Facilitating a Statewide GIS Metadata Standard through Training, Outreach and Programmatic Metadata Evaluation

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Abstract— **Under the supervision of the North Carolina Geographic Information Coordinating Council and Statewide Mapping Advisory Committee, a committee defined and developed a State and Local Government Metadata profile intended for use in North Carolina. This profile is based on the International Organization for Standardization 191** standards. In addition to dictating best practices and conventions for existing metadata entries such as the Title, Publication Date and Use Constraints, this standard accounts for evolving technologies that did not exist when original metadata standards were first developed. While the rate at which geoinformation is created has exponentially increased, the time dedicated to cataloging and subsequently assessing and evaluating this metadata information remains nearly the same. In addition to educating the North Carolina Geographic Information Systems community on the use and application of metadata, as well as this new standard, the research team is developing tools so GIS managers can gauge standard compliance more efficiently and proactively than in the past. In this paper, the research team has been using programming methods in which metadata entries from multiple layers in large geospatial databases can be assessed and evaluated. These methods were tested using various quantitative methods, including the Technology Acceptance Model. This can provide insight into the various accuracies (horizontal, vertical, temporal, etc.) of layers which in turn can dictate future efforts. It can also be used to identify inconsistencies in metadata entries with an end goal of understanding misinterpretation and misunderstanding of the profile so it can be improved in future incarnations.**

Keywords-GIS Metadata; Metadata; Metadata Profile; North Carolina State and Local Government Profile.

I. INTRODUCTION

A Geographic Information System (GIS) serves as the tangible and intangible means by which information about spatially related phenomena can be created, stored, analyzed and rendered in the digital environment [1]. Experts in many dissimilar fields have seen the utility of GIS as a means of quantifying and expanding their research. GIS is used in disciplines such as business, sociology, justice studies, surveying and the environmental sciences. In the North Carolina GIS community, GIS is used to represent transportation routes, elevation, delineate land ownership parcels, school attendance, highlight patterns of crime and help make zoning decisions. The manner in which geospatial data is captured varies. Some methods include using a Global Positioning System (GPS) unit, extracting or improving existing GIS data, downloading data from a web site, connecting to a service, the use of an Unmanned Aerial Vehicle (UAV) or some other remote sensing platform, or creating data from an analog format via digitization or georectification. Regardless of the method, the resources (e.g., the computers, time and people dedicated to the process of collecting and creating geospatial data) are the most time-consuming portion of a GIS-related project [2]. As a result, the GIS community needs to ensure the quality of geospatial data created from these methods is captured, stored and assessed in a systematic way.

Geospatial metadata serves as the formal framework to catalog descriptive, administrative and structural information about geospatial data. Geospatial metadata is inherently different from other forms of electronic metadata because each metadata file can be applied a spatial component that is not implicit with other forms of metadata. These spatial components encompass a wide array of information to include the date, methods and sources by which geospatial information was captured, means to ensure that the geospatial information adheres to acceptable standards and/or aligns with other geospatial datasets to ensure seamless analysis, projection information of the dataset and bounding coordinates of the dataset. All of these entries, in addition to the data's non-spatial components can be queried within the confines of geospatial data portal such as one found at North Carolina OneMap, the geospatial data portal for the state of North Carolina [3].

Given the capricious rate at which all forms of geoinformation can be created, formal metadata (i.e. metadata stored using a widely-recognized and agreed-upon format) serves as a lifeline between the tacit knowledge of the data creator and current and future generations of geospatial data consumers. In the United States, the Federal Geographic Data Committee (FGDC) metadata standard, commonly referred to as the Content Standard for Digital Geospatial Metadata (CSDGM) allows for more than 400 individual metadata elements. The North Carolina GIS community has been proactive about understanding the importance of metadata.

Maintaining a complete and comprehensive metadata record is a continual and interactive process. GIS metadata is one of the most overlooked and underappreciated aspects of any GIS enterprise or project. If time or resources need to be sacrificed in the course of a project, it is usually at the expense of metadata. Information is key to an organization's vitality, sustainability and success. Metadata should be treated as an investment. Maps and analysis are only as good as the data on which they are based. Metadata is a direct reflection of this investment and the organization which makes this investment. Metadata captures important information related to data creators, data quality and the various accuracies (horizontal, vertical, temporal, attribute, semantic, etc.) with which we can quantitatively measure GIS data. These measurements help guide the decision-making process, especially in larger (hundreds of layers) spatial databases. Not only is good metadata a wise business practice, but saves time, money and resources in the long run. Unfortunately, metadata's true value is not realized until it is absent, and few studies have been done to place a direct monetary value on metadata.

Under the supervision of the North Carolina Geographic Information Coordinating Council (NCGICC) and Statewide Mapping Advisory Committee (SMAC), a committee was tasked to develop a State and Local Government Metadata profile for geospatial data intended for use in North Carolina as well as educating the North Carolina GIS user community about this standard. This standard is based on the International Standards Organization (ISO) 191** format and is an improvement over prior metadata standards to account for evolving technologies such as remotely sensed imagery, online services and ontologies. These were not considered when original metadata standards such as the CSDGM (formally known as *FGDC-STD-001-1998)* were first published.

At this time, assessing and evaluating adherence to this standard for large spatial databases is an exhaustive process, as users must toggle through multiple levels of metadata records among multiple features a using a metadata editor. In this day and age, it is ''unrealistic to depend on traditional humanly generated metadata approaches'' when attempting to assess metadata integrity [4]. However, a happy medium must be found between quality assurance, quality control and the necessary human component involved in this process that cannot be replicated in the digital environment. While some research [5] subscribes to the mechanization of metadata assessment processes as the most effective and efficient, other research [6] [7] concedes that metadata is best managed through the integration of the human and digital components. While the level of human interaction in this process should be minimal, it should not be eliminated altogether. On that end, the goal of this paper is to propose a programmatic and faster assessment and evaluation alternative within the context of statewide metadata training that can be used by GIS management to facilitate decision-making. In doing so, it addresses and reinforces how programmatic metadata assessment and evaluation has begun to be implemented by the professional community.

The rest of this paper is organized as follows. Section II describes the evolution of metadata. Section III describes the specific use and application of the North Carolina State metadata profile. Section IV addresses the how standard compliance is addressed. Section V discussed preliminary results. The acknowledgement and conclusions close the article.

