The Efficacy of Utility Database Management
BD544-27

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submitted to

The Florida Department of Transportation

by the

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Disclaimers

SI* (MODERN METRIC) CONVERSION FACTORS
APPROXIMATE CONVERSIONS TO SI UNITS

SYMBOL	WHEN YOU KNOW	MULTIPLY BY	TO FIND	SYMBOL
LENGTH				
in	inches	25.4	millimeters	mm
ft	feet	0.305	meters	m
yd	yards	0.914	meters	m
mi	miles	1.61	kilometers	km

SYMBOL	WHEN YOU KNOW	MULTIPLY BY	TO FIND	SYMBOL
AREA				
in^2	Square inches	645.2	square millimeters	mm^2
ft^2	Square feet	0.093	square meters	m^2
yd^2	square yard	0.836	square meters	m^2
ac	acres	0.405	hectares	ha
mi^2	square miles	2.59	square kilometers	km^2

SYMBOL	WHEN YOU KNOW	MULTIPLY BY	TO FIND	SYMBOL
VOLUME				
fl oz	fluid ounces	29.57	milliliters	mL
gal	gallons	3.785	liters	L
ft^3	cubic feet	0.028	cubic meters	m^3
yd^3	cubic yards	0.765	cubic meters	m^3
NOTE: volumes greater than 1000 L shall be shown in m^3				

SYMBOL	WHEN YOU KNOW	MULTIPLY BY	TO FIND	SYMBOL
MASS				
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams (or "metric ton")	Mg (or "t")

SYMBOL	WHEN YOU KNOW	MULTIPLY BY	TO FIND	SYMBOL
TEMPERATURE (exact degrees)				
°F	Fahrenheit	5 (F-32)/9 or (F-32)/1.8	Celsius	°C

SYMBOL	WHEN YOU KNOW	MULTIPLY BY	TO FIND	SYMBOL
ILLUMINATION			
fc	foot-candles	10.76	lux	lx
fl	foot-Lamberts	3.426	candela/m^2	cd/m^2

SYMBOL	WHEN YOU KNOW	MULTIPLY BY	TO FIND	SYMBOL
FORCE and PRESSURE or STRESS			
lbf	Pound force	4.45	newtons	N
lbf/in^2	Pound force per square inch	6.89	kilopascals	kPa

APPROXIMATE CONVERSIONS TO SI UNITS

SYMBOL	WHEN YOU KNOW	MULTIPLY BY	TO FIND	SYMBOL
LENGTH			
mm	millimeters	0.039	inches	in
m	meters	3.28	feet	ft
m	meters	1.09	yards	yd
km	kilometers	0.621	miles	mi

SYMBOL	WHEN YOU KNOW	MULTIPLY BY	TO FIND	SYMBOL
AREA			
mm^2	square millimeters	0.0016	square inches	in^2
m^2	square meters	10.764	square feet	ft^2
m^2	square meters	1.195	square yards	yd^2
ha	hectares	2.47	acres	ac
km^2	square kilometers	0.386	square miles	mi^2

SYMBOL	WHEN YOU KNOW	MULTIPLY BY	TO FIND	SYMBOL
VOLUME			
mL	milliliters	0.034	fluid ounces	fl oz
L	liters	0.264	gallons	gal
m^3	cubic meters	35.314	cubic feet	ft^3
m^3	cubic meters	1.307	cubic yards	yd^3

SYMBOL	WHEN YOU KNOW	MULTIPLY BY	TO FIND	SYMBOL
MASS				
g	grams	0.035	ounces	oz
kg	kilograms	2.202	pounds	lb
Mg (or "t")	megagrams (or "metric ton")	1.103	short tons (2000 lb)	T

SYMBOL	WHEN YOU KNOW	MULTIPLY BY	TO FIND	SYMBOL
TEMPERATURE (exact degrees)				
°C	Celsius	1.8C+32	Fahrenheit	°F

SYMBOL	WHEN YOU KNOW	MULTIPLY BY	TO FIND	SYMBOL
ILLUMINATION				
lx	lux	0.0929	foot-candles	fc
cd/m^2	candela/m^2	0.2919	foot-Lamberts	fl

SYMBOL	WHEN YOU KNOW	MULTIPLY BY	TO FIND	SYMBOL
FORCE and PRESSURE or STRESS				
N	newtons	0.225	Pound force	lbf
kPa	kilopascals	0.145	Pound force per square inch	lbf/in^2

*SI is the symbol for the International System of Units. Appropriate rounding should be made to comply with Section 4 of ASTM E380.
(Revised March 2003)

(chart from http://www.fhwa.dot.gov/aaa/metricp.htm)

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16. Abstract This report details a study of information technology solutions to the challenge of maintaining an ongoing record of utilities facilities installations for the Florida Department of Transportation. A geospatial data management system with graphical capabilities was investigated. Recommendations for the development of such a system were made. A preliminary benefit/cost analysis indicates that the system will be productive and effective.		
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Nomenclature

In this report no special nomenclature or symbols are utilized.

Executive Summary

Introduction

Utility facilities consist of conduits, junction boxes, wires, support structures etc. joined in a distribution network to deliver services to customers. Utilities often share the transportation right-of-way with the roadway by law; yet accommodation of utilities is complicated by the fact that many facilities are buried underground and difficult to locate during planning and construction activities. Even those facilities which are installed above ground are sometimes difficult to document and track. Thus the individuals requiring knowledge of how a particular section of the utility corridor is configured (planners, engineers, installers and permit authorities) are not likely to be able to recover or use this information in an efficient and timely manner.

The purpose of this study is to examine information technology solutions to the challenge of maintaining an ongoing record of utility facilities installations for the Florida Department of Transportation. Attention has been focused on understanding the benefits and pitfalls of developing a system to archive, manage and access available records of facilities installations. The term Utilities Information Management System (UIMS) has been introduced in this report to describe a collection of software applications and procedures intended to satisfy this need. The purpose of this investigation is to examine the efficacy of a UIMS. To accomplish this task it is essential to determine the functional requirements for such a system and outline the steps leading to implementation.

A system with substantial graphics capabilities is envisioned, fostered by the belief that a visual image of facilities organization is of considerable value to the UIMS client, beyond the simple presentation of textual material. Within the geographic information systems (GIS) community a model for this type of management system is the geospatial database. While such a system should be considered as a basis for a UIMS, it is not clear that this choice is cost-effective or even feasible, although GIS incorporates a number of application tools that would be of substantial use. A highly desirable capability of any UIMS is the ability for the user to "point and click" on a map to indicate the location of the site of interest. The system response would then be to retrieve all data from various sources pertaining to this area. Obviously other means of specifying location should also be available, including direct entry of a geographic location description.

A major stumbling block to the implementation of a UIMS identified during this investigation concerns the fundamental incompatibility between computer assisted drafting and design (CADD), which is undeniably the most widely used method for the production of construction drawings and the geographic information system (GIS) approach to graphical presentation of data. While the

ability to overlay and merge visual images from different sources such as CADD and GIS files is highly desirable, these actions are not possible without the assistance of additional application software.   The current state of the art is not fully developed and it is often reported that manual intervention is required to improve alignment and coordinate matching.   Feature extraction, the ability to identify and convert object descriptions to the point, line and area designations of GIS (along with files containing attribute data) is still a relatively primitive tool. Thus, it can be expected that manual intervention will still be required, especially in cleanup, rectification and scaling if the data brought into the UIMS comes from a wide variety of sources.

Four factors contribute to making a UIMS a more complex entity than typical governmental geodatabases intended for other applications; 1) to be useful, facility location information requires a high level of accuracy, 2) it is important to be able to understand the utility network topology, 3) a critical component of location is the vertical position of facilities, and 4) not only are the sources of as-built information regarding facilities diverse but in general this information is incomplete.

As a prelude to the discussion that follows, several concepts regarding the notion of accuracy of location are required. It is necessary to establish an understanding of the idea of an exact position.   The term geodetic data describes a location on face of Earth (but treating the shape as it is, not as a sphere), for example latitude/longitude coordinates.   Thus any point of reference could be specified (or measured) in this manner, and any other point on a map could be determined to some absolute accuracy relative to this reference point. Absolute accuracy on the face of the Earth would be ideal, but not realizable. For practical reasons it will be assumed that the location specification of a reference point has been determined to the best possible accuracy by means of the best available global positioning system (GPS) equipment, so that this point could be recovered at a later time. Then all other descriptions of points, lines and areas will be georeferenced to the absolute coordinates of the reference point. Since other points may not be specified in the same coordinate system, conversions may be required, possibly introducing additional error. For depth specification, the topography (slope and elevation) must be considered when examining a planimetric map). Depth of burial information (or other elevation information) is a separate measurement made from the geodetic surface where a georeferenced point has been provided.

While the most useful type of information for a typical UIMS client is likely to be a highly accurate as-built plan, in fact this kind information is probably the most difficult to produce with a desirable level of accuracy.   Fortunately, other data that can be used to supplement and extend as-built knowledge is available in the form of site investigative reports and ancillary documentation.   Even hand sketches can be useful in some circumstances, but the problem with all of these

various types of information, including as-built, is that the quality of the data (particularly accuracy and completeness) varies and the format in which it is available may not be compatible with the requirements of the UIMS. In order to be useful, data entered into the UIMS must be evaluated for quality, transformed to a compatible format, and geospatially referenced for location. Ideally, it would be possible to inspect and interpret the data found in any resource automatically.

To summarize, it is likely that planimetric view of the R/W corridor will be presented by the UIMS. Starting from a base map including the roadway, this view will be constructed from an overlay of all available plans showing all systems in the vicinity. Additionally point information for the location of SUE excavations and above ground features will be added to the graphic display. Scaling, labeling and other operational characteristics remain to be specified.

Literature review

An extensive review of the literature related to the UIMS was conducted as a part of this investigation. The research team examined work in several states reporting similar efforts to track utility installation as-built information to better understand the motivation for FDOT to construct a UIMS. Sources of information both inside the FDOT itself and outside were investigated. Considerable time was devoted to understanding the flow of information, the quality of data available (especially accuracy) and the processes by which this data could be transformed to become more useful. An examination of available data revealed that a substantial body of relevant as-built information exists as well as the possibility of recovering even more, providing suitable steps are taken. Unfortunately much of this potentially valuable information is either not saved in effective formats or not recovered at all and therefore is lost for all practical purposes. This circumstance means that a considerable amount of costly effort is wasted, and may require duplication at a later date as new projects come on line.

A better understanding of the challenges facing the developers of a UIMS was obtained by studying several prototypes and system models. While none of the examples was exactly the structure envisioned for a UIMS, many were close analogs and all had some features or characteristics which could be potentially valuable if incorporated into a UIMS. From this work, two references stand out as particularly germane examples of prototype efforts showing both the prospects and downside of the establishment of a UIMS [1, 2].

Basis for system requirements and implementation of a UIMS

As a further result of the review of literature, the following is a listing of important issues regarding the development of a UIMS which have been identified during

the course of this investigation. These issues form a basis for establishing the functional requirements and path to implementation for a UIMS.

- It is essential to separate thinking about data quality and availability into the past and the future.   There exists a large body of information regarding current and past installations, but much of this data is either of questionable quality or not in a form amenable to organized database archiving.   If an effective UIMS is constructed and phased in, practice with regard to data collection and storage will likely have to change.   Thus future information should be much easier to handle.

- Spatial accuracy and quality control of original data emerges as a major concern to the effectiveness of the UIMS. Additionally, data referenced spatially in different coordinate systems will require some transformation which may also introduce errors. An accuracy target of +/- 0.5 feet for location specification was suggested as part of the original scope of this investigation. This level of accuracy cannot be assured for all sources but virtually all information is of some value, as long as a parameter indicating quality is attached.

- Spatial alignment and recognition of identical components between data sets introduces yet another level of uncertainty and it is not clear what applications and methods can be used to address incomplete or missing information.

- The transfer of many currently existing records into a UIMS, some of which may be paper based and some in electronic format is potentially a time consuming and expensive task. Existing records of past projects are likely to be in the form of CADD electronic files, SUE logs or paper-based diagrams and not immediately suitable for transfer to a GIS type system. While some degree of commercial automation may be possible, manual effort to transform data can be extremely costly and prone to error. It is also assumed that desired attribute information available including the determination of a spatial reference point, legacy (origination, description, etc), file name and address has been recovered and is available in file format.

- CADD and GIS are quite different in nature and offer different application methods. While CADD has an "engineering" quality with regard to organization and presentation, GIS has imbedded capabilities which could be quite useful for a UIMS. At the present, there are problems with interoperability between CADD and GIS. Considerable effort is ongoing (within the engineering software industry) to develop methods to alleviate this problem. The available data are in a wide variety of formats

(Geospatial, CADD, paper based, etc).   A well constructed UIMS should be able to handle this variety.   Conversion and transformation is likely to require some manual effort, however.

- The advance of technology cannot be discounted.   Whatever decisions are made today, maintenance of the ability to migrate data upwards to new systems is an important consideration.

- Maintaining strict standards on the structure of the database and also attention to the practices developing in other related areas at FDOT as well as other agencies is very important to the viability of the UIMS.

- It is particularly important to choose an appropriate set of standards for the data/metadata associated with the UIMS. Choosing the wrong set of standards may limit the functional capabilities associated with the database and may make upward migration of data into future embodiments of the UIMS difficult.

- No matter what structure is eventually adopted for the UIMS, important data for a specific project or area is likely to be incomplete.   Applications tools will be needed to make the available data more useful.

Structure of the UIMS

Exactly how to construct the proposed UIMS is a major determining factor in this investigation, since any discussion of benefits and costs will depend strongly on the final approach selected.   Prototype UIMS are discussed below.   The differences between these prototypes may be seen in the manner in which data will be tied to a spatial representation or the underlying data structure for the UIMS.   No matter which structure is adopted for the UIMS, a set of application tools will be required to facilitate user interaction with the system. Lack of complete information, accuracy and the ability to tie together disparate data are likely to be serious limitations.

It seems realistic to assume that whatever system is adopted it should conform to existing standards (to permit eventual migration) and direct linkage with current practice is essential (i.e., the system could 'piggyback' on an existing schema). Understanding the current interrelationship and data flow at FDOT is critical. Several different database configurations are possible but it is essential that information regarding utilities is tied to some referencing system.

Four distinct models for a UIMS were examined during the course of this investigation. In the order of increasing complexity, systems which might be considered are

1. <u>Document management system with graphic capabilities</u>

At the present, a considerable amount of information is generated but then for all practical purposes not easily retrieved, even though it is archived. For example, a large number of textual records (contract documents, notes, permits, SUE reports) are scanned and stored in the Electronic Document Management System (EDMS). These documents are not given an attribute incorporating a spatial reference (latitude-longitude or other coordinate system) and therefore cannot be searched for by position. While some location information is provided, it is not amenable to efficient recovery. Furthermore, scanned documents cannot be electronically searched except by conversion through optical character recognition.

