1976

Caminosca

INGENIERÍA QUE GARANTIZA SUS OBRAS

PRESENCIA NACIONAL E INTERNACIONAL



IDENTIFICACIÓN DE PROYECTOS REPRESENTATIVOS

074	CHONE, PROYECTO DE PROPOSITO MULTIPLE, ESTUDIOS DE PREFACTIBILIDAD
087	CHONE, PROYECTO DE PROPOSITO MULTIPLE, DISEÑOS DEFINITIVOS
095	CARRIZAL - CHONE, ESTUDIOS DE FACTIBILIDAD
100	OTAVALO-SELVA ALEGRE, ESTUDIOS DE FACTIBILIDAD
101	TIXAN-SILVERS, ESTUDIOS DE FACTIBILIDAD
102	SOPLADORA, ESTUDIOS DE FACTIBILIDAD
103	SHUCOS-SILVERS, ESTUDIOS DE FACTIBILIDAD
105	PAPALLACTA, SISTEMA DE AGUA POTABLE, FISCALIZACIÓN
108	SANTA ELENA, ESTUDIOS DE FACTIBILIDAD
113	BLOQUE 16, FACILIDADES, FISCALIZACIÓN
117	INTAG, FASE 1, ESTUDIOS DE FACTIBILIDAD
120	OCCIDENTE DE PICHINCHA, RECURSOS HÍDRICOS Y CLIMA, ESTUDIOS DE MONITOREO
121	LA JOSEFINA TUNEL, ESTUDIOS DE FACTIBILIDAD
124	PINDAL-ZAPOTILLO, ESTUDIOS DE FACTIBILIDAD
125	PAUTE PRESA ESTABILIZACION, SUPERVISIÓN
128	CUYUJA, ESTUDIOS DE PREFACTIBILIDAD
130	PLAYAS, ESTUDIOS DE FACTIBILIDAD
132	DAULE - PERIPA, FISCALIZACION
135	EL BEATERIO, REUBICACION, DISEÑOS DEFINITIVOS
136	GUÁPULO, DISEÑOS DEFINITIVOS
144	BOGOTA-ALCANTARILLADO SANITARIO, FISCALIZACIÓN
145	MANTA PLAN MAESTRO, ESTUDIOS DE FACTIBILIDAD
147	AV. FRANCISCO DE ORELLANA, FISCALIZACION
148	LLANOS GERENCIA, DISEÑOS DEFINITIVOS
149	PASAJE PAVIMENTACION, FISCALIZACION
153	EL TRIUNFO - LA TRONCAL - COCHANCAY, FISCALIZACIÓN
155	MINISOTE, INGENIERÍA BÁSICA Y DE DETALLE
156	INTAG, DISEÑOS DEFINITIVOS
160	RIOBAMBA, AGUA POTABLE Y ALCANTARILLADO, DISEÑOS DEFINITIVOS
161	STA. ELENA -MANGLARALTO-AYAMPE, FISCALIZACIÓN
162	PONCIANO-CARCELEN-CARRETAS,COLECTORES, DISEÑOS DEFINITIVOS
163	PINDAL-SAUCILLO-ZAPOTILLO, FISCALIZACIÓN
164	EL BATAN, ESTABILIZACION QUEBRADA, DISEÑOS DEFINITIVOS
165	OCP, ESTUDIO SISMICO, VULCONOLOGICO
166	REFINERÍA LA LIBERTAD, ASENTAMIENTO MUELLE, DISEÑOS DEFINITIVOS
168	QUITO, ALCANTARILLADO RED SUR, DISEÑOS DEFINITIVOS
171	EL SALITRE, BOX CULVERT, DISEÑOS Y SUPERVISIÓN
172	EL DORADO, RED MATRIZ, DISEÑOS DEFINITIVOS Y FISCALIZACIÓN
