Quality Management in GIS

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Abstract: This paper centers on the crucial elements of quality control (QC) and quality assurance (QA) in the domain of geographic information systems (GIS). A dependable and resilient GIS database is at the core of any spatial system, and it is of utmost significance across a wide range of fields, including Hajj, Umrah, tourism, real estate, and natural resource management. Given the inherent intricacy of spatial databases and their requirement for specialized technical upkeep, applications that depend on them also necessitate specialized technical expertise. To address inconsistencies within the database, best practices for database maintenance are implemented.

This paper presents a systematic approach to the updating of comprehensive spatial databases and provides an overview of the quality procedures that are essential to this process. It also discusses the various safeguard mechanisms that are employed to enhance data consistency, completeness, integrity, and other qualitative aspects. The primary objective is to establish a customer-focused quality standard for spatial databases. Considering the broad definition of quality as "the extent to which project deliverables meet requirements," GIS projects face the challenge of precisely defining specifications and relevant quality standards that are tailored to specific project types and deliverables. The increasing demand for digital maps and GIS applications in Egypt emphasizes the urgent need for quality control and quality assurance procedures. This paper describes the implementation of these procedures in the creation of ten geological maps of Egypt at a scale of 1:500,000. This collaborative effort involves Cairo University and the Ministry of Water Resources and Irrigation in Egypt. Additionally, this project provides an internship opportunity for students in the College of Engineering, Civil Department, enabling them to gain practical experience in the field.

Key-Words: Quality, Spatial Data, Data acceptance Criteria, Automated Quality Control, Quality Control, Quality Assurance

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1 Introduction

The definition of quality in GIS projects is based on the degree to which project deliverables meet requirements. This overarching definition presents a challenge for GIS projects, as they must precisely define specifications and quality standards appropriate for various categories of GIS projects and their associated deliverables. In the field of GIS projects, quality can be effectively defined, estimated, and evaluated in the context of specific deliverables, such as reports and documents that include tasks such as needs assessment and design documents and plans. Quality is also central to the foundational structures of conceptual and physical database designs. Spatial data derived from aerial surveys or satellite images and then processed for dissemination to end users, as well as GIS data derived from field data collection, map digitization, or other data acquisition methods, require distinct quality considerations and evaluations. GIS applications, including user interfaces and specially designed functions derived from GIS software, also require quality evaluations. To avoid spatial errors and attribute errors, the QA/QC checklist can be used.

2 Quality parameters for typical GIS project outputs

The establishment of quality standards for GIS project deliverables is a crucial aspect of project planning, as it provides a fundamental framework for project implementation and quality assurance endeavors. Precisely documented specifications of project deliverables serve as the foundation for efficient quality management. The quality standards pertaining to different categories of GIS project deliverables are outlined as follows:

Project reports, documents, and MAP products

The content pertains to domains, while the document's structure, lucidity, and comprehensibility are taken into account. Additionally, the quality of design and user-friendliness of mapping products are evaluated. Furthermore, grammatical accuracy, spelling, and currency are also considered, with the latter being updated to reflect current conditions.

The following are key considerations in the process of data collection:

- Adherence to aviation and equipment specifications
- Accuracy of data collection
- Compliance with processing requirements
- Positional accuracy
- Picture quality
- Commitment to data delivery file format
- Processing and delivery time

Custom Geographic Information System (GIS) applications should possess the following characteristics to meet the desired standards:

1. Suitable job allocation: The application should be designed to fulfill the specific requirements of the intended tasks.
2. User-friendly interface: The application should be easy to navigate and adhere to established user interface standards.
3. Efficiency, performance, and response time: The application should be designed to operate swiftly and effectively, ensuring optimal performance and timely responses.
4. Compliance with coding and programming standards: The application should adhere to established coding and programming guidelines to ensure consistency and maintainability.
5. Flexibility and maintainability: The application should be adaptable to changing needs and easily maintainable to accommodate future updates or modifications.
6. Clear and user-friendly map display design: The application should provide a clear and intuitive map display, ensuring ease of understanding for users.
7. Sufficient access to data sources: The application should have adequate access to relevant data sources to ensure accurate and comprehensive information.
8. Thorough and comprehensible documentation: The application should be accompanied by complete and clear documentation, facilitating ease of understanding and usage.