Much the same is true for as-built contractor plans. Although final as-built plans are nominally stipulated, in reality there appears to be only marginal adherence to this requirement at present. A rigorous procedure ensuring that high quality as-built information prepared to uniform standards with quality assurance measures and complete attribute information (including especially spatial referencing) needs to be in place.

The emphasis here would be on a central repository of all data, facilitating retrieval of graphic and textual in a useful format. Elevational data might be stored as attributes, as appropriate. Graphic presentation would be limited to simple visualization or a schematic. Relational database management systems such as Oracle may be utilized for this purpose.

2. <u>A document management system linked graphically and spatially to a Location Referencing System (milepost, station etc.)</u>

A location referencing system (LRS), which many states utilize in various embodiments to record information about roadways could serve as the basis for a UIMS (including FDOT SLD). LRS methods use a reference or anchor point and then describe a position along the roadway to a feature (linear offset). Such methods are "natural" for use with roadways which are characteristically long and narrow. In many instances the basic structure is already present and it may be possible to attach a utility database to this structure. Functional requirements are nominally met although a significant problem is accurate representation of lateral offset from centerline position, which is critically important to making a database useful. A LRS approach is not three dimensional and not easy to tie to coordinate systems or CADD drawings. Possible disadvantages include accuracy questions (discussed elsewhere), and the possibility that these systems will eventually be replaced by more accurate geospatial referencing systems.

As a means of documenting the facility organization in the corridor this type of system cannot be recommended, primarily because these systems may be unstable as the roadway is realigned or renovated in other ways. Due to the custom and practice of utilizing linear referencing methods in many applications, it is recommended that the UIMS be equipped with the capability of generating information in this format, including the possibility of representing some facilities in the context of straight line diagram. It is emphasized that this is a desirable subsidiary application tool and not the principal focus of the system.   In the same manner the ability to utilize an LRS to describe the location of the site may be valuable, but should not be viewed as an alternate to an absolute coordinate system.

3. Fully structured geodatabase system

The most advanced system considered consists of a complete geospatial database, incorporating GIS applications and capabilities, utilizing a complete geospatial referencing system (latitude/longitude). The principal advantage of this choice is that all the software tools and power of GIS can be brought to bear on problems and tasks facing the user.   In principle this type of system would meet all functional requirements and have the advantage of good spatial organization.   The largest problem likely to be encountered will be attempting to bring in accurate data from a variety of sources. Thus the geodatabase approach would appear to satisfy the requirement to bring all facilities in the area of interest together, with graphic visualization. An additional advantage would be that an LRS or roadway centerline diagram could be superposed in the same manner.

There are several ways in which such data could be presented and examined. In addition to conventional approaches, one advanced possibility would be to be able to call up a cross sectional view of the corridor (normal to the centerline) as well as a profile view and plan view of the local conditions inside the corridor volume. These views would be interpreted as as-built diagrams and stored with maximum attainable accuracy.   Associated attribute data would be stored in relationship to these diagrams.

4. A hybrid system, based on a GIS format and application tools with the ability to combine GIS and CADD

The system envisioned would permit the display of CADD files aligned directly on a GIS background layer. Scanned paper maps and plans could be projected in the same manner, assuming that these documents could be georectified with manual effort. With this type of system other data could be readily combined as, for example, point information acquired

from site investigations - including subsurface utility engineering procedures (SUE) - and referenced to either a geodetic system or a project coordinates system. Thus a limited amount of integration of data from different sources could be accomplished. It appears that a system of this nature could be developed using current technology and a strategy of evolving this system from the first alternative above would be logical. This option closely resembles the efforts discussed in References 1 and 2. In time, technology will undoubtedly improve and this system could continue to evolve towards Option 3, described previously. Although the level of effort exceeds that of the first option, the hybrid system has much to offer.

Summary of recommendations

1. Establish "ownership" and an oversight committee responsible for the developmental direction and maintenance of a UIMS. The committee should carefully monitor trends and new developments in all related areas (GIS, GPS, SUE, etc). The committee should also provide liaison with the state-wide GIS enterprise system. Until such time as other private and public utilities can be integrated into the system, FDOT owned facilities should be managed by the UIMS.

2. Adopt a structure for the UIMS based on a GIS geodetic reference system (latitude-longitude coordinates). For the present however, maintain a CADD based overlay procedure that avoids feature extraction. Acquire applications software to accomplish transformation of data to appropriate formats. Linearly referenced coordinates for plans, etc. should be available, for convenience. This recommendation (Option 4) would lead to a georeference for all data that is consistent and stable, while at the same time coordinates for other referencing methods can be generated. This recommendation also anticipates the further development of extremely accurate GPS data acquisition.

3. For visual presentation to the user, adopt an "area of interest" concept so that all available data around a specific site is accessible via a point and click visual interface.

4. For textual materials and some other document types, a direct link to the EDMS system is essential; however in all cases a geospatial attribute for relevant data contained in the EDMS will be required. Several other important information sources are available and need to be accessible by the UIMS. For example, from other FDOT databases, the Five Year work plan, data from the Roadside Characteristics Inventory, State maps, etc. should be easily obtained during routine operations.

5. <u>Adopt robust data standards and metadata format</u>.   Ensure that data stored at the present will easily migrate to future systems.

6. <u>Inventory and evaluate</u> all available data concerning utility facilities (to be an ongoing process). A clear chain of data stewardship should be established. The approach needed to incorporate old data into a UIMS is quite different than information being currently developed (see next recommendation). Recognize that, the older the data is, the more difficult it may be to bring this information into a UIMS in a cost effective manner (for example, paper based plans and documents).

7. <u>Include quality control for all data archived in the UIMS</u>. Attach to each data set an attribute indicating the relative accuracy (in the same manner that SUE information is rated D, C, B, A).   For example,

Level I: Paper maps, plans, and recollections only
Level II: Onsite verification of aboveground facilities, markings etc.
Level III: Onsite detection by sensors, with GPS spatial reference
Level IV: Survey or SUE information; sealed plans document

8. <u>Initiate a program to archive newly developed data</u> from current and planned projects in a suitable form for incorporation into a UIMS as soon as possible. While the establishment of a final system structure is being implemented, it is very important not to lose the value of this incoming data stream. At the very least, all new data should conform to proposed standards and textual data should be georeferenced (Option 1).

9. <u>Make policy changes to improve as-built quality.</u> Avoid loss of any useful information including capturing raw data at sites (utility marks, photographs of open excavations, etc). Require as-built documents from contractors in machine readable formats. The importance of high quality as-built information cannot be overemphasized. Consider changes in law to require utilities to release information regarding facilities. Implementation of this recommendation for FDOT owned facilities should be relatively straightforward.

10. <u>Merge or attach the UIMS to existing enterprise GIS</u> efforts in the State. Linking the UIMS activity to major ongoing efforts will build on experience and other data sources, to make the transition period smoother, save money and help to deflect resistance to the adoption of a "new" system. Regarding overall adoption, it is recommended that the UIMS be phased in gradually, rather than an instantaneous changeover, to minimize transitional problems.

11. <u>Provide a prototype UIMS for adoption by each district</u> but maintain a decentralized structure (rather than a centralized system).   Most utility installations and relocations are confined to one district and are best handled at the local level. Projects crossing FDOT District boundaries can be treated by facilitating communications between the districts. The intent of this recommendation is that the Central Office would provide the system protocols and the UIMS software (to be implemented without deviation) but leave the operation of the UIMS to the Districts.

12. <u>The use of commercial software for GIS applications and other data operations is strongly recommended</u>. Any software adopted should conform to standards chosen and also be totally compatible with existing software.

13. <u>Defer extensive feature extraction</u> (especially from older documents) until commercial software capabilities improve. It is unlikely that GIS will replace CADD for the generation of engineering plans.   In time, merging information from different sources will synthesize virtual as-built documents for locations of interest.

14. <u>Consider a strategy of data integration and improvement</u> "on the fly", as opposed to a massive project to incorporate all older data in the UIMS. In this approach, available older information would be examined and integrated into the UIMS in an area of interest at the onset of a new project, when there is a strong motivation to obtain the most complete data inventory possible. If implemented, this method would focus attention on those areas with the most current interest and avoid wasting or duplicating effort on areas not immediately needed. Furthermore, projects in the future could presumably take advantage of improvements in technology.

15. <u>Begin with a pilot study.</u>, perhaps a single district or a distinct region. If integration of public and private utility information proves to be initially unmanageable, consider as a first effort just FDOT owned facilities. A pilot study could offer several benefits and many important lessons could be learned. For example, a realistic measure of the effort involved to incorporate older data would be obtained and the cost of developing and maintaining a UIMS could be gauged.   Once the system is functional, user feedback and experience would be invaluable for system improvement.

16. <u>Actively search for data partners</u> (who will often also be potential users).   The utility companies themselves represent the largest of this group. Other stakeholders include SSOCOF as well as county and municipal utility coordinators. Obviously, many obstacles to obtaining this

important data remain (communication, data ownership, security, standards, etc).

17. <u>Consider web based and wireless access</u> for remote users of the system (consistent with security concerns). Provide for onsite acquisition of GPS data for utilities facilities mapping, with direct downloading capabilities to the UIMS. Consider direct capture of raw data such as open excavation photographs and utility markings at worksites. A small additional investment will likely enable a much broader use factor for the UIMS.

18. <u>Establish an ongoing training and education program</u> to introduce and explain the UIMS to potential users and data partners.

19. <u>Regarding overall UIMS adoption</u>, it is recommended that the UIMS functionalities be phased in gradually (possibly a few functionalities at a time), rather than a complete instantaneous change-over, to minimize transitional problems.

Summary of benefits and resources needed

The principle outcomes of the implementation of a UIMS are expected to be an improved planning process along with reduction in claims, traffic delays and accidental utility cuts. Efficient reuse of valuable information is anticipated. In addition:

1. The UIMS capability for recovering and visually displaying information regarding site conditions will enable the client/user to better understand the situation at the project site.

    a) Improved speed of acquisition – avoids confusion and overlooking important material

    b) Provide quality statement to accompany data -minimize mistakes due to quality control issues

    c) Improved compatibility and access with other sources of information - all relevant factors can be considered simultaneously

2. Data from ongoing projects will continue to accumulate, but is useless if not organized and readily available.

    a) Avoid duplication of the effort to acquire information

b) Lost (or irretrievable) data is a wasted opportunity to improve future knowledge

3. Subsurface Utility Engineering represents a special case of the first two items and in fact provided one of the original motivations for the present study.   Utility projects frequently require the application of SUE (at considerable expense to FDOT), but these reports are not retained in a directly accessible spatially referenced format, so that SUE data cannot be easily reused.   It has been estimated that some utility facilities must be located by SUE techniques as many as five times over the life of the facility.   Thus each reuse of SUE data multiplies this benefit.

4. The introduction of a UIMS offers a unique opportunity to capitalize on existing effort at FDOT.   The current mode of operation regarding planning for utilities installation involves a number of steps, many of which are manual and labor intensive tasks.   The processes related to the UIMS operation recommended here would capture and archive this work. Thus all the effort related to current planning could be reused effectively on future projects, avoiding wasteful duplication.

5. FDOT is currently in the process of adopting an Enterprise Geographic Information System (EGIS).   If the recommendation to attach the UIMS to this effort is adopted then the benefits associated with the EGIS will accrue additional leverage.

Frequently it is observed that the implementation of systems such as the UIMS is front end loaded with respect to investment and the benefits are realized slowly in the future. It is not possible to quantify the costs of UIMS implementation at this time, since a system structure has not been chosen.   The following observations are offered, however:

1. Additional personnel will be required and these individuals will require sufficient background in database, GIS and CADD software. Any additional staff effort would be devoted to transferring information to the UIMS.   Depending on the level of UIMS functionality adopted, digitizing and other manual effort would also be required (it may not be realistic to archive some types of older data). The total time spent in these activities would be in part offset by the reduction in staff time required to research poorly archived data, and general improvement in the overall work effort.

2. Realistically, there will be an increase in cost associated with acquiring high quality, verified as-built information.   It is noted that this increase may be marginal, since this data is already being collected. What will be required is to put the information in machine-readable form instead of

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hand annotation. Most of this effort will come from outside FDOT workforce and will result in increased prices for effort.

3. There will be some associated increase in computer hardware, particularly in storage capacity and routing.   The impact of equipment should be marginal however, since FDOT has an established computational infrastructure and especially if the UIMS is tied to the EGIS effort.   Furthermore, much client access will be from existing desktop PCs.

4. Most major software required to support the UIMS is already in place at FDOT. It is anticipated that some bridging applications packages will be required, however.

5. Training for all personnel involved in the UIMS should be planned as both an initial and ongoing activity. Furthermore, to maximize the benefits of the system, training for all potential clients (both inside and outside FDOT) should be planned.

6. Just as some benefits are intangible, there are intangible costs associated with <u>not pursuing</u> a course of action, which might be referred to as the value of lost benefits or opportunities. This category includes items such as reduction in claims, reduction in damage due to utility cuts, reduction in traffic delays, all of which have economic impact which will not be fully realized if the UIMS approach is not adopted.

Conclusions

The benefits and advantages of implementing a UIMS for the FDOT appear to be significant, and are expected outweigh anticipated costs of adoption. It is recommended that the FDOT pursue the course of action outlined in this report.