II. THE EVOLUTION OF METADATA SCIENCE AND ASSESSMENT

Metadata serves as an organized means to describe a dataset, and it provides the formal framework for providing information about a dataset's lineage, age and creators. Metadata is composed of both qualitative and quantitative information and while metadata's original use was simply as a means to catalog data, its storage and assessment has become a science in itself.

The FGDC regularly meets to determine all possible values, parameters and domains that can be captured and expressed within the confines of GIS metadata. First formed in the early 1990s, the FGDC serves as a governing body for geospatial data and metadata in the United States. The FGDC defines metadata as the following:

> A metadata record is a file of information, usually presented as an XML document, which captures the basic characteristics of a data or information resource. It represents the who, what, when, where, why and how of the resource. Geospatial metadata are used to document geographic digital resources such as Geographic Information System (GIS) files, geospatial databases, and earth imagery. A geospatial metadata record includes core library catalog elements such as Title, Abstract, and Publication Data; geographic elements such as Geographic Extent and Projection Information; and database elements such as Attribute Label Definitions and Attribute Domain Values [8].

FGDC metadata standards dictate that a plethora of individual entries (now more than 400 and counting) are populated for compliant GIS metadata [8]. Thus, ensuring metadata integrity for large spatial data sets is a time-consuming process if done by hand. It is not uncommon for organizations to employ thousands of individual data layers within their digital warehouses. Since traditional GIS data are ever-evolving, metadata standards must be flexible enough to account for new technologies. Policy should dictate that these standards be revisited periodically to ensure adaptability that can be implemented through large-scale changes or the publishing of new metadata standards. The GIS community has employed a set of content standards to ensure compatibility across the entire GIS community. The updated State and Local Government Metadata profile developed by the NCGICC based on the ISO 191** discussed in this paper highlights this adaptability and is an example of one of these standards.

While regarded as a relatively new concept, both formal spatial and non-spatial metadata has existed in one form or another for the past 50 years. *MARC* (Machine Readable Cataloging) and its successor *MARC 21* are used by the Library of Congress to catalog bibliographic resources. This system has been in place since the 1960s, but it was not originally designed for computer interfacing, and the format is not very intuitive [9]. A more popular format called the *Dublin Core* was created in 1995 for electronic recourses such as web pages and software applications. While the FGDC and GIS metadata standards described here actually predate this more generalized format, GIS metadata data contains a variety of geographically-explicit descriptors that may not be fully understood by the non-GIS community [10].

Dublin Core and FGDC generally share a base level of descriptive metadata elements. While Dublin Core is used to describe electronic resources and digital representations of physical resources such as artwork, GIS metadata adheres to FGDC and more recently ISO standards. These requirements are always changing as dictated by technology. Because of the spatial nature of GIS data, FGDC requirements dictate that information pertaining to absolute location be retained. These fields include datum, coordinate system, false easting, false northing and bounding coordinates. While Dublin Core does make accommodations for place keywords and spatial descriptors, it does not contain placeholders for elements that help describe geodetic elements associated with the quantitative representation of location with as much detail as GIS metadata.

Because of the different goals of each standard, a precipitous balance between MARC, Dublin Core and FGDC Metadata must be found. Cross-walking, a tedious and sometimes imprecise process where either people or algorithms find matching elements between the different standards may be necessary because various organizations use these popular formats interchangeably on a routine basis. Cross-walking methods have been used to match geospatial data to standards outside of FGDC, such as examining the feasibility of compatibility with the Dublin Core metadata standard [11][12].

Current research in the field of metadata can be closely associated with statistics and high-speed processing. Given the exponential increase in electronic resources and media, technologies must be able to accommodate the automation of resources that are viewed, accessed, and assessed. Research examined the role of metadata and its ability to be assessed, arguing that metadata for metadata's sake does no good [13]. Metadata must have some utility as it needs to be assessed and have a role within the decision-making process. Metadata must ultimately serve a purpose and specifically the greater good of the user community. While other research proposes a quality assessment for metadata, it fails to do so with regards to changes in metadata quality, their accompanying values and the holistic structure used to store them [14]. With the standardization of XML-based FGDC and ISO metadata standards, metadata can be compared from one time period to the next. One of these structures is through ontology, a semantic representation of a concept through various domains and properties. Most recently, e-learning technologies were applied to these ontological metadata structures [15]. However, the lack of human cognition within these ontologies cannot eliminate unnecessary or ambiguous terms using results from previous analysis, sometimes referred to as semantic accuracy within the confines of GIS Quality Assessment/Quality Control (QA/QC) circles.

The role of metadata assessment can be seen in a variety of different fields. An Electronic Metadata Record (EMR), for example, is an emerging technology that is produced and edited when an electronic document is edited or created, such as a patient record or digital x-ray. A number of other related technologies for the medical industry have been developed to serve as a quality assurance and administrative tools. The process of accessing, viewing, and commenting on patient files or x-rays by physicians in electronic form can be documented and stored in a metadata file. Hardcopy records are often times time-consuming to complete, and they can be easily lost or destroyed. Thus, the ease of storing, accessing, and retrieving electronic metadata and files for medical data can help prevent litigation against malpractice lawsuits [16]. For example, a complex statistical analysis was developed to retrieve biomedical articles from more than 4,800 journals to help support the decision-making process [17]. It is impossible to scrutinize each of 14 million individual manuscripts. Clustering and classification methods performed on metadata derived from traditional statistical techniques are used to explore and retrieve related information within biomedical literature. If properly maintained, metadata serves as a capable surrogate when querying scanned imagery or hard copy information is not feasible and further validates in-situ decisions as they are reinforced by easily accessible support literature.

