ELECTRIC POWER RESEARCH INSTITUTE

Monetizing the Geospatial Information System (GIS): The Value of GIS Data Quality for Electric Utilities

An EPRI Smart Grid Assessment Report

2012 TECHNICAL REPORT

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Product Description

The smart grid is dramatically changing the way we deliver electrical energy. What has historically been a uni-directional flow of energy from generation to customer is now increasingly paralleled with a bi-directional communication network to optimize the use and flow of electricity. However, the intelligence of the smart grid relies critically on geospatial data to represent and track the locations of numerous devices within the connectivity model of the distribution system. A GIS (Geospatial Information System) fills this role. This project used surveys and financial modeling to quantify the costs and benefits that can be expected from improvements in GIS data.

Background

The quality of GIS data has become increasingly important as the smart grid matures. Although conceptually understood to be a vital enabler of smart grid functionality, the true value of quality data is not widely understood. Poor quality data can be a frustration, an impediment, or even a danger to the utility and its staff. The actual cost of poor data is elusive. In contrast, the cost to improve data quality is a known quantity. Data improvement can be a lengthy and expensive undertaking so it is important to quantify the potential impacts and benefits of data improvement initiatives.

Objectives

This project seeks to better understand the costs and benefits experienced by utilities due to quality GIS data.

Approach

In order to better understand current GIS data quality issues and practices, EPRI undertook surveys of member utilities during May and August 2012. The survey respondents, which included investor-owned integrated and distribution utilities, coops, and municipals, illuminated many of the current issues faced in GIS use. The project team used the results of these surveys to craft a financial model that quantifies the benefits of data improvement using standard metrics and the probabilities of achieving the desired impact.

Results

This report identifies a variety of options and paths to data quality improvement. Technology investments, integration, and process can each yield data benefits. The decision to pursue one or more paths will be a context and resource-specific decision for each utility. Given this circumstance, realization of benefits will be incremental. However, accumulating experience, higher levels of expectation for GIS functionality, and the gradual realization of promised smart grid benefits will encourage further investment in data quality.

Applications, Values, and Use

This report is intended for GIS professionals and utility professionals who depend on accurate GIS data. The methods in this report and the associated spreadsheet may be used to justify a GIS data quality project.

Keywords

GIS
Geospatial information system
Geographic information system
Cost benefit analysis

Abstract

Utilities continuously struggle with the quality of geospatial information system (GIS) data. With the advent of the Smart Grid and advanced metering infrastructure, utilities are facing increased pressure to resolve data quality issues. GIS quality issues are primarily related to:

- Gaps, e.g. certain key data is missing;
- Redundancies with other systems, e.g. data is captured in many systems and it is inconsistent or requires duplicate data entry to update;
- Lack of currency with system "as-built", e.g. untimely work order completion / backlog;
- Inaccuracies with the field, e.g. GIS has data but does not represent the actual system in the field;
- Inaccurate or unavailable land-base, e.g. varying degrees of accuracy of land-base data based on the source;
- Customer to transformer connectivity by phase is in doubt; and
- GIS model itself allows for "bad" data.

With the advent of the Smart Grid, distribution companies can no longer ignore poor GIS data quality. In many cases, utilities are finding that their capital intensive Smart Grid investments are not yielding anticipated benefits simply because the utility does not have an adequately accurate representation of the distribution system. In more extreme cases, the safety of employees and the public has been compromised due to misrepresented facilities in the GIS.

The report intends to provide utilities with an adaptable template and set of tools that can be used to assess, improve, and ensure ongoing data quality. Following the recommendations of the report and using the associated tools will provide utilities with a strong foundation to ensure data quality on an ongoing basis.

Executive Summary

Smart grid technologies have received great fanfare and investment in the preceding decade, which have overshadowed investment in GIS data as a foundation to the smart grid. Recently, the proliferation of smart grid systems has made the centrality and importance of GIS data quality more obvious. Despite the importance of GIS data, electric utilities have not invested significantly in its improvement due to an inability to cost-justify the effort. Intuitively, better data should beget improved business process and efficiency, however a true cost-benefit analysis and business case were often difficult to substantiate the potentially significant expenditure of time and money to cleanse and improve data.

This report seeks to identify data quality benefits and to inform the creation of a thorough business case for data quality improvements. It includes a discussion of the role of GIS in the utility technology suite, common data quality issues and their sources, and quality measurement strategies. Additionally, the report discusses mitigation strategies utilizing technology and integration best practices, as well as business process to affect data quality improvement. Two surveys were performed to guide the report's recommendations and accompanying financial model. The financial model will assist utilities to address the multitude of factors inherent to data quality investments. In addition to a utility's assessment of monetary benefit, surveys were used to judge additional likelihood and experience with data quality investments to weight the financial model parameters.

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Section 1: Introduction

On September 12, 2005 amid anniversary terror hype, fifty-percent of the Los Angeles Department of Water and Power (LADWP) service area lost electricity[1,2]. Just after noon, a technician installing SCADA at a receiving station mistakenly cut into a control wire. Generating stations tripped off and the blackout cascaded through the system. Two million customers, including downtown Los Angeles, were without power for as much as 1.5 hours. The incident was close to a utility general manager's worst nightmare: it was a preventable accident caused by an outdated schematic which led technicians to believe the cables had been de-energized. The LADWP experience, while large in scale, is not unique. Poor data quality presents a clear threat to the business. This threat, and the importance of data have only increased in the modern smart grid paradigm.

More typical are the day-to-day inefficiencies and re-work that are required due to the errors and timeliness of the GIS (Geospatial Information System) data. A typical situation is outlined by Meehan[3] in chapter 9 of his book, "Empowering Electric and Gas Utilities with GIS". In this chapter, Meehan illustrates the efficiency penalty paid when an integrated GIS with accurate and up-to-date data does not exist. In a scenario that is all too familiar to any utility veteran involved with new construction, the process that does not have GIS as its core system, is bound to create unnecessary re-work.

The smart grid is dramatically changing the way we deliver electrical energy. What has historically been a uni-directional flow of energy from generation to customer is now increasingly paralleled with a bi-directional communication network to optimize the consumption and flow of electricity. However, the intelligence of the smart grid is critically reliant on geospatial data to represent and track numerous devices' location within the connected model of the distribution system. A GIS fills this role. The quality of GIS data has become increasingly important as the smart grid matures. Although conceptually understood to be a vital enabler of smart grid functionality, the true value of quality data is not widely understood. Poor quality data can be a frustration, an

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[1] "Short Circuit Causes Blackout for Half of Los Angeles." Public Power Weekly. No. **37**. September 19, 2005.

[2] Randal C. Archibold. "Accident causes blackout in much of Los Angeles." New York Times. September 12, 2005.

[3] Bill Meehan, "Empowering Electric and Gas Utilities with GIS", ESRI Press, Redlands, CA 2007

impediment, or even a danger to the utility and its staff, but the actual cost of poor data is elusive. In contrast, the cost to improve data quality is a known quantity. Data improvement can be a lengthy and expensive undertaking. This report seeks to better understand the costs and benefits experienced by utilities due to quality GIS data.

The GIS provides the foundational data for the smart grid through the connectivity model of the distribution system linking customer to transformer to feeder to substation. Spatial knowledge of these facilities, devices, and customers is necessary to accurately locate them within the smart grid. Precise knowledge of relative spatial location of devices along this path enables the proper operation of smart grid components, such as OMS and DMS for real-time system management, as well as other applications for system planning and engineering.

The aspirational smart grid model in Figure 1-1[4] presents a variety of energy sources, systems and customers to be tracked and managed. Spatial knowledge of these facilities, devices, and customers is necessary to accurately locate them within the smart grid. The GIS provides the foundational data for the smart grid through the connectivity model of the distribution system linking customer to transformer to feeder to substation. Precise knowledge of relative spatial location of devices along this path enables the proper operation of smart grid components, such as OMS (Outage Management System) and DMS (Distribution Management System) for real-time system management, as well as informs other applications for system planning and engineering.

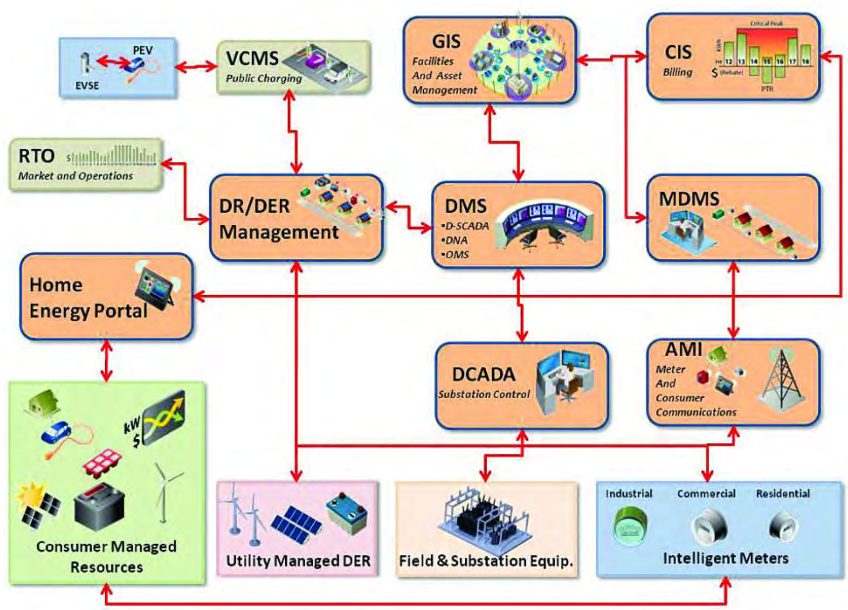

Figure 1-1
Systems of the Smart Grid

GIS is no longer a novel technology for utilities. It has been in place for two decades at some utilities and is entering its third generation of functionality: the mystique is long gone and GIS is viewed as another enterprise system. However, the role and importance of GIS data has come to the forefront with the advent of the smart grid. Data quality has become more important than previously realized. Despite this, many utilities have overlooked data quality, and under-invested in its maintenance in favor of other, more in-vogue or glamorous smart grid

[4] *KCP&L Green Impact Zone Smart Grid Demonstration: Smart Grid Implementation Plan*. KCP&L, Kansas City, MO: 2010.

technologies, such as advanced metering (AMI) or distribution automation technologies.

This report will serve to highlight the importance of GIS data quality to support the functionality of the smart grid. Presently, the true costs of bad data remain unknown and therefore, utility efforts toward data quality improvement must be made on good faith. Through two utility surveys, the current state of data quality will be assessed and efforts for improvement better understood. With this information, it is possible to quantify and monetize the benefits of quality GIS data. This report provides an analysis of data quality tradeoff and a financial model to assist this decision-making process. This report will enable the utility to address questions such as:

- How good does data need to be?
- What are the repercussions of bad data?
- How can a utility assess a financial cost due to bad GIS data?
- How should data quality improvement initiatives be prioritized?
- What options exist for reconciliation and maintenance of data?

This report includes six sections and two appendices:

1. Introduction – provides an overview of the document;
2. GIS for Asset Management – describes the importance of GIS in the asset management strategy;
3. Data Quality Issues – highlights the issues which commonly plague utility data;
4. Perceived Costs and Values – reflects the industry experience of the costs/benefit of data quality;
5. Data Quality Mitigation – provides opportunities and solutions to data improvement;
6. Summary – considerations for successful management of GIS data;

Appendix A – Survey Questions; and

Appendix B – Cost-Benefit Financial Model.

Section 2: GIS for Asset Management

Although the full-featured smart grid may be a distant goal for many utilities, an accurate representation of the electric grid is a must. GIS is a vital component of a utility's central data store which is commonly accepted as the foundation of the utility's asset management program. A building block of the smart grid is the asset management functionality provided by the GIS, in conjunction with real-time data from MDMS (Meter Data Management System) and SCADA (Supervisory Control and Data Acquisition) data. Figure 2-1[5] depicts the typical smart grid systems and the centrality of the GIS for asset management. These systems together provide the connected model on which the smart grid relies. Quality GIS is crucial to leveraging smart grid investments and realizing their full potential.

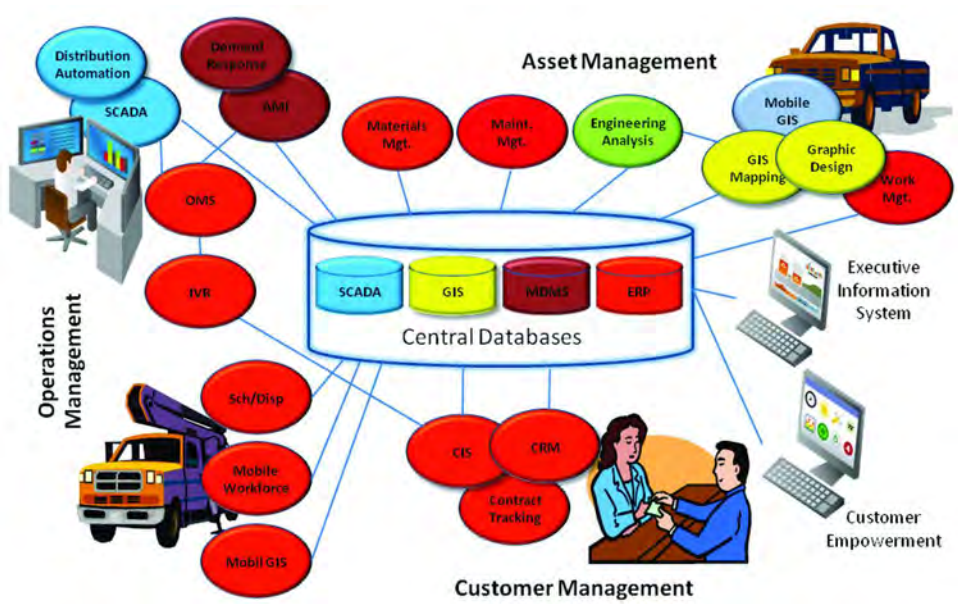

Figure 2-1
Smart Grid Systems

[5] R.J. Sarfi, M.K Tao, J.B. Lyon and J.J. Simmins. "Data Quality as it Relates to Asset Management." IEEE PES Transmission and Distribution Conference. Orlando, FL May, 2012.

Asset Management

Ownership, management and maintenance of large numbers of assets over expansive geography require a comprehensive asset management program. Such programs often require the deployment of a spatially enabled central data store for the management of asset and location data. Data accuracy is critical to the effective maintenance of millions of dollars worth of assets. The GIS is a proven system and effectively serves the role of a vital foundation of a spatially enabled central data store.

Utilities are increasingly finding the results of their smart grid investments to be lackluster without the necessary level of data quality. Before the advent of the smart grid, asset management was the primary process by which the utility optimized the cost of asset lifecycle ownership. This methodology enables the utility to balance operations and maintenance with capital spending to improve reliability and customer satisfaction. Through asset management, the utility is able to leverage scarce resources through intelligent and prudent spending.

Asset management is decision making supported by quantitative data analysis. Better system planning and maintenance can be achieved through visibility and statistical analysis of system performance. Therefore, the absence of accurate and timely data is the most commonly cited factor preventing thorough asset management practices.

Uniquely enabled as storage of geographically referenced data, the GIS is a major repository for asset management data. Typical GIS data elements include:

- Facility/Asset Attributes – including Primary, Secondary, Service Point;
- System/electrical connectivity – Meter/customer to transformer, to circuit and circuit configuration; and
- Landbase – including street, parcels/lots, township boundaries, land features, and land rights.

Data quality is key to the success of the asset management program. A key component of data quality (discussed in the following section) is the correlation of the data between systems as assets' data are necessarily stored and exchanged between GIS and other asset management systems. As depicted in Figure 2-2,[6] the GIS provides as-built locational data to enable real-time data in SCADA and OMS, as well as to support load forecasting and system planning of the distribution system.