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AASHTO	American Association of State Highway and Transportation Officials
ADAM	Automated Access Management System
AGF	Above ground facility
AM/FM	Asset management/facilities management
ANSI	American National Standards Institute
API	Application programmer interface
ASCE	American Society of Civil Engineers
ATM	Automatic teller machine
BLOB	Binary Large Object
CADD	Computer assisted drafting and design
CFPMS	Construction Final Plans Management System
CGA	Common Ground Alliance
CGDI	Canadian Geospatial Data Infrastructure
CORS	Continuously Operating Reference Stations
COTS	Commercial off-the-shelf software
CSM	Conceptual site modeling
DIRT	Damage Information and Reporting Tool
DMBS	Database management system
DSS	Decision Support System
EDMS	Electronic data management system
EIP	Enterprise Information Portal
EGIS	Enterprise Geographic Information System
EST	Environmental Screening Tool
ETDM	Efficient Transportation Decision-Making
FDEP	Florida Department of Environmental Protection
FDOT	Florida Department of Transportation
FGDC	Federal Geographic Data Committee
FGDL	Florida Geographical Data Library
FHWA	Federal Highway Administration
FIT	Framework implementation team
FLUG	Florida User Group
FUCC	Florida Utilities Coordinating Committee
GDF	Geographic data format
GAIP	GIS Architecture and Infrastructure Project
GIS	Geographic information system
GIS-T	Geographic information system-transportation
GML	Graphics Markup Language
GPS	Global positioning system
GRIP	Geo-Referenced Information Portal
GSOC	Gopher State Onecall
GUI	Graphical user interfaces
INDOT	Indiana Department of Transportation
ISO	International Standardization Organization

IT	Information technologies
ITS	Intelligent Transportation Systems
IUPPS	Indiana Underground Plant Protection Service
LIDAR	Light Detection and Ranging
LRA	Local Road Authority
LRE	Long range estimating
LRM	Linear referencing method
LRS	Location referencing system
MnDOT	Minnesota Department of Transportation
NASA	National Aeronautics and Space Administration
NAVD	North American Vertical Datum
NCHRP	National Cooperative Highway Research Program
NCITS	National Committee for Information Technology Standards
NSSDA	National Spatial Data Accuracy Standards
ODAIMS	Outdoor Advertising Inventory Management System
OGC	Open GIS Consortium
PEDDS	Professionals' Electronic Data Delivery System
PITS	Permit Information Tracking System
PLSS	Public Land Survey System
QC	Quality control
R/W	Right of way
RA	Road Authority
RCI	Roadway Characteristics Index
RDIS	Roadway Data Integration System
RDMBS	Relational database management system
RITA	Roadway Inventory Tracking Application
ROW	Right of way
RWMS	Right of Way Management System
SBIR	Small Business Innovative Research
SDSFIE	Spatial Data Standard for Facilities Infrastructure and Environment
SIS	Strategic Intermodal System
SLD	Straight Line Diagram
SPO	System Planning Office
SSOCOF	Sunshine State One Call of Florida
SUE	Subsurface utilities engineering
TIMS	Project navigator
TxDOT	Texas Department of Transportation
UAM	Utility Accommodation Manual
UC	Utility Company
UIMS	Utilities information management system
WPAGIS	Work Program GIS Application

Chapter 1: Introduction

There are over 100,000 miles of roads in the State of Florida, of which the Florida Department of Transportation (FDOT) is responsible for about 12,000 miles. These roads share the right-of-way with utilities, which are permitted by law to install their facilities in acceptable locations (coordinated with the FDOT). Unfortunately, corridor occupancy by utilities has been allowed to develop and grow without much oversight, and in many cases with little record keeping. This problem is especially evident in the case of buried facilities which are not visually apparent. Installation, maintenance and expansion activities in the transportation right of way (R/W) are continual and extensive.   Not only are new utility facilities placed in the corridor, but due to roadway construction and modification, it is often necessary to relocate existing facilities.   The lack of adequate record keeping regarding the location of facilities results in poor planning for new installations, costly claims for compensation, damage to existing infrastructure, and unnecessary delays for traffic. Attempts to avoid these problems have resulted in expensive efforts to locate existing facilities. FDOT is currently spending about $6,000,000 annually on subsurface utility engineering (SUE), at least some fraction of which is spent on locating the same facilities several times.

Doing nothing at all towards addressing these issues is unrealistic. As time goes by the infrastructure of underground and aerial utilities will grow dramatically while the available right-of-way will decrease.   Increased congestion will generate more problems in terms of access, damage and delays for traffic. It is essential that a system be designed and implemented to organize and make accessible the available information about this infrastructure.

The study reported here is concerned with a means to improve management and record keeping regarding the location of utility facilities. A succinct question was raised in the initial scope document:

> "What would be the personnel, hardware, and software requirements to support a utility graphic, as-built database"?

The intent of the present effort is to attempt to answer this question and to recommend the implementation of a system that could mitigate the types of problems outlined above.

The owner of a particular facility may or may not have good as-built records. At present there is little incentive for this record to be made available to the agency managing the right of way at the time of installation and relatively little authority exists to require this submission. When it does exist, substantial obstacles can block the transfer of this information to stakeholders who need the data. Utility companies may have this information but do not readily share it. On the other hand, there are many other potential sources of information (including original plans, SUE investigations, physical markers, etc) which can provide alternate

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information in the absence of high quality, as-built documentation. As a practical remedy to this problem, it may be possible to broaden the definition of "as-built" to include these different types of records, all of which have variable quality. Diagrams, in the form of computer assisted drafting and design (CADD) files and paper based plans present special challenges as will be discussed.   Finally, there is a substantial difference in currently existing information about past installations and likely advances in the manner of acquiring and recording information about installations in the future.

To provide some perspective for the project discussed here, a recent article on BBC news detailed a pilot project for the eventual mapping of the entire underground pipe network in the UK, expected to cost £2.2 million [1.1].   A strong motivation for this effort was the fact that there are 30-40 excavation incidents each year with serious injuries, caused in part by lack of location information. This project will involve the new, highly accurate Galileo system, a European innovation for global positioning.

Recognizing that reliable as-built information regarding utility facility installations is rarely available, this investigation envisions a system for archiving all available information that could be potentially utilized as an indication of how facilities were constructed. Furthermore, it is assumed that an indication of quality/accuracy can be attached to this information. For example, consider an existing subterranean installation of a pipeline along the roadway. An as-built record of the installation would consist of spatially accurate coordinates for the depth of burial and the horizontal position along the R/W corridor (measurements to be made at certain intervals along the length as a practical consideration). Because most installations tend to lie parallel to the pavement, substantial deviations from the original planning (avoidance of obstacles, for instance) would be specially noted. Other relevant detail about the actual construction would be similarly recorded.   A record of the reference coordinates for all plans would be retained.

A central question here is concerned with the level of spatial accuracy that is realistic for the facility spatial location records.   Obviously the potential user desires the most accurate information possible, but in fact currently spatial accuracy may not permit all potential applications for as-built data. Because the subterranean corridor is hidden, information is often inaccurate. The aerial corridor is only slightly easier to deal with in this regard. Furthermore, records are frequently incomplete (insufficiently resolved). Especially for legacy data without sufficient pedigree (older paper records, for example), accuracy and precision may be only marginally useful yet expensive to transfer to a database. Even some newly gathered information will lack accuracy, completeness or adequate spatial reference.

While properly referring to a formal, structured approach to archiving and retrieving data, the word "database" has become a popular phrase and is so commonly used that the true meaning of the word may be misinterpreted.   In this

report, the phrase "Utility Information Management System" (UIMS) has been introduced to describe the projected development of a graphical as-built database and associated software applications for utility facility installations (as originally discussed in the Scope document) and this acronym will be used instead of the term "database", to avoid confusion. It should be noted that the system manages other information (in addition to location information) such as temporal aspects related to the subject information, utility inventory ownership, etc. Furthermore, it is a goal of this investigation to place the research and findings into the formal structured approach that drives much of IT related implementations at present.

At this point, it is valuable to discuss the scope and the potential uses of a UIMS in relation to the business activities of the FDOT. A number of "clients" might be expected to utilize the proposed UIMS, including planners, installers, managers, designers, excavators, coordinators and others. An important aspect of the construction and maintenance of the UIMS is to understand how these clients would utilize such a resource and what they would expect to receive from an inquiry. The information and workflow for each of these potential clients will undoubtedly be different.   A preliminary concept regarding utilization is adopted for the present discussion. A client is likely to have a specific geographical location in mind (a specific point or "area of interest").   Thus a routine query should trigger a call-up of all stored spatially referenced information within the specific region should result.

A significant part of the problem associated with defining a UIMS is to understand how it is going to be used and who the likely users are. Potential notable applications expected to benefit from an integrated UIMS include:

- Permit granting (installation)
- Planning-Engineering design services
- Utility operators (service and maintenance)
- Contractors/Installers
- Emergency response (emergency, repair, or access)
- Right of way management
- Maintenance of traffic
- Reimbursement negotiations
- Data correlation and reporting

For each potential application a list of proposed capabilities should be developed. A corresponding list of UIMS capabilities will likely include:

- Storage and inventory of existing information
- Finding all records relating to an "area of interest"
- Query, associated attributes and metadata
- Rectifying spatial or location information

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- Overlay of new planning and identification of conflicts
- Overlay of information from several sources (creating a composite image)
- Generate new or hybrid views from existing data
- Manipulation and improvement of existing knowledge
- Access to other data bases and merging of information

Obviously a principal function of such a system would be related to the planning and execution of utility installations along the roadway, in conjunction with new facilities or the relocation of older, existing facilities. At the earliest concept stages of a particular project, records of existing installations might be extremely useful in avoiding poor choices altogether.   During planning and installation, accurate information could be extremely valuable in verifying locations and avoiding collateral damage, as well as avoiding poor locations due to clearance limitations. Status reporting and facility inventorying functions would also be facilitated.

In 2005 researchers at the University of South Florida completed a project for the FDOT entitled "Optimum Placement of Utilities Within FDOT R/W" [1.2]. This project was a speculative effort to determine if optimization could be applied to the problem of utility placement in order to achieve a better utilization of available corridor resources, both for cases where facilities were to be placed or relocated in existing corridors or in the case of planning for new corridor development.   As part of this effort, the possibility of automated permitting was investigated. It was determined that optimization could serve as a planning and assessment tool, and that a properly constructed program could be used to consider locations and possibly issue a permit directly. The primary barrier to implementation was the fact that the location of existing facilities would need to be entered into such a program manually, as there was no clear path for data query and electronic transfer of this information.   If a utility database of the nature being considered here were to be established, a direct transfer of this information might be implemented.   Such a step would be a distinctly valuable direction for this software development.

1.1 Application of Information Technology (IT) regarding utility facilities

Utility facilities are collections of physical objects - conduits, wires, poles, boxes, risers, valves, etc. - installed in specific location to provide distribution of services. Facilities may be buried, suspended aerially, or found at ground level depending on type and function. The concept of facility installation usually implies an attachment, or other connection to a transmission network, a fact that expands the notion of specific point location to a larger region of space. A utility network can be described in many ways, most importantly here in terms of operation, location and specification. Supervision of any aspect of the facility usually requires managing the information about the facility, and this statement

applies as well to the role of the state in regulating the occupancy of the right of way resource for the utilities. Such information is often spatial in nature but is presented in a variety of formats. Legacy data (including records of maintenance, cost data, documentation etc.) are frequently found associated with specific facilities but not necessarily directly linked through any management process.

To facilitate understandability, several terms and concepts frequently used throughout this report are defined next.

1. Database

A database [1.3-1.5] can be thought of as a computerized filing cabinet. This filing cabinet electronically stores data defined and "filed" by users within the organization, usually referred to as the "enterprise", that maintains the database.

The database system has both hardware and software components. Hardware is the physical storage medium for the data; i.e., hard disk, tape, etc. The software is the medium through which the user accesses the physically stored data. This software is called the *database management system (DBMS)*. The DBMS allows the user to store, retrieve, and update data without having particular knowledge about the physical location of data or how related data is stored. In effect, the user is provided a *view* of the data that makes it easy for him or her to access and use.

Today, the most widely used DBMSs are relational (RDBMSs). There are three classes of database systems with different levels of complexity and sophistication: enterprise databases, workstation databases, and personal databases. An *enterprise database* is a large database that runs on one or more servers and may have client users spread throughout many locations. It must be capable of handling a large quantity of transactions and the execution must be in real-time. For example, a transaction involving an ATM debit should be recorded in the time frame of seconds. It uses sophisticated security measures and can allow different levels of access by client users. Database management systems such as Oracle[©] (Oracle Corporation) and DB2[©] (IBM) are typically used for these applications. A *workgroup database* typically runs on one server and distributes information to several client machines running on the same local area network. The level of transaction processing is much lower than that of an enterprise database, but the DBMS must be capable of handling multiple clients that are independently generating transactions that change the contents of one or more databases running concurrently on the DBMS. Microsoft's SQL Server[©], which supports client/server architecture, is a popular choice for workgroup applications. A *personal database* runs on a single personal computer. This type of database has

a lower transaction-handling rate and is not designed with sophisticated administrative tools for setting levels of security. Access DBMS$^{©}$ is a good example of a personal database.

2. Document management system

A document management system [1.6] is a set of computer programs used to track and store electronic documents and/or images of paper documents. Document management systems commonly provide storage, versioning, metadata, security, as well as indexing and retrieval capabilities. Typically, metadata stored for each document include the date the document was stored and the identity of the user storing it. The document management system may also extract metadata from the document automatically or prompt the user to add metadata. Some systems also use optical character recognition on scanned images, or perform text extraction on electronic documents. The resulting extracted text can be used to assist users in locating documents by identifying probable keywords or providing for full text search capability. Simple retrieval of individual documents can be supported by allowing the user to specify the unique document identifier, and having the system use the basic index (or a non-indexed query on its data store) to retrieve the document. More flexible retrieval allows the user to specify partial search terms involving the document identifier and/or parts of the expected metadata. This would typically return a list of documents which match the user's search terms.

3. Data warehouse

A data warehouse [1.3, 1.4] is a subject oriented, integrated, time-variant, and non-volatile collection of data in support of management's decision-making process. The ultimate goal of data warehousing is to integrate enterprise-wide corporate data into a single repository from which users can easily run queries, produce reports, and perform analysis. A data warehouse is a decision support environment that takes data stored in different operational sources, organizing it and making it available to decision makers throughout the organization.

4. Geographic information systems (GIS)

GIS is a computer-based technology comprised of methods, strategies and applications used to represent information about regions on the face of the Earth. GIS has found wide application in the environmental sciences, hydrology, and biology as well as many other areas of study. Geographic Information Systems for transportation applications (GIS-T) support the concept of a unified system to store the vast amount of information regarding utility facilities in the transportation R/W. The

potential importance to the topic of the current investigation is obvious. In fact investigations of the potential for Geographic information systems (GIS) development by governmental agencies frequently suggest utilities as an important theme. It seems most likely that any UIMS development would rely heavily, if not completely, on GIS technology.

5. Geodatabases

A relatively recent development is the "geodatabase" system [1.7], which utilizes the principles of GIS to store a large amount of information in common formats allowing for the use of conventional database queries. Geodatabases are also classified as "personal" or "enterprise" in nature. Personal geodatabases are organized around one (or possibly several) users with limited application. An enterprise geodatabase takes its name from the business enterprise model: a group of people and practices organized to deliver goods and services. Many states and other governmental entities have turned to an enterprise approach to manage the large amounts of data that they wish to publicize and distribute. Because much of this is spatial in nature a geodatabase is a logical strategy to adopt. An enterprise geodatabase involves many individual users, accessing databases which are usually in different formats. Users are provided with different levels of access and editing abilities, according to need and qualification.

6. Computer assisted drafting and design (CADD)

CADD (mentioned earlier) is a software tool which has evolved as the standard for accurate plans generation. The engineering community has wholeheartedly embraced the use of CADD to produce electronic plans and associated design work. Like GIS, CADD is supplemented by many application software packages intended to provide specialized results.

7. Asset and facilities management (AM/FM)

An area of software development of interest in this investigation is asset and facilities management (AM/FM) software packages which are used by facilities owners to maintain, rehabilitate and improve various assets under their control. This software links to or incorporates the "legacy" data which is available in diverse databases, including items such as maintenance records, costs, and other historical data. Again, much of this data is spatial in nature and in many cases the facilities are either utilities facilities or systems that are closely related.

AM/FM systems might seem peripheral to the current problem and the interests of FDOT since the Department does not generally manage facilities (except in some cases of direct ownership). However, these

systems are developed to the point where much useful information about the state of utility facilities can be provided to the client. Furthermore, the level of knowledge included in these systems may be particularly attractive to some potential data partners. Other related applications for the information contained in the system may be of interest, as for example, the ability to link spatial data for a sewer system to a hydraulic performance module.

