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Using Geographic Information System to Maintenance and Upgrading Public Utility Networks Using Technology AM / FM

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ABSTRACT: Many applications using Geographic Information Systems technology exist today. From facility mapping to inventory management, from land use analysis to trash collection routing, GIS technology is enhancing the ability of government agencies to provide services to its citizenry. Public utility networks comprise the most important and infrastructure in any city, state, or country. They provide essential support for running a society on uninterrupted daily basis, in most countries. The service area of a single utility company could vary from several hundred to many thousands square miles, and may serve anywhere from a few thousand to several millions customers. With many distributed facilities remotely located, utility systems become more sophisticated to manage and maintain. Traditionally, there are three major challenges facing the utility industry: large service areas, many distributed customers, and remotely distributed aging facilities. Recent deregulation and increasing market competition also have imposed more sophisticated difficulties. Utilities are seeking new technologies to tackle these challenges, and automated mapping/facilities management integrated with emerging technologies, provides vital solutions. (AM/FM) applications consist of water and wastewater, electricity, cable television, telephone, gas, telecommunication. The scope of this article is to find the best solution for managing the public utilities networks, and performing monitoring and maintenance process by combine automated maps which are useful for organizing data in layers overlay with facility management systems, which is responsible for the public utilities network management, reporting, maintenance. The combination of two systems called automated mapping/facilities management which will achieve a better improve, work-order, management, better integrating, and inventory control.

KEYWORDS: GIS, AM/FM, maintenance, management, map.

1 INTRODUCTION

Utilities have used 'intelligent computerized mapping' systems, also known as automated mapping/facilities management (AM/FM) or geographic information systems (GIS), which have been defined as "a geographic information system that integrates non-graphic facilities management information into a database that is tied to facilities maps". In most cases, the topological data structures employed by modern AM/FM software also include sufficient information to store and update connectivity relationships between facilities, thus simplifying utility network analysis applications.

Public utilities have many uses of AM/FM, most of which focus on the need to provide cost-effective services to consumers and better management of resources. Companies across utility industries have demonstrably accepted GIS as a necessary tool for their business. When one takes a look at the nature of information with witch utilities deal, it becomes clear that AM/FM can play a critical role for them.

Public utilities networks are unique in that they have distribution networks that must be maintained, and the locations and selected attribute information on such networks must be shared with other utility providers working in the same areas, and are grouped into two categories:

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- pipeline-based systems: gas, water, and wastewater.
- Cable-based systems: electricity, telecommunications, cable TV, and the Internet.

These two categories have historically been the most powerful users of AF/AM technology. Although the components of a public utility vary from one utility to another, with respect to facilities and services, utilities do have the following common characteristics:

- All utilities possess a physical network infrastructure with facilities/plants locally or remotely attached. This network must be maintained and its information (especially location data) shared with other utilities that share the same land use.
- They usually provide services in a similar way within a regulatory framework.
- They require similar geographic information to support their operations, including: (1) property/land use maps, (2) locations of pipelines and cable systems, (3) street/road networks, and (4) locations of other municipal facilities.
- They use similar spatial datasets and have similar work order management requirements with three basic processes: production, transmission, and service.
- Their routine operations are supported by the same types of spatial data management, analysis, and output functions, including: (1) load and network analysis, (2) records keeping and reporting, (3) facility mapping, (4) outage analysis, (5) maintenance and inventory, and (6) market analysis and customer service [1].

2 AM/FM/GIS Basics

The term AM/FM/GIS mostly refers to GIS software that allows utility users to digitize, manage and analyze their utility network data. This data is stored in an underlying GIS database which also maintains the associations between the graphical entities and the attributes.