Metadata has the flexibility to capture many forms of qualitative and quantitative information stored as numbers, text strings, domain values and dates. However, it does have its drawbacks. In addition to the time, resources and expertise required to populate the information, ancillary concerns exist. Metadata can be applied to any electronic resource, but there are data privacy concerns, especially within the medical community. For example, metadata can be updated and collected to determine the number of times a medical professional has viewed patients' information within the EMR [16]. Not only does this address privacy concerns by documenting access to particular records, but serves to report when, by whom and how long a digital record was viewed. In addition, EMR should not serve as an end-all diagnostic tool, especially when clinical data do exist. Metadata should aid in the evaluation and decision-making process. Other research used image sharing community to further reinforce this point and brought up more excellent points [18]. Metadata for an image (date of image, place, context, etc.) is collected and stored with the image. Furthermore, social metadata not only explores information about the image itself within its place in the social media environment, but also tangential information related to an image such as comments about the image, information about people who have posted comments about the image and the user groups to which these commenters belong [19]. Limiting this information greatly reduces the amount of analysis that can be performed on the accompanying image, decreasing the availability to knowledge in order to make sound business decisions. As this applies to GIS metadata, a happy medium must be found so privacy concerns can be satisfied while dutiful analysis can be performed. Given the relative infancy of these subjects and lack of established doctrine, the body of knowledge is still growing in this subject.

The very nature of spatial data dictates that a different approach must be taken for assessment and reporting within the digital environment. The proliferation of spatial technologies underscores the widely accepted and legitimate role of metadata within the GIS user community [20]. All elements intrinsic to spatial data, such as those associated with position (e.g. latitude, longitude) as well as its representation (e.g., accuracy) must be carefully documented and recorded in GIS metadata. It is important that information about the data format, a description of the data, the processes by which the data were created, the areal extent of the data and the people who aided in data creation be retained. Formal controls may dictate specific tolerances for horizontal and temporal accuracy. This information is not only important from a legal standpoint, but it also validates GIS analysis by speaking directly to such necessary components as its horizontal and temporal accuracy. Since GIS analysis is only as good as the data on which it is based, metadata reinforces the data and ultimately the analysis and organizations which develop the GIS data.

As mentioned previously, metadata is important in helping to document dimensions of quantifiable GIS data quality such as attribute accuracy, horizontal accuracy and attribute completeness. Other forms of GIS data accuracy do in fact exist. FGDC and spatial data transfer standards (SDTS) also consider vertical accuracy (error in measured vs. represented elevation), data lineage (source materials of data) and logical consistency (compliance of qualitative relationships inherent in the data structure) as part of data quality [21][22]. In some GIS circles, temporal accuracy (age of the data compared to usage date) and semantic accuracy or "the quality with which geographical objects are described in accordance with the selected model" are also considered elements of data quality [23]. Placeholders within FGDC metadata exist to capture all of this information either quantitatively or qualitatively.

Early pioneers of GIS recognized the importance of data quality, not only from a cost efficiency standpoint, but because of the legal ramifications in publishing incorrect spatial information which may lead to accidents or the misuse of data [24]. Even then, they understood the reconciliation between accuracy, the cost of creating accurate data and the eventuality that some error will occur. It is unreasonable to expect an organization such as the North Carolina Department of Transportation (NCDOT) to photo-revise and field check every single road in their GIS database, re-attribute it correctly and then verify them using another party in a timely manner given current personnel and financial constraints. This compromise is referred to as *uncertainty absorption* [25]. Regardless of resource allocation, verification of data quality should be done by discipline experts with a long-term goal of developing data quality standards. This helps to protect the GIS data producer from the potential misuse of GIS data and metadata serves as the means to formally inform the data user of data quality measures applied to data, as well as protect GIS data stewards from its mismanagement [26].

In and of itself, data quality has no inherent value or worth, but is ultimately realized when action is taken on information pertaining to data quality [27]. Along those same lines, the end goal of information quality is to satisfy customer needs, in this case being the many users who utilize GIS data with the understanding that the data have undergone some form of validation [28]. Quantitative measures related to this validation with qualitative processes needs to be highlighted in metadata.

Early research and commentary on the concept of geospatial metadata has touted its value as an effective decision-support tool, regardless of its native format [29]. These formats include Hyper Text Markup Language (HTML), Extensible Markup Language (XML) along with its various ISO standards (19115, 19115-1, 19139), TXT (Text File), Geography Markup Language (GML) and Standard Generalized Markup Language (SGML), as well as proprietary formats. Methodology has explored the ability to integrate spatial metadata to a stand-alone database long before GIS metadata was stored in a standardized format, as well as compiling statistics about metadata elements within the confines of specific software [30] [31].

To that end, the population of geospatial metadata is a monotonous process and subject to error, although research has explored the large-scale production of standards-based metadata in order to alleviate these issues [32] [33]. Because of this, research maintains that human nature alone undermines the immediate and long-term goals of metadata for an organization and the GIS user community [34]. While the omission of one minor element would not degrade a layer's metadata or invalidate the geospatial data on which it is based, it may compromise quantitative data quality measures captured from which decisions can be made. More recently, feature level metadata has been able to capture data quality information, but is typically limited to quantitative measures of positional accuracy and qualitative information related to data lineage within eight of the more than 400 entries that comprise a complete FGDC-compliant metadata file [35] [36]. Even now, the population of these metadata elements is not fully automated and some entries must be done by a GIS data steward. However, methodologies to explore its assessment and evaluation are evolving. Efforts have been made to quantitively assess metadata quality using both a human and statistically-automated element [37] and this paper explores this notion within the confines of and applied to a particular standard.

III. THE NORTH CAROLINA STATE AND LOCAL GOVERNMENT PROFILE

Geospatial metadata standards serve as a cohesive and standardized means by which organizations can define, store and more importantly share information about geospatial data. It defines the categories of information that needs to be stored, individual entries, or tags, of individual elements within these categories and the types of data (text, date, number) and their lengths that can be stored while representing these tags. FGDC metadata is divided into 7 sections or divisions that transcend descriptive, administrative and structural components. They are: Identification Information, Data Quality Information, Spatial Data Organization Information, Spatial Reference Information, Entity and Attribute Information, Distribution Information, and Metadata Reference Information [38].

Within these high-level divisions, subdivisions and eventually individual metadata tags can be populated to catalog various forms of information about the GIS data layer. The hierarchy of these divisions and subdivisions are consistent with a standard. In addition to providing this structure, the FGDC also creates guidelines by dictating which metadata elements are to be populated. The FGDC requires seven metadata elements be populated for all GIS data. The FGDC also suggests that fifteen metadata elements be populated. These suggested and required elements are included in Table I below.

TABLE I: REQUIRED AND SUGGESTED FGDC ELEMENTS.