[6] ibid

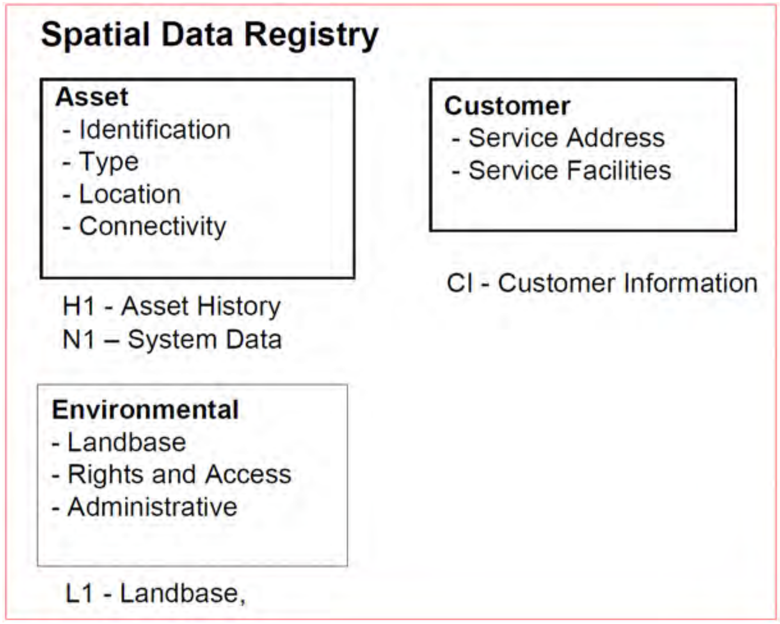

Figure 2-2
GIS Data

Asset Data Organization

The GIS is not ideal for storage of all asset data. In contrast to geometry and location, financial information, historical data, and customer records are ill suited to be stored in the GIS. Additionally, the GIS is not suitable as a precise drawing tool or as the repository of such data. These functions are often left to a CAD (Computer Aided Design) system interfaced to the GIS to provide a seamless user experience of the data. Figure 2-3 depicts the different types of data required for an asset management strategy, however the strategy is not reliant on a single asset management system. Instead, thorough asset management leverages the integrated strengths of different systems to build a comprehensive strategy which houses specific data in appropriate systems.

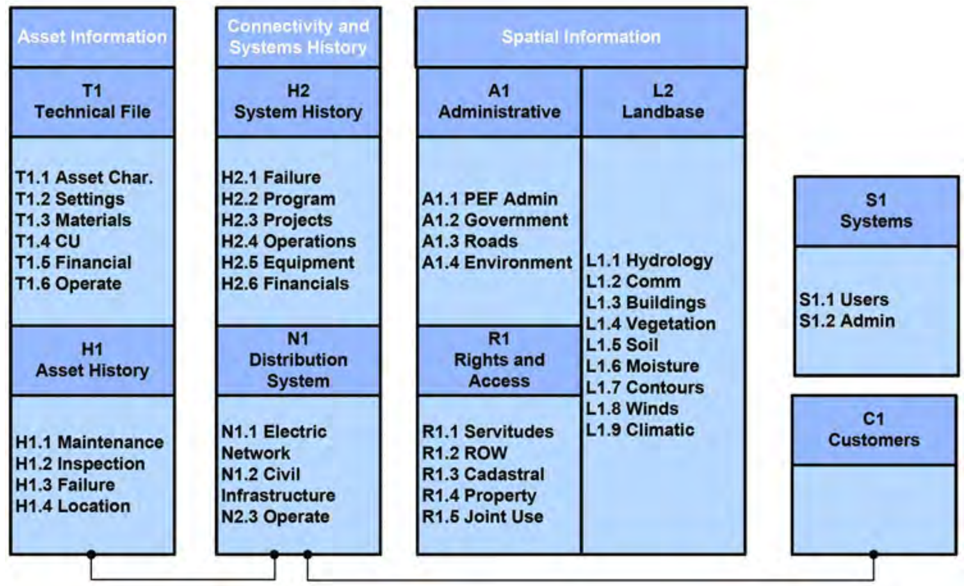

Figure 2-3
Asset Management Data Requirements

Identification of optimal data storage locations is not always obvious. Often, utilities attempt to pile too much data into the GIS for which it is simply not best suited. The GIS is optimized to store location-based data for display and analysis spatially. Historically, maintenance or customer data are poorly suited to the GIS database. Alternatively, the GIS may be underutilized when other databases are burdened with the data which may be better managed in the GIS. Integration of these different systems is crucial for seamless access, visualization and analysis of disparate data to inform priorities and maintenance planning. Table 2-1[7] identifies data typically confused or incorrectly located between the GIS and other systems of record.

[7] Boreas Group. "A Practical Guide to Ensuring Data Quality." Cooperative Research Network, NRECA. March, 2010.

Table 2-1
Typical Areas of Confusion for Geospatial and Non-Geospatial Data

Information		Principle System of Record	Link to GIS
1	Detailed engineering drawings (i.e. station or equipment)	CAD System	Through to Document Management System/Depository
2	3-D data	CAD System/Custom Application	May represent link to region or structure within GIS
3	Maintenance and Inspection	Maintenance Management	Reference equipment in GIS through unique identifier
4	Load information	CIS	Duplicate within GIS with periodic update
5	Customer information	CIS	Duplicate within GIS with periodic update
6	Compatible units (labor and materials)	WMS and MM	Duplicate within GIS with periodic update
7	Engineering analysis data	GIS or analysis application	May be maintained within GIS or application package
8	Non-destructive and destructive test results	Computerized Maintenance Management System (CMMS)	Reference equipment in GIS through unique identified
9	Outage statistics	Outage Management System (OMS)	Through OMS representation of network
10	Project estimation	GIS or Work Management System (WMS)	Dependent on Staking/Graphical Work Design system Implementation
11	Joint Use Data	GIS for location information	CIS or specific application for accounting
12	Meter records	GIS for locations	CIS, custom meter tracking database, or CMMS
13	Protection device settings	Engineering analysis tool	GIS for device information with link to identify settings
14	Poles	GIS for location	CMMS for maintenance and inspection related information
15	Transformers	GIS for location	CMMS for maintenance and inspection related information, CIS for customer to transformer connectivity
16	Meter	GIS for location	CIS or Meter Data Management System (MDMS) for asset data
17	Premise	GIS for location	CIS for physical address

Data Dependencies

The GIS-based asset management strategy requires the close integration of the GIS to many other systems, including CIS, CMMS (Computerized Maintenance Management System), WMS (Work Management System) and OMS. In order to leverage the individual data management strengths of each system, each must be integrated with the GIS to provide seamless, accurate and timely data transfer. Thoughtful integration will enable users across the utility to access and maintain data for which they have responsibility without GIS users' duplicative update efforts.

Modern GIS implementations provide data accessibility across the business through thin and thick-client solutions to many types of end-users. The scope and quality of data accessible through the GIS is dependent on linkages to those other systems. Table 2-2 lists some of the data dependencies.

Table 2-2
GIS Data Dependencies

Data/Function	Source System of Record
Customer	CIS
Account	CIS
Usage/Demand	CIS
Service Information	CIS
Premise Address	CIS
Equipment	CIS
Historical Information	CIS
Landbase	External entity, i.e. State, City, County
Landbase	Internal GIS Group
Standard Item/Stock Number	CMMS
Asset Information	CMMS
Location Information (X,Y)	GIS
Construction Design	Graphic Design Tool
CAD Diagrams, Schematics	Document Management

Utility systems are not silos. Because systems are heavily reliant on each other for different data, bad data can easily go viral throughout different systems. Inaccuracies can propagate and expand within one system and across systems. When poor quality data is used for analysis and to inform decisions, it will necessarily reduce the efficacy of those decisions, which can lead to further reduction of data quality. Poor data quality can initiate a positive feedback loop whereby bad data creates worse data.

The GIS and its data play a central role in asset management. Pacific Gas and Electric's (PG&E) San Bruno gas pipeline explosion demonstrated the disastrous consequences of inaccurate data for asset management[8]. On the evening of September 9, 2010, a 30-inch gas transmission pipeline ruptured in a residential neighborhood of San Bruno, California. The explosion, flying debris and resultant fires destroyed thirty eight homes and took eight lives.

When poor quality data is used for analysis and to inform decisions, it will necessarily reduce the efficacy of those decisions, which can lead to further reduction of data quality.

This disaster, which was largely preventable, was the result of inaccurate data and asset history, and a sewer project which exposed pipeline weaknesses, according to the California Public Utilities Commission investigation. The sections of pipe which failed were more than a half-century old; however, maintenance and inspection had been ignored because the pipeline's characteristics were misidentified in the GIS which serves as one of PG&E's data stores. Because the data is not centralized, pipeline records were either unavailable or inaccessible for update, quality assurance and analysis. Although PG&E had a risk analysis process to identify and prioritize inspection, maintenance and repair of its underground pipelines, missing data meant many fields were filled with default values. Without the accurate knowledge of the construction characteristics and attributes of the segment, it was not a priority. The PG&E experience provides a disastrous example of the importance of accurate asset data management for utilities.

Without a thorough asset management plan and system, including the GIS and associated systems, utilities will be hard pressed to realize the potential of the smart grid. Increasingly GIS-centric functions of the smart grid will be hampered by the lack of data accuracy and completeness.

[8] California Public Utilities Commission. "Report of the Independent Review Panel: San Bruno Explosion." June 24, 2011.

Section 3: Data Quality Issues

The issues that plague electric utilities' data are not unique. Although frustrating, the issues are pervasive throughout the industry, regardless of utility size or structure, municipal, investor or cooperative ownership. Small coops and large IOUs (Investor Owned Utilities) alike are challenged by their need for accurate GIS data. The utility which has solved its data quality issues remains an aberration in the industry. Maintaining data quality can be a challenging goal for the electric utility due to the sheer volume of data and the number of means by which data quality can be compromised. Poor data quality stems principally from two sources:

- Initial data quality; and
- Maintenance-induced and ongoing deterioration.

Data quality is a long-term goal. Data erosion or improvements are each slow processes and effective management of data must take a lifecycle approach. The following sections describe common causes of data quality erosion over the life of the data. These impacts may be felt at the creation of the GIS or over the long period. An opportunistic time to address data quality issues and perform data cleansing is during migration to a new GIS platform or a greenfield GIS implementation. As the effective 'birth' of the data within the system, a thorough initial cleanse will facilitate maintenance throughout the data lifecycle.

The pitfalls of data erosion extend beyond the utility sector. In this era, all companies require good data to improve their business efficiencies. This is particularly true of the airline industry which operates on thin margins, tight time schedules and with fierce competition. British Airways pursued and enjoys the benefits of data quality and supporting processes. Data is central to the business of balancing 240 aircraft and 33 million passengers between 150 global destinations. Business data is crucial to forecasting, routing and capacity planning, in addition to day-to-day ticketing and seat assignment. Faced with eroding data due to a variety of data stores and mismatched maintenance plans and ownership, British Airways undertook a three-phase process to align its different data formats, standards and data cleanse. The project required buy-in and involvement of directors and data owners in each area of the business. By implementing business rules and automated quality checks to input data, monitoring the data with metrics and key performance indicators, and instituting an enterprise data strategy, the company improved its ability to make strategic and operations decisions. Perhaps most telling, the improvement in the quality has been felt as increased employee confidence in the data. The success of the project required time and effort.[9]

Conversion/Migration

Data quality can be poor before even being loaded into the GIS. Due to the inefficiencies of paper-based process and busy workload, many utilities' paper maps are out of date. Devices may not be represented on maps, crews may construct according to field conditions and not redline drawings, or limited resources may simply be unable to accommodate data updates in a timely manner. This is an important consideration for utilities initially implementing or upgrading a GIS: data quality will not be improved simply by conversion to digital format or a new application. Without intervention, poor paper data will become poor GIS data. The data migration process will not solve data quality issues. It is imperative that, during an initial GIS data load, staff expectations be managed, and processes implemented which will realize data quality improvement from efforts other than simply digitization of the data.

Similarly, poor GIS will result if the data are degraded during migration and conversion. Data which is improperly migrated may be missing certain geographies and features. An inadequate conversion specification may incorrectly interpret symbology or device location when placed into the GIS model. Although these errors should be foreseen and can be prevented through the use of experienced migration resources, they are only known if they are found through a rigorous quality assurance and quality control process.

Maintenance

On-going data maintenance presents a greater risk to data quality than the data conversion and migration process. Unlike the initial implementation of a GIS which can be well planned, supervised, and includes opportunities to accept or reject data, the day-to-day maintenance of the data is intricately coupled with its use by numerous staff, with different missions, who are housed throughout the utility. The GIS data are accessed by many processes and systems, external to the GIS, which have an impact on their accuracy, timeliness of update, or the representation of the as-built system. Day-to-day maintenance and use can impact the data quality in one of four major ways:

- Lack of data ownership;
- Lack of data access/change control processes;
- Poor data quality control processes; and
- Deferred data update.

Clearly defined data ownership with adequate change control is an enabler of data quality. Conversely, without ownership and access rights defined, data are left to whither in the absence of an interested and responsible party. Because GIS

[9] Trillium Software. 2011. Case Study: British Airways.

data are used by numerous staff and departments throughout the utility, many will assume the other is tasked with the responsibility for data maintenance. A system in which everyone defines him or herself as a data 'user', and not a responsible 'owner' of data, data quality will erode. Section 5 will discuss data quality mitigation strategies, including process change and change management, which include definition of data ownership.

On-going data quality control is integral to data quality maintenance. Data maintenance must include daily automated QA/QC of data, including object features and attributes. In contrast to initial data conversion and migration, which include structured data review and acceptance processes, many utilities' daily data use does not include regular and rigorous assessment of the data. Infrequent data quality checks will not provide the utility with adequate lead time to correct issues, particularly systematic errors which may propagate through the entire system if given time. Automated checks can identify problems when they can still be corrected easily.

Deferred data maintenance and update can render data useless. Even if the utility has recorded as-built designs accurately, if they are not posted to the GIS in a timely manner, resources are using an out-of-date - and inaccurate - representation of the distribution system as basis for their work. Deferred update can be the result of resource and staffing constraints, but is often the result of poorly aligned work processes. Paper-based and redundant processes often delay data QA/QC and prevent timely updates of the GIS.

End-users of data are rarely satisfied with its quality. Due to daily reliance on the data, there is always a desire for it to be better. Often in conflict with the data users, the staff assigned to data maintenance are viewed as overprotective of the data, particularly to access and data update capabilities. Maintenance is challenging when restricted to a small number of authorized staff. Although these staff desire greater data quality, they likely feel a significant challenge in building a business case to justify the necessary improvement efforts. These process-oriented data maintenance challenges require concerted process re-engineering, training, and change management efforts to improve the organizational structure responsible for the data and its use.

Facets of GIS Data Quality

GIS data quality is a challenge because each record, feature, and attribute includes several facets which define its complete quality. More than simply its geographic accuracy, or existence in the GIS, data quality is determined by multiple attributes of the data, each of which can be impacted separately by the previously described issues. The following facets of data quality can define specific challenges:

- Accuracy, with respect to the real world;
- Completeness;
- Ease of correlation;

- Timeliness of update; and
- Cost, including update and consequence.

Accuracy: In the context of geographic information systems data and asset management, data accuracy with respect to the real world is often the primary concern. After all, GIS is, by name, defined to provide location information for devices and facilities in the field. Therefore, it is a priority that the GIS match the real world location. Accurate location drives wayfinding, asset location, taxation and revenue, connectivity, and easements and right of way. Although important and a fixation of data quality improvement, GIS location is but one facet of GIS data quality.