AM/FM/GIS is a combination of four separate systems:

- Automated Mapping (AM)
- Facilities Management (FM)
- Automated Mapping/Facilities Management (AM/FM)
- Geographic Information System (GIS)

Table 1. The differences between (AM/FM/GIS) systems

Feature	AM	FM	AM/FM	GIS	AM/FM/GIS
Layers	Y	N	Y	Y	Y
Topology	N	N	N	Y	Y
Network definition	N	Y/N	Y	Y	Y
Lines	Y	N	Y	Y	Y
Nodes	N	Y/N	Y	Y	Y
Polygons (areas)	N	N	N	Y	Y
Attributes	N	Y	Y	Y	Y
Actual locations	Y/N	N	Y	Y	Y
Map intelligence	N	N	N	Y	Y
Facilities management	N	Y	Y	N	Y

Notes: Y = Yes; N = No; and Y/N = Both Yes and No.

2.1 Automated Mapping (AM)

Automated mapping (AM), also known as computer-aided mapping (CAM), is a CAD application for producing maps. It can be considered an alternative to the traditional manual cartographic maps. Data are organized in layers that are conceptually like registered film overlays. Layers organize data by theme (streams vs. roads) and type (linework vs. text). There are no spatial relations (topology) among data elements except orientation.

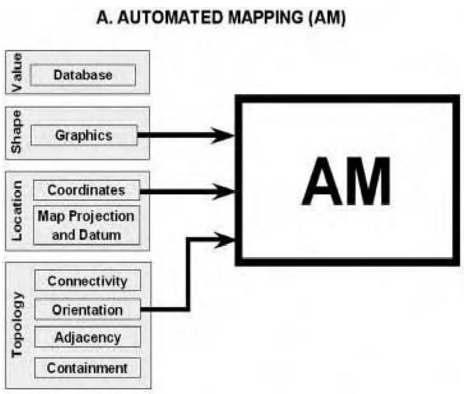

Fig. 1. AM capabilities

2.2 Facilities Management (FM)

Facilities management (FM), also referred to as asset management, is a CAD technology for managing utility system data. FM consists of such activities as inventory, inspection, and maintenance performed by cities, utilities, and government agencies. Organizations incur considerable expenses and resources as these functions are performed on a routine basis. FM includes an infrastructure management database.

Compared with AM, there is less emphasis on graphical detail or precision and more emphasis on data storage, analysis, and reporting. Relationships among utility system components are defined as networks. Because FM systems have network definitions, an FM system "knows" the pipes connected upstream or downstream of a given pipe. As shown in figure 2, FM systems generally do not have full topology; they offer connectivity and orientation only.

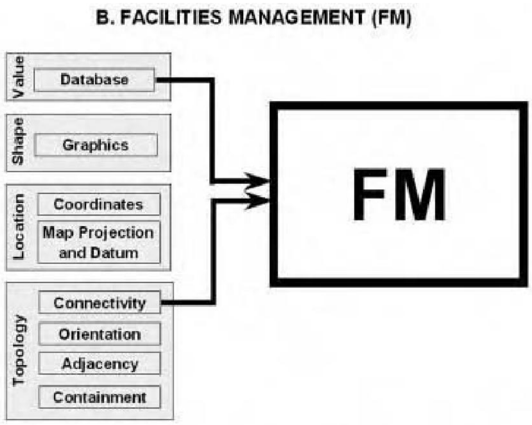

Fig. 2. FM capabilities

2.3 Automated Mapping (AM)/Facilities Management (FM)

AM/FM is a combination of AM and FM technologies. AM/FM software is used to automate maintenance. It allows the integration and automation of maintenance management.

In the past, when a map was needed, a crew of surveyors, draftspersons, and geographers would combine their resources and develop a map on paper. This map was created by hand, updated by hand, and reproduced by a professional printer.

AM/FM systems have both orientation and network definitions as

shown in figure 3. The benefits of AM/FM are improved work-order management, better integrated inventory control, capture of maintenance data and costs, and allocation of costs [2].