174	LOJA-EL TIRO-SAN FRANCISCO, ESTUDIOS DE FACTIBILIDAD
176	Y DE ALAMOR-PINDAL-LALAMOR, ESTUDIOS DE FACTIBILIDAD
186	AYAMPE - MANGLARALTO, FISCALIZACIÓN
190	10 DE AGOSTO - LOS BANCOS, ESTUDIOS DE FACTIBILIDAD
192	NUEVA LOJA - COCA, FISCALIZACIÓN
193	NUEVA LOJA - PUENTE SAN MIGUEL, FISCALIZACIÓN
195	NUEVA LOJA - LUMBAQUI, PUENTES, DISEÑOS DEFINITIVOS
198	EDEN YUTURI, ESTACION, DISEÑOS DEFINITIVOS
203	SANTA CLARA - TENA, FISCALIZACIÓN
212	PROGRESO-BUENOS AIRES, DISEÑOS DEFINITIVOS
217	PARQUE REAL, CONJUNTO HABITACIONAL, FISCALIZACIÓN
226	CHORRILLOS, ESTUDIOS DE FACTIBILIDAD
227	QUITO, NUEVO AEROPUERTO, ESTUDIO DE COSTOS
234	JONDACHI - TENA, FISCALIZACIÓN
235	CHANCHAN, LÍNEA ÉERREA, DISEÑOS DEFINITIVOS
236	JIPIJAPA, PLANTA TRATAMIENTO, FISCALIZACIÓN
240	QUEVEDO VINCES, DISEÑOS DEFINITIVOS
241	SIGSIG - PRAGUAS, DISEÑO DEFINITIVOS
245	MANTA - MONTECRISTI, BY PASS, ESTUDIOS DE PREFACTIBILIDAD
246	CASALES GABRIELA, ASESORÍA TÉCNICA
248	QUITO, AEROPUERTO MARISCAL SUCRE REHABILITACION PISTA,FISCALIZACIÓN
249	AV. SIMON BOLIVAR, FISCALIZACIÓN
251	ABANICO, DISEÑOS DEFINITIVOS
253	CHONE - FLAVIO ALFARO, ESTUDIOS DE FACTIBILIDAD
255	USA EMBAJADA, INGENIERÍA BÁSICA
256	USA EMBAJADA, ESTUDIOS EN GENERAL
257	SAN FRANCISCO, INGENIERÍA DE DETALLE
263	LAS BAHAMAS, DISEÑOS DEFINITIVOS
264	MIRADOR, TOPOGRAFIA MINA, INGENIERÍA BÁSICA
266	CONAM, PROYECTO PILOTO MICROHIDROELECTRICO, ESTUDIOS DE
267	JONDACHI, ESTUDIOS DE PREFACTIBILIDAD
270	CRUSHER-PIT CAMPAMENTO, DISEÑOS DEFINITIVOS
271	MIRADOR, MINA, ESTUDIOS DE GEOLOGIA Y GEOTECNIA
272	MIRADOR, ACCESO A MILL SITE, ESTUDIO DE ALTERNATIVAS
276	ERMITA SUR, ESTABILZIACIÓN, DISEÑOS DEFINITIVOS
277	ABANICO, INGENIERIA DURANTE LA CONSTRUCCION
278	PAPALLACTA, OPTIMIZACION RAMAL SUR, ESTUDIOS DE FACTIBILIDAD
279	CUENCA, EDIFICIO DE LA JUDICATURA, FISCALIZACIÓN
280	MAZAR, GERENCIA DE LA CONSTRUCCIÓN
281	QUITO, HOSPITAL UN CANTO A LA VIDA, DISEÑOS DEFINITIVOS
285	SAN JOSE DE TAMBO, DISEÑO DEFINITIVOS