FGDC -Required Elements	***FGDC- Suggested Elements***	
Title Reference Date Language Topic Category Abstract Point of Contact Metadata Date	• Dataset Responsible Party • Geography Locations by Coordinates (X) • Geography Locations by Coordinates (Y) • Data Character Set • Spatial Resolution • Distribution Format • Spatial Representation Type • Reference System	• Metadata Character Set • Lineage Statement • Online Resource • Metadata File Identifier • Metadata Standard Name • Metadata Standard Version • Metadata Language

Organizations actively create content standards for new technologies and manners in which geospatial data are collected and stored. One such example is the FGDC content standard for Remotely Sensed Data. This includes two divisions germane to the equipment and methods such as platform name, sensor information and algorithm information used to capture the imagery, in addition to the seven existing aforementioned divisions [39]. In order to further elucidate descriptive, administration and structural information, additional addendums to existing metadata standards are also attached to specific geospatial-specific data such as addresses, biological data, shoreline data, and vegetation data. Standards such as these must be increasingly flexible and updatable to account for the evolving technologies in which geospatial data can now be captured (crowdsourcing, Unmanned Aerial Vehicle, large scale geocoding), processed (new geostatistical and interpolation algorithms) and ultimately delivered (web map service, web feature service) to the GIS user community.

In recent years, the North Carolina SMAC has recognized most GIS data managers lack the time and resources necessary to learn and apply a metadata standard that maintains dataset integrity and retains pertinent information while not being too demanding on existing resources, most notably time and people. To address the problem of missing or incomplete metadata records among state and local data publishers, the SMAC chartered an ad-hoc Metadata Committee in October 2012 to "recommend ways to expand and improve geospatial metadata in North Carolina that are efficient for the data producer and benefit data users in the discovery and application of geospatial data." The Metadata Committee submitted a draft of this profile, based on the ISO 19115 (for Geographic Information – Metadata: 2003), ISO 19115-1 (for Geographic Information – Metadata – Part 1: Fundamentals: 2014) and ISO 19119 (Geographic Information – Services: 2016) standards. After review and modification by SMAC and its standing committees, the most current version of this standard has been in effect since December 30, 2016 and is available through the NCOneMap portal [40]. While not entirely ground-breaking, North Carolina has been a forerunner in developing sub-country metadata standards. The SMAC worked with the Canadian Province of Alberta, who has already developed a standard germane to their province while states such as Missouri and Virginia have developed some level of uniform metadata available with their products. Internationally, GeoDCAT-AP is a metadata profile designed to facilitate interchange for data portals operated by EU Member States. It uses the aforementioned ISO 19115 format and the INSPIRE metadata standard, which is primarily used in Europe [41].

Given seven required and fifteen recommended metadata elements are fairly ambiguous and less than ideal for many organizations whose data is integrated into the NCOneMap, the North Carolina state geospatial data portal, this profile provides explicit guidance on required/suggested metadata elements, wording for these elements, standardization of naming/date conventions and domain fields for topic categories for more than 75 metadata tags [42]. A few examples of the rules for geospatial metadata include:

1. Title is required as a free-text entry.
2. Publication Date is required and the format for Publication Date is YYYY-MM-DD or YYYYMMDD. If day is not known, use YYYY-MM and use YYYY if month is not known.
3. Abstract is required as a free text entry. Do not use YYYYMM since it can't be distinguished from the incorrect, but still used YYMMDD.
4. Status is required and only possible values are 'historicalArchive', 'required', 'planned', 'onGoing' 'completed', 'underDevelopment' and 'obsolete'.
5. Topic Category is required and can be one of 23 possible values from domain table.
6. Use Constraints required as a free-text entry to describe any restrictions with using the data.

7. Online linkage is required to an URL address that provides access, preferably direct access, to the data.

In addition, given their nature and distinct differences between their geospatial data counterparts, the SMAC has defined rules for geospatial services to include the following:

1. Metadata Scope code must be ‘service’.
2. Online Function code is required from domain of one of five possible values.
3. Title is required as a free-text entry.
4. Metadata Contact is required as a free-text entry, representing Organization Name of the agency that serves as a point of contact for the metadata record.

This richer metadata enables content consistency and improves the search and discovery of data through NCOneMap.

As part of a needs assessment for this project, a survey was developed to help dictate and direct metadata needs within the state of North Carolina. This survey was developed in 2017 and distributed to the North Carolina GIS user community. Forty (40) respondents answered the survey, who ranged from GIS Technicians and Property Mappers to GIS Coordinators and Managers throughout the state of North Carolina. Questions were asked about respondents’ experience with data development, metadata, as well as organizational requirements as it pertains to metadata.

Most prominent was the schism between respondents’ experience with data development and experience with metadata, as shown in Figures 1 and 2. Respondents generally had an ‘excellent working knowledge’ of data development, but only ‘some experience’ or ‘working knowledge’ on the metadata created as a result of these data development techniques. These underscore technical experience in creating new data in support of analysis and projects, but less experience in cataloging these same data used for analysis and maps.

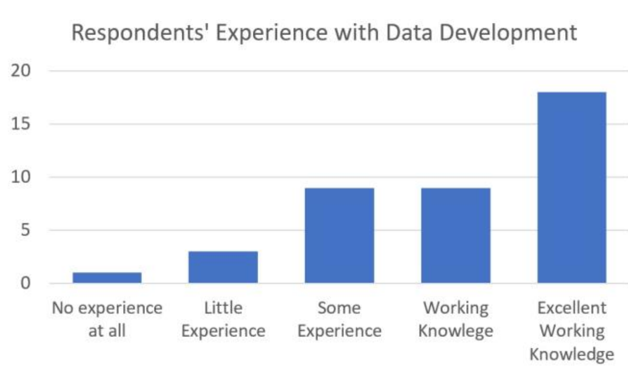


Figure 1: A survey of GIS professionals and experience with data development.

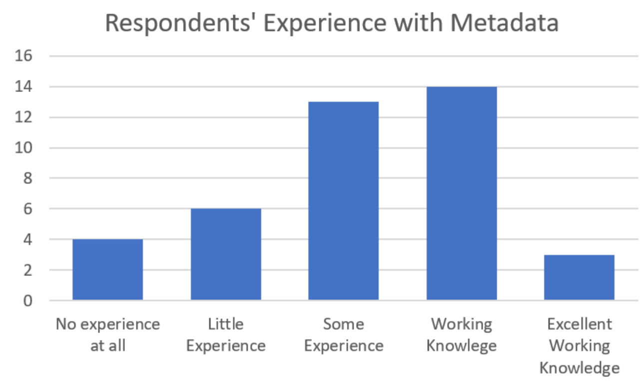


Figure 2: A survey of GIS professionals and experience with metadata.