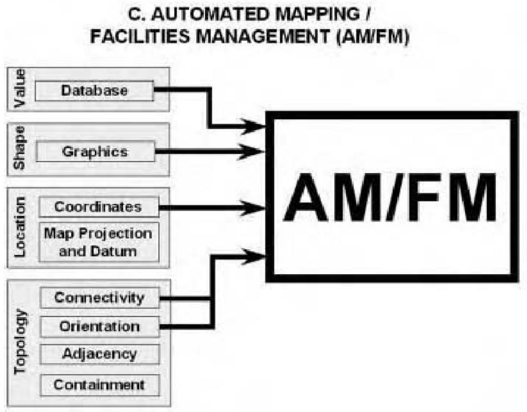

Fig. 3. AM/FM capabilities

AM/FM examples

- locating pole or facility item by street address
- generate reports about puplic utility netowrks
- generate maps of electrical circuits or feeders at prescribed scale
- produce continuing reports on property
- provide reports for tax purposes[3].

2.4 AM/FM/GIS SYSTEMS

GIS and AM/FM are different systems but each has its own advantages and applications. A GIS can help locate the worst pipe. An AM/FM can help users prioritize the work required to bring their worst pipes up to a minimum operating standard. For many years, people have used the GIS and AM/FM systems separately. Developing and maintaining two different systems is expensive and inefficient. Thanks to the latest advances in computer hardware and software, integrated AM/FM and GIS systems called AM/FM/GIS systems are now available. These systems are especially useful for asset inventory, inspection and maintenance, and work management. They are especially popular among visual learners who prefer maps over tables and databases. Visual learners like to click on a manhole in a GIS map to initiate a work order rather than locate it by querying a database. As shown in figure 4. AM/FM/GIS systems have more capabilities than AM/FM systems, such as orientation, network, database, and topology [2].

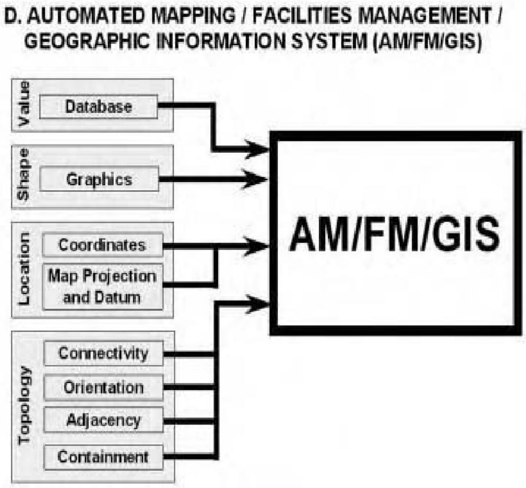

Fig. 4. AM/FM/GIS capabilities

2.5 AM/FM APPLICATIONS

AM/FM technology has been applied to many areas in public utilities. These include automated mapping and map maintenance, infrastructure sitting, records keeping and management, planning/routing, customer information service, network analysis, work order management, and decision making.

As integrated systems become more powerful and alternative spatial datasets become more widely available, more important value-added applications have been realized, including market analysis, decision support, and work order management. Now most utilities are focusing on reducing cost, attracting and keeping customers, and remaining competitive in the market. Under the continuing pressure of deregulation and distribution, utilities are even facing more challenges in using AM/Fm to support new application such as collaborative decision-making and distributed map services.

Spatial analysis is the most outstanding capability in AM/FM systems which support facilities design and planning, operations management, and customer service applications. Because the topological nature of utility networks (connectivity relationships in particular) may be modeled using fairly generic and well-developed tools and data structures, network analysis has become one of the workhorse applications' underline AM/FM usage in most utilities. The applications of AM/FM technology in the utility workplace are numerous. The next Table lists specific applications of spatial analysis capabilities in selected utility sectors.

The spatial analysis application areas common to all utilities are :

- Engineering planning and design
- Network planning, modelling, and simulation
- Trouble spots/plants identification
- Emergency/service crew dispatching
- Market and needs pattern analysis.

In addition, AM/FM systems have proven their principal worth with regard to basic mapping and inventory functions. However, information integration and modelling capabilities of AM/FM systems make them even useful for strategic planning and support of day-to-day routine activities. Strategic planning may include expansion of existing facilities, planning of new services, and sitting of new transmission lines.