286	YANUNCAY, PLANTA DE TRATAMIENTO, FISCALIZACION
287	MACARA, PUENTE INTERNACIONAL, ESTUDIOS DE TOPOGRAFIA
289	SHYRI, PROSPECCIÓN MINERA, ESTUDIOS DE IMPACTO AMBIENTAL
290	SABANILLA, GERENCIAMIENTO
291	RIO MAYO, ESTUDIOS DE PREFACTIBILIDAD
292	ACEQUIA PUERMAL, DESARENADOR, DISEÑOS DEFINITIVOS
293	AMBATO, VASOS DE REGULACIÓN, ETAPA II, ESTUDIOS DE FACTIBILIDAD
294	ANGLO FRENCH COLECTOR, ESTUDIOS DE FACTIBILIDAD
295	BLOQUE 16, PUENTES, DISEÑOS DEFINITIVOS
296	ZUMBELTI, ESTUDIOS DE FACTIBILIDAD
302	ANGAMARCA - SINDE, ESTUDIOS DE IMPACTO AMBIENTAL
304	PUERTO BOLÍVAR, AGUAS RESIDUALES, TRATAMIENTO, DISEÑOS DEFINITIVOS
305	LA PLATA, MINERA, ESTUDIOS DE IMPACTO AMBIENTAL
307	FYBECA, LEVANTAMIENTO ARQUITECTÓNICO
308	ENERMAX, INGENIERÍA BÁSICA
311	ABANICO 2DA. ETAPA, ASESORÍA TÉCNICA
313	SALTO DEL BIMBE, DISEÑOS DEFINITIVOS
316	ANCHOLAG, RESERVORIO, DISEÑOS DEFINITIVOS
317	MIRADOR, PROYECTO VIAL, DISEÑOS DEFINITIVOS
318	GUANUJO - ECHEANDÍA, ESTUDIOS DE FACTIBILIDAD
320	ANCHOLAG, RESERVORIO, FISCALIZACIÓN
322	ZUMBAHUA - LA MANÁ, FISCALIZACION
323	QUITO, NUEVO AEROPUERTO INTERNACIONAL, INGENIERÍA PARA EL CONCESIONARIO
324	CHUCHUMBLETZA - PUERTO BOLIVAR, INVENTARIO DE PUENTES
326	TOMEBAMBA, LINEA DE CONDUCCIÓN DE AGUA, DISEÑOS DEFINITIVOS
327	PERU - ECUADOR, EJE VIAL No. 1, FISCALIZACIÓN
328	JOYA DE LOS SACHAS, DISEÑOS DEFINITIVOS
329	PUENTE ZAMORA, DISEÑOS DEFINITIVOS
330	WAWAYME, ENCAUZAMIENTO, DISEÑOS DEFINITIVOS
332	BABA, MULTIPROPÓSITO, FISCALIZACIÓN
333	SAN JUAN BOSCO - TUCUMBATZA, FISCALIZACIÓN
334	ISLAS GALAPAGOS, AGUA POTABLE, FISCALIZACIÓN
335	VALLADOLID, DISEÑOS DEFINITIVOS
336	PAPALLACTA, RAMAL SUR, DISEÑOS DEFINITIVOS
340	LA LIBERTAD, TERMINAL COMBUSTIBLES, DISEÑOS DEFINITIVOS
349	QUITO, NUEVO AEROPUERTO INTERNACIONAL, ASESORIA TÉCNICA
353	LEME, ASISTENCIA TECNICA
355	AMBATO- RIOBAMBA, POLIDUCTO, INGENIERÍA BÁSICA Y DE DETALLE
356	QUEVEDO, ANILLO VIAL, DISEÑOS DEFINITIVOS
359	YANUNCAY, REDES, FISCALIZACIÓN
360	HOLLÍN - LORETO - COCA, FISCALIZACIÓN
361	OCAÑA, GERENCIAMIENTO