Not only is this schism evidenced at the individual level, but also at the organizational level. In a same survey of these 40 GIS professionals, they describe their organization’s approach to metadata as shown in Figure 3. More than half of all respondents’ organizations have no metadata requirement whatsoever and only five respondents work in an organization that has a firm metadata requirement. The rest do have a metadata requirement, but it is not upheld.

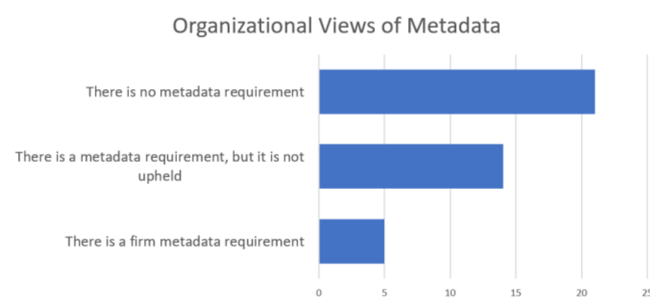


Figure 3: A survey of metadata requirements at the organization level.

In response to this need and the motivation for this paper, the research team earned a research and education grant through the NCDOT and NCGICC to provide metadata training, education and support to the state of North Carolina. The goal of the “Facilitating the New Statewide GIS Metadata Standards Through Training and Outreach” grant ran from August 2016 through March, 2019. The goals of this project include:

1. Assessing the existing knowledge base of GIS users on the subject of GIS metadata through surveys given to training attendees.
2. Technical and material support to the implementation and education of the new metadata profile to the North Carolina GIS user community.
3. Understanding needs of GIS data managers when it comes to metadata population and requirements for data under their purview through surveys given to GIS data managers.
4. Determining best methods to deliver metadata training to the North Carolina GIS user community that close gaps

between existing knowledge base and needs of GIS data managers and the larger NC GIS community.

5. Assessment and evaluation of training activities to determine best practices for future training and future support through post-training quantitative and qualitative surveys.

This grant has provided support to the North Carolina GIS user community through an assessment and evaluation of current metadata activities by the North Carolina GIS user community, work on the North Carolina State and Local Government Metadata Profile, development of online and face-to-face training materials and data in response to this evaluation, and the delivery of face-to-face and virtual training to the North Carolina GIS user community. This grant has provided the opportunity for North Carolina Central University (NCCU) students to develop metadata skills and interface with members of the North Carolina GIS user community in this niche and unique training opportunity relatively unique to this state. As such, specific measurable research tasks over the life of the project include:

1. Curriculum Review and QA/QC
2. Material and Training Support
3. Data Development
4. Facilitation of Online Resources
5. Development and Assessment of Metadata Templates
6. Development of Metadata Scripts
7. Report of Training Activities
8. Outreach to Educational Institutions and Professional Organizations

In support of many of these tasks, face-to-face training was provided on the campus of North Carolina Central University (Figure 4), as well as online.

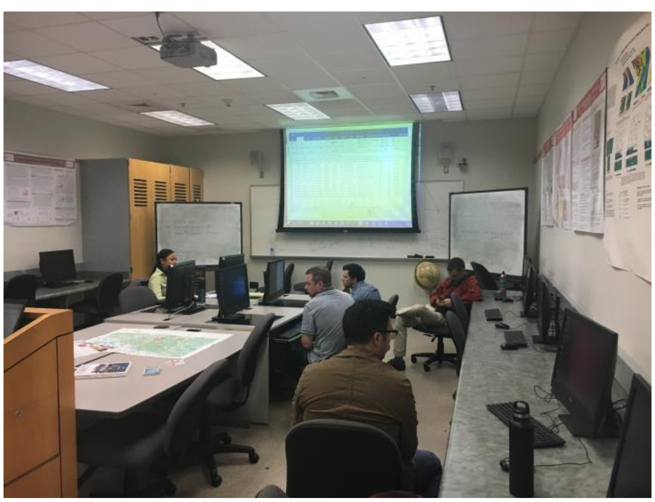


Figure 4: Face-to-face metadata training given at North Carolina Central University in 2018.

The Department of Environmental, Earth and Geospatial Sciences (DEEGS) at NCCU hosts YouTube tutorials ranging from metadata basics and the use and application of the North Carolina State and Local Government Profile to more advanced topics such as XML translators and Python programming solutions in metadata assessment and evaluation [43]. These tutorials have been utilized more than 3,500 times.