Completeness: The completeness of the data set and each feature have bearing on data quality. Completeness suggests that features are represented in their entirety. A GIS data set may have variability in the quality of data across a service territory. Often urbanized areas have complete data and rural areas may not be fully represented in the GIS due to infrequent work, long distances and lack of density. An important component of accuracy is the landbase to which facilities are referenced. Both accuracy and completeness rely on the quality of the landbase. The landbase, including roads, parcels, and right of way may be incomplete in rural regions.

Correlation: Features and assets within the system must be uniquely identified to enable cross referencing amongst systems and integration to different data stores. Although the GIS contains many attributes about the utility's facilities, it truly excels at storage and maintenance of geographic information. Other attributes and data are best stored elsewhere, such as CMMS, MDM or CIS and linked back to the GIS via a unique identifier to provide a seamless user experience.

Timeliness: GIS data, notwithstanding its quality, must be entered into the GIS in a timely manner. Data is useless if it is not updated in a timely manner to the GIS to reflect the as-built; otherwise the GIS remains reliant on out of date data. Timeliness of data is a major challenge for utilities due to the volume of data, extent of the facility network and scarcity of resources to update the GIS. Surveys indicate a wide range in time necessary to update the GIS following work completion. Very few accomplish this task in less than a week, yet some require more than six months. During this interval, the GIS does not represent the work done and cannot facilitate accurate design, system analysis or planning.

Cost: The cost of data maintenance is a significant concern for utilities. The time and resources necessary for data maintenance activities are expensive and often, can be viewed as cost prohibitive. Resources for field surveys, additional mappers for data entry, and staff oversight of QA/QC can be daunting for a utility. Although maintenance costs can be quantified, the value of the data quality cannot be assessed easily. Justifying the cost of data maintenance or the repercussions of poor data are challenging without greater understanding of the costs and consequences of poor GIS data quality. Section 4 of this report reflects the surveyed utility industry's collective experience with data quality, and the costs for such data quality.

Typical Data Issues

Given the numerous facets which define data quality and potential sources of data quality erosion, there are many data quality issues. Many of the data issues are common and widely experienced by utilities. Understanding the common data issues will provide a wealth of knowledge and experience to mitigate the impact of poor data quality, which will be discussed in Section 5.

The major, common GIS data quality issues faced by utilities include:

- Data Gaps – Either in initial conversion or through incomplete maintenance, certain key data is missing from the GIS. These gaps can be geographic or non-geographic. They can be data which have not been collected and therefore limit the utility's knowledge of field facilities.
- Redundancies with other systems – If similar data are captured in many systems by different staff, the likelihood of inconsistency is high. Storing similar data in multiple systems require duplicate data entry which is usually inefficient and confusing.
- Lack of currency with system as built – It is extremely common for the utility to experience deferred data maintenance and update of the GIS. Although redlines or mark ups have been recorded on paper field maps, they have not been entered into the GIS and thus, render the GIS data obsolete. Untimely updates of the GIS are often the result of delayed work order completion and closeout, and also due to inefficient business process and technology alignment.
- Inaccuracies with the field – In contrast to data gaps, data quality also suffers when the GIS has data, but it does not represent the actual system in the field. In addition to locational or GPS inaccuracy, these issues are often the result of misaligned design/ build process and poor communication with field crews. For example, site conditions require the installation a transformer on a different pole, which although predictable, is not addressed during the design phase of the work order.
- Inaccurate or unavailable landbase – Not all landbases are created equal. Utilities negotiate varying degrees of accuracy of landbase data based on the source. Commercially-available landbase products may not adequately represent the entirety of the service territory because the landbase vendors simply do not have access to better data or a sufficient customer base to improve the data themselves.
- Customer connectivity by phase is uncertain – Customer connectivity by phase information is vital to ensure the proper operations of the smart grid components such as OMS or DMS. Although the field decision to connect a service transformer to a different phase of the distribution line may not be arbitrary, that information, or redlines to the construction drawings, are not updated to the GIS. In dense urban service areas, without specific data on the customer to transformer connection and the connection of the transformer to the distribution by phase, it may be impossible to accurately

determine if the customer is affected by certain forced outages or planned service interruptions.

Although the number of data quality issues is large, the number of utilities confronting and overcoming them is similarly great. The next section will detail the experiences of utilities' cost/benefit analysis of data quality and its improvement.

Validation Rules

Data maintenance is facilitated through regular checks and validation of the data in, and being entered into, the GIS. Regular and thorough validation routines provide opportunities to identify systematic data errors and to prioritize data cleanup. Validation can be achieved through automated testing or manual testing, each of which is a necessary component of the overall validation and maintenance strategy.

Automated Test Samplers

Automated test procedures have the advantage of requiring minimal staffing resources and the ability to check 100% of the database in order to ensure data integrity throughout. Typical quality assurance includes the following data validation tests:

- Data Set Formatting - This test ensures the data is correctly structured and conforms to the format currently used in the GIS. The test should confirm:
  - Correct coordinate system definitions are specified;
  - Database extents are valid;
  - Correct projections are defined;
  - Database resolutions are correct;
  - Data set version is correct; and
  - Database schema matches that used by target platform.
- Data Loads - This check ensures that items such as field lengths, numeric/character types and required/ optional schema definitions are valid by attempting to load the file into the target platform application database.
- Unique IDs - This check ensures that the feature numbers and objects IDs used are not duplicated within the database.
- Dangles - This check ensures that the features are properly snapped to the succeeding/preceding linear/point features in the facility network according to the defined rules.
- Valid Data for Each Attributed Element - This check ensures that attributes with a pre-defined value domain do not fall outside the limits specified**.** The attribute entries themselves are manually checked at a later stage.
- Connectivity - This check validates the graphic and corresponding database connectivity for all of the graphic features and database tables according to the target platform specification.

- Feature properties - Ensures all features are defined on the correct graphic layers and networks.
- Orphan graphics - Ensures all features are defined on the correct database record & there are no graphic features lacking a corresponding database record.

Manual Test Samples

To ensure an acceptable level of quality, data should be randomly sampled for a more rigorous manual check of quality. Manual quality assurance cannot touch the amount of data, but can provide greater detail into individual attributes' accuracy. Manual sampling should be done on a representative, random sample of all data types or of the data and feature types of interest. Manual data review can compare attributes to source data, to written work orders or to field conditions. This section provides a sample of data quality measurement criteria. The formula for calculating the accuracy rate percentage shall be as follows.[10]

$$\textit{Accuracy Rate} = E_e/E_T$$

Where E_e = Total number of attributes and graphic elements found to be in error in a sample population\
and E_T = Total number of attributes and graphic elements included in the sample population

Table 3-1[11] provides a sample of a quality test that a utility put in place to assess the quality of its GIS data and the criteria that the utility considered a minimum criterion.

Table 3-1
Sample Data Acceptance Criteria

Quality Test	Quality Criteria
Validate devices/equipment/facilities connectivity in database.	100%. All connectivity records for entities must be present in accordance with the requirements of the GIS data model.
Validate all code-listed attribute values.	100%. All code-listed attributes will contain a valid code-list value.
Graphically validate connectivity between devices/equipment/facilities.	100%. All devices/equipment/facilities must be graphically connected in accordance with their portrayal on the Source Data Records.

[10] Boreas Group. "A Practical Guide to Ensuring Data Quality." Cooperative Research Network, NRECA. March, 2010.

[11] Boreas Group. 2011.

Table 3–1
Sample Data Acceptance Criteria (continued)

Quality Test	Quality Criteria
Check for presence of sheet edge nodes.	100%. All network devices/equipment/facilities that intersect a batch boundary must be terminated in an edge node. Edge nodes must not be present elsewhere in the batch.
Sample landbase base completeness.	$\leq$ 10 landbase base features per 1000 sampled are omitted from captured provisional landbase base.
Sample landbase base accuracy of feature coding and attributes.	$\leq$ 20 feature codes for landbase base features per 1000 sampled are incorrect.
Sample devices/equipment/facilities for completeness (presence in database).	98% on an entire delivery, based on the elements described to the left and below
Sample devices/equipment/facilities for accuracy of values for attributes (i.e. where the values of mandatory attributes are valid but in error, or where values of optional attributes as shown on the original Source Data Records area in error or omitted).	
Sample relevant devices/equipment/ facilities for accuracy of any optional connectivity or ownership records that can be inferred from the original Source Data Records.	
Sample devices/equipment/facilities for accuracy of placement relative to the landbase. [+/- 10' at real scale(1:1)]	
Sample devices/equipment/facilities for presence and accuracy of label point positions.	
Sample all map sheets in batch to check accuracy of the attributes in provenance record (date of conversion, conversion vendor, class of map record, scale of map vendor).	

In most cases the utility does not have the resources to perform a complete validation of its data. Under these circumstances it is necessary to use random sampling techniques to assess data quality. Most data projects rely on a random sampling technique identified in MIL-STD-105E[12]. This standard prescribes a minimum number of features to sample in order to achieve a level of confidence in the data. Applying this approach requires the use of a random number generator to identify which assets to validate. The utility simply:

[12] Webber, Richard T., "An Easy Approach To Acceptance Sampling: HOW TO USE MIL-STD-105E", ASQC Quality Press, Wisconsin (1991)

- Identifies the level of confidence in the data required;
- Each feature class will be an individual lot for inspection. For example all poles will be a lot, all transformers will be a lot, all fuses will be a lot, etc... This will be true for all feature classes in the GIS.
- Samples the features to meet the confidence level required, the features being selected by a random number generator.
- Each delivery will be broken down into lots by feature class with a count of the number of features in that feature class. Using the MIL-STD-105E Standard, a sample size for each feature class will be determined using 105E Standard Table I General Inspection Level III (tightened sampling) alpha code. Also, a sample size and acceptable quality level for each feature class will be determined using the 105E Standard Table II-A.
- Feature inconsistencies will constitute an error and will count towards the number of rejections to that lot. Table 3-2 provides an overview of the number of features, the number to be sampled, and the number of defects allowed in an example case.

Table 3-2
Sample Table for Random Sampling

Lot	Number of Features	Sample Size	No. Defects Allowed
Poles	34,000	500	10
Transformers	5,643	315	8
Cutouts	6,867	315	8

Required Data Accuracy

Experienced utility-GIS administrators have come to understand it is difficult to assign numerical value to determine data quality. Instead, data quality must be maintained at a sufficient level to ensure that users will use and depend on the GIS for its intended functions.

- Critical – A high quality level must be maintained to support critical GIS and specialized non-GIS functions. Experience gained from utilities with mature GIS systems indicate that less than 5% data error rate level must be achieved during initial system start up and continuously be maintained so as not to erode user confidence in using the GIS, e.g. 5% mismatch of field and GIS.
- Standard – This level of quality is usually assigned to data sets which support utility mapping and map information distribution functions. A 25% or less data error rate is deemed sufficient by experienced GIS administrators to maintain user confidence.

It is important to note that the quality recommendations presented are based on a statistical spread (even distribution) of error across all asset data stored in a GIS (poles, cross-arms, wires, switches, etc.). This is to say that a 5% data error rate in

GIS data means 95% of all asset data stored in a GIS is accurate and correct. It should not be interpreted as a 5% error rate in each or any particular GIS attribute class like poles or wire. For example a 5% error in GIS data does not mean one out of twenty times a crew search for a pole it is not found or the pole class is incorrect.

It is important to remember that regardless of the data quality, certain systems require mandatory data to function. This is to say that regardless of the quality of the data, the data needs to be available and adhere to certain rules in order for a system to function. Many utilities populate the mandatory data with a best guess in order to ensure that they can use dependent systems, but apply professional judgment to interpret the results: some utilities include a flag on key attributes to indicate how trusted the data is. While this practice is common, we have already seen in Section 2, that the results of including default or best guess information might be disastrous. Specific to the GIS, the following systems are dependent on the availability of mandatory data:

- OMS requires the following mandatory data:
    - A complete connectivity model (100% connectivity).
    - No parallel circuits unless a network is supported.
    - In excess of 80% customer to transformer matching.
    - Phasing is consistent with fundamental engineering practices, e.g. no phase mismatches.
    - Substation data is not mandatory nor is substation modeling possible in all GIS, but the breaker configuration at the substation can be useful to avoid false outage predictions.
    - Customer to transformer relationships.
    - Transmission data is not mandatory nor is transmission modeling possible in all GIS, but transmission modeling allows the automated inclusion of transmission level outages.
    - Engineering Analysis requires the following mandatory data:
    - A complete connectivity model (100% connectivity).
    - Mapping of transformers, conductors, capacitors, regulators to their associated electrical parameters.
    - Mapping of protective devices to their protective characteristics.
    - Substation data is not mandatory nor is substation modeling possible in all GIS, but the breaker configuration at the substation can be useful to avoid false outage predictions.
    - Transmission data is not mandatory nor is transmission modeling possible in all GIS, but transmission modeling allows the automated inclusion of transmission level outages.
    - CIS requires alignment of the addresses with the GIS. This is typically a complicated process but is necessary as this will enable more accurate outage predictions.

Additionally, it is often prudent and useful to include non-electric assets in the GIS. Although these data layers are not essential to core utility systems, their presence can be of significant use to both system planning and maintenance functions. Inclusion of additional utility assets, such as gas, communications, or water, can enable identification of potential points of damage during installation or maintenance by any third party utility, or points of critical interaction, such as powerline – gas crossings. Although these data layers may be very useful for identification of potential issues from the office, the GIS, the data quality should be validated for safety. Safe field practices will prevent dig-in, not accurate GIS data. However data can alert users to potential conflicts. This is a significant opportunity for utility data sharing and transfer, for which a rectified, accurate landbase and assets is requisite.

Maintenance Performance

The quality of a utility's GIS data is directly affected by the processes and staff dedicated to ongoing data maintenance and use. The number of designers and GIS technicians who are actively involved in use and maintenance of the data will provide the day-to-day hands on improvement of the data.

Surveyed utilities express a wide range of staffing levels in ratio of their size. Although most fall into a range of one design/GIS staff member per 11,000 – 18,000 customers, there are many examples above and below. Effective, streamlined work order process defines the differences between these utilities. Although a ceiling exists to the number of work orders which can realistically and accurately be handled by a single designer/tech, well designed process and technology integration can enable a ratio of up to 28,000 customers per designer at the most efficient utility surveyed. Figure 3-1 depicts the range of staff-to-customers employed at a variety of utilities ranging from 80,000 to 4,200,000 meters and staff sizes of 5 to 455.

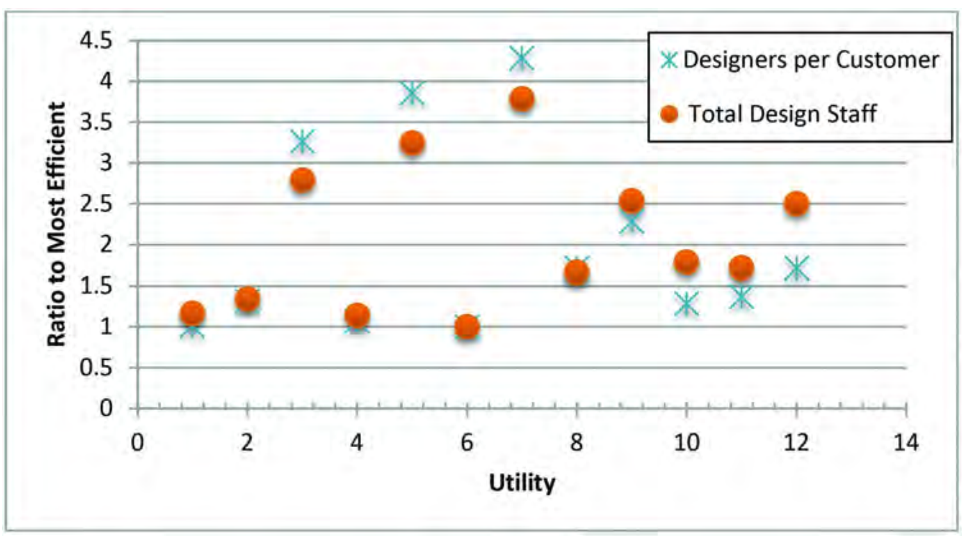

Figure 3-1
Design Staff Ratios at Utilities[13]

[13] Boreas Group LLC, August 2012.