365	GLP, ZONA SUR DEL PAIS, DISEÑOS DEFINITIVOS
366	IBARRA - TULCÁN - RUMICHACA, AMPLIACION, DISEÑOS DEFINITIVOS
367	SOPLADORA, DISEÑOS DEFINITIVOS
369	ISOLUX CASA DE MÁQUINAS, ARGENTINA-NEUQUÉN, DISEÑOS DEFINITIVOS
372	LAGARTO - ANCHAYACU, FISCALIZACIÓN
374	GUANUJO - ECHEANDÍA, FISCALIZACIÓN
375	PASCUALES - CUENCA, POLIDUCTO, INGENIERÍA BÁSICA Y DE DE TALLE
376	BLOQUES 7, 15 Y 31, PETROAMAZONAS, INGENIERIA BÁSICA Y DE DETALLE
378	TONCHIGUE - GALERA -BUNCHE, FISCALIZACIÓN
379	METRO PLAZA, CONJUNTO HABITACIONAL, FISCALIZACIÓN
381	SAN PABLO - QDA.GUAYAQUIL, DISEÑOS DEFINITIVOS
384	QUIMSACOCHA, LÍNEA DE TRANSMISIÓN, ESTUDIOS DE PREFACTIBILIDAD
385	SEVILLA DE ORO - SAN PABLO, DISEÑOS DEFINITIVOS
388	STO DOMINGO - ESMERALDAS, FISCALIZACIÓN
391	AMAGUAÑA, NUEVAS INSTALACIONES FARCOMED, DISEÑOS DEFINITIVOS
392	CHIRAPI-MANDURIACU, ESTUDIOS DE FACTIBILIDAD
393	SULLANA - EL ALAMOR, BINACIONAL, FISCALIZACIÓN
394	QUININDÉ - ESMERALDAS, DISEÑOS DEFINITIVOS
397	AMBATO, PASO LATERAL, ESTUDIOS DE FACTIBILIDAD
399	FARCOMED, CONSTRUCCIÓN PRIMERA ETAPA, FISCALIZACIÓN
400	CUENCA, EL SALADO, FISCALIZACIÓN
401	GLP, ZONA SUR DEL PAIS, GERENCIAMIENTO
404	CUENCA - AZOGUES - BIBLIÁN, ESTUDIOS DE FACTIBILIDAD
405	AZUA, MANTA, AGUA POTABLE Y ALCANTARILLADO, FISCALIZACIÓN
406	SAYMIRIN, DISEÑOS DEFINITIVOS
407	CARDENILLO, DISEÑOS DEFINITIVOS
408	CARDENILLO, INVESTIGACIONES GEOTÉCNICAS
410	PUYANGO - TUMBES, FISCALIZACIÓN
412	MATANGA - GUALAQUIZA, ESTUDIOS DE FACTIBILIDAD
413	POECHOS-PERU, FISCALIZACIÓN
414	LA CONCORDIA Y LA UNION, PASOS LATERALES, DISEÑOS DEFINITIVOS
415	SOPLADORA, GERENCIAMIENTO
418	CALDERÓN, FOTOVOLTÁICO, ESTUDIOS DE FACTIBILIDAD
419	BLOQUE 31, INGENIERÍA BÁSICA Y DE DETALLE
420	METRO DE QUITO-LOTE 1, DISEÑOS DEFINITIVOS
421	"T" DE EVENETZER - MACUMA - TAISHA, ESTUDIOS DE FACTIBILIDAD
422	QUEVEDO, ANILLO VIAL, FISCALIZACIÓN
423	BLOQUE 7, COCA 13, INGENIERÍA BÁSICA Y DE DETALLE
424	BLOQUE 7, COCA A, INGENIERÍA BÁSICA Y DE DETALLE
425	COSMOPOLITAN, CONJUNTO HABITACIONAL, FISCALIZACIÓN