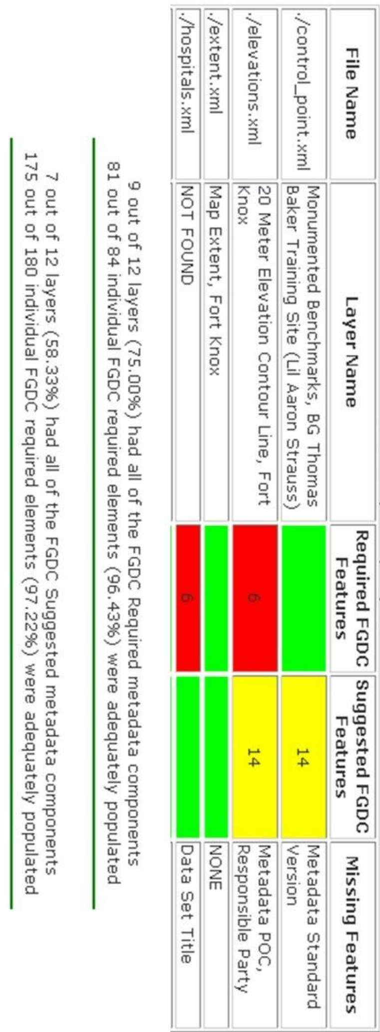
IV. ASSESSING STANDARD COMPLIANCE

Given the ever-increasing size of GIS data sets and the metadata requirements for each data layer, there needs to be a mechanism to assess the quality of these metadata not seen in previous generations or documented in existing literature. There also needs to be a means by which individual metadata entries adhere to predefined profiles and standards. This is in support of Task 6 of the research tasks. Computer programming languages and templates have helped to streamline this process. Templates populate redundant features that are common throughout an entire GIS database such as the purpose, supplementary information, distribution liability statements and ordering instructions that can be specific to an agency or department. These templates can be imported one at a time, but programming techniques and software packages have allowed users to assess information that would take a human days or perhaps weeks to do. The NCGICC provides a number of templates through their web portal, NCOneMap [44]. The themes for these templates are at the request of North Carolina GIS users, and include buildings, cadastre, municipal boundaries, school attendance districts, street centerlines, address points and orthoimagery. These templates contain much of the verbiage about a layer's description and creation processes, and can be easily imported and edited specific to the user's contact information. A sample of the identification information for the cadastral data template can be seen in Figure 5.

```
  Description:
    Abstract: Digital cadastral data describing the parcel dataset of ZZZZZ County,
North Carolina.  This dataset includes attributes such as parcel boundaries,
ownership, acreage, source references, assessments, and other core cadastral
attributes.
    Purpose: This dataset was generated to publish a geospatial inventory of real
property in ZZZZZ County, NC.  It serves to support and assist governmental agencies
and others in resource management decisions. Additionally, these data provide a set
of core attributes defined by North Carolina Content Elements for Statewide
Publication of Core Geospatial Parcel Data and is used to facilitate the sharing,
display, and use of cadastral data across the state.  The core data are intended to
integrate local parcel information on a statewide level and eventually build a
seamless parcel map for North Carolina.
    Supplemental_Information: This dataset is prepared for the inventory of real
property found within this jurisdiction and is compiled from recorded deeds, plats,
and other public records and data.  Assessed value of real property is based on
market value as defined in the Machinery Act of North Carolina (Section 105-283). The
latest assessment was completed in 88888.  Users of this dataset are hereby notified
that the aforementioned public primary information sources should be consulted for
variation of the information contained in thes data.  ZZZZZ County assumes no legal
responsibility for the information contained in these data.
  Time_Period_of_Content:
    Time_Period_Information:
      Single_Date/Time:
        Calendar_Date: 20051207
```

Figure 5. Identification information metadata entries for cadastral template provided through NCOneMap web portal.

Open source programming solutions using Perl and R have been used to assess and evaluate metadata by traversing geospatial metadata stored in XML format as per FGDC requirements, resulting in quantitative metrics, graphs and reports regarding metadata compliance, as shown in Figure 6 [45].



FGDC Compliancy Report

File Name	Layer Name	Required FGDC Features	Suggested FGDC Features	Missing Features
./control_point.xml	Monumented Benchmarks, BG Thomas Baker Training Site (Lil Aaron Strauss)		14	Metadata Standard Version
./elevations.xml	20 Meter Elevation Contour Line, Fort Knox	6	14	Metadata POC, Responsible Party
./extent.xml	Map Extent, Fort Knox			NONE
./hospitals.xml	NOT FOUND	6		Data Set Title

9 out of 12 layers (75.00%) had all of the FGDC Required metadata components
81 out of 84 individual FGDC required elements (96.43%) were adequately populated

7 out of 12 layers (58.33%) had all of the FGDC Suggested metadata components
175 out of 180 individual FGDC required elements (97.22%) were adequately populated

Figure 6: Sample of Metadata Compliance Report Generated Using Open Source Assessment Tool.

As applied to the NC State and Local Government Profile, one major challenge exists. Primarily, geospatial data and metadata is typically software specific. While optimal open source solutions could be used to gleam information from metadata stored in XML using an appropriate xPath, these software-agnostic solutions are typically loosely-coupled and not intuitive to the average user. As a result of reliance on Esri products throughout the state, the Python programming language is being used to run this iteration of an assessment and evaluation tool before open source solutions are explored.

Using the NC State and Local Government Profile as a guideline, the research team has been developing tools for data managers to access and evaluate metadata entries. At the current time, metadata entries are written to CSV (Comma Separated Values) files. While doing this, string operations are run to ensure that required entries are populated, date entries comply with required conventions and domain entries match those in the domain table, all while agglomerating results and statistics at the database, layer (record) and tag (attribute) level. This can provide GIS managers with insight on non-compliant metadata entries to determine relationships between non-compliant entries and the responsible data steward or particular attributes that are continually non-compliant.

While QC procedures need to be performed to determine if a metadata entry is accurate, below are a few examples of the many programming rules employed to determine if entries are populated properly.

1. *Title*, *Responsible Party Organization Name*, *Online Linkage*, *Abstract*, *Use Constraints*, *Feature Catalogues*, *Process Description*, *Spatial Reference Information* and *Metadata Contact Name* cannot be Null
2. *Data Type* can only have values of 'creation', 'publication', or 'revision'.
3. *Publication Date*, *Temporal Extent of Data* and *Metadata Creation Date* must follow appropriate format. This entails:
   a. The date cannot be Null and must be populated.
   b. The date can only have a length of 10 (YYYY-MM-DD) 8 (YYYYMMDD), 7 (YYYY-MM) or 4 characters (YYYY).
   c. Besides the hyphens ('-'), the date can only contain numbers whose value range from 0 through 9. Letters and other characters are not allowed.
   d. If a date contains hyphens ('-'), there will be 2 hyphens in a string that has a length of 10 (YYYY-MM-YY) and there will be 1 hyphen in a string that has a length of 7 (YYYY-MM).
   e. Regardless of the format used, the first character of a string will either be '1' or '2' since the year of publication or creation will begin in only those 2 numbers.
4. *Metadata Contact Role Code* can only have values of 'custodian' or 'pointOfContact'.
5. *Progress Code* can only have values of 'completed'. 'historicalArchive', 'obslete', 'onGoing', 'planned', 'required' or 'underDevelopment'.
6. *Maintenance and Update Frequency* can only have values of 'continual', 'daily', 'weekly', 'fortnightly', 'monthly', 'quarterly', ' biannually', 'annually', 'asNeeded', 'irregular', 'notPlanned' or 'unknown'.

The current application has a basic GUI (Figure 7) that allows for 4 input parameters: 1) an input database that contains the features classes for which metadata will be checked 2) an output folder to which XML metadata is written. Python cannot directly access metadata in geodatabase format, so this proprietary metadata is converted to XML format and traversed. Options exist so these XML files are immediately deleted. 3) The name and location of the output entries that store all metadata entries that are checked from the North Carolina State and Local Government Profile, as well as a summary of the percentage of individual metadata elements that are correct and a summary of percentage of correct elements on a feature class by feature class basis and 4) the location of an error file that highlights errors within the metadata (Figure 8).