When undertaking data improvement initiatives, it is common to be dismissive of improvements which don't include significant hiring. However, experience demonstrates the opportunities exist to further leverage existing, small staff through efficient process and technology.

Section 4: Perceived Cost and Values

The true cost of bad GIS data quality is not clear to many utilities. Although a majority of surveyed utilities recognize and cite the benefits of good data, significant repercussions of poor data are largely unfelt. Despite it being preferable that utilities have not experienced catastrophic problems attributable to GIS data, the absence of such experience confuses the business case and motivation for data quality improvement. This section describes GIS data quality based on utility experience. Through a better understanding of data quality benefits, utilities will be positioned to make cost effective investments in data improvement.

In order to better understand current GIS data quality issues and practices, EPRI undertook surveys of member utilities during May and August, 2012. The survey respondents, which included investor-owned integrated and distribution utilities, coops, and municipals, illuminated many of the current issues faced in GIS use. This section describes utilities' varying use of and experience with GIS data.

The survey illuminated one of the significant challenges to data quality improvement. Although everyone can conceptually appreciate that better quality data would be beneficial to the business, only 46% of respondents have actually witnessed significant benefits from high quality data. In contrast to repercussions of poor data, benefits can be harder to visualize. Conversely, only 15% have experienced significant repercussions due to low quality data. These statistics combine to neither pull nor push a utility to invest in data quality improvement. Without witnessed benefit or alarming problems, a business case can be difficult to justify the necessary allocation of resources. Therefore, while 69% of utilities have programs to improve data quality, only 54% have staffed an internal team; data quality remains a low, underfunded priority. Therefore, it is of little surprise that a minority of only 23% of utilities compare data to their peers. Although this has left many utilities to assume their average data is far worse than industry standards, it has not accelerated the data improvement process. The level of discourse and collaboration for data quality remains low.

GIS Architecture and Goals

The survey revealed utilities' varying uses of GIS for data storage; only 31% maintain a full representation of the distribution system in the GIS. But 64% supplement the GIS with data in an asset management system. Agreement does not exist on how to best divide data between the GIS and the asset management system. Utilities' reliance on the GIS ranges from exclusive storage of geographic location, to storage and function as the primary system of record for assets. However, experience has proven a strategy somewhere between the two extremes best leverages the GIS's strengths, as well as those of other databases.

There exists general consensus and movement toward representation of both the primary and secondary network in the GIS. Utilities have made efforts to track assets with unique identification codes between systems. Presently, 69% have instituted such numbering across the distribution system. This underscores experience that unique identifiers are crucial to an asset management strategy. Without IDs, asset data cannot be correlated between different systems, i.e. GIS, WMS, CIS, much less accurately maintained without great redundancy. However, it is of less importance to physically tag each device: only 31% have physically tagged the assets in the field. Devices can be referenced and located by GPS or pole route/number, instead.

Data accuracy and quality can depend heavily on the organizational structure of system ownership and maintenance. Figure 4-1 and Figure 4-2 demonstrate the current split in thinking about these tasks. As shown in Figure 4-1, the majority of GIS is owned by the IT department, a smaller number of utilities have housed the GIS with users and the suite of technical software in engineering or operations. Although IT may appear a natural administrator of the GIS, as it is for most other systems within the utility, this has the effect that the owner is not the user of the system. Additionally, IT skillsets are typically disparate from GIS skillsets.

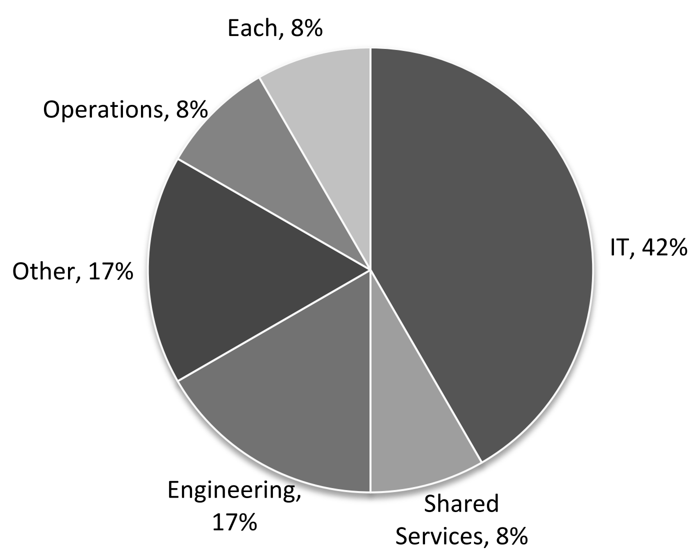

Figure 4-1
GIS Ownership

Survey responses demonstrate a very different geography of GIS data maintenance within the utility. End-users of the GIS data are much more commonly tasked with that data maintenance than the IT department, as shown in Figure 4-2. Although there is no consensus on which unit is best suited to perform maintenance and upkeep, it is apparent that IT is not the preferred source. A majority of utilities place data maintenance in the hands of one group, but a number have disseminated this responsibility between several or many groups. In this scenario, each group takes responsibility for the data which it most closely and commonly uses. The benefit of entrusting end-users with data maintenance is clear: these users have the greatest knowledge of the data and system, as well as a daily stake in its improvement for their work processes. These end-users utilize and touch the data on a daily basis allowing them to realize the benefits of data accuracy, as well as to affect these changes during normal workflows.

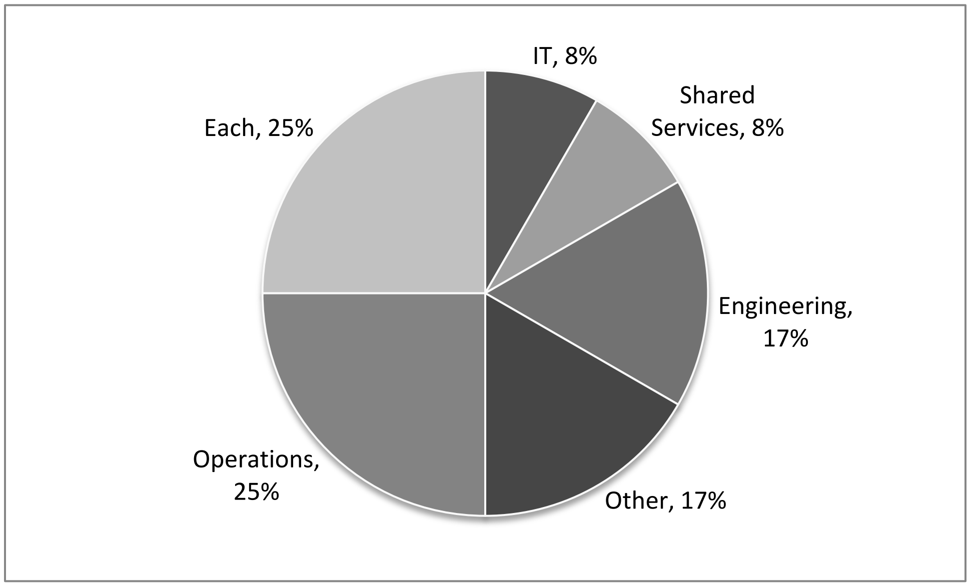

Figure 4-2
GIS Maintenance Responsibility

Utilities' ability to affect data quality improvement will rely heavily on the infrastructure and system architecture of their unique context, in addition to business process. As a point of comparison, the vast majority of utilities have migrated to the ESRI platform, as seen in Figure 4-3. Although many, particularly Tier-1, utilities continue to use longstanding alternatives; ESRI has made great leaps in market share due to its ease of integration with other systems crucial to data maintenance.

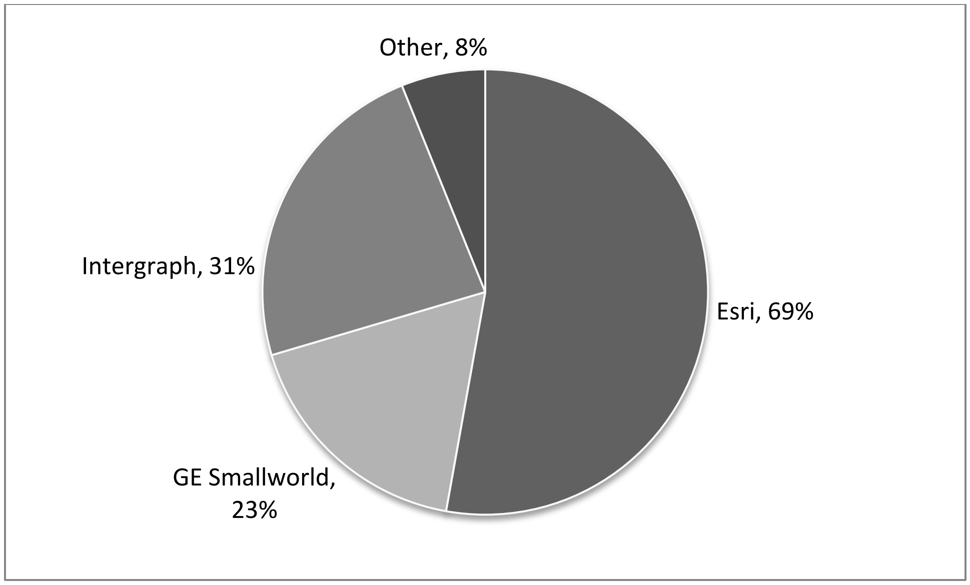

Figure 4-3
GIS System

Data quality maintenance relies heavily on systematic integration. Seamless integration between the GIS and other business systems enables data sharing, widespread use and single-entry. Utilities demonstrate different patterns of integration and data dependencies between systems. Currently, the majority of GIS provide data to OMS, CIS and engineering analysis applications. Other systems' reliance on the GIS for data are less common, although likely to continue to rise in the smart grid era.

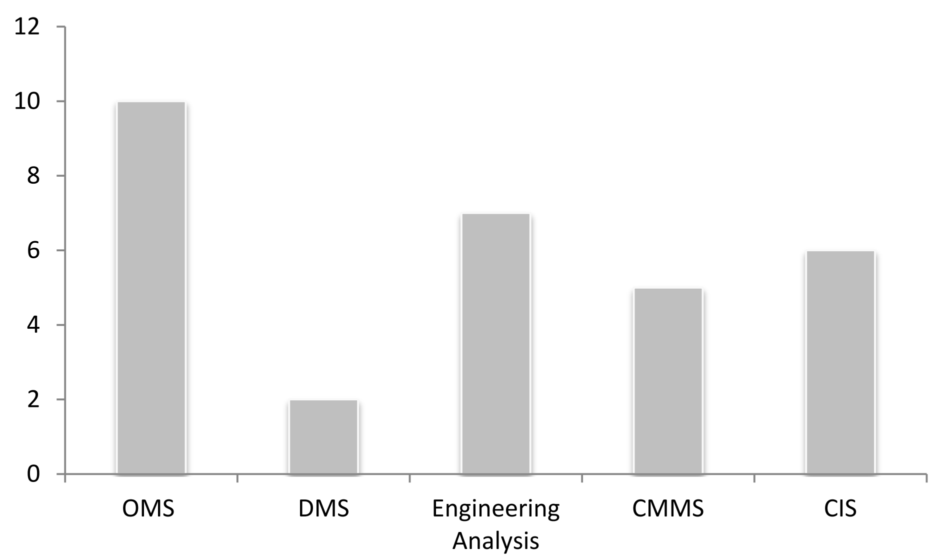

Figure 4-4
Data Dependencies on the GIS

In contrast, few other systems are interfaced to provide data to the GIS. Figure 4-5 demonstrates that the GIS commonly has dependencies on the asset management, customer information and work management systems. These systems complement and typically are leveraged to enhance the data stored in the GIS. WMS and CIS are necessary for design and outage functionality.

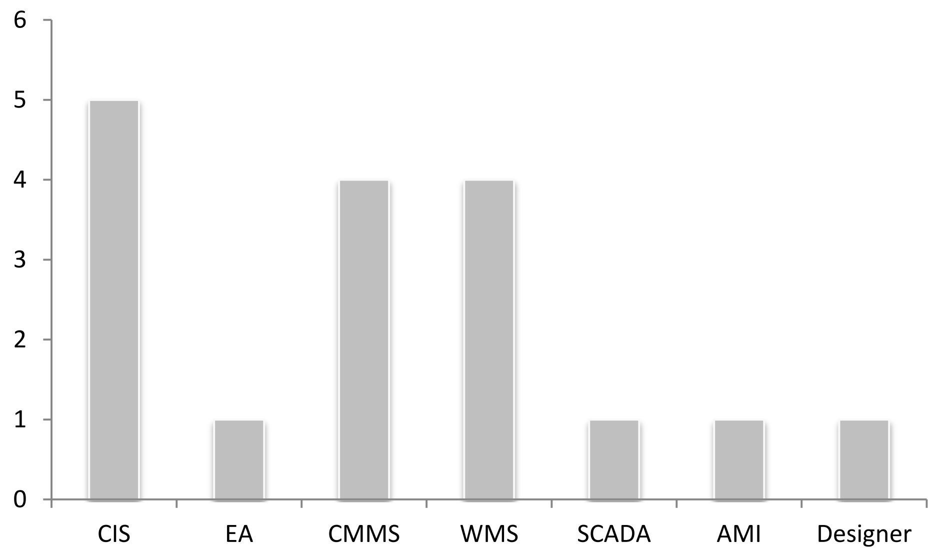

Figure 4-5
GIS Data Dependencies

Utilities approach GIS data dissemination and access very differently. Although the old GIS model required a core team of GIS technicians and mappers to produce paper maps as requested for users, increasingly GIS access is being provided to more users. It is now common practice for utilities to develop both thick- and thin-client GIS applications to support different users' requirements. Traditional users of the GIS, such as mappers engaged in data entry and maintenance, require greater tools. A streamlined, simpler web-based tool provides access, query and basic analysis tools to many more users. Figure 4-6 demonstrates the increasing dissemination of GIS access throughout utilities. Traditional users, such as GIS technicians and engineers have most access, but other staff, such as customer service and real estate departments is gaining GIS functionality. Additionally, linemen as a group stand to gain much from GIS access. However, their mobile requirements, technology and cost have delayed a solution at many utilities. Deployment of GIS to linemen and access to the data will not only serve their routing and normal work function, linemen provide a front line for data maintenance and correction as inaccuracies between the as-built and model are located.