Compiled Data

The following is a compilation of Geographic Information System (GIS) data that has been assessed for various criteria, including map feature completeness, map feature positional accuracy, graphic and topological connectivity correctness, proper placement of features in their respective files, tables, and feature classes, attribute data completeness and accuracy, and correctness of annotation.

Collected data.

• The map exhibits comprehensive features.
• The map demonstrates positional accuracy.
• The graphic and topological connections are correct.
• Features are appropriately placed in the file, table, and corresponding feature class.
• The attribute data is complete.
• The accuracy of the attribute data is ensured.
• The annotation is correct.

In GIS projects, there is a significant emphasis placed on quality management, particularly in relation to GIS data and custom application development.

In extensive GIS database development endeavors, such as the ongoing project being undertaken by the City of Metropolis, it is customary to commence by formulating a preliminary database design and establishing database development procedures, which incorporate measures for quality control (QC). Subsequently, a pilot project is initiated as a crucial component of the overall database development project. The primary objective of this pilot project is to assess various aspects, including the design and management of source materials, data capture techniques, development procedures, quality control methodologies, and more. Insights derived from the results of the pilot project are then utilized to enhance the design and procedures prior to commencing full-scale production work..

In the realm of GIS database initiatives, the notion of incremental data optimization carries substantial significance. For instance, consider a substantial GIS database project undertaken by a water utility organization, with the objective of establishing a comprehensive GIS database to support its operational activities.

2.1 The GIS software:

Provides a range of tools to modify applications according to the specific needs of users.

Customization tasks that are commonly encountered in GIS projects often involve:
Simplify access, facilitate integration with external systems or databases, and enable the import/export of data with external databases and applications.
Draft and develop interactive forms with intelligent data entry features, including drop-down selection menus, automated error checking, and other user-friendly controls.
Create application scripts that can be easily executed through a simple menu selection and integrate multiple individual functions.
Design and create templates for standardized maps and text reports.
Formulate data quality control and quality assurance applications using verification tools provided by the software package.

Develop a repository of consolidated queries that can be easily accessed through a user-friendly menu. Program intricate analysis functions using fundamental GIS processing commands. Design customized geospatial statistics or analysis models, including network analysis.

When it comes to software and application development, various formal methodologies can be employed. The crucial factor is the implementation of a structured and systematic methodology throughout the project execution. In terms of quality management, the critical stages of the process (such as assessing user application needs, designing, prototyping, deploying operationally, and documenting) should be characterized by well-defined phases for user evaluation and feedback. This feedback loop is valuable in iteratively refining applications, ultimately releasing applications that meet the specified requirements.

2.2 Quality management comprises of four primary components:

To effectively lead and oversee an organization, the leadership must first establish a comprehensive quality policy and establish quality objectives that align with said policy. Subsequently, they must delineate initiatives pertaining to quality planning, quality control, quality assurance, and continuous improvement. The primary objective of quality management is to guarantee the efficient and successful execution of all company endeavors aimed at augmenting customer satisfaction and fulfilling the expectations of other stakeholders. Quality management encompasses not only the quality of the product or service, but also extends to the methodologies and processes employed in its delivery.

2.3 Quality management components:

Quality Planning: Quality planning is an essential element of quality management, encompassing the establishment of quality objectives and the identification of the necessary processes and resources to achieve these objectives. It is a systematic procedure that transforms quality policy into measurable goals and outlines a series of steps to accomplish them within a predetermined time frame.
Quality Control: Quality control, a constituent of quality management, concentrates on meeting predetermined quality specifications. This facet aids in evaluating the performance of both the process and the product and implementing corrective measures in response to any deviations between actual performance and planned targets.
Quality Assurance: Quality assurance, another facet of quality management, is dedicated to instilling confidence in the ability to meet quality requirements. It serves the dual purpose of ensuring customer satisfaction and providing management with assurance of quality, particularly in situations where direct supervision of operations is not feasible.
Quality Improvement: Quality improvement, an integral part of quality management, focuses on enhancing the capability to meet quality requirements and continuously elevating the standards of quality.