The AM/FM technology permits the integration of base mapping, ownership information, property and political boundaries, and existing/proposed land use information to identify potential opportunities and constraints to development. Another important application area is work order management that includes issue work orders, dispatch service crews, schedule equipment (e.g. transmission and distribution equipment), inspection programs, and control workflow [51].

Scattered geographic service areas require work order management systems that identify costs related to specific activities by location. AM/FM helps provide the data necessary to evaluate efficient operations and integrate data into work orders and tasks. In addition, many tools within AM/FM systems provide routine operational support, to other real-time data acquisition applications, for trouble call/outage analysis, distribution automation, customer service, leak detection, maintenance, automated meter reading, and SCADA. For example, there are three benefits that could be gained by using AM/FM to perform an outage analysis:

- Helping operators of a trouble-call system to quickly pinpoint the problems
- Providing valuable information online for dispatching trouble crews, such as site maps, routing, and maintenance records of the faulty facilities
- Providing vital data for the infrastructure replacements through cumulative analysis of outage records.

Table 2. Specific spatial analysis applications for various utilities

Utility	Spatial analysis applications
Electricity	Outage analysis (dealing with trouble calls) Transmission line sitting Load pattern and growth analysis Impact analysis in facilities sitting
Water/wastewater	Breakage and leakage diagnosing Water network flow analysis Modelling damage to water distribution systems Water resource planning and management Simulation of ground water mass destruction Prediction of runoff rates Determination of pressure zone when planning new water distribution facilities
Telephone/cable TV	Network/cable routing Facilities sitting and location optimization Outage and performance problem analysis Black spot/zone analysis in cable television
Telecommunications	Radio propagation and area coverage analysis Optimum antenna heights and locations using DTM information Optimal design of a broad band network layout Analysing tower coverage areas and service accessibility of a mobile communications network Network traffic analysis by combing demography.

3 AM/FM/GIS SOFTWARE

There are currently a variety of computer applications on the market, which were developed for specific components of facility management. In applying automation to these diverse functions, vendors have taken approaches that originate from two different technical directions: CAD or relational database management systems (RDBMS).

GIS-based facilities management requires AM/FM software extensions that can be run from within the GIS software. These add-on programs are also referred to as AM/FM/GIS software. Representative AM/FM/GIS software is listed in Table 3. According to this table, there are two types of AM/FM/GIS software:

1. AM focus: These software provide more mapping (AM) capabilities. ArcFM is an example of this type of software.
2. FM focus: These software provide more database (FM) capabilities. Cityworks is an example of this type of software.

- Software with an AM focus provide better data editing and mapping capabilities and generally require an FM add-on to provide work-order management functions.
- Software with an FM focus provide maintenance management functions (e.g., work-order management) but may lack the map maintenance functions.
- Projects that require both strong AM and FM capabilities may have to use two software products.

For example, ArcFM's strong suite of CAD-like map-editing capabilities can be supplemented by Cityworks' work-order management functions [4], [5]

Table 3. AM/FM/GIS Software Examples

Software	Company	Web Site
	AM Focus	
ArcFM	Miner and Miner	www.miner.com
ArcFM Water	ESRI	www.esri.com
FRAMME	Intergraph	www.intergraph.com
GeoWater and GeoWasteWater	MicroStation	www.bentley.com
	FM Focus	
Cityworks	Azteca Systems	www.azteca.com
GBA Water Master and Sewer Master	GBA Master Series	www.gbamasterseries.com
GeoPlan	Regional Planning Technologies	www.rpt.com
WATERview, SEWERview, STORMview	CarteGraph Systems	www.cartegraph.com
	Proprietary Systems	
CASS WORKS	RJN Group, Inc.	www.rjn.com
IMS-AV and IMS-ARC	Hansen Information Technologies	www.hansen.com

4 MAINTENANCE APPLICATIONS

GIS can be used to prepare inspection or maintenance work orders simply by clicking on a sewer pipe or manhole. This approach simply takes just a few minutes compared to the conventional method of locating and copying maps and typing the work order forms, which usually takes several hours.