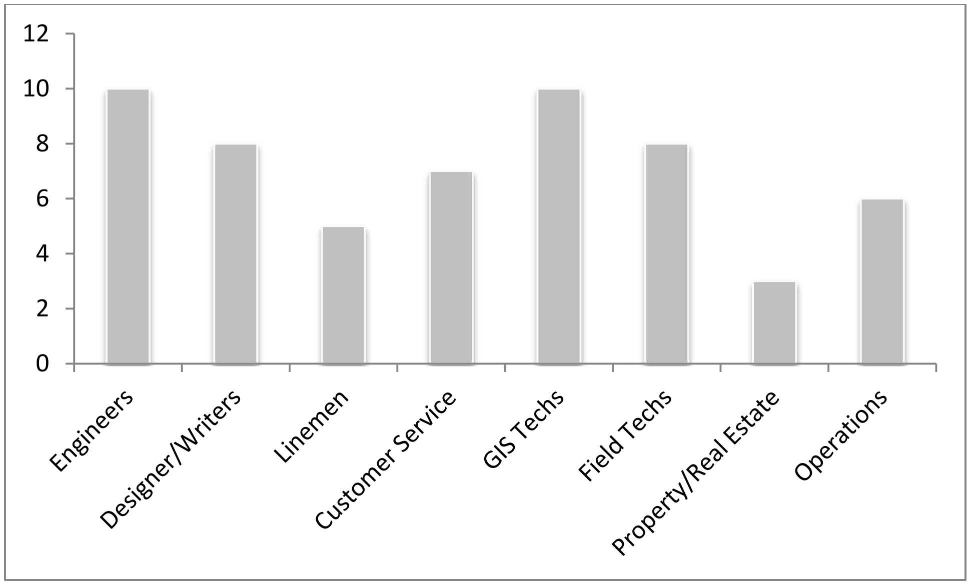

Figure 4-6
Direct Users of GIS Data

Figure 4-7 demonstrates the variety of functions requested of the GIS. Although a few emerge as dominant and common functionalities, others such as vegetation management and property management have yet to commonly leverage the GIS capabilities. GIS functionality continues to spread throughout the business as new extensions and applications bolt onto the existing GIS and other departments recognize the benefits of GIS or receive funding. GIS data provides benefits to many users and will rise in importance as increasing numbers of functions are reliant upon its quality.

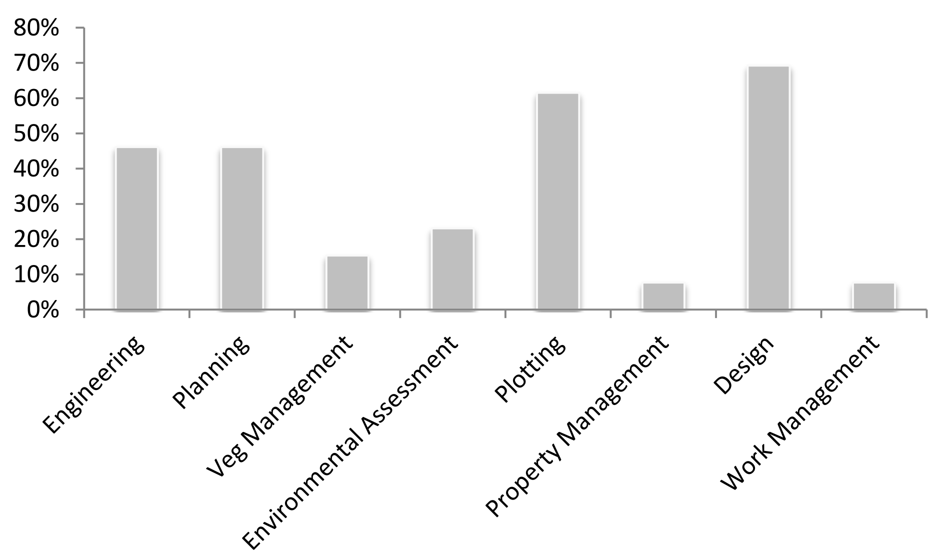

Figure 4-7
GIS Functionality

Data Quality

Surveyed utilities reported generally good levels of data quality. Figure 4-8 presents the utilities' perceived level of data quality for accuracy and completeness. The majority of utilities fall in the very functional and acceptable range of data quality above 75%. Few utilities experience lower quality data. This threshold has from experience been a cutoff point for the reliable function of an OMS. Figure 4-8 presents the self-reported data quality of surveyed utilities. In fact, 77% of utilities had not experienced erosion in data quality over time.

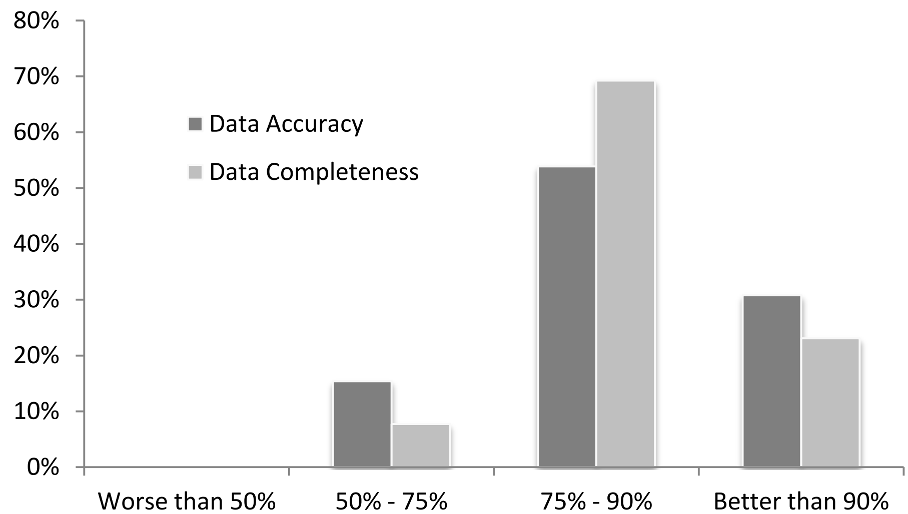

Figure 4-8
Utilities' Expressed Level of Data Quality

Although high expectations downplay the quality of data, the survey suggests that end users are generally confident in the data. More confident in their data completeness than accuracy such that 77% of utilities reported user confidence in the completeness of data, but 69% reported user confidence in the accuracy. Existence of the data can be a lower hurdle than accuracy as which can be a much more objective, i.e. it could be closer to the as-built, rather than the binary presence-absence of completeness. Although potentially more feasible, completeness is far from realized. The challenge presented by greater completeness will likely be less than the greater goal of accuracy which reflects the as-built condition. Many of the priority concerns of utilities are completeness, principally of the meter-to-transformer connectivity. This belies the necessity of GIS data for OMS and the importance of OMS as a tool to meet customer and regulator expectations.

Although the utilities generally have good self-reported levels of data accuracy, their internal measurements and quality analysis vary widely. Metrics include field inventory and survey, real-time automated validation, and cross matching customers, premises, transformers between the GIS and CIS. Additionally, some utilities perform circuit traces for connectivity or review unique ID matches for devices, however, none are consistent. Some utilities do not perform any regular or automated data quality validation. There exists no standard practice for maintenance and quality levels vary accordingly. Identification of inaccurate, eroded and incomplete data is the first step to a coordinated program of improvement.

Data Improvement

Utilities report a variety of accuracy issues. Efforts have been concentrated on improvements to essential data, such as that which breaks the connectivity model fed to the OMS. Because these data are regularly utilized by and effectively 'checked' by the OMS, their upkeep is highlighted and prioritized by staff. Similarly, data which are regularly used by operations for switching and sectionalizing are necessarily maintained to a higher level. Of the few utilities which report 'catastrophic' repercussions from poor data, inability to respond to outages was the unanimous result. Although individual scenarios vary, all share the common and unmet need to accurately sectionalize the circuit to restore service more quickly.

Some utilities have realized data improvements through concerted efforts. Improvement is attributed primarily to two actions:

- Field feedback as part of regularly work; and
- Automated electrical tracing of circuits and business rules.

Although average or existing data quality may suffice for utilities' requirements, there exist many benefits to improved data. Increased data accuracy and completeness provide the following:

- Reduction in the overall cost of operations as a whole - Sloppy data may be easier and cheaper to maintain, but yields poor engineering decisions;
- Increase efficiencies in implementing and troubleshooting Smart Grid communications issues;
- OMS and DMS improvement – Outage and distribution management systems are heavily reliant on the accuracy of the connected model. As connectivity and switching increase in accuracy outages can be isolated and repaired more quickly resulting in reduced outage duration, metrics and cost;
- Improved crew efficiencies - Improved distribution system representation allows crews to locate field assets more quickly, to drive less and have correct replacement parts;
- Improved load forecasting and system planning effectiveness;
- Reduced work order creation, construction, and close out process time – Designs are posted to the GIS more quickly such that staff have maps which actually reflect the as-built;
- Improved material management and forecasting efficiency;

- Enabled information exchange with internal and external agencies; and
- Improved safety due to more accurate facilities records – Crews should never rely solely on mapped information to protect their health and safety.

Expectations and Optimism for Data Improvement

In order to fine tune the accompanying financial model for GIS data quality improvement initiatives, a survey was conducted to gauge utilities' experience with and potential realization of benefits with improved data quality. The survey, and financial model, included 58 benefits and 22 costs of data quality improvement. A complete list of the benefit parameters is available in Appendix B. Responses to the survey, ranking each parameter from *Very Unlikely* to *Very Likely*, revealed the utilities' likelihood to realize each benefit. Benefits are not equally achievable, separate from cost, other factors may combine to make desirable benefits too difficult to attain. Existing technology, business process, relationships with customers and regulators may be beyond the scope of the data quality improvement project and combine to minimize changes to some benefit areas.

The survey results demonstrate a broad range of expectations for improved data. It was not uncommon for a single question to elicit responses from the whole spectrum of likelihood. Although each utility's context is unique, the responses illuminate the general optimism of utility staff that improvement in data quality will provide tangible, meaningful benefit to daily work processes. However, these benefits are not seen in all areas of the business.

Survey respondents indicated that data improvements will be likely to improve their landbase accuracy. Landbase accuracy improvement initiatives are central to the overall data cleanup. Spatial location is the hallmark of the GIS and as such should be given high priority to facilitate the location-sensitive smart grid technologies. As such, respondents are optimistic they are 'likely' to witness reduced data correction work and associated time savings. Although correction time savings may be realized in the long term, the initial efforts will require significant setup and corrective activity. Respondents were almost unanimous in their belief of the 'very likely' realization of accurate condition-based maintenance thanks to data improvement. Presently, poor location and ID information results in wasteful time-based maintenance strategies which do not make use of the full lifespan of the asset. An accurate asset database will enable the utility to pinpoint specific assets, or classes of assets, for action, i.e. PCB equipment tagging and change-out.

Data accuracy is anticipated to have high benefits for operations, as well as maintenance and engineering business units. Respondents are optimistic the improvements will enable improvements in the development of switching plans. Through an accurate understanding of the as-built system, operations can prevent unplanned outages due to error in switching. This same as-built accuracy is 'likely' to enable system planners and engineers to forecast system loads and requirements. This knowledge will also be invaluable in disaster response. Many utilities are thrown into disarray during disaster events because existing maps do not accurately reflect the system at the time of the event. System restoration is thus delayed in order to re-engineer necessary changes and provide the correct materials.

In contrast, the survey also indicated a number of areas which respondents are particularly pessimistic about the incremental value of data quality investments. Particularly, respondents were not convinced accuracy could 'democratize' data maintenance throughout the organization. Despite the benefits of end-users taking responsibility for data maintenance of the data which they use and are most familiar with in their daily work processes, respondents did not feel this is likely to occur. This may result from skepticism of widespread edit capabilities when many current GIS responsibilities are very centralized. This is in contrast to a large number of respondents which have already disseminated GIS data maintenance to user groups.

Respondents indicated that on average, correction to the rate base was unlikely. Data accuracy can provide great benefit in determination of all field assets for accurate determination of the rate base. However, realization that the rate base has been historically over or under-calculated can pose a daunting mitigation challenge. Although more than one utility has deferred data improvement efforts for fear of uncovering a miscalculated rate base, it may not be a general concern to future operations to rectify such charges.

Data quality improvement is expected to require additional staff time. Improvement efforts will undoubtedly require reallocation of staff time or outside assistance. However, as the initiative transitions from initial phases into steady-state integration with normal workflows, the technology and system integration which have facilitated improvements may be further leveraged. These investments will enable users to reduce duplicate entry and potential entry errors.

Section 5: Data Quality Mitigation

Following the decision to proceed, there exist many opportunities to improve data quality. Data quality improvement can be a significant undertaking requiring several years to realize benefits and improvement. Quality can erode over time and data should be improved when it drops below a threshold to support business needs. Data may be supported through process change, technology integration, as well as thorough survey of the field condition. An end-to-end data maintenance process design can prevent quality erosion and improve data.

In addition to ongoing strategies, data migration and conversion provides an ideal time to perform data cleanse and improvement activities. Although data will not automatically be improved through migration, a migration without improvement is a lost opportunity. As data must be checked and accepted during migration, it is time efficient to improve the data in preparation and address anomalies and errors as they are discovered in acceptance.

In cases of particularly poor data completeness, a field survey may be necessary to bridge gaps. Although many contractors provide resources for field surveys, utilities have found small scale deployments of retirees and light-duty staff to be cost-effective solutions. Although a smaller number of resources will cost less, this type of field survey will require more time or necessitate a more sharply defined focus and narrower scope, i.e. specific town or unmapped feeders. Current and past employees of the utility have the great advantage of local knowledge and experience over contractors.

Maintenance Processes

Geospatial data are checked to an industry standard 98% for visual-checks and 100% for automated quality checks. However, over time data, as the data is used and added to, quality drifts to 75-90% accuracy and slightly better completeness. Poorly aligned processes result from staff taking shortcuts, discontinuous data flow and duplicative entry which drive down accuracy through errors or assets may be omitted from the database should be discouraged. The use of ongoing automatic checks of the database is desirable for their efficiency. Although many features and attributes cannot be effectively confirmed through automated checks, the checks can identify erosion and provide automated feedback and performance indicators for data quality as well as other business processes.

Typical ongoing process issues which impact data quality can include:

- End-to-End Process flow – Without well-considered and planned process, workflows may not make efficient use of technology and may be poorly integrated to provide data flow between work types. This can result in inefficient use of time, duplicate entry and errors.
- Process Adoption/Change Management – Optimal design of business process is a challenging process in itself to understand current work, necessary process alignment and efficiencies, but is nothing without adequate change management and buy-in from stakeholders to actually implement and use the new process.
- Access – Although GIS data is a powerful tool to be spread throughout the organization through a series of thick-client and web viewing tools, access to the data to make changes should be controlled and tracked. As changes are made they should be stamped and digitally signed for historical tracking and record keeping.
- Ownership – Data maintenance should not be “someone else’s problem.” Improvement is founded on ownership of and responsibility for the data. All users should feel ownership of and responsibility for data to identify inaccuracies and improve quality.

Solutions

Data quality challenges are not insurmountable, nor are the mitigation methods onerous or cost prohibitive. Many utilities have demonstrated the efficacy of a two-fold strategy for data maintenance and improvement through (1) business process and (2) technology and integration. The primary challenge in the data maintenance phase is how to maintain sufficient data quality to ensure confidence. It is imperative that a data quality maintenance and continuous improvement program be implement so that Management can have a clear understanding of how the GIS is performing and what action should be implemented to appropriately further improve user confidence.

Although automated (software) QA/QC tools can and should be executed periodically to assess data quality, the establishment of a structured maintenance program to assess and improve data quality and solicit user feedback is imperative. This program should include:

- The establishment of a GIS User Group consisting of key GIS users and the GIS Administrator to establish usage guidelines and to share ideas of data/system improvement/enhancement, as well as, to solicit periodic user feedback;
- The execution of automated QA/QC procedures upon posting a design or GIS version to the master version, as well as, bi-annually using software solution and/or conversion services vendors provided tools (software);
- The provision of field operating guidelines that are understood by all stakeholders to ensure that any permanent changes to field equipment (transformer, pole, fuse, etc.) and system connectivity and phasing (opening

and closing of switches, etc) be reported to the GIS Administrator within an agreed upon period (3 days is a commonly accepted standard);

- The preparation of procedures to allow GIS users and field personnel to report any GIS data error/anomalies to the GIS Administrator so that quick data correction can be made; and
- The provision of procedures to ensure that the Staker/Designer will field validate GIS data used in all Service and Work orders. GIS data errors and anomalies when noticed, should be reported to the GIS Administrator within a reasonable time period (2 days is a commonly accepted standard).