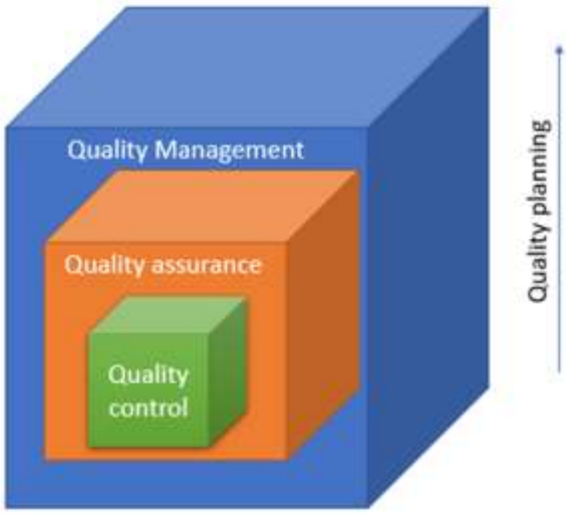

Figure 1: Quality Control Chart

The diagram shows that quality control acts as a primary focal point in quality management. It depicts how quality control efforts within a given system raise overall quality to the level of quality assurance.

Once quality improvement initiatives are subsequently taken, guided by analysis of process/product measurement data and customer feedback, quality management advances further. It is important to note that throughout this progression, quality planning maintains its integral role across all steps of quality management.

2.4 Quality Management:

The Project Management Body of Knowledge (PMBOK) defines quality management as "all activities undertaken by the organization to define the policies, objectives and responsibilities that the organization must perform in order to satisfy the needs of which it operates.".

Figure 2: Stages of quality development

Rose has identified four fundamental components in the field of quality management, which are quality planning, quality assurance, quality control, and improvement of quality. These four elements are essential in supporting the concept of total quality management, with continuous improvement serving as the central principle. The driving force behind Total Quality Management is the desire to enhance user satisfaction, and it embraces an improvement philosophy that is rooted in the core quality functions of planning, assurance, and control. These functions embody the essence of Total Quality Management.

2.5 Quality Management:

Expenses are incurred because of substandard quality, either due to insufficient quality or the necessity to ensure compliance with established quality standards, or because of difficulties in meeting those standards. Quality cost refers to the expenses accumulated to avoid or address issues related to products of low quality. This encompasses costs associated with preventing quality issues, evaluating quality, addressing internal failures, and addressing external failures. Quality cost categories are classified into four types: prevention costs, evaluation costs, internal failure costs, and external costs of failure. The total quality costs are determined by adding together the prevention costs, evaluation costs, and internal and external failure costs.

2.6 QA/QC Checklist:

Expenses are accrued because of subpar quality, stemming from either inadequate quality or necessity:

2.6.1 Documentation and file structure:

- All pertinent documents
- Comprises a concise depiction of the project:
  - The customer's requirements
  - The manner in which they were fulfilled
- Initial summary
  - A delineation of the undertaken steps
- Metadata
- Consistent file organization
- Any additional documents
  - Spatial references
  - Output formats
  - Any physical documents utilized.

2.6.2 Project checklist:

Relevant title

Project initiation

- Initiate without any errors
- The designated location
  - The scope of the system
  - A specific geographical location
- Accurate arrangement of drawings
- Classification states or definition queries
- Symbols

Does the Geographic Information System (GIS) fulfill its intended purpose?

2.6.3 Data Checklist:

The following criteria must be met in order for data to be considered relevant and suitable for use:

1. Correctly Named: All data must adhere to established naming conventions and be in a suitable location, such as C:\AMFM\ABC_Cooperative.
2. Predefined Model: Data must be compatible with predefined models and other billing or staking programs.

It is imperative that all data meets these requirements to ensure accuracy and consistency in any analysis or application.