426	FARCOMED CD2 AMAGUAÑA, EDIFICACION, DISEÑOS DEFINITIVOS
427	BLOQUE 31, FISCALIZACIÓN
428	TULCÁN, ANILLO VIAL, ESTUDIOS DE FACTIBILIDAD
429	YANAQUINCHA ESTE, HIDROCARBUROS, ESTUDIO
430	FYBECA EL BATAN, HIDRÁULICO, DISEÑOS
431	CALDERON, FOTOVOLTAICO, ESTUDIOS
432	DELSITANISAGUA, HIDROELECTRICO, ESTUDIO
433	QUITO, BRISTOL, FISCALIZACIÓN
434	PAYAMINO A, HIDROCARBUROS, DISEÑO
435	YAMANUNKA 01, HIDROCARBUROS, DISEÑO
436	FYBECA EL BATAN, FISCALIZACIÓN
437	GUAYLLABAMBA-COCHASQUI, CARRETERA, ESTUDIOS
438	HUACA-JULIO ANDRADE, VIAS, ESTUDIOS
439	NAPO PAKA SUR, HIDROCUARBUROS, DISEÑO
440	PAPALLACTA-SIMON BOLIVAR, CARRETERA, FISCALIZACION
441	MANDURIACU, HIDROELÉCTRICO, ASESORÍA
442	OCAÑA, DESLIZAMIENTO, ESTUDIO
443	SUYUNO - GACELA, HIDROCARBUROS, ESTUDIOS
444	FRUTA DEL NORTE, PROYECTO MINERO, ESTUDIO
445	NAIQ, CARRETERA, ESTUDIO
446	JIVINO-LAGUNA, HIDROCARBUROS, ESTUDIO
447	LA INDEPENDENCIA, ALCANTARILLADO, ESTUDIO
448	SACHA ESTACION, HIDROCARBUROS, ESTUDIOS
449	MIRADOR, CARRETERA, ESTUDIOS
450	HAZOP BLOQUE 12 15 18, HIDROCARBUROS, ESTUDIOS
451	YUCA PLATAFORMA, HIDROCARBUROS, ESTUDIOS
452	EL COLORADO, REFINERÍA DEL PACIFICO, CARRETERA,ESTUDIOS
453	EPF, SISTEMA INTEGRAL, HIDROCARBUROS, ESTUDIOS
454	SHUSHUFINDI, HIDROCARBUROS, ESTUDIOS
455	MONTEVERDE, TERMINAL MARITIMO, FISCALIZACION
456	IBARRA, CARRETERA, ESTUDIOS
457	OTAVALO, CARRETERA, ESTUDIOS
458	OTAVALO - CAJAS, CARRETERA, ESTUDIO
459	ZAMORA RIO, SOPORTE TÉCNICO, DISEÑO
460	CPF BLOQUE 15, HIDROCARBUROS, ESTUDIOS
461	RDP-EL COLORADO, CARRETERA, FISCALIZACION
462	TAISHA, AEROPUERTO, FISCALIZACION
463	MINAS - SAN FRANCISCO, HIDROELECTRICO, FISCALIZACION
464	GACELA-PAYAMINO-COCA, HIDROCARBUROS, ESTUDIOS
465	JIVINO B INYECCIONES, HIDROCARBUROS, ESTUDIOS
466	LIMONCOCHA 07, HIDROCARBUROS, ESTUDIOS
467	GLP, ASESORIA
468	TUMALI PLATAFORMA, HIDROCARBUROS, ESTUDIOS
469	PAÑACOCHA PLATAFORMA, HIDROCARBUROS, ESTUDIOS
470	TANGAY PLATAFORMA, HIDROCARBUROS, ESTUDIOS
471	PACAY PLATAFORMA, HIDROCARBUROS, ESTUDIOS