Another challenge often faced is how to manage and incorporate changes to GIS data by Service and Work Orders in a timely manner. Update of GIS data should be made with a reasonable time period. Although no industry standard yet exists, 3 working days following completion of a work order is a commonly accepted goal. The actual end-users of the data should be responsible for the update process as well as data integrity. In an ideal environment, the end-users would have a field red-line tool to perform data correction graphically and use an integrated graphical staking application to create new facilities. There is still however the need for a GIS coordinator or group. The role of the GIS coordinator or group is to validate the accuracy, manage versions, and ensure cartographic standards are adhered to when posting versions.

Business Process Change

GIS data quality cannot be effectively and accurately achieved without a structured and comprehensive business process flow. GIS data must be treated cohesively with an end-to-end perspective which gives rise to a process inclusive of work order initiation, design, review, construction, billing and close out activities. Because GIS data is utilized throughout the utility by numerous end-users, it must effectively account for and respond to each of those uses. Data quality improvement cannot be addressed without specific attention to the interaction, control, flow, edit and use of GIS data by each group throughout the business process. Neglecting one leaves the data open to inefficiencies and degradation.

Figure 5-1 depicts an example workflow process to carry GIS information through from work initiation to close out. The integrated GIS and graphical design process provides end-to-end alignment which enables the business to leverage the strengths of geospatial data. Regular use promotes accuracy and improvement. Additionally, the holistic view and use of the data minimizes the number of manual processes to input and maintain the data. A GIS data improvement strategy must begin by identifying the data problem and source. Analysis of the existing use of data and the flow of data will improve data integrity.

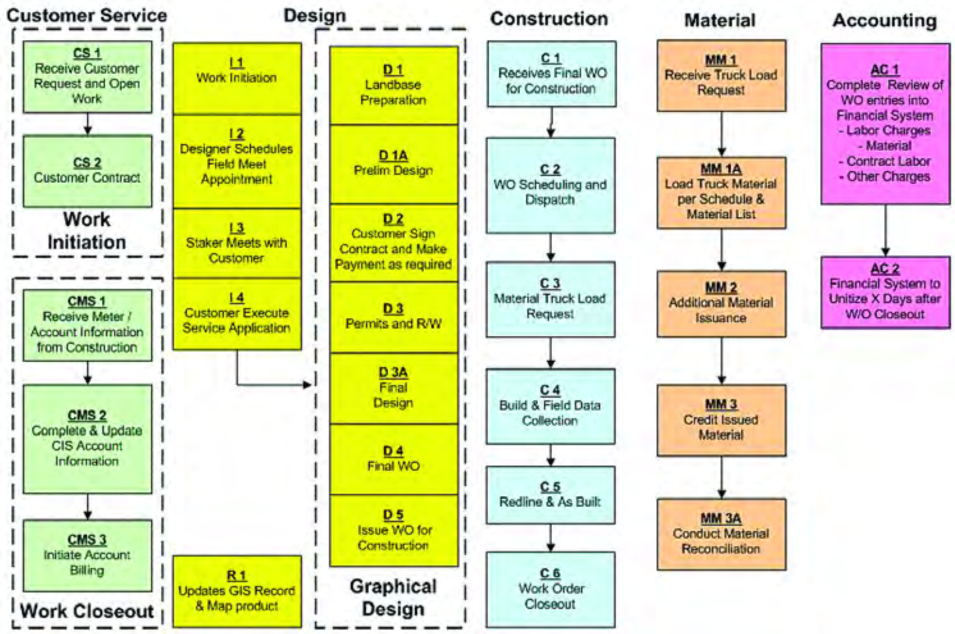

Figure 5-1
Work Order to Close-Out Process

A holistic approach to data and business process provides the opportunity to not only prevent data quality erosion during daily workflow, but also to integrate data maintenance and improvement into work processes. Instead of requiring a large team dedicated to data maintenance processes, the users and creators of the GIS data – from customer service to mappers to designers – can improve data during normal work. The benefits of an integrated design process include:

- Create facility data more accurately and quickly;
- Manual data entry is minimized through integration of graphic design, work management and GIS;
- Business rules can be effectively enforced in scope implementation;
- Use of construction units in the design process will enable efficient design, accounting and construction of facility changes and additions; and
- Design documents and drawings can be assigned a unique number, including versions. Links can be made from other applications for easy access to these documents.

Although a graphical design process integrated with the GIS is the preferable solution, situations exist in which the utility will not be able to implement such technology and process. In these rare cases, the utility must simply apply more resources to the duplicative work of designing, drawing, correcting, and uploading to the GIS.

Change Management

Appropriate and thorough design of business process is challenging, however, acceptance and implementation of the process is no less difficult and important. The ideal process can fail without the support of two crucial groups: managers and end-users. Technology projects are too complex to succeed without people. The early and regular involvement of stakeholders cannot be underscored enough.

As with any capital and time-intensive business endeavor, the support of management is critical to success. Without an active and enthused executive sponsor, the intricacies of data improvement are destined for failure. Not all utilities have the benefit of a management dedicated to and concerned about data quality, but one must be found or created. Without an advocate, improvement is unlikely to be a funded priority. Although the sponsor needs to be involved on a daily basis, he or she must be an informed and active proponent of the necessary process, committed to completion.

The second crucial group to process change success is the end users. Although improved data quality can be appealing, the task to achievement can be daunting. Particularly, data improvement processes can be viewed as additional responsibilities on already busy resources. Process design relies heavily on stakeholder participation in workshops to understand current practices, opportunities for improvements and creative solutions from the individuals who know the process best. Their participation can be tempered by concern for their jobs and workload. Yes, workflows and individual tasks may change with new processes, therefore outreach and information are critical to creating buy-in during the initial stages of process design. This smaller group of stakeholders and users will ideally become process change evangelists to their colleagues. Greater participation and understanding of the benefits of change and data improvement will facilitate not only process redesign, but implementation of the processes. Any changed process and workflow will require a period of adjustment to begin to see efficiency and quality gains. Training is necessary to gain these efficiencies, but also to assuage concerns about the process and changes for employees. Without the end-users' support and acceptance of the process, it will never be implemented.

Improving data quality is not the sole responsibility of the GIS group. Instead of data being "someone else's' problem", all users should have a stake in the quality of the GIS data. The GIS group should position themselves as facilitators of a process that enables engineering and operations, as well as, customer services employees to add and update GIS data in a time efficient manner. Simply stated, the end-users of the data should become the data owners. This requires an understanding of the touchpoints with other parts of the business: who are the users and what data do they use and maintain.

Technology Solutions

In addition to business process and staff training, technology alignment can enable data maintenance efficiencies. Technology integration has great demonstrated ability to reduce duplicative and manual processes which result in data quality erosion. Many utilities have implemented the systems shown in Figure 2-1. The GIS and its data are of high importance to central databases supporting all other technology systems within the utility.

Virtual Data Store

Figure 2-1 describes a typical architecture and demonstrates the number of interfaces necessary to facilitate data transfer between utility systems. The GIS, MDM, ERP and SCADA form the central information databases, each with its own unique data specialty. Although data is separated and spread across these different systems for optimal storage and maintenance, the systems must be integrated to form a 'virtual data store'. In this model, the data are conceptualized to be housed in a single, virtualized repository. Although only some data is stored in the GIS, for end-users, all data appears to be stored and accessible through the GIS.

To facilitate the virtual data store model, data must be resident in the optimal system. Division of data between the GIS, ERP, MDM, and CMMS is handled differently by each utility. It can be tempting to overload the GIS with information or to use the GIS only for geographic location linked to the asset management system. As with many things, the best solution is a compromise of the two approaches. The optimal data management strategy must leverage the spatial strengths of the GIS and the data and historical management strengths of the CMMS. As a guideline, the GIS-stored data should be simplified to that which is:

Object to be represented is characterized by an X, Y, and Z location;

- Attribute information is of interest to the GIS user (identifier, size, type, vintage, status, nameplate information, and manufacturer are minimal requirements);
- Necessary to identify how customers are connected to network; and
- Necessary to identify how facilities (line segments, transformers, fuser/switches, etc.) are connected.

GIS users require ready access to a subset of the attribute data for most assets. This information should be stored in GIS, more detailed asset history and information is best served by the CMMS. Although the GIS may only contain geographic information, connectivity and basic attribute information for assets, more detailed, historical information is linked to the GIS to appear concurrently with GIS information. System integration enables data flow between repositories and the GIS as the viewing and access platform. Correct location of the data will enable efficient maintenance processes and result in higher quality data.

Figure 5-2 describes the number of integration points between GIS and other systems, and the individual functions enabled by each data integration.

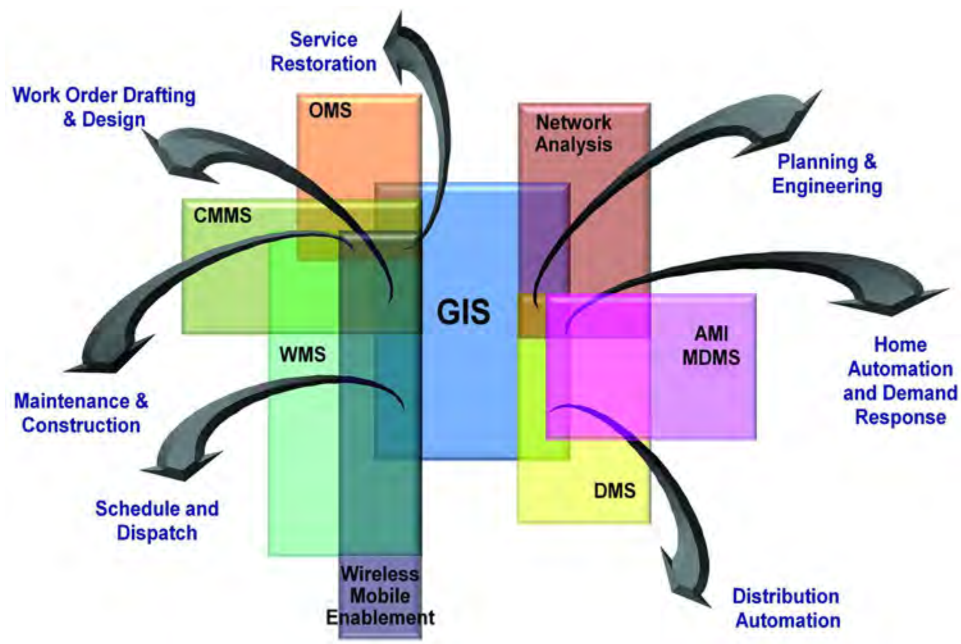

Figure 5-2
GIS Data Integration with Other Systems

The implementation of a virtual data store and centralized data management strategy provides many benefits to the data. One repository enables to centralizations of enforcement, validations and business rules. These efforts and staff need not be duplicated across systems. Indeed, data access is improved as are efforts to measure and assess the data. Centralization provides the opportunity for enterprise performance measures, of business metrics, productivity, and efficiency, as well as, data quality. These key performance indicators provide an easy-to-use digest and real-time indication of utility success. Lastly, a virtual data store is a prerequisite to a concerted data quality improvement plan. Without consolidated data, analysis and metrics to provide understanding of the scope and shape of the quality issue, an effective strategy cannot be developed.

GIS Data Quality Financial Model

Prior to undertaking any data quality improvement program, the utility must weigh the expected benefits with necessary costs. The accompanying Financial Model (Appendix B) for GIS data quality cost-benefit analysis has been designed following EPRI and DOE guidelines.[14,15] The model includes a set of cost and

[14] *Methodological Approach for Estimating the Benefits and Costs of Smart Grid Demonstration Projects*. EPRI, Palo Alto, CA: 2010. 1020342.

[15] *Guidebook for Cost/Benefit Analysis of Smart Grid Demonstration Projects: Volume 1 Measuring Impacts*. EPRI, Palo Alto, CA: 2011. 1021423

benefit parameters to guide the utility's analysis. Although most benefits and costs are felt within the utility's resources and workflows, an effort is made to also address benefits to customers. These parameters have been classified by their end goal. These categories include:[16]

- Reliability - frequency and duration of customer interruptions;
- Utility Operational Efficiency - people and how they do their jobs, such as non-fuel O&M, non-production assets, safety;
- System Operational Efficiency - the power system and how efficiently it operates;
- Utility Asset Efficiency - production assets required;
- Power Quality - harmonics, sags/swells, voltage violations;
- Customer Efficiency - consumption required to provide desired benefits; and
- Other - theft reduction, Customer service, and satisfaction.

Figure 5-3 provides an overview of the EPRI methodology for cost-benefit analysis. The attached financial model adheres to address impacts, metrics, costs and benefits of data quality.

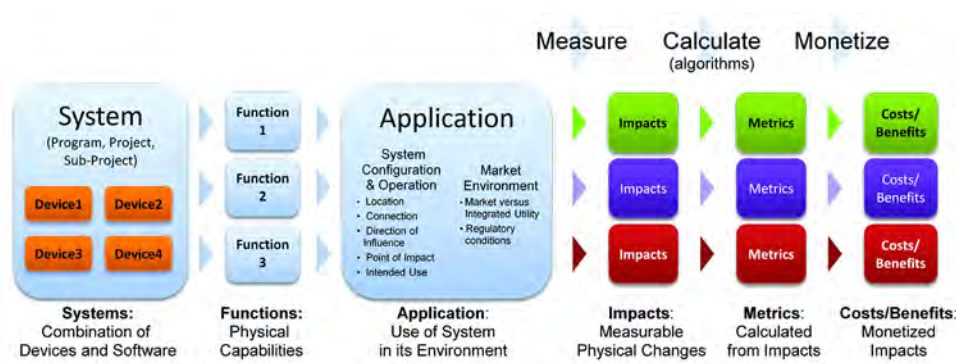

Figure 5-3
Financial Modeling Process

Monetization of the benefits of data improvements is challenging. Many of the costs are very direct, but the benefits are more widespread: reductions of existing workflows, improved forecasting and planning, and data integration, for example. Therefore, the data benefits must include the processes which data leverages and facilitates, not just direct cost savings.

The model includes parameters describing a multitude of benefit and cost areas which are described in Table 5-1 and Table 5-2. Additionally, the criteria have been weighted according to the responses from surveyed utilities. Their responses reflect a priority or realization potential for each criteria being achieved.

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[16] Roark, Jeffrey D. Cost/Benefit Analysis for Advanced DMS Applications. Strategic Topic Webcast. EPRI. May 8, 2012.

Although a particular area may have financial benefit, the likelihood of realization may be so low, difficult or unnecessary that it be significantly discounted to provide a more realistic cost-benefit analysis. The model includes the average weightings from surveyed utilities, but may be changed to reflect local conditions and business expectations.

Table 5-1
Benefit Parameter Definitions

	Parameter	Purpose	Description
1	Asset records integration	Utility Operational Efficiency	Systems of record are integrated to enable each to share information without creating an orphan database of lost, misplaced or unassigned assets
2	Unique ID Numbers	Utility Operational Efficiency	Each asset must have and be identified with a unique number to provide correlation between databases linking the asset between different systems of record.
3	Landbase accuracy	Utility Operational Efficiency	The assets are correctly referenced to real world location such that they are represented on the map with correct location as well as accurately located with GPS coordinates for real world location.
4	Standardized address format and fields	Utility Operational Efficiency	All addresses are standardized such that a unique street is always entered the same, spelled the same, suffixes are not entered in abbreviation and do not require clean up to display on the same street.
5	Prevent duplicate entry	Utility Operational Efficiency	Process and integration provide accurate flow of the designs digitally between systems and into the GIS such that staff don't draw and re-draw designs, or digitize paper.
6	Data Timeliness	Utility Operational Efficiency	Data and designs are available more quickly following entry to the GIS and its users such that it reflects the as-built more quickly and is ready for future designs.
7	Take-off point connectivity	System Operational Efficiency	Each new extension, meter and design is electrically connected to model initially to support fault location, response and OMS functionality
8	Automated data population on Work Orders	Utility Operational Efficiency	System integration to auto-populate fields, specifications and default values from existing databases reduce data entry and opportunities for miss-typed errors.
9	Fewer field visits	Utility Operational Efficiency	Although design will always require field visits, greater accuracy to the field condition will enable increased work from and efficiency in the office.
10	Reengineering from field/field changes	Utility Operational Efficiency	Field changes and redesign can be obviated with accurate information on field conditions allowing designs to be done correctly the first time.