2.6.4 Data Structure Checklist:

The data has been appropriately organized within the designated layer.

- All fuses are located within the fuse layer.
- All transformers are situated within the transformer layer.

And so forth...

Attributes Checklist:
Verification of Data
Representation of an attribute.
- Is the value of this field complete?

- Does it contain a subtype or block reference?
- Is the label derived from an attribute?
- Is it documented?

2.6.5 Data Conversion Checklist:
When converting or importing data into a GIS from another platform, it is important to follow a checklist to ensure the accuracy and integrity of the converted data. The following steps should be taken:
1. Check for any lost data during the conversion process.
2. Verify that there is a one-to-one match between the original data and the converted data.
3. Ensure that the conversion is done properly, maintaining the integrity of the data. This includes converting polygons to polygons, points to points, and polylines to polylines.
4. Confirm that the converted data retains the same relative location as the original document.
By adhering to this checklist, the converted data can be trusted and used effectively within the GIS platform.

2.6.6 Network Checklist:
Connectivity Assessment
Identification of Loops
Determination of Direction of Flow. Identification of Sources or Sinks.
Verification of Established Rules and Procedures
Review of the Document.

2.6.7 Relationship Checklist:
Relationships with Other Datasets
- One-to-one
- One-to-many
- Database connections

2.6.8 Annotation Checklist:
The visibility of the annotation should be clearly defined in terms of when and where it is required. It is important that the annotation is relative to the context in which it is used. The annotation may be dynamic or stored in a database. It is recommended that multiple copies of the annotation are made to ensure accessibility and availability.

2.6.9 Custom Applications Checklist:
1. Do the applications load properly?
2. Do the applications function correctly on clients' devices?

3 Study project and data availability
Ten geological maps of Egypt, each with a scale of 1:500,000, were utilized for this project. These maps were originally produced by the Egyptian Survey Authority (ESA) and the Military Survey Department (MSD). The base maps underwent a scanning process at a resolution of 400 dots per inch (dpi), followed by conversion to a raster format. Subsequently, correction was performed through projection adjustments. The project team, composed of ten individuals, converted these maps into vector format using geographic types. A quality control (QC) procedure was then conducted, during which various errors were identified and are outlined in the subsequent table.

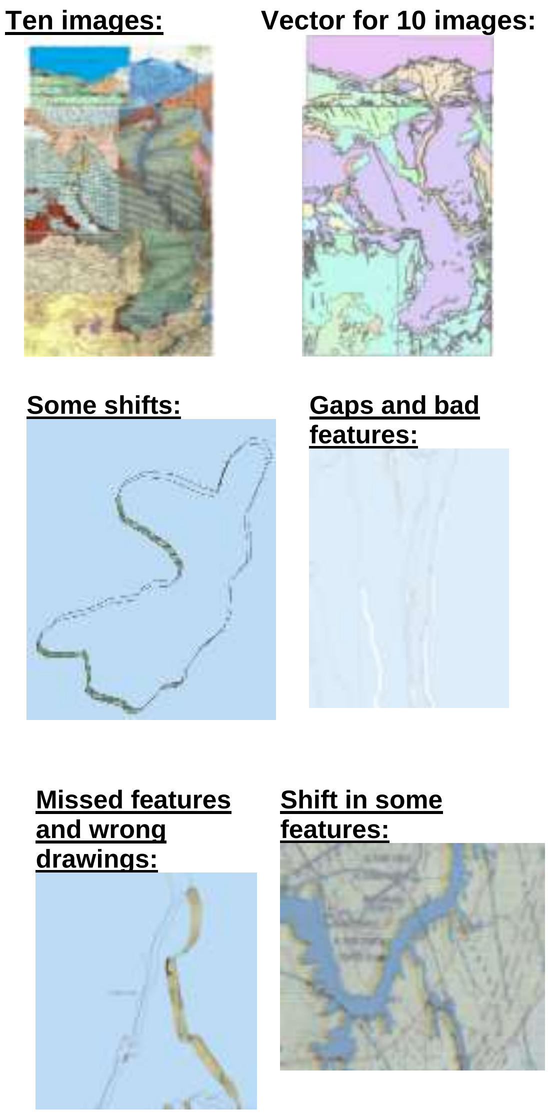

Figure 3: Spatial Errors

Process/Method: Evaluation of various approaches for determining quality. A random sample of geological features is selected and assessed for compliance with specifications. The size of the sample is determined based on the desired level of confidence. Random samples are extracted from geological features. Independent evaluations of records are conducted. The errors identified in the table above were discovered during this process.