1.2 Literature review

A key task of this project has been to accumulate and review a body of appropriate literature to provide background information and material. This information will help develop a rationale and motivation for establishing a UIMS along with an understanding of the benefits and barriers to implementation The research team found that the amount of literature bearing directly and indirectly on this study is quite large and diverse. Rather than one overall review section, relevant sources will be discussed as appropriate throughout the document.

Sources for this report consisted of library and database searches, web searches as well as interviews and discussions with informed professionals. The result of this effort indicated that the majority of materials located consisted of reports and references obtained from internet searches, rather than conventional engineering literature. An exhaustive review of all materials has not been attempted. Only those items of immediate interest to the present discussion will be referenced, and for convenience these sources will be listed at the end of the chapter where first cited, in the order presented in the text. References are presented in a conventional manner to the extent that it was possible to identify authorship and publication information. In some cases, it was only possible to provide Internet addresses.

1.3 Establishing a UIMS-type system

As a starting point in this report, several papers and reports relevant to the material in this chapter are discussed with the purpose of providing a rationale for the establishment of a UIMS. The reader should be aware that this list represents a selection from a much larger body of related literature and is therefore not exhaustive.

The group of references examined below can be collectively described as concerned with analyzing the need and rationale for developing GIS/database information systems as applied to utility planning, beginning with a study conducted in Florida and directly concerned with the present research topic. As might be expected Florida is not the only state to recognize problems with Utility location information. The search of available literature conducted during this study found several reports concerned with similar issues. Attention is also called

to a review of the practices with regard to GIS and right of way issues in several states, prepared for the Federal Highway Administration in 2004 [1.8].

1. Florida

A problem of concern to many motorists in Florida is the frequency of delays encountered as a result of installation and adjustment of utilities along the roadway. At least in part, this problem is caused by the difficulty in determining what facilities are likely to be encountered during construction and where they are located. A recent report [1.9] identifies several potential solutions to the delay problem including the adoption of a strong policy with regard to the implementation of Subsurface Utility Engineering (SUE) practice.

There are two documents attached to Reference 1.9 as appendices that, from the standpoint of the current investigation may be at least as important as the subject report itself.   The first of these (Appendix M) is a report by the FDOT State Utilities Engineer on current practice regarding utilities location information. Several points are made:

- The fact that facilities information is often lacking means that "unforeseen conditions" result during planning and construction.

- SUE not a comprehensive answer to the location problem, since only points are located accurately. There is no guarantee of what happens between these points.

- As-built information is a "must" for the future and the importance of archiving records is emphasized. An estimate is made that facilities are typically investigated as many as five times over a twenty year life cycle.

- A database of information for utility facility location information is strongly suggested. Adoption of standard practice using SUE and GPS techniques combined with a GIS is recommended. Other new technologies such as Ground Penetrating Radar (GPR) should also be considered.

- Issues concerning interaction between the utilities themselves and the FDOT may require changes to improve cooperation and communication.

A second document or "white paper" (attached as Appendix N) is even more specific about the need for as-built records and a means to archive this information. Several highly relevant recommendations are made:

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"…all utilities should be depicted and labeled on drainage structure x-sections."

"….permits…. Should require construction layout using PLS and PLS signed as-builts"

"….Should provide offset, station and elevation information specific to a defined point on their conduit, manhole, pipe, etc…."

"…Should….have a preferred placement for proposed or relocated facilities……to…. maximize use of ROW"

The increased use of GIS to manage this and related information is suggested.

2. Minnesota

In 2000, Minnesota Department of Transportation produced a report that summarizes a typical situation in many states [1.10]. The process of utility relocation is addressed beginning with the first phases of conceptual design through the construction phase and finally the outcome benefits and problems. The state one-call organization was also involved with this study, so that a relatively comprehensive picture of the entire process of relocation (as current in 2000) could be given. In this initial discussion it is stated that

"Once the utility is installed, the permit requires the UC to provide Mn/DOT with as-built information describing the actual installation and location of the facility"

however it is not clear that this procedure is always followed and in fact a principal issue (#5 in the Summary) was

"Accurate locations of existing facilities owned by UCs, communication companies, and local governments are often not provided. These are necessary for early planning and design, and later for safe construction."

No attempt was made in this investigation to research the Minnesota statutes for authority on this question. With special relevance to the current study, this report summarizes several important recommendations, including a proposal that

"Utilities should create and retain accurate installation information"

"Utilities should provide accurate and timely location information maps, as-builts, and/or field location information when requested"

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Furthermore, the State should enforce access to this information as needed. Work of installation should provide as-built diagrams and there is legal reference to this proposal. Revision of special provisions language is recommended.

> **"**<u>Recommendation 1.</u> Revise permit special provisions language regarding installation information requirements.
>
> <u>Implementation</u>
> Mn/DOT will revise permit special provisions as necessary to include requirements for as-built information. Enforcement provisions/conditions will be developed for failure of UC to comply with permit as-built information requirements."

Especially noteworthy are the following summary suggestions:

> *"Utility Installation Phase*
> 1. Revise permit special provisions language regarding installation requirements for as-built information by UCs (by July 2000).
> 2. Create and maintain a data base of as-built utility locations (by 1/1/01 and ongoing). "

Again, in the body of recommendations:

> "<u>Recommendation 1.</u> UCs should create and retain accurate installation information.
>
> <u>Implementation</u>
> UCs must provide the best record location/map information available on utility installations in compliance with current Minnesota Rules. If the road authority (RA) needs additional, updated accurate mapping information, UCs must comply with GSOC Statutes. Field locates may be necessary if maps or other information provided is not sufficient. UCs must retain accurate records and assist in locating their facilities for highway design purposes. Accuracy of locations and information provided will be per statutory requirements.

It is interesting to note that the Utilities commented that

> "UCs cannot supply maps that are more accurate than what is in their files. "

Discussing the utility installation phase the report concludes that

> "1. UCs should create and retain accurate utility installation information."

"2. Mn/DOT and local road authorities (LRAs) should develop appropriate enforceable conditions for instances where utility installation information is not received as required by permit."

Finally, the report itemizes two relevant continuing issues:

"1. The accurate location of in-place and future utility facilities. Both the contracting industry and the road authorities (RAs) deem it very important to have accurate location of in-place utilities in order to both design accurate plans and to safely perform excavation during contract operations. Utility companies (UCs) do not have precise historical utility information and are aware of the need for installations to be more accurately recorded."

"2. The method of accurately locating future utility installations in the field for later reference remains an item that needs further discussion. There is available technology that will give XYZ coordinates on above-ground utilities and below-ground utilities if readings are taken before the facility is covered and backfilled. The new technology, known as Global Positioning System, will position objects in the X and Y coordinate within inches and the Z coordinate with half the horizontal accuracy. To position within inches today either requires considerable post processing of data, or requires instruments that cost in excess of $10,000. Less expensive instruments are available, but not with the capability of locating features within inches. The existing statutory location requirements are general for design location, with no specific accuracy defined, and approximate for excavation, with accuracy of two feet horizontal and no vertical requirement. This is not considered sufficient accuracy for contractors and RAs. UCs are hesitant to commit to accuracy of such locations due to changes to the surrounding environment after installation and cost of accurate information."

3. Indiana

Recognizing that there was a lack of coordination leading to excessive costs and inconvenience, in 2004 the State of Indiana commissioned a study of problems associated with utility relocations [1.11]. A number of recommendations were made, including better policy regarding the choice of location for facilities installations. Of particular relevance to the present study was the recognition that future installations could be anticipated, that abandoned or unidentified facilities can pose challenges and that SUE could be a cost effective approach in avoiding conflicts. Of particular interest is Recommendation 9, which discusses the possibilities for a database of utility locations. A comment is made that utility companies often do not follow their own plans, which causes locating problems in the future. The report also made strong reference to the policies of the State of Wisconsin as a model.

"Issue 2: IMPROVE THE PROCESS OF OBTAINING INFORMATION ON THE LOCATION OF UNDERGROUND UTILITY FACILITIES

Accurately locating underground utility facilities during the initial design stage of a highway improvement project is vital for coordinating the needs of the highway project with the needs of the underground utility operators. The current One-Call locate system in the State of Indiana, sometimes referred to as Holey Moley, is managed by the Indiana Underground Plant Protection Service (IUPPS). All requests to mark the location of a utility facility for a highway project start with IUPPS. However, a request for design purposes does not always result in a facility being marked. Many times the request goes unanswered unless digging activities are reported. Priority is given to marking the facilities that will be impacted by construction. Although some utility companies may respond to a design-locate request, there is still no guarantee that all utility facilities in the highway corridor will be located and marked. The lack of reliable information on the location of utility facilities during the design phase of a public works project may result in the needless relocation of those facilities. Identifying the location of all utility facilities during the early design stages may make it possible to design the highway improvements around those facilities. In July 2003, the One-Call locate system was enhanced by Senate Enrolled Act (SEA) No. 438. This law requires all underground facility operators to join IUPPS by September 1, 2004. As a result, IUPPS anticipates its membership will triple from approximately 400 members to nearly 1200 members. In addition, IUPPS estimates that the number of calls for all locates – highway projects and other purposes – may increase significantly. (Indiana's One-Call law, including the provisions of SEA 438, can be found on the IUPPS website at www.iupps.org/Law.htm.)

Recommendation 2C:
INDOT should consider increasing the use of SUE on urban highway improvement projects.

Benefits:
• By providing better information on the location of their facilities during the design process, utility companies may not have to relocate their facilities.
• Contractors should benefit by having accurate information on the location of utility facilities and how those facilities could impact construction.
• INDOT should benefit by avoiding construction delays resulting from the relocation of utility facilities and getting bid prices from contractors that better reflect the impact of these relocations on construction.
• Motorists and adjacent property owners should benefit when a highway is completed on schedule.

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• The benefit of stakeholder participation in the upcoming IUPPS meetings should be a One-Call system that fulfills the needs of the highway construction industry.
• SUE provides supplemental underground utility facility information that could minimize or eliminate problems during construction and thereby avoid costly delays. A Federal Highway Administration July 2002 report cites documentation to support project savings of $4.62 for every $1 invested in SUE"

"Issue 9: DETERMINE THE ROLE INDOT SHOULD TAKE IN MANAGING THEPUBLIC RIGHT-OF-WAY ALONG STATE HIGHWAY CORRIDORS"

"….If INDOT does not adequately manage the public road right-of-way, utility companies are likely to compete with one another for the "best" location in the right-of-way. Coordination among utility companies is sometimes lacking. Some utility companies do not provide adequate information on their relocation plans or proceed with work that differs from their submitted relocation plan. There may also be a lack of information on where utility facilities are located within the right-of-way. This lack of information occurs, in part, because INDOT has not compiled a database about the placement of utility facilities within the right-of-way even though utility companies must obtain permits to install or service facilities within the right-of-way. It also occurs, in part, because some utility companies do not always follow their own plans for placing facilities or in keeping records of the actual placement locations."

Two specific recommendations are especially important to the present study:

"Recommendation 9B:
INDOT and utility companies should work together to develop guidelines regarding which utility facilities go in which part of the right-of-way and why, and to resolve any conflicts among the various utility companies. The findings of a Joint Transportation Research Project conducted by Purdue University regarding INDOT's Utility Accommodation Policy should be considered in developing these guidelines."

"Recommendation 9C:
INDOT should consider enhancements to its permit process that would allow it to develop a database that uses Geographic Information System (GIS) coordinates and provides information on the location of newly placed or maintained utility facilities."

Two potential benefits mentioned for these recommendations were:

"Guidelines on the placement of utility facilities within the right-of-way should help provide a basis for initial decisions and a way to resolve potential conflicts. Instead of an 'each utility company for itself' approach, guidelines should help establish a closer working relationship, speed up the process and reduce potential conflicts during construction. Inconvenience for the motoring public should also be reduced."

"Collecting accurate horizontal and vertical location information when utility companies obtain permits to install new facilities or work on existing facilities within the right-of-way should allow INDOT to develop a database of such information. This database should help INDOT know when future planned improvements may conflict with existing utility facilities."

5. Kentucky

The State of Kentucky maintains an well organized website (through the Public Service Commission) devoted to utilities (primarily GIS) [1.12]. In addition to a discussion of their mapping standards and available files, a number of sites directly concerned with utility maps. Numerous related links are included.   There are some security restrictions on the access and use of available data.

Several examples serve to highlight some of the problems that are likely to be encountered; conversion of paper maps and ultimate attainable accuracy from older records. For example a statewide layer for electric transmission is obtainable but would probably be of limited use for accurate determination of location due to the scale (1:24,000). The sources of data (as well as the conversion of those data) present similar problems. For example

"1984 Pipelines: The Kentucky Public Service Commission (PSC) scanned the paper map published by the Kentucky Department of Economic Development in 1984. Given the scale of the original map and the way that adjacent pipelines are symbolized, it is estimated that the pipelines are depicted within 2 miles of their ground location. "

7. Ohio

The Ohio Department of Transportation Utilities Manual [1.13] contains a well defined procedure of the accommodation of utilities in the right of way (Sections 8100-8200).   The need to maintain information regarding the spatial location information for installed facilities is detailed and includes requirements that existing underground utilities must be shown on highway construction plans as obtained from the owners (153.64 Ohio Revised Code). The Utilities Manual requests that utility locations be furnished in a written form that can be accurately transferred to the project plans (or mark). While the requirements (and the authority) are specific, a system to manage this information does not seem to be in place.

8. <u>Oregon</u>

The State of Oregon [1.14] has embarked on a massive program to create statewide geodatabases for a number of applications.   This effort is noteworthy due to the scale and completeness of documentation available. Consequently the system (currently under development) will be referred to and reviewed repeatedly in this report.   Although utilities are referred to as a theme to be eventually included, at present this part of the overall effort is only in planning stages.

1.4 Problem statement

The premise of this investigation is to evaluate the effectiveness and worth of a Utilities Information Management System to the FDOT. The following tasks constitute a statement of the problem at hand:

1. Describe a UIMS appropriate to the needs of the FDOT in terms of a set of functional requirements and performance goals.

2. Examine currently available resources and sources of data.

3. Make recommendations regarding the structure of the system and steps for implementation, including an approximate timetable.

4. Evaluate the benefits and the challenges of moving to this system.

In anticipation of the material to follow a list of open-ended questions has been generated.   Partial answers to some of these questions have already been discussed and the answers for many others will emerge in later sections of this report. In some cases, complete answers cannot be given at this time but it is still important that these questions be placed on the table for discussion before final decisions are made and implemented.