Table 5–1
Benefit Parameter Definitions (Continued)

	Parameter	Purpose	Description
11	Dispersed data maintenance responsibility	Utility Operational Efficiency	Associated process and data access enable more users to have ability to edit basic attributes, to take responsibility for data accuracy and affect changes as necessary and identified.
12	Defined data model and data location	Utility Operational Efficiency	Fundamental to ongoing accuracy, a well defined and documented data model enables future changes and forethought for logical and best-fit placement of data in the model instead of simply in a comment field.
13	Duplicate data entry	Utility Operational Efficiency	Data do not require multiple staff to 'touch', amend, add to or correct the data.
14	Reduced data correction work	Utility Operational Efficiency	Accurate data does not have to be regularly corrected.
15	Reduced data model changes	Utility Operational Efficiency	A well designed and implemented data model will not require changes for additional data fields.
16	Reduced street naming errors and correlation to CIS	Utility Operational Efficiency	Street naming will match the corporate atlas to facilitate integration to CIS and customer database.
17	Crew Response Time	Utility Operational Efficiency	Accurate locations will enable faster routing and problem location identification for field crews.
18	Customer-to-Transformer linkage accuracy	Utility Operational Efficiency	A thorough connected model from substation to transformer to customer will enable OMS and fault prediction speed and accuracy.
19	Address accuracy	Utility Operational Efficiency	Premise address accuracy will address crew frustration and 'no address' calls received at dispatch.
20	Materials	Utility Operational Efficiency	Knowledge of the as-built will enable crews to identify and carry correct replacement materials, reduce duplicate trips and need to measure conductor size.
21	Equipment Operations Costs	Utility Operational Efficiency	Accurate locations can result in lowered equipment miles.
22	Materials forecasting	Utility Operational Efficiency	Understanding of the as-built will allow better forecasting of necessary equipment for replacements and swaps.

Table 5–1
Benefit Parameter Definitions (Continued)

	Parameter	Purpose	Description
23	Safety	Other	Crew safety will be improved with accurate information on field conditions.
24	Accurate Condition Based Maintenance	Utility Asset Efficiency	Condition-based maintenance is predicated on the ability to find and reliably track assets in order to analyze their life expectancy.
25	Accurate switching plans, operations	Reliability	Accurate representation of the distribution system enables thorough switching plans and operations while preventing unplanned outages.
26	Timeliness/Currency	Utility Operational Efficiency	In addition to data availability, paper and mobile maps reflect the as-built field condition.
27	Information/Data availability/access	Utility Operational Efficiency	More eyes on the data, shared ownership
28	Respond to customer inquiries faster	Utility Operational Efficiency	Customer service and designers have improved access to customer/premise information in their interaction with customers.
29	Export from GIS to OMS	Utility Operational Efficiency	Reduce export time and effort to OMS through accurate location and connectivity.
30	Troubleshooting smart grid communication issues	Utility Asset Efficiency	The smart grid is predicated on accurate geographic location for devices to interact and communicate effectively.
31	Data acceptance and confidence	Utility Operational Efficiency	Staff acceptance and use of data will improve as the level of accuracy improves.
32	Outage Metrics	Reliability	SAIDI, CAIDI, SAIFI will be reduced as data facilitates reliability, forecasting and response.
33	Loss - Technical	System Operational Efficiency	Accurate data can be used to analyze and mitigate power line losses.
34	Loss - Non-technical	Other	Illicit connections and tampering can be identified through fine-grained and accurate spatial data.
35	Reporting	Other	Statistic and metric accuracy will provide greater confidence in reporting.
36	Balanced Phase load	System Operational Efficiency	Engineering analysis will be improved to facilitate balanced loading to three phases through the customer-transformer linkage with phasing.

Table 5–1
Benefit Parameter Definitions (Continued)

	Parameter	Purpose	Description
37	Reduction of parallel databases and sources	Utility Operational Efficiency	Good data will obviate other sources and files which have been necessary to supplement bad data, require time for maintenance and do not integrate correctly with other systems.
38	Engineering predictive capabilities	Utility Operational Efficiency	Forecasting and predictive capabilities will be increased as the connected model's accuracy rises.
39	Avoid capital investments	Utility Asset Efficiency	Costly capital investments can be avoided through identification of opportunities for efficiency or excess capacity.
40	Engineering analysis accuracy	Utility Operational Efficiency	Engineers and management will have greater confidence in analysis based on stronger data.
41	Disaster response	Reliability	Accurate as-built data will facilitate disaster response and recovery through certainty of the existing system.
42	Public relations	Other	Data accuracy will enable the utility to create goodwill and headline avoidance in weather and outage situations.
43	Customer Satisfaction	Other	Customers will positively perceive the utility's proactive investments and opportunity to prevent problems.
44	Critical /VIP Customer Satisfaction	Other	Accuracy enables goodwill with important, critical and large customers.
45	Shareholder Value	Other	Demonstrated accuracy and responsiveness will inspire confidence in company direction and management which will be translated to shareholder value.
46	Regulator Satisfaction	Other	Investments, accuracy and management will translate to confidence and goodwill of regulatory agency and public utility board.
47	Employee Satisfaction	Other	Workplace satisfaction and dedication can be increased through ease of use of systems with improved data.
48	Facilitate compliance with regulatory mandate	Other	Accurate asset management and field inventory will enable efficiency with replacements, i.e. PCB phase-out.
49	Rate base	Other	The rate base will accurately and completely reflect the true investments made by the utility, i.e. number of poles and miles of conductor.
50	Rate base timeliness	Other	Assets are added to the rate base and capitalized more quickly.

Table 5–1
Benefit Parameter Definitions (Continued)

	Parameter	Purpose	Description
51	Taxing districts	Other	In instances where facilities cross jurisdictional and taxing boundaries, accurate data will enable cooperation with and payment to correct districts.
52	Lost Revenue - Streetlights	Other	A thorough inventory of streetlights will enable accurate billing and prevent lost revenue.
53	Lost Revenue - Third Party Attachments	Other	A thorough inventory of third party attachments will reduce unknowns and prevent lost revenue.
54	Data sale to external agencies	Other	The benefits of accurate data extend beyond the utility. There exist opportunities to market data and realize Potential revenue from sale of quality data to external agencies.
55	Data exchange with internal and external agencies	Other	Data accuracy will facilitate data exchange with external agencies.
56	Data consulting services to peers	Other	Following investment in data accuracy, the utility will have gained significant insight into required levels of accuracy, benefits, methodology and process which can be capitalized in consulting with peer utilities.
57	Staff Time /Efficiency	Utility Operational Efficiency	General accuracy will result in staff efficiency.
58	Key Performance Indicators/Dashboard	Utility Operational Efficiency	Accuracy throughout systems will enable improved metrics and visibility in real-time data quality for utility workflows.

Table 5-2
Cost Parameter Definitions

	Parameter	Purpose	Description
1	Data creation	Utility Operational Efficiency	Data quality improvement will necessitate some more time and effort during the process of data creation to assure accuracy and completeness.
2	Data maintenance	Utility Operational Efficiency	Efforts involved in data maintenance may initially rise but should plateau and fall as workflows and systems facilitate accuracy.
3	Current data assessment	Utility Operational Efficiency	Prior to undertaking any data quality improvements, a thorough understanding of the current data limitations is necessary and will require analysis and documentation.
4	Staff/Retirees/Vendor Time	Utility Operational Efficiency	Improvement and clean up efforts will require significant staff, retiree or vendor time commitment and cost.
5	QA Team equipment	Utility Operational Efficiency	If the clean-up and improvement is accomplished utilizing in-house resources, they will require computers, large monitors, and workspace.
6	Software Licenses	Utility Operational Efficiency	Additional seats or concurrent licenses will be required to support additional GIS users during the process.
7	Awareness of Inaccuracies	Utility Operational Efficiency	Following analysis and documentation of the data quality problem, there may be increased awareness of current state of data and negative perceptions.
8	Automated Routines	Utility Operational Efficiency	Data quality maintenance and improvement through automated routines requires specialized knowledge and staff time for programming and testing.
9	Vehicles	Other	Resources tasked with data improvement or quality assurance will require access to light trucks for field survey and validation of the GIS data with the field as-built.
10	Staff Time or Contractor	Other	In addition to office staff, validation will require field resources knowledgeable in the area and electrical system.
11	Data Input	Other	Additional staff time or responsibility for input and oversight
12	Data acceptance review	Other	Staff time and training will be necessary to review data for acceptance and inclusion in the GIS.

Table 5-2
Cost Parameter Definitions (Continued)

	Parameter	Purpose	Description
13	Equipment	Other	For an in house field survey, resources will require mobile devices as well as office equipment for GPS download.
14	Historical Inaccuracies in Rate Base	Other	Following the improvement of the data, there exists the potential to discover that the rate base has been miscalculated.
15	Programming	Other	Ongoing maintenance of the data accuracy will rely on seamless integration and the development of interfaces between GIS and other systems.
16	Staff Testing and Acceptance Time	Other	Interface testing and quality control will be required to accept any new systems or interfaces prior to their use in production.
17	Licenses	Other	Any solutions which are purchased will require ongoing maintenance and license fees.
18	Software Cost	Other	Commercial solutions, including interfaces or bus, must be purchased.
19	Interface Maintenance	Other	Purchased and developed interfaces will require ongoing maintenance.
20	Process Change Workshops	Utility Operational Efficiency	Development of necessary business process change to support data quality improvement will require stakeholder meetings, process diagramming, development and approval of new processes.
21	Change Management Training	Utility Operational Efficiency	Necessary changes to process will require staff training and support materials to assure acceptance and implementation.
22	Data Use Training	Utility Operational Efficiency	Associated with the improved data, the utility may realize reductions of costs associated with intuitive data, processes and systems.

Section 6: Summary

The smart grid era has spot-lighted the previously unexpected importance of GIS data quality. This incipient awareness, however, has yet to be met with sizeable or widespread investments in data quality improvement. Utilities have generally been resistant to investment of scarce resources into the potentially long-term process of data quality improvement. Although few have achieved perfect data quality, respondents' experiences demonstrate the benefits of improved data quality and accuracy many, if not all, business practices. As such, "good" data many not be perfect, but is worth the time, effort, and technology to attain it.

There exist a variety of options and paths to data quality improvement. Technology investments, integration and process can each yield data benefits. The decision to pursue one or more paths will be a context and resource-specific decision for each utility. Given this, realization of benefits will be incremental improvements. However, the rising experience, level of expectation for GIS functionality, and realization of promised smart grid benefits, will encourage the investment in data quality.

Opportunities for Future Research

This research has revealed a number of shortcomings in the way in which utilities typically manage and handle GIS data. There exist several notable opportunities for future research to facilitate improved processes and best practices. Of note within the survey work was a general frustration with data, paired with a resignation that quality and accuracy were unlikely to be improved. A significant component of this resignation is the general and omnipresent realities of budget and staffing resources. Despite the evidence that data quality can improve business practices, the money to do so is not readily available. It is therefore necessary to encourage and facilitate discussion and information sharing between utilities. Collaboration and discussion will help individual utilities gauge their data quality in the context of the industry and their peers, as well as develop best practices and efficient improvement strategies. Due to the incipient need for GIS data quality improvement, a generalized body of knowledge on the subject has yet to develop. Individual utility efforts in a vacuum are likely less efficient than knowledge sharing. One forum for such exchange is the EPRI GIS Working Group which commissioned this report and meets monthly to address emerging issues.

Secondly, this report indicates the complete lack of standardization for GIS data quality within the utility industry. It would be beneficial and instructive to be able to report metrics by which data should be measured and standards to which the industry should aspire, however these simply do not yet exist. There exists a wide range of accuracies or standards for timeliness of update. The fastest or highest may be the aspirational standard, but likely a more realistic and functional standard can be established which best balances cost and benefit of improvement. Establishment of such standards will require the collaboration of the industry to continue to understand the current status of GIS data with respect to evolving technology.

Appendix A: Survey Questions

The initial survey included the following questions:

1. Do you store all line asset data in the GIS?
2. Provide a summary of the data that you store within your GIS.
3. Do you store line asset data in an Asset Management and/or Asset Maintenance system?
4. Provide a summary of the data that you store within your Asset Management and/or Asset Maintenance system.
5. Do you store non asset data (for example, Vegetation Management and Property Management, etc.) in the GIS.
6. Do you have a unique asset ID across all T&D systems? Do you physically tag your assets in the field with this unique ID?
7. Provide a summary of the functions that you perform with your GIS.
8. Which other T&D systems are dependent on data from your GIS?
9. Which other T&D systems is your GIS dependent on for data?
10. Who are the users (direct access) of GIS data?
11. How to you measure and assess GIS data quality at the present time (timeliness of update, accuracy to true field conditions, referential integrity, completeness, redundancy, etc…)?
12. How would you assess the accuracy of your GIS data? Better than 50, 80% or 95% correct?
13. How would you assess the completeness of your GIS data? Better than 50%, 80% or 95% complete?
14. Are the users confident about the accuracy and completeness of your GIS data?
15. Have you ever encountered a catastrophic event due to poor data quality? If so, please describe it and how it was a result of poor data quality.
16. Have you ever experienced an extraordinary benefit due to high data quality? If so, please describe it and how it was the result of good data quality.
17. Do you compare your data quality with that of your peers?

18. Do you have any programs in place to improve data quality? If so, what are they, how did you prioritize them, and how did you justify them?
19. Do you have an internal team dedicated to data quality assessment and improvement programs?
20. Where do you think you experience the most issues with data quality at the present time? What has led to the deterioration of this data?
21. Which data is maintained to the highest quality? What lessons learned are there from these data elements?
22. Have you invested in automated routines to assess and correct data issues? If so, please describe them.
23. How would you approach measuring the value of data quality?

The second survey included the following questions:

1. What system do you use to store GIS information: ESRI, Smallworld, Intergraph, Milsoft, Autodesk?
2. What is the version of the system?
3. When performing a cost/benefit analysis, do you consider qualitative benefits? If so, how do you factor them in?
4. Do you quantitatively measure the quality of your data on an ongoing basis? If so, what do you do and how frequently?
5. Would you consider spending external funding to clean your data?
6. Who owns your GIS: IT, Shared Services, Engineering, or Other?
7. Who maintains your GIS data: IT, Shared Services, Engineering, or Other?
8. Below are questions that impact the benefits incurred by correcting GIS data. What is the likelihood that your utility will experience each of the listed benefits?

Asset Records Integration
Unique Id Numbers
Landbase Accuracy
Standardized Address Format And Fields
Prevent Duplicate Entry
Data Timeliness
Take-Off Point Connectivity
Automated Data Population On Work Orders
Fewer Field Visits
Reengineering From Field/Field Changes
Dispersed Data Maintenance Responsibility
Defined Data Model And Data Location

Duplicate Data Entry
Reduced Data Correction Work
Reduced Data Model Changes
Reduced Street Naming Errors and Correlation to CIS
Crew Response Time
Customer-to-Transformer Linkage Accuracy
Address Accuracy
Materials
Equipment Operations Costs
Materials Forecasting
Safety
Accurate Condition Based Maintenance
Accurate Switching Plans, Operations
Timeliness/Currency
Information/Data Availability/Access
Respond to Customer Inquiries Faster
Export From GIS to OMS
Troubleshooting Smart Grid Communication Issues
Data Acceptance and Confidence
Outage Metrics
Loss - Technical
Loss - Non-Technical
Reporting
Balanced Phase Load
Reduction of Parallel Databases and Sources
Engineering Predictive Capabilities
Avoid Capital Investments
Engineering Analysis Accuracy
Disaster Response
Public Relations
Customer Satisfaction
Critical/VIP Customer Satisfaction
Shareholder Value
Regulator Satisfaction
Employee Satisfaction

Facilitate Compliance with Regulatory Mandate
Rate Base
Rate Base Timeliness
Taxing Districts
Lost Revenue - Streetlights
Lost Revenue - Third Party Attachments
Data Sale to External Agencies
Data Exchange with Internal and External Agencies
Data Consulting Services to Peers
Staff Time/Efficiency
Key Performance Indicators/Dashboard

Below are questions that impact the costs incurred by correcting GIS data. What is the likelihood that your utility will experience each of the listed costs?