4.1 ASSET MANAGEMENT

At present our water and wastewater infrastructure, especially in the older cities, is in critical stages of deterioration and has started to crumble. Nationally and internationally, aging water and wastewater infrastructure is imposing enormous costs on local communities.

For water and wastewater systems, asset management can be defined as managing infrastructure capital assets to minimize the total cost of owning and operating them while delivering the service levels customers. A typical asset management system has five components :

1. Facilities inventory: Describes each system element in an asset group. GIS can be very useful in completing this task.

2. Condition assessment: Classifies each asset according to its capability to perform the intended function.

3. Valuation: Assigns a financial value to inventoried assets consistent with Generally Accepted Accounting Principles (GAAP).

4. Operations, maintenance, repair, and replacement management: Arguably the heart of a management system, this component tracks and records data about work orders and customer complaints, issues and tracks preventive and predictive maintenance schedules, and generates crew assignments and work-site maps. GIS has extensive capabilities to fulfill this part.

5. Analysis and evaluation: Considered as the brains of an asset management system, this component prioritizes work effort, analyzes cost-effectiveness, and optimizes asset performance.

An asset management system helps predict the future condition of assets and major rehabilitation costs for planning purposes. An effective asset management system can reduce the cost of system operation and maintenance (O&M). Every successful maintenance program should begin with an accurate system map because it is difficult to maintain a system if the users do not know where the water or sewer lines are. A well-constructed GIS should be used to create the system map. Historical maintenance data should also be linked with the GIS because it is difficult to schedule maintenance when you do not know the last time it was done.

4.2 WET WEATHER OVERFLOW MANAGEMENT APPLICATIONS

Management of wet weather overflows is a fertile field for GIS technology. By using geographic information in mapping, facilities management, and work order management, a wastewater system manager can develop a detailed capital improvement program or operations and maintenance plan for the collection system.

Broken and damaged sewers, laterals, and manholes usually contribute significant amounts of wet weather inflow and infiltration (I/I) to a wastewater collection system. This contribution often results in combined sewer overflows (CSO) from combined sewer systems and sanitary sewer overflows (SSO) from sanitary sewer systems. This systems require implementation of a Capacity, Management, Operations, and Maintenance (CMOM) program.

CMOM refers to the entities responsible for the administration and oversight of the sewer system and its associated staff (in either a municipal or industrial context); capacity evaluation, management, operation, and maintenance programs; equipment; and facilities. The owner and operator may be two different entities. For example, the owner may own the infrastructure and be responsible for its maintenance while it designates responsibility for the day to day operation of the system to the operator [6].

- CMOM requires the system owners/operators to identify and prioritize structural deficiencies and rehabilitation actions for each deficiency.
- CMOM requirements offer a dynamic system management framework that encourages evaluating and prioritizing efforts to identify and correct performance-limiting situations in a wastewater collection system.
- CMOM is a combination of planning tools and physical activities that help communities optimize the performance of their sewer systems.
- CMOM requirements mandate that the system owner/operator properly manage, operate, and maintain, at all times, all parts of the collection system.
- The owner/operator must provide adequate capacity to convey base flows and peak flows for all parts of the collection system.
- The owner/operator must provide adequate capacity to convey base flows and peak flows for all parts of the collection system.
- CMOM requirements include “maintaining a map”, which is the simplest application of GIS.

4.3 CCTV INSPECTION OF SEWERS

As sewer system networks age, the risk of deterioration, blockages, and collapses becomes a major concern. As a result, municipalities worldwide are taking proactive measures to improve performance levels of their sewer systems. Cleaning and inspecting sewer lines are essential to maintaining a properly functioning system; these activities further a community’s reinvestment into its wastewater infrastructure.