CAMPOS DE ACTIVIDAD

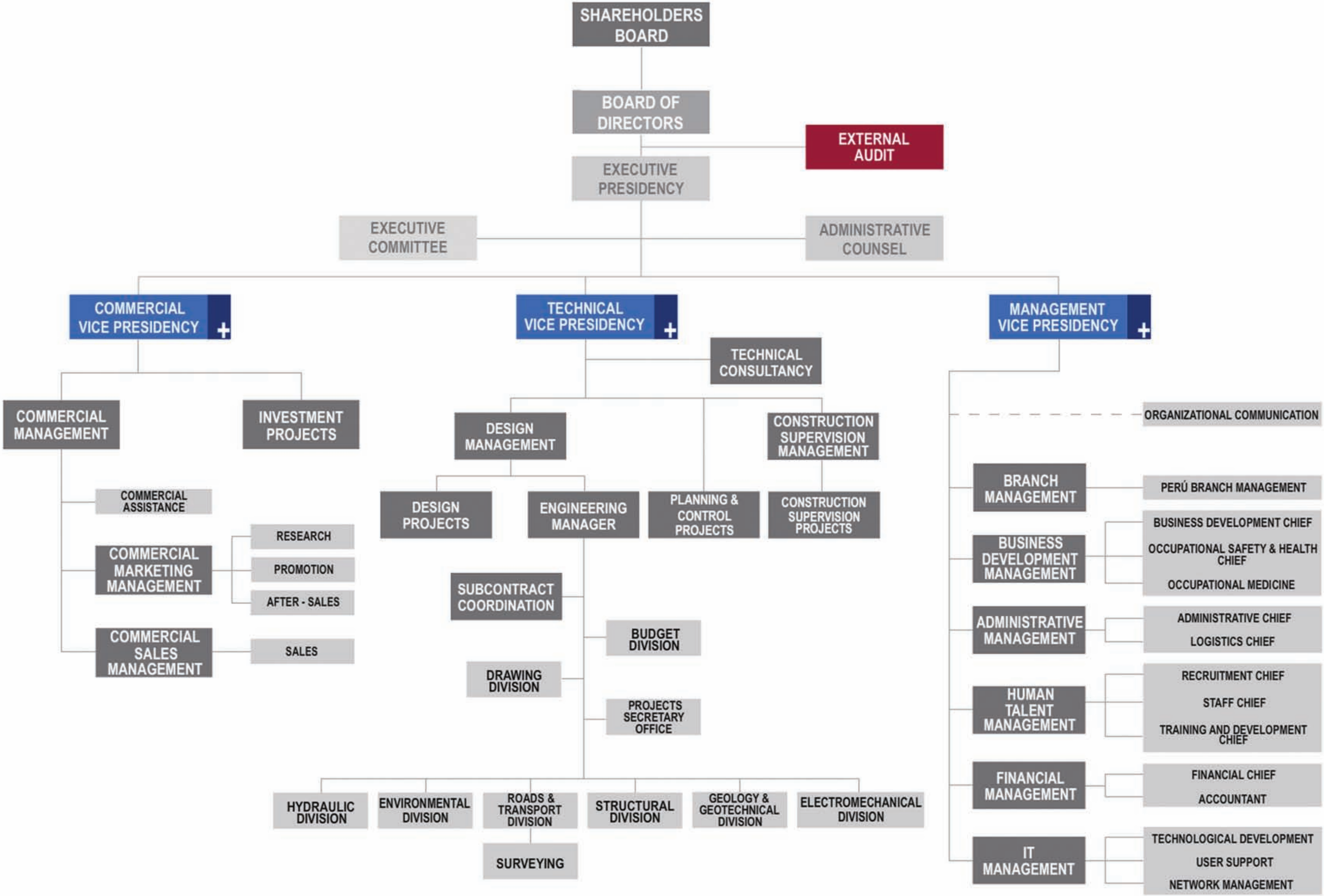
- HIDROELECTRICIDAD
- AGUA POTABLE Y ALCANTARILLADO
- HIDROCARBUROS MINERÍA Y AMBIENTE
- DESARROLLO URBANO Y AEROPUERTOS
- VÌAS Y TRANSPORTE
- RIEGO, DRENAJE Y PROPÓSITO MÚLTIPLE