- What is the framework of the UIMS
- What is the authority for establishing a UIMS
- What is current status of information flow
- What are the sources of information
- What data/information is to be stored and accessible
- What is the expected level of accuracy, precision and pedigree of data
- How will spatial locations be referenced
- How will data flow in and out of the system
- What standards will be imposed on new data flowing into system (QC)
- How will older (past installation) data be integrated into the system
- Who will utilize the system
- What will be the work flow patterns when this system is utilized

- What level of interpretive analysis should be adopted
- What will the effect of technological/software/hardware advances
- Should commercial software tools be adopted
- Should a UIMS system be developed in-house
- What will be the projected benefits of any system adopted
- What are the technological limitations to implementation
- What are barriers to implementation (legal, political, security etc)
- What will be the criteria upon which to judge success of the system
- What is a realistic time frame and schedule for implementation
- What will be the projected costs of implementation

As a prelude to the ensuing material in the next chapters, it is worthwhile to begin to assemble preliminary understanding of the nature of a UIMS. The typical client for the UIMS is concerned with a site along a roadway where utility work is planned, proposed or ongoing. From the perspective of the user the function of the UIMS is relatively simple. The user should be able to request all documentation available regarding utilities present in some region of interest. At least some of this information would be in the form of as-built plans from previous projects, which would be presented graphically. The ability to view a collection of spatial facilities data pertaining to the particular site of interest would presumably enable the user to make sound decisions during planning stages or regarding anticipated work.

What the user thinks of as a specific site is in fact a volume of space centered on the point of interest, extending along the transportation corridor and to the right of way in each direction perpendicular to the centerline of the roadway.   In the vertical direction this volume extends from the deepest burial to the top of highest utility pole within the area. Within this volume is contained not only the roadway but all the various utility facilities that are located along side the pavement, both above and below ground. A query to the UIMS then must result in the identification of all available documentation related to the site in question.   This action requires that all information available to the UIMS be spatially referenced. For best practice, all information should include attributes to amplify the understanding of the data.

Because of the physical nature of the transportation right of way, there is a natural tendency to envision a referencing system linked to a roadway that starts at some point and moves along the centerline.   In principle, any point in the corridor can be referenced to such a system by specifying linear and lateral offsets and an elevation relative to the ground at that point. Unfortunately, this type of description while natural and convenient is not well connected to a geodetic coordinate system.   Using a different approach, the application of GIS techniques to utility facilities differs from more conventional methods in that information about elevation as well as accuracy constraints add extra burdens to the system.   Not all information regarding location will be in the same

coordinates or of the same quality and it may be difficult to choose a common basis for reporting.   Furthermore, especially older data may not be in a useable electronic format which will require extra (manual) steps to make the information accessible by the UIMS.

Now consider what the consequences are if information of variable quality is returned to the user.   A major goal for the UIMS is to provide a comprehensive understanding of site conditions while in reality, the user will often be presented with information which may be inaccurate or incomplete. An elementary example could be sets of plans - purported to be as-built information from two independent installations completed at different times in the past near to the site of interest - containing conflicting information. Plans that overlap a particular area may show the same utility conduit but with incorrect alignment between the drawings. When plans are available, it is very important to understand the accuracy of the diagram, the manner in which the plans are referred to particular coordinate references, as well as the format for the storage of information.

A conventional definition of an as-built diagram would encompass the idea that what is represented is a facility system consisting of the components actually installed, and a specification of where these components are actually located, as contrasted to what installation was originally planned. The existence of accurate as-built plans is problematic. A discrepancy between planning and as-built diagrams may occur simply because a contractor did not install according to plans or possibly was given latitude to install with options to be determined on site at the time of construction.   In some cases the planners may have issued changes that were not reflected in final construction plans.   As-built diagrams are prepared after the fact and should contain statements regarding scale, accuracy and precision of the information conveyed.   Due to additional costs and other considerations, as-built diagrams are not always produced as a part of construction work.   It may be the duty however, of the contractor or the planner (or possibly a third party) to deliver surveys or sealed as-built plans depending on contractual requirements.

In the most general interpretation, as-built information is not limited to plan diagrams of the sort described above.   As stated previously, for the purposes of this investigation the definition of "as-built database" has been extended to mean a formally constructed database containing information from a variety of sources. Other than plans, additional useful data about the location of facilities exists and may be considered to be part of the total reservoir of as-built information. Because there may be discrepancies between actual installation and original planning, detection and locating of utility installation in the field is employed. Procedures vary depending on the type of work anticipated.   In the field, spatial location may be referenced with coordinate distances to some landmark (coordinate frame or location referencing system, perhaps) or placed in some coordinate frame by conventional surveying techniques.   The Global Positioning System (GPS) is frequently used to acquire latitude/longitude information directly.

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Unfortunately, much of this data is "lost" in terms of potential use in a UIMS, simply because it is not efficiently archived with a spatial reference or quality attribute. Physical markers that are visible or detectable may serve to accurately locate facilities. Application of locating technology followed by markings for visual identification serves the same purpose.

The presentation of information to the user is closely tied to the capabilities of the UIMS. The primary task of the system is to archive and retrieve data concerning the location of utility facilities. The graphic display of recovered information is then limited by the original format of the data unless other capabilities are built in to the system. For example, if as-built plans for a facility installation were only available in a paper format, scanning the document would enable storage in digital form and the visual display of this information would be a simple raster graphic. CADD drawings could be brought up in CADD format and likewise GIS files could be displayed. In principle, it is relatively easy to combine information from two files with the same format. Integrating, overlaying and linking of information from different formats however, are much more challenging operations. The same considerations apply to textual material. Scanned text can be displayed and read by the user but not searched for specific text by database applications unless the proper tools are provided.

The most elementary model for a UIMS is a simple graphic document management system with capability to locate and display relevant information. At the other end of the spectrum of solutions, a totally GIS geodatabase system might be envisioned. Ideally, very accurate information about utility facility placement (including elevations to obtain three dimensional information) at any point along the transportation right of way could be easily retrieved and this information automatically placed in context of a particular network. Typically the mapping of transportation assets such as roadways and major pipelines consists of vector lines superposed on a large geographical area. If elevation data is provided, the network can then be understood in terms of topology and connectivity. The final choice of the structure for a UIMS will eventually be determined by an economic analysis of benefits and costs. It appears that no matter what system is adopted, practice will be driven by advances in technology. Thus it is reasonable to expect that with time there will be increasing pressure to upgrade to better systems. This observation does not imply however that upward migration of data to improved systems must take place immediately or with every intermediate improvement in technology. An economical approach is a measured response, instituted only when a clear benefit is obtained. Since these moves tend to be costly and time consuming, it is important that each step retain as much flexibility so that changes in format and technology do not overwhelm future migrations.

1.5 Applications examples

While conducting an examination of literature pertaining to utilities information management, a number of applications systems were identified as being of interest to this study, but not necessarily specifically intended for utilities. In general these systems were highly diverse in character, limited in scope and typically were concerned with one specific application. Descriptions of these systems are located throughout this report as appropriate to the thread of the discussion. While none had all the desired characteristics of a UIMS, in many cases these examples incorporated one or more highly desirable features. It is believed that some aspects of these systems could serve as partial models for a UIMS, at least as envisioned here in preliminary concept, and lead to a better understanding of the potential capabilities and limitations of an effective system.

1.6 Sources of utilities facilities data

In the original scope for this research sources where utility location information might be found were listed:

- planning maps
- FDOT straight line diagrams
- traffic operation plans
- GIS plans
- CADD plans on current FDOT projects
- SUE information
- FDOT red, green, brown plans markups
- one-call services
- local governmental units
- utility records
- property rights
- FDOT archiving system (EDMS)

With regard to as-built plans, utilities are not required to provide complete plans to the FDOT for the facilities they own. They are required to "markup" plans during the initial phases of proposed construction.   While this requirement results in valuable information it is not directly accessible by means of an automated information system.   Similarly, contractors are usually required to file "as-built" documentation at the completion of a project, but accessibility of this information may be limited by the storage format as well as the lack of spatial referencing and quality assurance measures.

1.7 Summary

Several investigations in other states have addressed the need for a system to help manage the installation of utilities in the transportation right-of-way as

described above. As far as can be determined at present no comprehensive system exists in practice, although some systems are in the development stage as will be discussed in the next chapters. It appears that many states have adopted or are moving towards a GIS based approach to maintaining spatial transportation information. These states recognize the need to be able to archive and retrieve the large amount of geographical information that they possess. Municipalities and other governmental subdivisions have adopted a similar strategy and private sector use of GIS is in substantial development.   Particularly noteworthy is the fact that some stakeholders are advocating the inclusion of utility facility spatial location information in such systems. It has been recognized that while some information regarding utility locations is usually available, it is not uniform, organized, complete or integrated with other sources. A phrase often seen is "islands of information", used to describe useful, important data not generally accessible because it is not linked to larger systems or cannot be easily transferred.

The primary motivation for the development of information systems for utilities installations relates to the planning and installation of new or relocated facilities. The rationale for the establishment of a UIMS can be simply stated. If more high quality knowledge regarding location becomes available early in the process then planning and coordination of activities will be more efficient, fewer compensatory claims will be made and less damage to existing structure will likely result. At the same time, agencies recognize that the current state of affairs, i.e. a rapidly expanding collection of diverse plans, documents and other data in inconsistent formats is not a viable source of reliable information regarding installed facilities for the future. An accurate, historical record of utilities installations is therefore highly desirable.

A critical issue to implementation of any system is timing and cost. Many decision makers are aware of the rapid development of technology and fear beginning too early with a specific project.   The more inclusive the scope of the project, the more costly it becomes.   Premature adoption of a specific course of action or adopting the wrong approach may prove costly. Thus it is important that any system be implemented in appropriate stages with a flexibility to move to better technology as it evolves.

Part of the purpose of this chapter is to describe a preliminary understanding of structure for a UIMS and to begin to examine a number of operational characteristics that could be attractive (noting that there will always be features and characteristics for a system, which although highly desirable are impractical or too costly to adopt). This review makes it possible to offer a working definition of the UIMS, which will be subsequently redefined and clarified later in this report.   These steps are essential, before an analysis of cost can be made, or recommendations for implementation can be put forth.

1.8 Methods of this investigation and organization of this report

This report is written with an admitted bias toward implementing a UIMS. The technology associated with acquisition, maintenance and retrieval of information is advancing rapidly. Failure to begin the process of developing a system in some form would be to risk being inundated by an increasing amount of information that will soon be impossible to retrieve in useful form. It is recognized in advance that many valuable aspects of a UIMS are difficult to quantify and an examination of the costs of not constructing a system may be elusive but equally important. It is not necessary that all recommended actions need to be in place immediately. Some aspects of a UIMS may well be deferred until technology advances somewhat. Hopefully, these issues will be resolved by a discussion of cost and benefits as well as the pros and cons of adopting a UIMS.

Because of the nature of the project and the current status of the research, an unconventional organization for the report has been chosen. The focus here will be on a set of issues currently being considered regarding the description and construction of prototype systems as an initial step to evaluation and recommendations for possible implementation. To avoid misunderstanding, this report will include extended discussions of the researcher's examination of the current IT situation at FDOT, the status of SUE, GPS and other related technologies, and an extended literature survey.

In this investigation, it has been assumed that some form (yet to be determined) of a UIMS would be developed. There exists an extensive inventory of methodologies in current IT practice to structure systems of this nature. It is essential to go through a formal process so that the resulting system is widely accepted, generally applicable and able to evolve as resources and requirements grow in the future. A series of recommendations will be presented at the end of this report. Often these recommendations will center on choices. Thus, the objective of this report is to explain the background and rationale for these recommendations, by attempting to bring out all relevant issues so that an informed decision can be made.

Starting from a summary of likely business activities and an understanding of user needs it is essential to develop a set of <u>functional requirements</u> for the UIMS. These requirements should be prioritized and separated into primary and secondary levels (ie. "must haves" and "desirables"). The final statement of functional requirements will have great bearing on the ultimate effectiveness of the UIMS. Likewise the judicious adoption of standards for the UIMS will determine the accessibility of the system and the potential for future migration of data.

As discussed below, at some point a choice of UIMS model will be made, based in part on the functional requirements and in part on an evaluation of a benefit/cost analysis. The availability of resources will undoubtedly be a major

factor influencing the development of a UIMS.   In this investigation, several options will be considered in the interest of maintaining a broad discussion.

Chapter 2 is a summary of the information resources, their organization, and documents related to this investigation primarily maintained by the FDOT. Other entities which maintain useful information resources such as the Federal Government are also included.   Chapter 3 investigates questions of accuracy and precision with respect to spatial data captured in transportation geodatabases.   Chapter 4 is concerned with limitations and challenges to developing a UIMS, especially in terms of graphic presentation of utility locations. Chapter 5 presents a summary of functional requirements for a UIMS and in Chapter 6 a recommendation is made for such a system along with a plan for implementation. Costs and benefits are summarized in Chapter 7. Finally, Chapter 8 summarizes the work presented along with major conclusions. Recommendations for further study are included.

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Chapter 2: Informational resources maintained by FDOT and other entities

This chapter is primarily devoted to the organization and information resources of the Florida Department of Transportation, as relevant to the present study. Supplementary and related resources maintained at other agencies, entities and the Federal Government are also included in this discussion.

2.1 Florida Department of Transportation

The Florida Department of Transportation (FDOT) comprises seven districts and the Turnpike Enterprise, as well as the Central Office located at Tallahassee, Florida. The organization of the FDOT may be described as decentralized. State Highway System has 41,000 lane miles and 6,381 bridges. Oversight is provided by the Florida Transportation Commission. An overall operational review is provided in Reference 2.1. The following offices within the FDOT maintain documents and information of specific importance to this study:

1. State Utilities Office

With respect to the present effort, the most important of the FDOT offices is the State Utilities Office, a part of the Office of Roadway Design. In addition to the Central Office, each of the Districts has a Utilities Office and administrator. Among other responsibilities, the State Utilities Office coordinates utilities activities in the FDOT right of way statewide, and maintains the Utility Accommodation Manual (UAM). The UAM [2.2] sets forth the rules and procedures regarding utility facility placement in the transportation right of way. In addition to coordinating relocation work, a major function of the Utilities offices at both the State and District level is oversight of the permitting process which is discussed in the UAM and will be further addressed later in this chapter.

The following items are specially noted:

   a) Definition of as-built plans (from the UAM):

       "Plans that depict the actual location of a facility after construction as determined by physical measurements in the horizontal and vertical plane".

   More information regarding as-built plans can be found in Sections 2.1, 3.7.4, 3.7.5, 10.11, 10.19, 11.2, 11.3, 12.1.6 (2004 UAM)

   b) Requirement for detection of underground facilities - Sections 3.7.5 and 10.11

       "All new or replaced underground facilities within the R/W shall be made electronically detectable using techniques available in the

Industry. Where as-builts are required in accordance with the UAM or FDOT Standard Specifications 555, 556, or 557 in Appendix A, an as-built plan of the utility facility location including a depth tabulation (when profile plots or elevations are not provided) shall be furnished at the time of the certification of completion of the project for which a permit was given."

c) Requirements for utility surveys and locates - Sections 11-1, 11-2, 11-3 and 11-4. These sections deal with responsibility and specifically discuss the principles of subsurface utility engineering. With regard to plans:

"For all other permitted work, the limits shall be delineated by distance from a well established point such as the center of an intersection, center of a RR, etc. When underground utilities are granted access to limited access R/W by the exception process, certified as-builts must be provided as a condition of the permit. All exceptions requesting use of any limited access R/W will require a certified as-built survey and plan signed and sealed by a registered land surveyor in accordance with Chapter 472, F.S., Land Surveying and Mapping. When as-built plans are required, they shall be submitted to the DUE no later than thirty (30) days following the completion of the permitted installation."