Inspection programs are required to determine current sewer conditions and to aid in planning a maintenance strategy. Ideally, sewer line inspections need to take place during low flow conditions. If the flow conditions can potentially overtop the camera, then the inspection should be performed during low flow times between midnight and 5 AM, or the sewer lines can be temporarily plugged to reduce the flow. Most sewer lines are inspected using one or more of the following techniques: *Closed-circuit television (CCTV), cameras, visual inspection, lamping inspection*.

Visual inspections are vital in fully understanding the condition of a sewer system. Visual inspections of manholes and pipelines are comprised of surface and internal inspections. Operators should pay specific attention to sunken areas in the groundcover above a sewer line and areas with ponding water. In addition, inspectors should thoroughly check the physical conditions of stream crossings, the conditions of manhole frames and covers or any exposed brickwork, and the visibility of manholes and other structures. For large sewer sewer inspection company, has deployed light-linebased and sonar-based equipment that measures the internal cross-sectional profile of sewer systems [7].

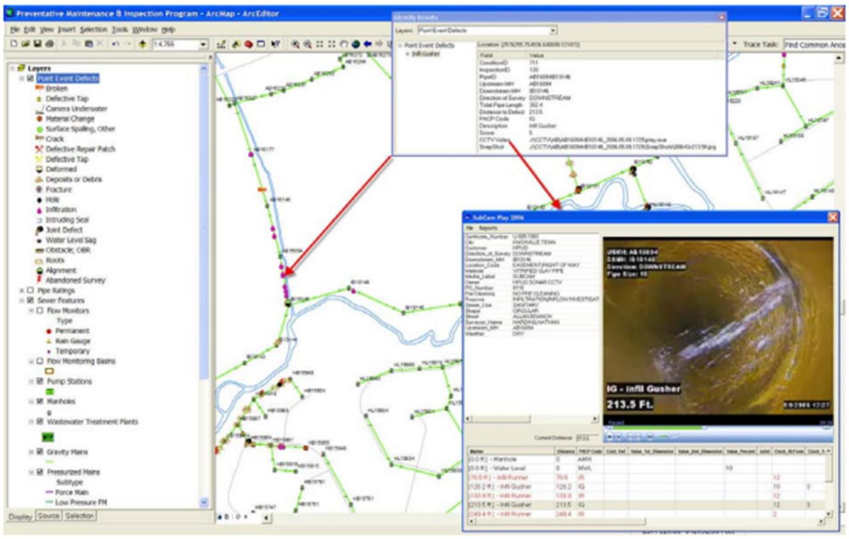

Fig. 5. TV inspection footage is hyperlinked for multimedia viewing within the mapping software

4.4 VIDEO MAPPING

Today, GIS map features can be linked to any kind of file to document inspection of a location through pictures, field notes, audio, streaming video, etc. When digital video, GPS, and GIS maps are combined, the possibilities are limited only by the user's imagination.

Geographic Information Systems are extremely useful for digitally mapping sanitary sewer defects. By locating defects that are spatially referenced to other GIS layers, one may make inferences about the cause of the defect, the type of repair, and an assessment of its repair priority and whether it is hazardous to public safety or the environment. Using field data collection computers, field crews are able to collect defect features with digital maps in the background. After locating the defect either manually according to background layers or by using GPS, the user attributes the defect with a predefined set of attributes. See figure 6 to view the application. Tabular attributes for defect features generally include the following:

- Date Tested
- Inspected By
- Ground Condition (wet, dry, moist)
- Precipitation Type (none, rain, snow)
- Leak Type (main line, manhole, public service line, private service line
- Leak Category
- Degree of Smoke (low, medium, high)
- Leak Cover
- Comments
- Defect Picture(s)