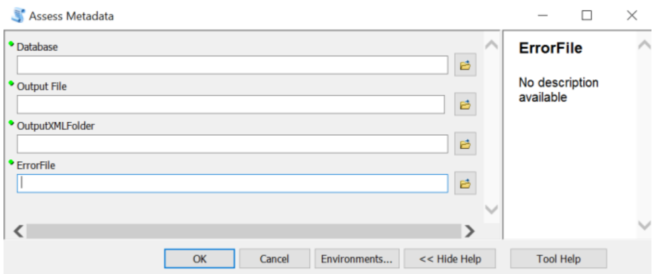


Figure 7: Metadata Assessment and Evaluation Tool.

spot_elevation_point:

The Title is: spot_elevation_point
THE PUBLICATION DATE IS MISSING
THE RESPONSIBLE PARTY IS MISSING
THE ONLINE LINKAGE IS MISSING
The Abstract is PRESENT
THE PROGRESS CODE IS MISSING
THE UPDATE FREQUENCY IS MISSING
The Theme Keyword Does Not Match The ISO Topic Categories Criteria -> landform
The Use Constraints are PRESENT
The Topic Category is PRESENT
The West Extent is PRESENT
The East Extent is PRESENT
The North Extent is PRESENT
The South Extent is PRESENT
THE BEGINNING DATE FOR THE TEMPORAL EXTENT IS MISSING
THE ENDING DATE FOR THE TEMPORAL EXTENT IS MISSING
THE FEATURE CATALOGUE IS MISSING
THE PROCESS DESCRIPTION IS MISSING
The Spatial Reference is: WGS 1984 UTM Zone 17N
The Metadata Creation Date Starts with '2', 21st Century
The Metadata Creation Date Has FULL Date Listed!
THE METADATA CONTACT NAME IS MISSING
The Purpose is PRESENT
THE POINT OF CONTACT IS MISSING

Figure 8: Sample Error File Output from Metadata Assessment and Evaluation.

V. RESULTS

The Technology Acceptance Model (TAM) was used to assess and quantify the effectiveness of the metadata assessment tool. The TAM that we know of today was originally created as a means to universally quantify the effectiveness of technology by exploring relationships between the technology's Perceived Ease of Use, Perceived Usefulness, Attitude Towards Using and the Intention to Further Use the technology [46]. Using Chronbach's Alpha, Principal Components Analysis and Simple Linear Regression, associations can be found between these various components, as shown in Figure 9.

Given that the intended usership of this research is geared towards GIS professionals as opposed to developers or programmers, a testing mechanism geared toward this group would be more appropriate than testing code efficiency or complexity. The TAM has served as a means to assess and quantify the effectiveness of a technology for more than 35 years and will do so once again for this research. The TAM was originally created as a means to universally quantify the effectiveness of technology [46]. It was born from the fact that the adoption of new technologies is dependent upon ambiguous and sometimes qualitative notions such as psychological disposition, attitudes, intentions and our own personal biases related to this new technology that make it difficult to test and validate [47]. TAM is actually the technical manifestation of the Theory of Reasoned Action (TRA) [48]. TRA is the theory in which beliefs, composed of attitudes, values and opinions at the individual level, eventually result in enacted behavior. Within the TAM, this enacted behavior is the decision to adopt technology.

Empirical studies on the use and application of TAM find that a technology's acceptance is most related to its 1) Perceived Usefulness and 2) Perceived Ease of Use. Perceived Usefulness refers to the quality in which a technology would help one's job performance. While research [49] [50] [51] has explored this usefulness dimension, TAM also looks at this in concert with this technology's "freedom from difficulty or great effort" [45]. This ease of use factor helps support the self-efficacy theory which focuses on one's innate ability to accomplish goals [52]. While there are differences between the roots of this effectiveness and seminal outcomes which at times can be paradoxical, TAM encapsulates this within one encompassing desired end-state of ultimately accomplishing one's tasks with as little effort as possible. Studies have actually shown the relationship between this Perceived Usefulness and Ease of Use with the adoption of technology is regardless of variables such as gender and computer experience [53].

Using these two indicators as a guideline, Davis creates questions that try to explain the usage and acceptance patterns of a technology as per TRA. Users of the technology are asked to scale responses to these questions similar on a 7-point Likert-type scale, representing "Strongly Agree" through "Strongly Disagree". Regression analysis between this effectiveness and ease of use variables is determined at various confidence intervals. In addition, principal components analysis is used to explain the variance of usage intentions as a function of Perceived Usefulness and this attitude towards the technology. This and other hypotheses related to Perceived Usefulness, Perceived Ease of Use, Attitude Towards Using the technology and behavioral intention of use are tested among each other [54].

TAM represents a milestone towards understanding human behavior as applied to the technology realm. Germane to this research, TAM has been applied to e-learning [54] as well as its place in the e-commerce environment as TAM integrates technology and human behavior when applied to online shopping [55]. Visiting an online store for the first time has overwhelming consequences on whether the visitor will visit again or make unplanned purchases. Making this online shopping experience an easy, enjoyable and memorable one is of utmost concern to these businesses. The order in which material is presented, the amount of material presented and the user's cognitive impression of this material, its volume and its underlying messages play into this perceived enjoyment factor. Finally, all of these facets need to be assessed in a manner free of bias, confusion, misconception and misunderstanding.

The validity of these assessment tools was tested using a TAM. Responses from GIS professionals regarding the results of this methodology were captured to find a relationship between this technology's Perceived Ease of Use, Perceived Usefulness, Attitude Towards Using and the Intention to Further use this technology.

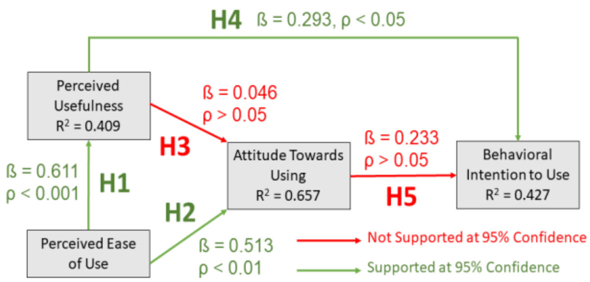


Figure 9: Regression Used to Test Research Hypotheses where TAM was Tested Against Null Hypotheses to Test Correlations.