SIMBOLOGÌA

LIMITE PROVINCIAL

Appendix B

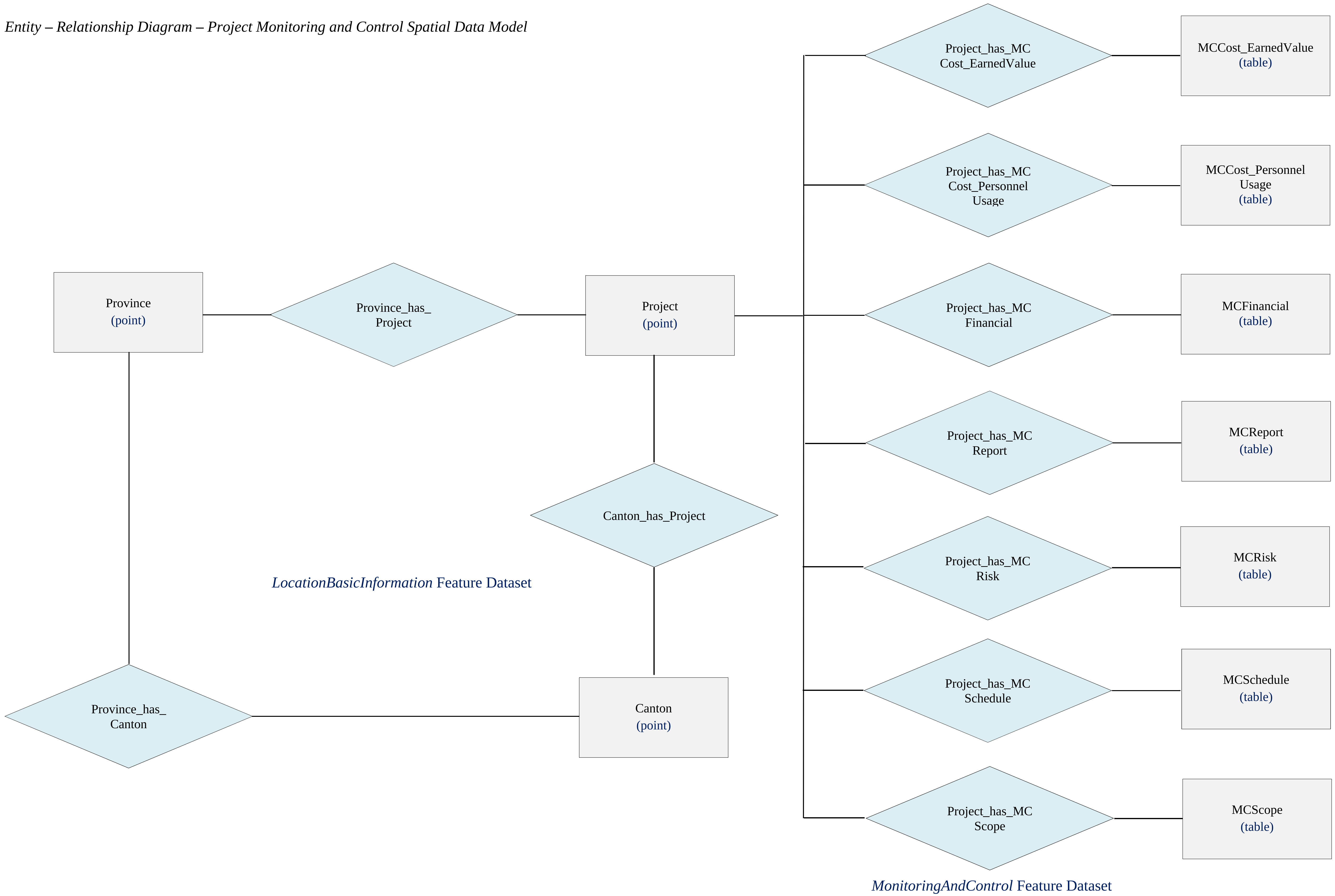
Caminosca S.A. Organizational Chart


SHAREHOLDERS BOARD
BOARD OF DIRECTORS
EXTERNAL AUDIT
EXECUTIVE PRESIDENCY
EXECUTIVE COMMITTEE
ADMINISTRATIVE COUNSEL
COMMERCIAL VICE PRESIDENCY +
TECHNICAL VICE PRESIDENCY +
MANAGEMENT VICE PRESIDENCY +
COMMERCIAL MANAGEMENT
INVESTMENT PROJECTS
COMMERCIAL ASSISTANCE
COMMERCIAL MARKETING MANAGEMENT
RESEARCH
PROMOTION
AFTER - SALES
COMMERCIAL SALES MANAGEMENT
SALES
TECHNICAL CONSULTANCY
DESIGN MANAGEMENT
CONSTRUCTION SUPERVISION MANAGEMENT
DESIGN PROJECTS
ENGINEERING MANAGER
PLANNING & CONTROL PROJECTS
CONSTRUCTION SUPERVISION PROJECTS
SUBCONTRACT COORDINATION
BUDGET DIVISION
DRAWING DIVISION
PROJECTS SECRETARY OFFICE
HYDRAULIC DIVISION
ENVIRONMENTAL DIVISION
ROADS & TRANSPORT DIVISION
STRUCTURAL DIVISION
GEOLOGY & GEOTECHNICAL DIVISION
ELECTROMECHANICAL DIVISION
SURVEYING
ORGANIZATIONAL COMMUNICATION
BRANCH MANAGEMENT
PERÚ BRANCH MANAGEMENT
BUSINESS DEVELOPMENT MANAGEMENT
BUSINESS DEVELOPMENT CHIEF
OCCUPATIONAL SAFETY & HEALTH CHIEF
OCCUPATIONAL MEDICINE
ADMINISTRATIVE MANAGEMENT
ADMINISTRATIVE CHIEF
LOGISTICS CHIEF
HUMAN TALENT MANAGEMENT
RECRUITMENT CHIEF
STAFF CHIEF
TRAINING AND DEVELOPMENT CHIEF
FINANCIAL MANAGEMENT
FINANCIAL CHIEF
ACCOUNTANT
IT MANAGEMENT
TECHNOLOGICAL DEVELOPMENT
USER SUPPORT
NETWORK MANAGEMENT