"Whenever the Utility already has and uses compatible CADD software, and as-built plans are required, they shall be provided in an electronic format. The plans shall describe the facility in detail and in accordance with Chapter 3 of the UAM. Underground facilities shall indicate their location in the horizontal and vertical plane in accordance with The North American Vertical Datum of 1988 (NAVD). For aerial facilities, elevation data is not required."

d) Placed Out-of-Service (Deactivated): Section 10-19
Note the specific wording used to describe facilities left in place but not actively used. Such facilities are described as "temporary" and must be removed if requested by FDOT.   It should be noted that utilities are not allowed to "abandon" facilities, i.e. to leave facilities in place while relinquishing any responsibility for them. Nevertheless, underground exploration occasionally reveals facilities without apparent ownership.

2. Engineering/CADD Systems Office

CADD drawings, required for many state roadway projects, are managed by the Engineering CADD Systems Office. The following resources are available:

a) FDOT CADD Production Handbook [2.3] - contains the formats and instructions for electronic plans preparation. Chapter 19 deals specifically

with utilities.   Coordinate referencing of plans is specified. The use of
scanned images is discussed (Roadway Design also maintains CADD
standards [2.4]). A 2006 report on CADD activities in Florida may be
found at [2.5].

b) Professionals' Electronic Data Delivery System (PEDDS). PEDDS is
the system used to sign and seal documents submitted under the Plans
Preparation Manual. Delivery is to be commented and indexed to be
compatible with the Electronic Document Management System (EDMS).
The Florida User Group (FLUG) maintains a site to explain the electronic
submission process [2.6].

An extremely useful reference, "Concepts and Tools in the FDOT
Electronic Delivery Process", [2.7] details both the electronic plans
process as well as the relationship to the Electronic Data Management
system (EDMS), discussed below.

3. Central Planning Office

This office is concerned with short and long term planning for FDOT
transportation projects.   The "Planning Pages" website provides a
comprehensive overview of activities managed by this office and there is much
information of interest to this study to be found there. The Planning Office
maintains the GIS data directory through the Transportation Statistics Office
(TSO), the Roadway Characteristics Inventory Program (including the Highway
Videologs), and provides systems support through the GIS Data Directory.
Numerous downloadable files and applications are available at this site.

a) FDOT GIS directory [2.8]

b) FDOT Base map [2.9]
The FDOT Central Planning Office maintains the shape files of GIS layers
(Statewide data in WinZip format-Projection: UTM 17; Datum: NAD 83)
including
- Roads
- Road Data
- Traffic Data
- ARC/Info[©] Coverage of the Basemap
- Geodatabases
- Metadata

The base map and metadata on roads, including base map routes with
measures (milepost information) may be found at References 2.10 and
2.11. The basis of the Florida State Plane coordinate system is explained
and well documented [2.12-2.15]. Policies concerning units of measure

for the state plane coordinate system of 1983 are available [2.16], as are the complete technical standards for the State Plane Coordinate System of 1983 [2.17]

c) The Roadway Characteristics Inventory (RCI) -The Roadway Characteristics Index (maintained by the FDOT Transportation Statistics Office) comprises an inventory of roadway features and information, as defined in the RCI Handbook [2.18]. Virtually any type of data can be connected to this database, but it is primarily used to record highway features having at least one defined characteristic. All data is stored using a roadway identification number, and referenced to a beginning and ending milepost. The RCI is re-inventoried every five years, monitored via the Roadway Inventory Tracking Application (RITA). The RCI could provide a potentially useful link for the UIMS because of the type of spatially referenced data contained.

The connection between the RCI and roadway safety is obvious and is the subject of a recent discussion (FHWA) concerning asset management [2.19]. Similar arguments apply to utilities in the R/W, supporting the inclusion of the RCI into the UIMS.

Two studies pertaining to the RCI are of particular interest. An early research project [2.20] was concerned with a prototype system, the Roadway Data Integration System (RDIS), intended to facilitate acquisition of data for the RCI from the desktop, rather than through field investigation.   A pilot study has been conducted and the system is now in testing in District 3. This system requires planimetric and base map information, and also utilizes a video log. Data layers incorporated into the RDIS application were from aerial photographs provided by FDEP at 0.2 meter resolution. The system has several potential disadvantages. Currently the transfer from the RDIS to RCI appears to be a cut-and-paste manual operation.   Secondly the application is written in the older, ArcView$^©$ 3.2 version. Newer software is currently available (ArcView$^©$ 8.1 and later) which would require reprogramming in Visual Basic (some comments about upgrading are mentioned).   It is noted that several other similar applications are under development at FDOT.

A more recent research project reviews and extends the Turnpike study [2.21]. Here, remote sensing (aerial, satellite photography) is combined with data and feature extraction techniques to provide a rapid source of updated information.

d) Straight Line Diagram (SLD) -Chapter 8 of the RCI handbook covers the generation of straight line diagrams (SLD). An SLD is a simple representation of the roadway as a linear graphic, with RCI features placed along the line representing the road.   A software application

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package, the Straight Line Diagrammer [2.22] is available to construct an SLD. Links to other data sources are possible. Other methods for constructing SLD using alternate software (Adobe) have been proposed [2.23] and one example is displayed in Figure 2.1.
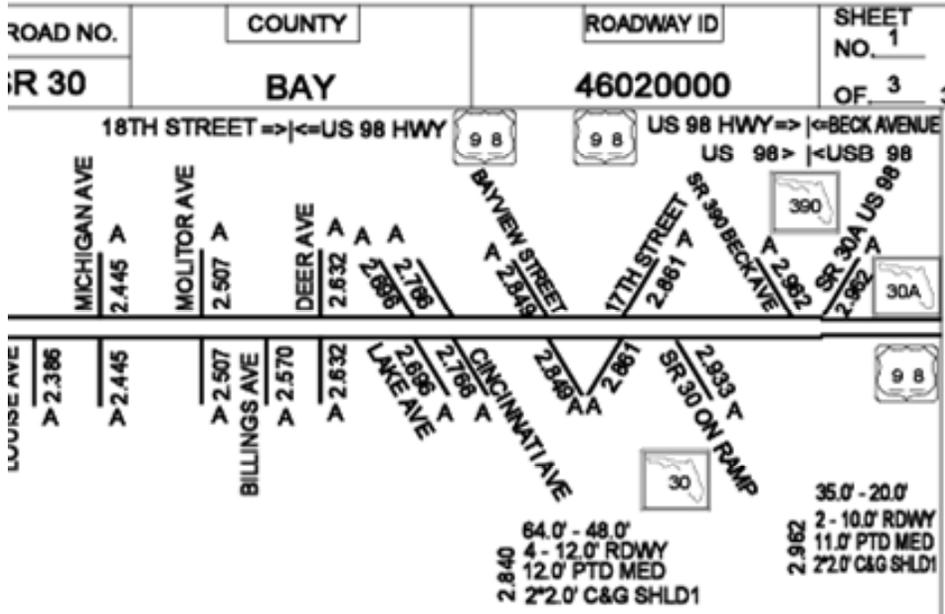
SLD Final Product Created in Illustrator

Figure 2.1: A straight line diagram prepared using Adobe Illustrator [2.23].

The Central Planning Office also includes the Environmental Planning Office. While not directly related to utilities projects, Environmental Planning has produced several interesting studies and applications relevant to the present effort as described later in this chapter.

4. Surveying and Mapping Office

This office deals with right of way and geographic mapping, aerial photography and surveying [2.24].

5. Office of Right of Way

This office is concerned with management of the FDOT owned R/W, including acquisition, appraisal, and relocation of tenants [2.25]. The office maintains the Right of Way Management System (RWMS), an electronic database system.

In July, 2004 representatives of several states and the FHWA met in Florida to discuss GIS and right-of-way issues (environmental concerns were included). There is remarkable overlap between systems with diverse goals (outdoor advertising sign locations, ROW asset management) and the current project. Two management systems have been implemented [2.26].

> a) GIS in ROW at FDOT - the Right of Way Management System (RWMS) a GIS system with data stored in a DB2$^{©}$ database.
>
> b) Outdoor Advertising Inventory Management System (ODAIMS) which uses ORACLE$^{©}$.

Reference 2.27 is an outside report of interest concerning the FDOT Office of Right of Way and a recent review [1.4] discusses various state efforts including Florida.

6. Office of Work Program

The Office of Work Program develops and maintains the Five Year Plan for FDOT. The plan is a resource for information on future work programs, budgets and schedules. An examination of the Five Year Plan is required as a part of the Utilities Permit procedure. The Work Program GIS Application (WPAGIS) is a tool designed to examine the Five Year Plan by providing a visualization function using a GIS interface [2.28]. In this way a considerable amount of labor intensive manual work is avoided.

This system is of interest because of the similarities in providing a graphical mapping interface anticipated when compared to a UIMS, as well as a query function. Attention is also called to a similar scheme relating to the Turnpike Authority [2.29]. Again the advantage of a visual presentation of related data is discussed.

2.2 Other State of Florida resources of special interest

The following studies, software applications and other documents are of special interest to the present effort and have been singled out for attention, to provide useful background information. The reader is advised that the items discussed

below are in a constant state of modification and revision. The material presented here reflects the best information available at the time of writing.

1. Automated Access Management System (ADAM)

This project (originally started as an SBIR grant from FHWA) involves the development of an automated access management system for driveways [2.30-2.32]. In a sense, this effort represents a bridging application and a primary reason for inclusion in the present discussion is that many aspects of the project are analogous to the task at hand. The site location for the subject research was FDOT District 3.   Of particular relevance to the current investigation is the use of a digital imaging system for data acquisition (accurate 3-D stereo imagery), as well as inclusion of the FDOT PITS system (discussed below) and justifications similar to those for automated permitting of utility installations. The management process does not currently file as-built plans in a central repository. Automated permitting is the eventual goal of this project. Many of the advantages claimed for this system apply also for the UIMS.

2. Florida – Surveying and Tax Maps

This work deals with a Florida project for paper survey maps and to old paper tax maps which have been converted to GIS and how to get from a paper based presentation to a georectified electronic mode [2.33].   The duplication of effort (redigitizing maps originally in electronic form), the need for data partners and centralization are all discussed. The advantage of digital orthophotography with a resolution of several feet is suggested. Matching of map corners is identified as an important problem. Utility companies are mentioned as potentially having an interest in sharing data and it is commented that in the past much utilities data was referenced to the road centerline or the R/W boundaries. The switch to GPS is accelerating but GPS positions on the base map may show inaccuracies due to poor base map data.

3. Florida Geographical Data Library (FGDL) [2.34]

This archive is maintained by the Geoplan Center at the University of Florida [2.35], which also maintains FDOT aerial maps, the Efficient Transportation Decision-Making (ETDM) system [2.36-2.38, see also 2.26] and the Environmental Screening Tool (EST) [2.39, 2.40]. The ETDM is an interesting software package incorporating a direct method to delineate the area of interest (as shown in Figure 2.2), a feature recommended for incorporation in a UIMS in this report.
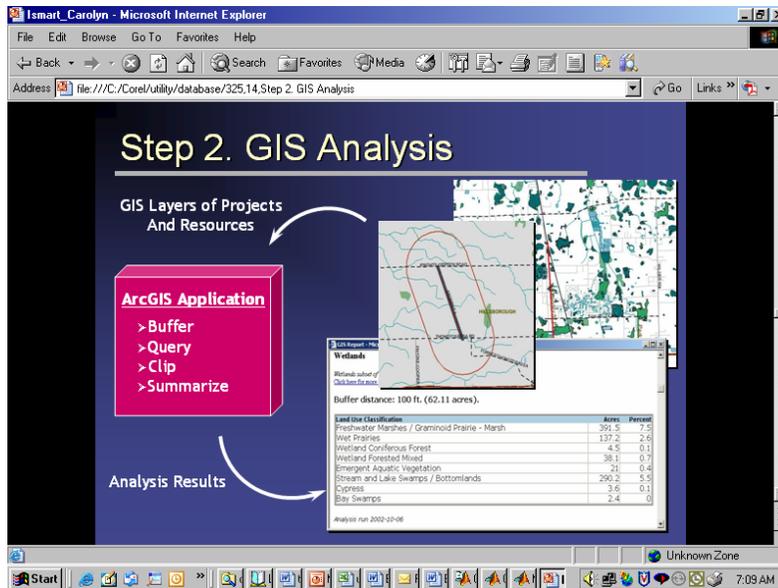
Figure 2.2: GIS analysis step for ETDM tool showing the break out of a region of interest.

4. FDOT Electronic Data Management System (EDMS)

The concept of a document management system is closely related to a database in that documents are electronically stored along with attached metadata related to content.   A database management tool such as ORACLE$^©$ can be used to retrieve the original document and associated metadata.   FDOT currently uses a commercial system (Hummingbird$^©$) as the basis for the EDMS [2.41 and 2.42] (no public access), although this vendor may change in the near future. Utility permits and some project documents (contracts and SUE reports, for example) are among the items of interest stored in the EDMS. Due to the potential importance of the EDMS in relation to any UIMS, the research team examined the structure of the system.