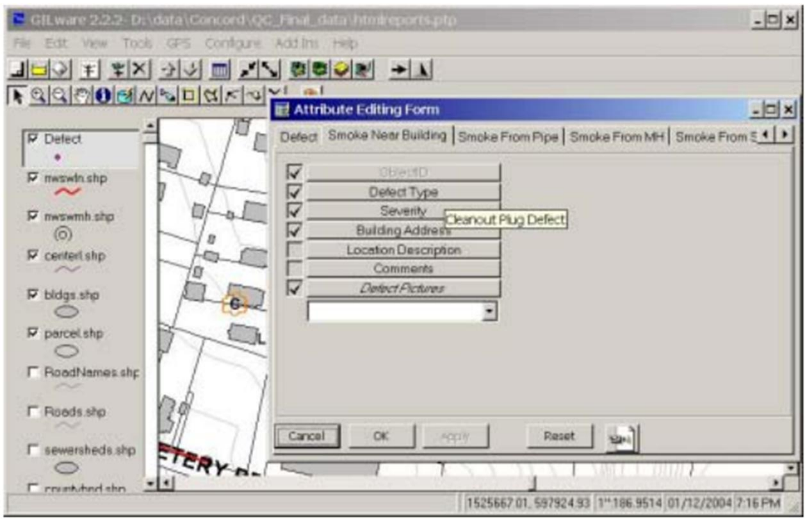

Fig. 6. A GIS application that allows field crews to attribute defects with both location and tabular data. Also, the application relates one or more digital pictures to the defect at the time of capture

Real-time mapping using GPS can accurately locate defects and sanitary sewer structures. By using GPS, field crews may locate defects more accurately to better relate them to a sanitary sewer layer or other layers. Field crews use GPS equipment with accuracy varying from sub-meter to 3 meter. It is important that defects be located with relatively high accuracy in order to be able to relate the defects to other features.

Digital picture documentation greatly helps one determine the type and magnitude of the defect. It also cues repair crews to what they can expect and the type of equipment and materials they will need to make the repairs. The application relates digital photographs to the feature at the moment the image is captured so as to maintain data integrity. Digital cameras are mounted onto the field computer. Additionally, pipe cameras (PipeCam) are special cameras mounted at the end of long poles that are rugged for entering sewer pipes and are equipped with their own lighting. All cameras feed live video to the GIS application where field crews may capture a single frame from the video stream to use as the digital documentation [8].

5 CONCLUSIONS

AM/FM/GIS Systems have been in existence long enough to have a proven track record for a variety of information management and facility management applications. From simple manual file and/or map consolidation uses for eliminating redundancy and increasing speed of reporting, to complicated infrastructure management programs for facility condition inventories, preventive maintenance programs, predictive modeling and real-time data from remote sensors, properly implemented and maintained AM/FM/GIS mapping and database management systems can improve an organizations quality of services delivered while reducing the costs of those services delivered. It is becoming easier for smaller organizations to take advantage of this information management technology due to the reduced cost of hardware and software, and the fact that a higher percentage of the work force is computer literate. Implementation costs can be minimized by sharing the costs of basemaps development with other organizations, and by taking a detailed look at what uses you actually want to implement through a full scale Pilot Study.

Public utilities have realized that AM/FM can be a valuable tool to improve efficiency and productivity. It is not only just for facility mapping, but also for better data integration, decision making, infrastructure management, work order management, and market/customer services. With the use of AM/FM, utility companies also have opportunities to change their industry images and strengthen their ability to compete in the market.

The AM/FM benefits do not come without a price. Typically, organizations incur high up-front costs associated the initial purchase of hardware and software. Further, any significant financial paybacks through saving and fees applications have been developed. Since neither may occur during the first 3-5 years of a program, the discounted B-C ratios for some periods may appear unfavorable to managers unfamiliar with the dynamics of AM/FM investments. As well, even with top-level support for the initiative, building consensus on data sharing at the corporate level can be very time-consuming and may deliver only limited results over the short term.

Even though GIS and AM/FM systems grew from different roots, their mission was the same to streamline map drafting and automate previously manual functions to achieve bottom-line savings. Older systems were implemented on a project or departmental basis. Today's systems tend to be interdepartmental with many different classes of users. The real payback in geospatial systems comes from the applications they provide in addition to the mapping of facilities. But access to spatial data is the key to achieving payback across the enterprise. True enterprise GIS for utility companies means access by virtually every employee through every corporate information system that deals with geographically dispersed assets or customers.

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