Appendix C

Entity-Relationship Diagram

Entity – Relationship Diagram – Project Monitoring and Control Spatial Data Model



Appendix D

Data Model XML Schema (CD)

Appendix E

Comparison of ESRI Geodatabases Types

Comparison of ESRI Geodatabases Types

Key characteristics	ArcSDE geodatabase	File geodatabase	Personal geodatabase
Description	A collection of various types of GIS datasets held as tables in a relational database (This is the recommended native data format for ArcGIS stored and managed in a relational database.)	A collection of various types of GIS datasets held in a file system folder.(This is the recommended native data format for ArcGIS stored and managed in a file system folder.)	Original data format for ArcGIS geodatabases stored and managed in Microsoft Access data files.(This is limited in size and tied to the Windows operating system.)
Number of users	Multiuser: many readers and many writers	Single user and small workgroups:many readers or one writer per feature dataset, stand-alone feature class, or table. Concurrent use of any specific file eventually degrades for large numbers of readers.	Single user and small workgroups with smaller datasets: some readers and one writer. Concurrent use eventually degrades for large numbers of readers.
Storage format	Oracle Microsoft SQL Server IBM DB2 IBM Informix PostgreSQL	Each dataset is a separate file on disk. A file geodatabase is a file folder that holds its dataset files.	All the contents in each personal geodatabase are held in a single Microsoft Access file (.mdb).
Size limits	Up to DBMS limits	One TB for each dataset. Each file geodatabase can hold many datasets. The 1 TB limit can be raised to 256 TB for extremely large image datasets. Each feature class can scale up to hundreds of millions of vector features per dataset.	Two GB per Access database. The effective limit before performance degrades is typically between 250 and 500 MB per Access database file.

Key characteristics	ArcSDE geodatabase	File geodatabase	Personal geodatabase
Versioning support	Fully supported across all DBMSs; includes cross-database replication, updates using checkout and check-in, and historical archiving	Only supported as a geodatabase for clients who post updates using checkout and check-in and as a client to which updates can be sent using one-way replication.	Only supported as a geodatabase for clients who post updates using checkout and check-in and as a client to which updates can be sent using one-way replication.
Platforms	Windows, UNIX, Linux, and direct connections to DBMSs that can potentially run on any platform on the user's local network	Cross-platform.	Windows only.
Security and permissions	Provided by DBMS	Operating file system security.	Windows file system security.
Database administration tools	Full DBMS functions for backup, recovery, replication, SQL support, security, and so on	File system management.	Windows file system management.
Notes	Requires the use of ArcSDE technology; ArcSDE for SQL Server Express included with ArcEditor and ArcInfo ArcGIS Engine ArcGIS Server Workgroup ArcSDE for all other DBMSs included with ArcGIS Server Enterprise	You can optionally store data in a read-only compressed format to reduce storage requirements.	Often used as an attribute table manager (via Microsoft Access). Users like the string handling for text attributes.

Source: ESRI, 2013