Unfortunately, the storage format does not utilize a direct geospatial reference; instead a milepost/route designation is employed. To be available for access by a UIMS spatial referencing would be preferable. Furthermore, documents are scanned and stored in TIFF-IV format rather than stored in original electronic formats. This means that without optical character recognition reading these files electronically is not possible. CADD files are not placed in the EDMS (construction diagrams are placed in PEDDS for bidding and as-built diagrams are stored elsewhere as

explained below). Figures 2.3 and 2.4 contain the attribute and search pages associated with the EDMS. Figure 2.5 is an actual a hard copy SUE report with hand-written annotations ready to be scanned into the system.
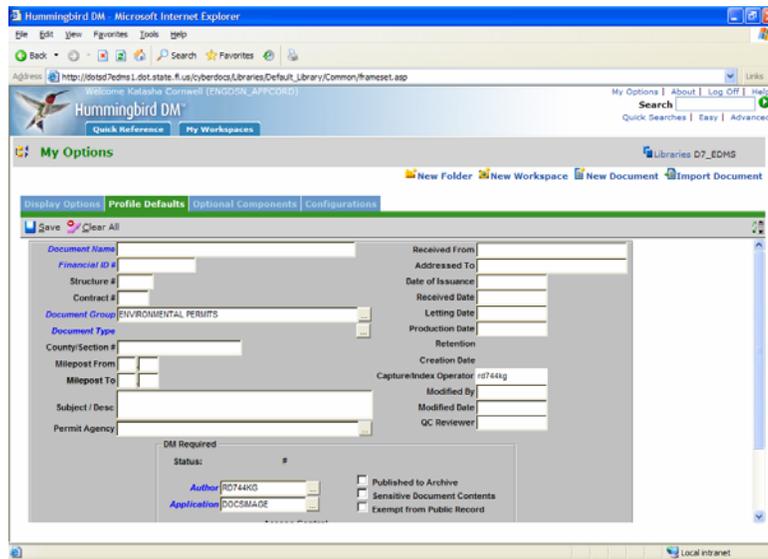

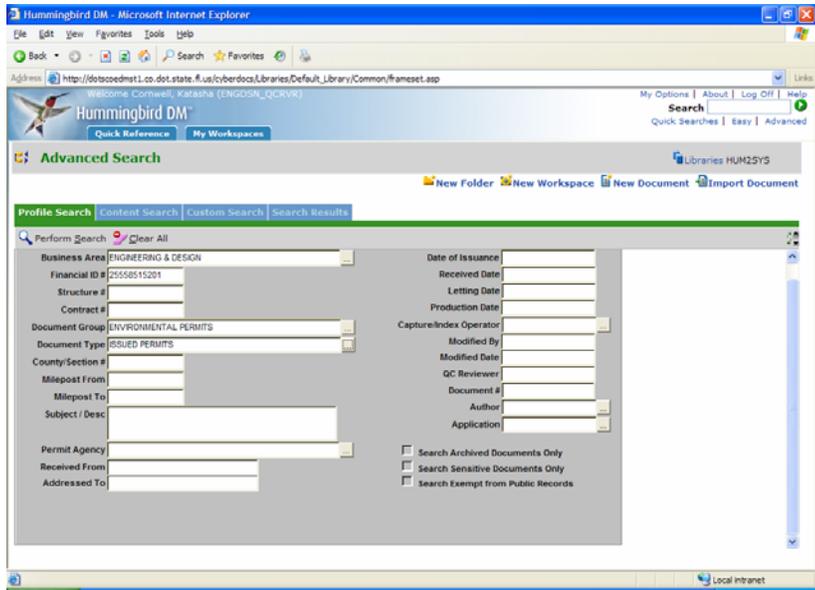**Figure 2.3:** EDMS Profile Screen for attribute entry (information provided by FDOT District 7).

Figure 2.4: EDMS Advanced Search screen (information provided by FDOT District 7). Note identifiers employed.

Figure 2.5: Typical SUE report to be scanned into EDMS. Note hand written annotations and incorrect directional arrow (document provided by FDOT District 7).

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5. Permit Information Tracking System (PITS)

Utility permit tracking is an important function, handled electronically via PITS (the research team was not able to obtain a public reference for this function). Permits are eventually filed in EDMS at the conclusion of a project.   The PITS system is apparently text based (no graphics).

6. Construction Final Plans Management System (CFPMS)

As-built construction plans are scanned into the CFPMS for a permanent record as shown in the Figures 2.6 and 2.7 (the research team was not able to obtain a public reference for this function). Apparently construction files are not officially retained in CADD format.

Figure 2.6: CFPMS Profile Screen for search. Note attributes for documents (information provided by FDOT District 7).
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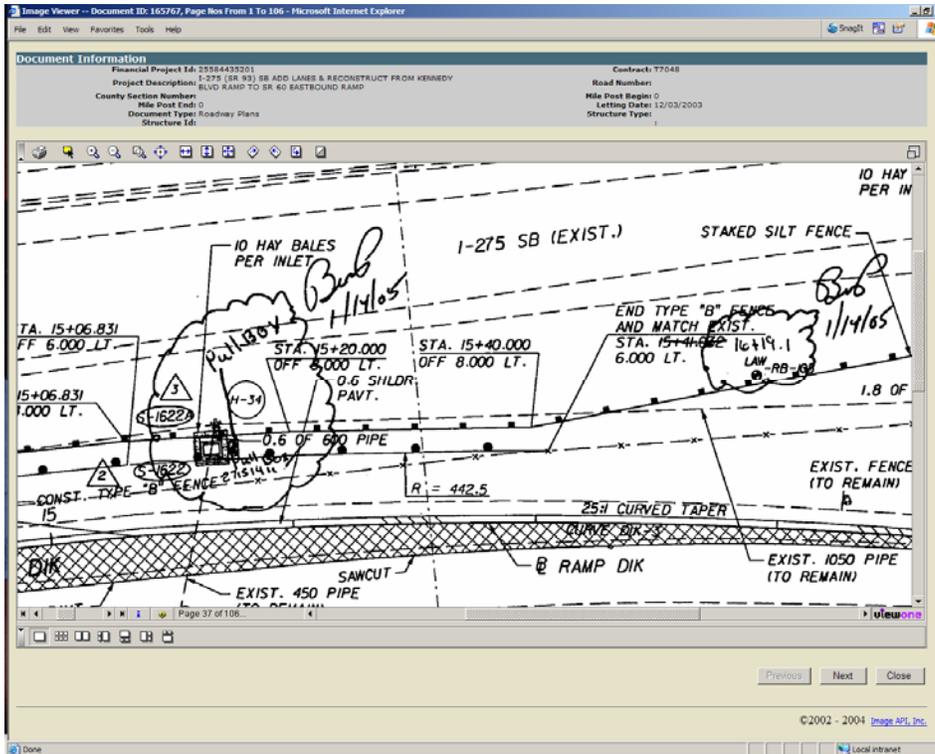
Figure 2.7: Typical CFPMS scanned document. Note hand written
annotation (information provided by FDOT District 7).
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7. Strategic Intermodal System (SIS):

The Strategic Intermodal System is defined as follows [2.43]:

> "Florida's Strategic Intermodal System is a transportation system that . . .

> - Is made up of statewide and regionally significant facilities and services (strategic)
> - Contains all forms of transportation for moving both people and goods, including linkages that provide for smooth and efficient transfers between modes and major facilities (intermodal)
> - Integrates individual facilities, services, forms of transportation (modes) and linkages into a single, integrated transportation network (system)"

The final report of the Steering Committee for the Strategic Intermodal System [2.44]

> "…calls for the development of a Strategic Intermodal System, which will be composed of transportation facilities and services of statewide and interregional significance providing for the smooth and efficient transfers for both passengers and freight."

An examination of early thinking with regard to Florida's Strategic Intermodal System provides an interesting perspective since the effort involved to bring about a SIS database has many analogies to the present study of a UIMS.

Not surprisingly utility pipelines are considered to be a part of this system. A "database" was envisioned and is the subject of a white paper was prepared in 2002 [2.45] as a database design study in support of the Strategic Intermodal System (SIS). The SIS database is to include a super-set of FDOT data and a mapping interface. There is a strong recognition of the fact that many items to be place in the proposed geodatabase are not in suitable format at present.

Of particular interest is Phase 1:

"*Development of Integrated Database and Visualization Tools to Support SIS Identification and Designation*
Phase 1 – Integration of data sets for criteria selection testing to designate the SIS components.
> "It first describes those data sources considered suitable candidates for the SIS databases, and evaluates the data

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formatting and conversion issues. These include digital geospatial data, such as the Roadway Characteristics Inventory (RCI) that are used to create FDOT's basemaps, as well as other transportation features, including bridges, tunnels, overpasses, and pavement sections that may be geospatially referenced ….."

*"….*The database design should specify the types of data to be stored and the data format. As a first step, Appendix A lists the currently available data sets and sources. These can be added to as the SIS evolves. The SIS database will be managing geospatial as well as non-spatial data from different sources, therefore a suitable metadata catalog will need to be adopted to ensure consistency across the data sets. GIS software such as ESRI's ArcCatalog provide this capability as well as conforming to the FGDC guidelines, and is therefore proposed as this tool in the data compilation. An example of the ArcCatalog metadata template is illustrated in Appendix B. During this stage the data sets will be converted into shapefiles and projected into the SPO's standard projection system (UTM zone 17: NAD 83)."

In Phase 2:

" Beyond the metadata, the data sets will need to be defined in a data model that will normalize the data and entity relationships, support the storage of spatial data objects as well as attribute data, and optimize performance for data access and query. This requires the use of a robust object-relational database management system such as Oracle together with a spatial indexing system employing ESRI software such as ArcGIS and ArcSDE. The formal data model should adhere to the NCHRP Report 460, "Guidelines for the Implementation of Multimodal Transportation Location Referencing Systems." This is consistent with the NSDI model proposed above. Another (optional) consideration is conformity to the ITS America Architecture Standards with respect to navigable databases and georeferenced networks. A draft international standard, the Geographic Data Format, is presently under review and likely to be adopted by ITS America, ANSI, and the ISO (International Standards Organization) later this year. It may be prudent for the SIS to ultimately incorporate this geographic data model into its design. The GDF is a more formal data model than NSDI but the two are not mutually incompatible; indeed, there are many areas of overlap. A decision on whether to implement the GDF data model is not critical and it is therefore recommended that this be put off until the SIS is in production. "

"Georeferencing includes the ability to geocode by coordinates (e.g., lat/long and x,y coordinates), by network feature (node or segment) or using FDOT's LRS. "

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8. Geo-Referenced Information Portal (GRIP)

GRIP [2.46, 2.47] was developed as an IT tool to assist as an interface in the delivery of transportation information at FDOT. Based on Oracle Spatial, at present it provides access to the RCI, the bridge management system, the work program, etc, and will eventually incorporate other similar information resources.

9. Intelligent Transportation Systems (ITS)

From Reference 2.48

> "Intelligent transportation systems (ITS) apply advanced technologies in communications, control, electronics and computer hardware and software to improve surface transportation system performance. Often several technologies are combined in one incorporated system, providing synergistic benefits that exceed the benefit of any single technology."

As with the SIS, useful analogies can be drawn between the ITS framework and the proposed UIMS. A recently completed study of data sources for the ITS [2.46] supported the concept of a central data warehouse (this study is currently being extended to include a proof-of-concept phase [2.49]).

10. Enterprise Geographic Information System (EGIS)

The FDOT is currently in the process of extending a GIS enterprise effort [2.50], which will eventually incorporate a large amount of the data resources available.   Much current effort at FDOT is centered on the development of the Enterprise Information System (Figure 2.8). The status of the EIS is presently evolving and eventually is likely to incorporate, or at least communicate with a number of other currently active geospatial systems at FDOT.

There has been considerable developmental effort for the FDOT EGIS, including organizational models, access and sharing of data as well as data stewardship issues. Currently access to the EIS is through the FDOT INFONET and limited to approved users. Unfortunately reports on this effort are limited to two internal documents at this time [2.51, 2.52]. Two overview presentations of the FDOT enterprise system have been made recently [2.53, 2.54].

FDOT GIS Community

All exisiting and potential spatial data providers, users and viewers within FDOT in include FDOT consutants
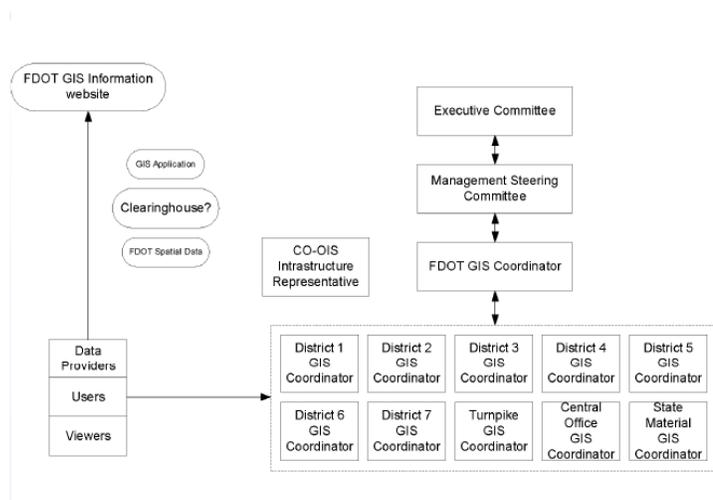
Figure 2.8: Organizational structure for FDOT Enterprise GIS (from [2.53])

At this time the correspondence between GRIP and the Enterprise Information Portal (EIP) is not clear. It seems unlikely that two separate systems would be left in place.

11. Addition items of interest (not reviewed)

      a) TRNS*PORT Decision Support System (BAMS/DSS) [2.55]

      b) Long range estimating (LRE) [2.56]

      c) Project navigator (TIMS) [2.57]

2.3 Business model for planning, permits, and construction

The processes of installation and relocation of utility facilities constitute the major business activity at FDOT for which the implementation of a UIMS would prove useful. To better understand these processes, a brief review of the associated business processes for utilities installations and relocations was conducted by the research team with the assistance of personnel from District 7.

Although a part of the overall pattern of workflow, the permit process is a self-contained activity preceding the start of installation [2.2]. In 2004, approximately

5000 utility installation permits were issued, spread across all districts. Information regarding permits is retained for a period of twenty years, and while filed in electronic repositories, at the local level (maintenance yards) information is retained as hard copy. Permits are filed by roadway section number and milepost. Depending on the nature of the project, the permitting process may begin as late as the 90% plans completion stage. At the present, the permit process is not highly automated at FDOT although there is some interest in doing so. Many states are at least considering an electronic, possibly web-based system.   The flow and eventual archiving of information at the time of permitting is especially important to any project.

Minimal information is required for the permit application. A simple sketch and a statement of the location are usually sufficient although the issuing authority can require more. It is the task of this authority to confirm the location and check for acceptability.   Permit managers need to consider many factors in the decision to issue a permit, including choice of location. It is instructive to examine some of the types of diagrams submitted by permit applicants. Figures 2.9-2.12 are examples taken from Reference 2.58, a District 5 presentation to explain the permit process.   Presumably these figures would be scanned in to the EDMS at the conclusion of the project, as part of the permit record. It appears that all were submitted as hard copy and two are hand drawn sketches.   The addition of cross section information is especially interesting.
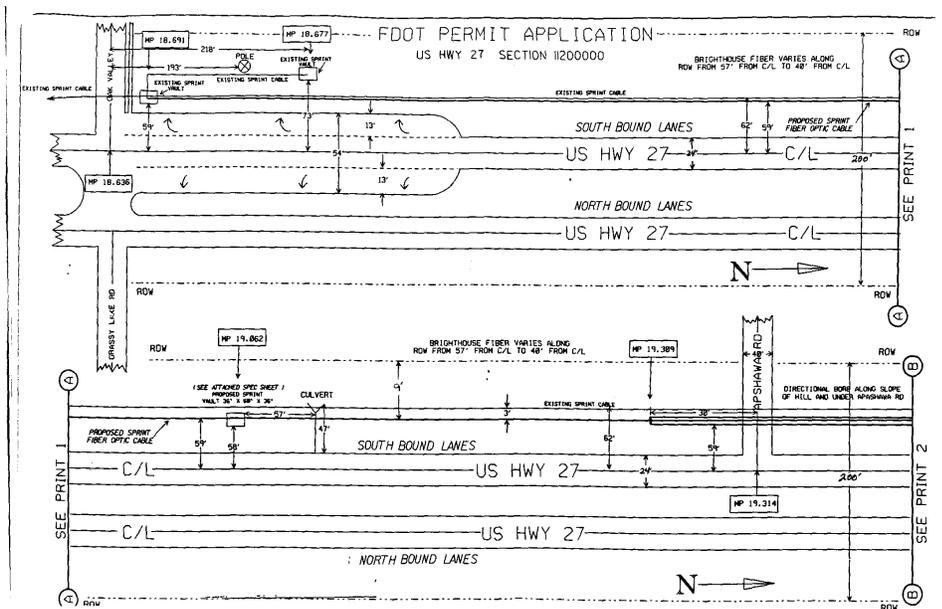
Figure 2.9: CADD plan print out attached to permit application [2.58]. Note annotation regarding Bright House© fiber placement.