Data Creation
Data Maintenance
Current Data Assessment
Staff/Retirees/Vendor Time
QA Team Equipment
Software Licenses
Awareness of Inaccuracies
Automated Routines
Vehicles
Staff Time or Contractor
Data Input
Data Acceptance Review
Equipment
Historical Inaccuracies in Rate Base
Programming
Staff Testing and Acceptance Time
Licenses
Software Cost
Interface Maintenance
Process Change Workshops
Change Management Training
Data Use Training

Appendix B: Benefit-Cost Financial Model

Cost Benefit Analysis Theory

To determine the course of action using a formal Cost Benefit Analysis (CBA) technique, one must consider the costs and benefits of at least two alternatives. In many cases one alternative is to "do nothing". If the "do nothing" scenario is a viable alternative, then the project is discretionary. If "do nothing" is not an alternative, then action is imperative and the alternatives become variants on "do something". The do nothing scenario is often called the baseline scenario and is illustrated in Figure B-1. If there are non-discretionary aspects of the project, the baseline scenario should include them. Thus the baseline becomes the sum of the costs of business as usual plus any mandatory actions that must be taken.

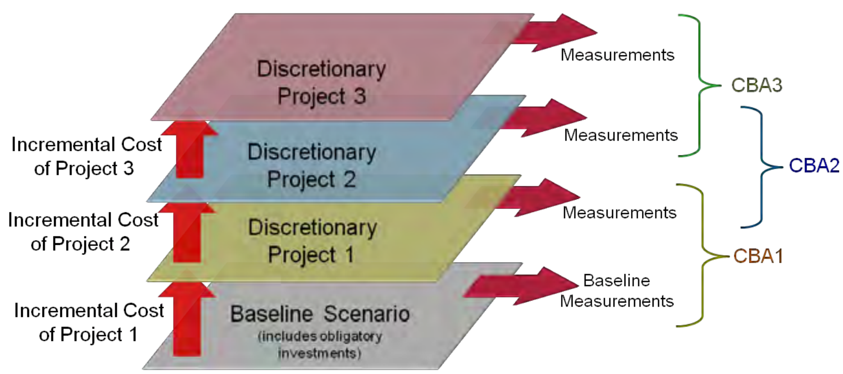

Figure B-1
Layered approach to CBA, including a baseline scenario for discretionary projects with a common objective from Roark[17].

The temptation in measuring costs and benefits for projects to improve GIS data is to lump all the efforts together. However, it is often more enlightening to separate out the projects into incremental efforts. These incremental efforts could be based on technology used to achieve the goal, fiscal periods, organizationally, or any way that makes sense in the context of the individual utility. There may be significant variation in the costs and benefits for each incremental project and the

[17] Roark, *ibid.*

law of diminishing returns becomes a factor. It may not be necessary to run all the projects to achieve the desired level of accuracy and breaking down a data improvement initiative into logical, incremental projects would identify the most beneficial efforts. If the problem is an imperative, the base case might be the lowest-cost alternative that solves the problem. The next-best alternative would be in terms of how much more it costs versus how much more benefit it provides, that is, incremental cost versus incremental benefit. It may not be necessary to run all the projects to achieve the desired level of accuracy and breaking down a data improvement initiative into logical, incremental projects would identify the most beneficial efforts.

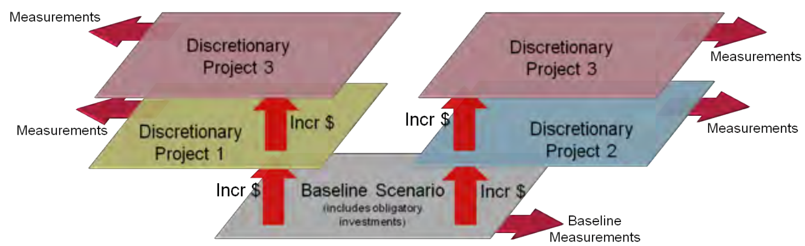

Figure B-2
Layered approach to CBA, including a baseline scenario for discretionary projects with mutually exclusive paths through alternatives from Roark[17].

There may be occasions to evaluate portions that are mutually exclusive that may create multiple paths through the various alternatives. They may end with different versions of the same end state with different benefits. Figure B-2 illustrates this scenario.

EPRI Cost Benefit Calculator for GIS Data Improvement

EPRI has developed a cost-benefit calculator for GIS data improvement projects. This cost-benefit calculator accompanies this report and is a Microsoft Excel[18] spreadsheet entitled "EPRI Cost-Benefit Calculator for GIS.xls". The spreadsheet has multiple tabs and is meant to be flexible and accommodate any number of alternative scenarios for comparison. The spreadsheet is delivered with two options, one of which could be a baseline option containing the "do nothing" and mandatory actions. The spreadsheet is expandable to include more options through a "copy and paste" of the fields on the other tabs to be described below.

The summary tab, illustrated in Figure B-2, contains several input fields. Here, the user can input the discount rate for each option, the name or description for each option as well as the name of the overall initiative. Several values are calculated for the comparison of options and these are displayed in tabular as well as graphical form. The present value (PV) for costs and benefits is displayed along with the overall net present value (NPV) for each option. The number of years before the benefits exceed the costs (breakeven years) is displayed along with the internal rate of return (IRR) for each option. The NPV and IRR are

[18] Microsoft Excel is a registered trademark of Microsoft Corporation, Redmond, WA.

calculated as shown below. For a more rigorous explanation of these metrics, consult an accounting book.

$$NPV = \sum_{t=0}^{n} \frac{(Benefits - Costs)_t}{(1+r)^t}$$

Where:

r=discount rate

t=year

n=analytic horizon (in years)

NPV is calculated by summing the dollar-valued benefits and then subtracting all of the dollar-valued costs, with discounting applied to both benefits and costs as appropriate. A CBA will yield a positive NPV if the benefits exceed the costs.

$NPV_{irr} = NPV_{cash\ in} - NPV_{cash\ out}$

The Internal Rate of Return (IRR) is another way to determine if a project should be done. It is expressed in a percentage where the NPV is expressed in terms of a unit of currency. The IRR is based on the same principles and math as the NPV and many people find it easier to understand than NPV. The IRR shows the discount rate below which an investment results in a positive NPV and should be made. In general, the higher a project's internal rate of return, the more desirable it is to undertake the project. Thus, IRR can be used to rank several prospective projects a utility is considering. Assuming all other factors are equal among the various projects, the project with the highest IRR would probably be considered the best and undertaken first.

The graphs on the summary sheet tab are expandable along with the rest of the spreadsheet. They were intended as quick indications of the relative value of each option and as an aid for the utility to develop a proposal to management. Each graphic can be copied and pasted into a proposal with relative ease.

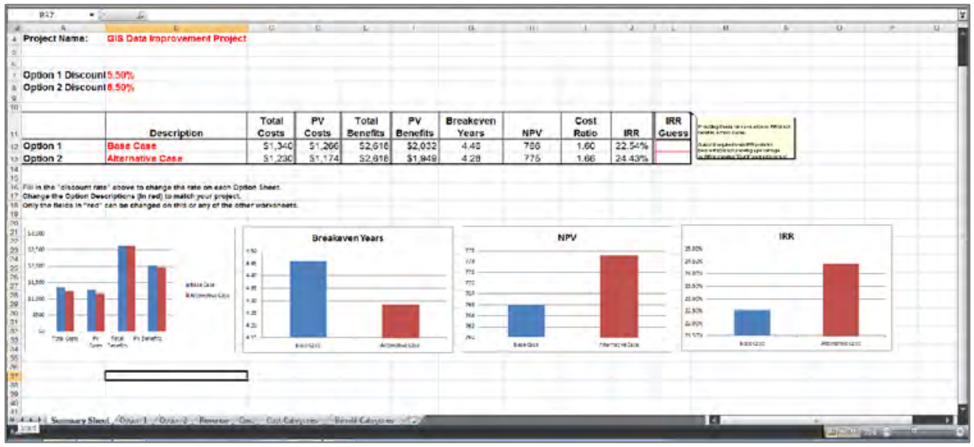

Figure B-3
Summary tab of the EPRI Cost-Benefit Calculator for GIS spreadsheet showing summary tables, graphs for comparison of options, and input fields.

The cost tab in the EPRI Cost-Benefit Calculator for GIS spreadsheet contains the costs categories established in this project and described in Section 6 of this report. The cost tab contains the one time and on-going costs for two options. More options could be added by copying and pasting. The options have the same costs listed in them but they don't necessarily have to have the same costs. The costs are summed and the aggregated one time and on-going costs are listed on the Cost tab for the period of analysis. Typical periods of analysis are ten years but could be more. The Cost tab contains options for 70 years of cost accumulation.

Option 1

Parameter	Description	Area	Primary Objective	One-time Cost	Ongoing Cost
Data creation	Time/effort for process of data creation	Clean-up	Utility Operational Efficiency	1000	20
Data maintenance	Reduced effort for maintenance	Clean-up	Utility Operational Efficiency		
Current data assessment	Required understanding of existing data limitations	Clean-up	Utility Operational Efficiency		
Staff/Retirees/Vendor Time	Actual time for clean-up process	Clean-up	Utility Operational Efficiency		
QA Team equipment	Computers, Monitors, Space	Clean-up	Utility Operational Efficiency		
Software Licenses	Additional seats for GIS	Clean-up	Utility Operational Efficiency		
Awareness of Inaccuracies	Increased awareness of current state of data	Clean-up	Utility Operational Efficiency		
Automated Routines	Programming time	Clean-up	Utility Operational Efficiency		
Vehicles	Light-trucks for field survey	Field Survey	Other	10	10
Staff Time or Contractor	Field resources knowledgable in electrical system	Field Survey	Other		
Data Input	Additional staff time or responsibility for input and oversigh	Field Survey	Other		
Data acceptance review	Staff time and training	Field Survey	Other		
Equipment	Mobile devices and office equipment, GPS	Field Survey	Other		
Historical Inaccuracies in Rate Base	Potential to discover rate base has been miscalculated	Field Survey	Other		
Programming	Develop interfaces between GIS and other systems	Integration	Other		
Staff Testing and Acceptance Time	Interface testing and quality control	Integration	Other		
Licenses	For any COTS solutions	Integration	Other		
Software Cost	Costs for interfaces or bus	Integration	Other		
Interface Maintenance	Ongoing maintenance of interfaces and service bus	Integration	Other		
Process Change Workshops	Development of necessary business process change to supp	Training	Other		
Change Management Training	Staff training workshops	Training	Other		
Data Use Training	Reduction of costs associated with intuitive data, processes	Training	Other		

Figure B-4
Cost Categories tab of the EPRI Cost-Benefit Calculator for GIS spreadsheet showing both one-time costs and ongoing costs for multiple options.

The Benefit Categories tab contains the benefits to improved GIS data as determined in this project. The name of each benefit, along with a brief description of the benefit is found in the Parameter and Description columns. A full description may be found in Section 6 of this report. The Realization Potential column is meant to be a probability that the utility will achieve the benefits listed in the spreadsheet. It was determined from the survey of GIS users described in Section 5 of this report. The remaining columns contain the cost of the resource, the improved resource efficiency due to each benefit, the savings systems, any increase revenue to the utility, and the aggregated annual benefit for each benefit.

	A	B	C	D	E	F	G	H	I	J
1	**Option 1**									
2	**Parameter**	**Description**	**Area**	**Primary Objective**	**Realization Potential**	**Resource Cost**	**Resource Efficiency**	**Systems Savings**	**Revenue Increase**	**Annual Benefit**
3	Asset records integration	Prevent orphan database	Data Creation	Utility Operational Efficiency	68%	$100	50%	$200	$100	$238
4	Unique ID Numbers	Provide correlation between databases	Data Creation	Utility Operational Efficiency	75%					
5	Landbase accuracy	Assets are correctly referenced to real world location	Data Creation	Utility Operational Efficiency	80%					
6	Standardized address format and fields	Not "St" or "Street"	Data Creation	Utility Operational Efficiency	60%					
7	Prevent duplicate entry	Staff don't draw and re-draw designs	Data Creation	Utility Operational Efficiency	63%					
8	Data Timeliness	Data reflects the as-built more quickly	Data Creation	Utility Operational Efficiency	50%					
9	Automated data population on Work Ord	Reduce data entry	Data Creation	Utility Operational Efficiency	63%					
10	Fewer field visits	Efficiency in office	Data Creation	Utility Operational Efficiency	67%					
11	Reengineering from field/field changes	Design correctly the first time	Data Creation	Utility Operational Efficiency	85%					
12	Dispersed data maintenance responsibility	More users have ability to edit basic attributes	Data Maintenance	Utility Operational Efficiency	40%					
13	Defined data model and data location	Documentation for future changes	Data Maintenance	Utility Operational Efficiency	47%					
14	Duplicate data entry	Time savings	Data Maintenance	Utility Operational Efficiency	67%					
15	Reduced data correction work	Time savings	Data Maintenance	Utility Operational Efficiency	80%					
16	Reduced data model changes	Balance storage and creation efficiency	Data Maintenance	Utility Operational Efficiency	64%					
17	Crew Response Time	Accurate routing and problem location identification	Operations	Utility Operational Efficiency	78%					
18	Address accuracy	Reduce 'no address' calls	Operations	Utility Operational Efficiency	60%					
19	Materials	Bring correct replacement materials, no need to meas	Operations	Utility Operational Efficiency	64%					
20	Equipment Operations Costs	Less drive time	Operations	Utility Operational Efficiency	72%					
21	Materials forecasting	Better understanding of existing plant	Operations	Utility Operational Efficiency	72%					
22	Timeliness/Currency	Maps reflect the as-built field condition	Operations	Utility Operational Efficiency	63%					
23	Information/Data availability/access	More eyes on the data, shared ownership	Operations	Utility Operational Efficiency	75%					
24	Respond to customer inquiries faster	Access to customer/premise information	Operations	Utility Operational Efficiency	60%					
25	Export from GIS to OMS	Reduce export time and effort to OMS	Operations	Utility Operational Efficiency	68%					
26	Data acceptance and confidence	Staff acceptance and use of data	Operations	Utility Operational Efficiency	78%					

Figure B-5
Benefit Categories tab of the EPRI Cost-Benefit Calculator for GIS spreadsheet showing benefits for Options 1 and 2.

The list of benefits is not meant to be an exhaustive one. There may be many more benefits or the utility may not see all of the benefits listed. As with the costs, the benefits for each option may not be the same and the benefits listed might be broken up into different options based on the type of project utilized to achieve the benefit. As with the Costs the benefits are summed and the aggregated one time and on-going costs are listed on the Revenue tab for the period of analysis.

The Option 1 and Option 2 tabs are where the year by year calculation of NPV and IRR occur. No data input occurs on these tabs but the formulas for NPV and IRR must be copied for the correct number of years in the period of calculation. The values for the NPV, breakeven period, and IRR are at the bottom of the spreadsheet. These values are linked to the Summary Sheet tab as described above.

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