The results from TAM analysis (Figure 9) show 3 out of the 5 research hypotheses (H1, H2 and H4) relating the tool's Perceived Ease of Use, Perceived Usefulness, Attitude Towards Using and Intention to Use were accepted at a 95% confidence interval. Another (H5) could be accepted at about a 70% confidence interval. In one non-supported hypothesis (H3), it seemed that the strong responses from the Perceived Ease of Use component obfuscated the Perceived Usefulness component. As a result, the Perceived Usefulness did not have much of an effect on the linear regression model used to support the hypothesis. In the other model (H5), the dependent variable is the Intention to Use component using the Attitude Towards Using component as the independent variable. The two components delve into the question of implementing these assessment tools onto their individual system and have elicited a wide array of responses from respondents due to technical experience and familiarity or understanding with the programming environment, which is essentially an extension to the typical GIS system and typically requires training above and beyond that of a GIS Technician or Junior Analyst. While the efficacy for these programming solutions exists, the efficiency may not reciprocate for this reason. Nonetheless, these are difficult to model. Even modeled by themselves without the Perceived Usefulness component, a linear regression model between these two factors (Attitude Towards Using MART vs. Intention to Use) only produces an R^2 value of .118. Other factors – either those not captured within the assessment or just unquantifiable by their very nature factor into the non-support of this hypothesis. For example, GIS Technicians working on few GIS data layers have little to no need for metadata assessment and therefore no intention to further use it. When enough GIS Managers have completed the assessment on which TAM is based, it will be run once again on this new tool to assess its effectiveness for a more germane usership. Regardless, these results help satisfy the theoretical impetus of this research and are both intriguing and promising for the future of GIS metadata and widening role as an effective tool to elicit action.

VI. DISCUSSION

While a powerful and efficient tool, the programmatic assessment and evaluation of geospatial metadata still cannot altogether replace the human component. While these technologies can traverse metadata schema and extract tags to deem if they are complete, compliant or belong to a particular domain, it does not necessarily mean they are correct. For example, while the *Publication Date* tag may be properly populated (2016-02-29 for example) as per the rules dictated in the North Carolina State and Local Government Profile, it may not necessarily mean the data were published on that date. QA/QC techniques should be used to determine metadata quality across the entire dataset via American National Standards Institute (ANSI), American Society of Quality Control (ANSQ) or other institution-wide QA/QC procedures that best fit needs, resources and limitations.

While the level of attribution within metadata has improved with each new standard and this particular profile, it is in no way complete. As technologies improve and there include more diverse ways to collect, manipulate and create GIS data, metadata must be flexible enough to accommodate all of these techniques. For example, the standard CSDGM does not contain placeholders germane to the collection of data created via a GPS unit like the various Dilution of Position (DOP) measures such as vertical, horizontal and 3D. In addition, detailed information directly associated with the quality of data specific to GPS-collected data such as ephemeris can be entered via a free text field, but lacks the placeholders within the CSDGM as well as this standard. In addition, GIS data now extend well beyond the typical raster and data models that a GIS professional may have solely encountered only a decade earlier. GIS data may now include stand-along tables, Triangulated Irregular Networks (TINs), relationship classes and even topologies. They each have their own intrinsic qualities that make their creation and update difficult to encapsulate within a single catch-all metadata format.

In addition, TAM does have its limitations. TAM may not adequately explain for social influences [56]. More specifically, it is difficult to discern whether intent, attitude or some other referent characteristic sufficiently explain usage behavior. Principal Component Analysis can only do so much within the paradigm of the testing environment. In addition, it is difficult to explain how this physiological attachment related to attitude and behavioral intention can be assessed within TAM. Research has attempted to explain this by expanding the dimensionality of testing elements within a rotated component matrix, but this begins to fall outside of the scope of this research [57]. Nonetheless, any technology is an investment. Even using this model, it is difficult to realize the value of the large-scale investment for an organization at an individual level given the multiple intrinsic behaviors and intentions independent of this organizational goal.

While the intersection of these various subjects serves as the theoretical impetus of this research, assessing these techniques can take on a variety of different forms. How will technology be further disseminated in the working world? How can this technology be assessed? While factors such as lost income and usership are quantitative in nature, they are interwoven with determinants such as marketing, depth and level of human-computer interaction, organizational structure and management of the technology, which are tangential at best to this technology. Some of these factors do not speak to the effectiveness of the technology, but the diffusion of this technology which helps to proliferate its use. With this 'chicken or the egg' scenario, it is sometimes difficult to compartmentalize a valid measurement scale to assess technology acceptance alone for a single piece of technology within the user community.

VII. CONCLUSION

The increasing schism between the rate at which data are created and the efficiency at which the metadata are assessed serves as the impetus of this research. GIS metadata serves as the means by which spatially-related phenomena can be catalogued within a formal framework. It is here where implicit information can be codified for use by the larger GIS community. Given the ever-increasing size of GIS data sets and the proficiency with which GIS data are created, there needs to be a mechanism to educate, assess and evaluate the human element to keep up with this proficiency. A means has been created to educate and inform a statewide GIS data community about a new standard, created by North Carolinians for North Carolinians based on input from North Carolinians. Programming techniques and software packages have allowed users to assess descriptive information about this standard that would take a human days or perhaps weeks to do.

In addition to addressing the quantitative need for metadata as well as a means to educate the GIS community about the salient procedures and technologies necessary to be conversant in the science of metadata, this paper addressed solutions to educate a statewide community about metadata as well as measure adherence to a state-level profile. As per one of the goals of this paper, a programmatic solution using the Python programming language has been implemented. However, it is too early to tell how well these can be integrated into business processes at organizations such as the NCGICC. Revisiting this at a later time will provide time for acceptance of these techniques into mainstream GIS with little to no prior programming knowledge.

This research highlights the importance and need of programmatic approaches to the assessment and evaluation of metadata for large spatial datasets. This information can provide GIS Managers with already limited resources with the tools to make informed decisions that are not feasible with visual inspection or a qualitative understanding of these increasingly large datasets.

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