Results: The random sampling process yielded consistent results. The main challenge encountered was the establishment of quality rules. A list is chosen based on ratings and attributes. The quality of the data affects the size of the sample. By utilizing the ANSI/ASQC standard, an acceptable quality level and the corresponding sample size can be determined (e.g., 180 out of 40,000 features allows for five errors). Manual and semi-automatic scanning of data is performed using a checklist. The classes tested exhibit accuracy rates ranging from 90% to 95%. The quality measures demonstrate high repeatability. Well-defined standards can serve as a guide for editing purposes.

Application Testing Checklist			
Tested By	Tester	Date	
Application Name	Keyboard Pro		
Procedure	Expected Result	Pass/Fail (P/F)	Actual Results/Comments
Application Functionality			
Performs primary functionality and maintains stability	Yes	P	Opens and allows students to practice keyboarding without program errors or hangs.
Windows Fundamentals			
Installs under a user account	No	P	Does not install under student user account
Installs under a power user account	Yes	P	Installs correctly
Installs under an administrator account	Yes	P	Installs correctly
Completes a minimal	NA	NA	NA

Figure 4: Application Testing Checklist

Application Testing Checklist (Sample): A checklist of Geographic Information System (GIS) applications can be created based on their functionality, as depicted in the image below.

4 Conclusion

The most comprehensive conclusions derived from this thesis are outlined as follows:

To accurately assess improvements, it is imperative to consistently measure all quantifiable parameters related to quality. This entails conducting an initial analysis of measurement data, conducting additional measurements and analyses as required, discussing the findings with relevant stakeholders, and documenting necessary revisions for future analyses. By utilizing the data, the underlying causes of non-compliance are identified, and the necessity for corrective actions is evaluated to prevent recurrence of non-conformity.

Corrective actions are devised and executed, encompassing the following elements:

- Identify the factors contributing to non-conformity.
- Address the root causes of non-conformity.
- Implement suitable measures to prevent the recurrence of non-conformities for corrective action.

Please ensure appropriate measures are taken to prevent non-conformity and promote preventive action. The impact of Quality and Quality Management in GIS projects is significant in modern computer science and computing techniques. It guarantees the reliability, accuracy, and efficiency of GIS data and processes, which are crucial in various applications and services that rely on geographic information. These practices contribute to the reliability, accuracy, and overall success of GIS applications in a rapidly evolving technological landscape. These research directions can help advance the understanding and practices of quality and quality management in GIS projects, enabling more reliable and effective geospatial applications in the future. Researchers can select from these directions based on their interests, expertise, and the evolving needs of the GIS community.

By attending to these research directions, scholars can make a valuable contribution to the advancement of the GIS field and guarantee that spatial data is of the utmost quality, satisfying the changing requirements of various applications and users.

5 Recommendations

The following recommendations present comprehensive suggestions for future research: Within an organization, quality activities are dispersed among various departments and functions, lacking a centralized entity responsible for all quality-related tasks. This fragmentation impedes the implementation of methods to measure and manage quality costs, resulting in a lack of awareness regarding the impact of these costs on company resources. It is advisable to designate a focal point to oversee all quality activities and establish measures for measuring and controlling quality costs.

Management and employees should prioritize quality assessment by effectively inspecting and identifying areas of non-compliance with specifications.

Incorporating quality assurance (QA) and quality control (QC) procedures, along with the creation of checklists, should be considered standard practice in every GIS and geodatabase project. It is recommended to allocate a dedicated portion of the overall project budget specifically for GIS projects and ensure that resources are appropriately allocated to support these initiatives.

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