TYPICAL CROSS SECTION OF US HWY 27
LOOKING NORTH

TYPICAL CROSS SECTION
OF DIRECTIONAL BORES UNDER
APSHAWA RD AND BISHOPS POINT
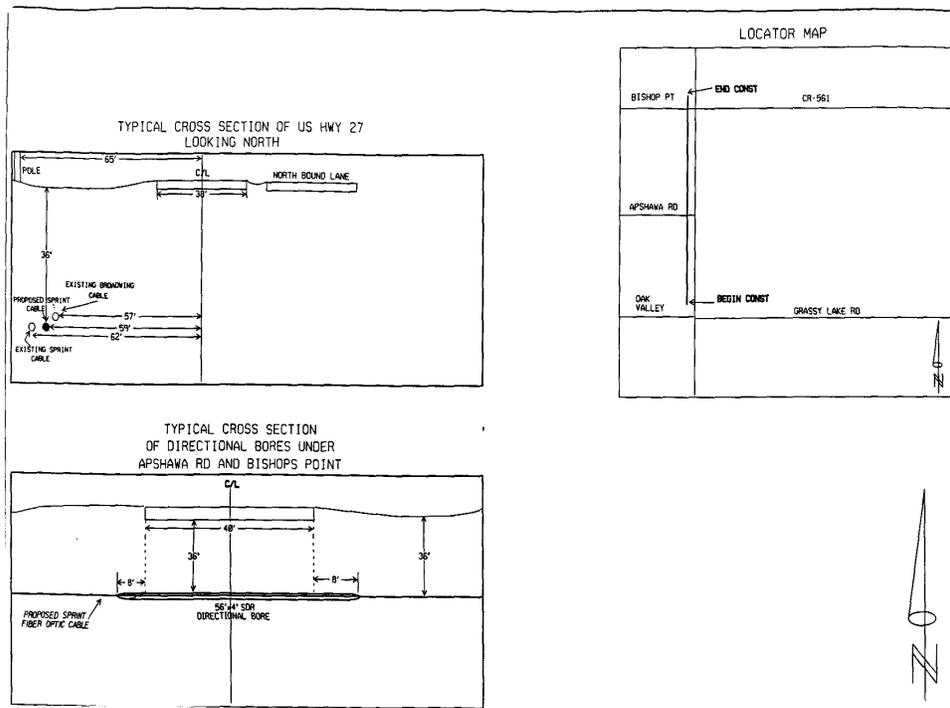
Figure 2.10: Cross sectional views and locator map from permit application [2.58].

MP 30.840 MP 30.852

UNIVERSITY AVE

—R/W—R/W—R/W—R/W—R/W—R/W—R/W—R/W— 20' —R/W—R/W—R/W—R/W—R/W—R/W—R/W—
FIBER OPTIC FOC
FIBER OPTIC FOC
WATER LINE W/L
GAS LINE G/L
36' 51' 56' 61'

SR 25 (SOUTHBOUND) 200'x2" SDR PIPE
48" MINIMUM DEPTH

200'

SR 25 (NORTHBOUND)

—R/W—R/W—R/W—R/W—R/W—R/W—R/W—R/W—R/W—R/W—R/W—R/W—R/W—R/W—R/W—R/W—R/W—

R/W R/W
200'

FLORIDA DEPARTMENT OF TRANSPORTATION
PERMIT APPLICATION.

C/L
61'
56'
51'
36'
24' 24' GAS LINE
WATER LINE
FIBER CABLE
FIBER CABLE
48" MIN.
200'x2" SDR

TYPICAL CROSS-SECTION VIEW OF SR 25
LOOKING SOUTH AT PROPOSED CONSTRUCTION.
DIRECTIONAL BORE 2" WITH SDR PIPE

Figure 2.11: Plan and Cross sectional views from permit application [2.59].

N LOCATION MAP
A
R/W Existing Pole
& Conductor
C/L STATION NO. -19
R/W Proposed
Pole &
Conductor
A Plan

LOCATION
POLE #12325
1.7 miles N
M/O TPK

Existing Pole
Proposed
Pole & Conductor
Ref.
1'
C/L
S.R-19
36'-0" 24" 36'-0"
50'-0" 50'-0"
R/W R/W
1'-0"

WILL MAINTAIN MINIMUM
18' CLEARANCE OVER
ROADWAY(S)

A-A
Section
(Looking North)

Figure 2.12: Sketch with hand annotation from permit application [2.58].

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2.4 Federal sources

Along with State authority regarding utilities, the Federal government (primarily through the Federal Highway Administration) regulates utility practices in the transportation right of way. Requirements include 23USC109 which covers general standards and criteria for utility accommodation; 23USC123, utility relocation reimbursement; and 23CFR645 regulations for relocation, adjustment and accommodation [2.59].   A guide to most programs including accommodation of utilities in the R/W has been provided [2.60].

The Federal Geographic Data Committee (FGDC) is the principal agency concerned with spatial infrastructure. The work of this group with regard to standards is discussed elsewhere. A related site of interest is the CADD/GIS Technology Center [2.61].

2.5 Other organizations of interest

1. One-call systems

Most states have an active "one-call" system, put in place so that interested parties can notify utilities with installed facilities of intent to excavate in a region where facilities may be located [2.62]. It is important to remember that these agencies are typically independent and not a part of the various entities regulating utilities installations. The purpose of this type of service is to reduce the chances of damage to existing facilities by the excavation process.   In principle, someone makes a call and supplies necessary information. Utilities have a certain time period to mark the location and a zone on either side. Only hand excavation is permitted within the marked boundaries.

A study commissioned by the Federal government in 1999 was concerned with best practices for damage prevention. Out of this study grew the Common Ground Alliance (CGA) [2.63] which is, in their words
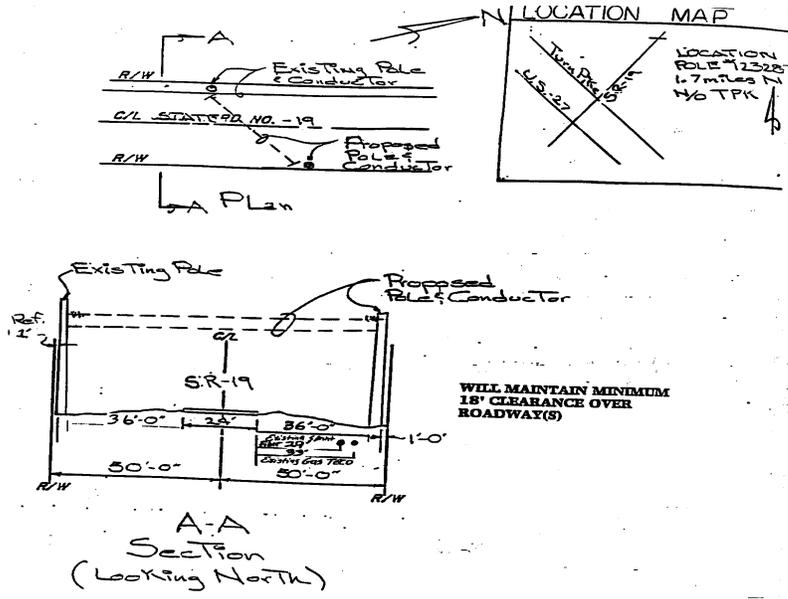
> "…. a member-driven association dedicated to ensuring public safety, environmental protection, and the integrity of services by promoting effective damage prevention practices.   …..Any 'best practices,' endorsed by the CGA come with consensus support from experts representing the following stakeholder groups: Excavators, Locators, Road Builders, Electric, Telecommunications, Oil, Gas, Railroad, Water, One Call, Public Works, Equipment Manufacturing, State Regulators, Insurance and Engineering/Design."

At present this organization maintains the document, Common Ground Alliance – Best Practices Version 2.0 [2.64]. The CGA also maintains the Damage Information and Reporting Tool (DIRT), a system for the collection and analysis of damage incident information.

In Florida, Sunshine State One Call of Florida (SSOCOF, a not-for-profit) is the agency responsible for one call service. SSOCOF (a member of the CGA) began with the adoption of Chapter 556, Florida Statutes, "Underground Facility Damage Prevention and Safety Act" in 1993 [2.65]. From the mission statement:

 "….SSOCOF has two main areas of responsibility:

1. Educate underground facility owners and operators, contractors, excavators, homeowners and the general public about the importance of calling before digging.

2. Provide a toll-free number, (800) 432-4770, to call for location of underground facilities.

By contacting SSOCOF, the risk of personal injury and property damage can be reduced. By being members, companies may reduce the risk of damage to underground facilities, service disruptions, environmental contaminations, loss of products and potential disasters."

SSOCOF provides both design and locate tickets. Due to the nature of this organization it may be possible to involve SSOCOF as a data partner in the UIMS for mutual benefit.

2. Florida Utilities Coordinating Committee (FUCC)

From the Committee's mission statement [2.66]

"The FUCC is a confederation of public and private utilities, public works departments, consulting engineers, contractors, state, city and county governmental agencies who work together through coordination, cooperation and communication to resolve problems and develop standards for coexistence in public rights-of-way. "

3. American Association of State Highway and Transportation Officials (AASHTO)

AASHTO provides a wide range of support services and includes a subcommittee on Right of Way and Utilities. For example, the Model Highway Data Dictionary Roadway Maintenance Data Elements is published by AASHTO with the collaboration of the Federal Highway Administration (FHWA [2.67]. This dictionary contains roadway characteristic data attributes.

2.6 Summary

It is apparent that there are numerous resources directly available from within the FDOT which may be profitably utilized by a UIMS. Conversely, users of these same resources may find the UIMS a valuable asset. As part of the eventual

recommendations it will be extremely important to detail how the UIMS will be integrated with ongoing activities and programs at FDOT. It will be especially important to understand how the UIMS will become a part of the business practice associated with installation coordination.   Building on successful applications and services available should be cost effective and efficient, however it is apparent that the status of some programs is rapidly changing and these developments should be closely monitored. Similarly, other entities including the Federal Government can provide much useful information.

At the same time, an examination of current practices regarding utility installation and relocation shows that the FDOT is in danger of slipping behind current technological advances.   Insufficient effort is currently being devoted to capturing valuable data in a spatially referenced electronic format, for possible use in a UIMS. A good example of this deficiency is the example set of scanned diagrams associated with the permit process.

At present the enterprise effort is evolving but many parts of the FDOT do not interface with EIS.

> "While FDOT is in the process of developing an Enterprise GIS application, the first phase of the RWMS does not currently interface with the GIS. The design recognizes that, as the Enterprise GIS matures, inclusion of Right of Way data will desirable, as a result, the system design was developed with an eye toward accessibility. The primary facilitator is the software translation layer that is designed to respond to queries from various sources and integrate data from several different databases." [2.26]

The findings of a 2005 study [2.68] show that the coordination of information between various existing databases at FDOT is lacking.   In the future, more integration of these information sources will be a necessity.

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Chapter 3: Representing the spatial location of utilities facilities

With regard to the capabilities of a UIMS, a principal question that must be addressed is how to specify reliably the location of utilities facilities in relation to the surface of the Earth.   The intent of the following discussion is to briefly summarize several important aspects of facility location information. It is convenient to think of a map of the utility network as a scaled and spatially referenced representation of the facility.   If this were completely true, then in principle each part of the facility could be located accurately, even if buried. In fact, information about the location of facilities is almost always incomplete and inaccurate. If two points of a continuous facility such as a pipeline are located, it is easy to imagine that they can be joined by a straight line, but this is at best a supposition. Even true as-built information suffers from accuracy problems, due to measurement errors, incomplete data collection and installation accuracy limitations. Finally, the depth of the facility, if underground, is not usually easily represented on a map.   A visual representation including depth requires the use of topographic reconstruction or some other means to present this additional dimension.

A key issue in the development of a useful UIMS is the ability to present the spatial location of utilities as accurately as possible.   As a target, it was originally suggested to the research team at the onset of this project that a reporting precision for facility location of +/- 0.5 ft would be desirable.   Along with the question of attainable accuracy are the problems of merging compatible files, as well as the overlaying or combining multiple data elements in correct registration from files in different formats. Compared to other types of transportation geodatabases, these issues present significantly greater challenges than usually encountered, due to the diversity of information sources, the desired reporting accuracy and the three dimensional nature of facilities installations.

As discussed earlier, a number of different clients are expected to utilize the UIMS, including planners, installers, managers, contractors and others. It is the capability to bring together in one location, all relevant information and then displaying the data in an integrated fashion that is most valuable to these individuals as they pursue their specific tasks. A definitive aspect of the construction and maintenance of the UIMS is to understand how these clients would utilize such a combination of resources and capabilities, and what they would expect to receive from a query to the system. The information desired and the workflow for each of these potential clients will undoubtedly be different.   A preliminary concept regarding utilization is adopted for the present discussion.   A client is likely to have a specific geographical location in mind (a specific point or area).   Thus a routine query based on this location should trigger retrieval of all stored features and files within a specified region around this area. The method of determining the extent this area of interest would probably be a client software application.

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Several questions a typical user might want to consider are:

a) Retrieving data regarding the location of a specific object from an archive: what kind of accuracy can be expected - especially when several different representations of this location may be stored?

b) After retrieving all available information regarding underground utilities located at a particular area of interest, what is the likelihood of accidentally striking one or more buried facilities during an excavation?

c) Data incompleteness - no matter how much data is available, there will still be large areas where no information exists. What are the limitations to predicting what facilities might or might not be buried?

This chapter includes several specialized discussions of relevant literature.

3.1 Describing the location of facilities

The location of utility facilities concerns not only accurate, as-built records of location archived at the completion of construction, but also the ability to find and accurately report the location of facilities (often underground) for which only limited information is available. A prime example of the potential usefulness of a UIMS concerns the need for information if excavation near a subterranean utility installation is anticipated. In the worst case, an underground facility may have been forgotten so that no record exists. Under current rules, facilities cannot be abandoned and left in place but that does not mean good location records are kept. Erroneous or inaccurate records are only helpful in that the presence of facilities may be suspected, subject to further confirmation. In Chapter 2 one-call notification services and the principles of subsurface utilities engineering (SUE) were discussed. Around 2000, a major report on the status of utility location technology needs was generated [3.1]. Much of the analysis and many of the recommendations are equally valid today, including issues of representations of location and detection methods.

When requested to indicate the location of their underground facilities, a utility company (or subcontractor) places a centerline mark and two side marks on the ground, which represents their interpretation of position, which could be determined from plans, detection methods or direct excavation. Depth and size of facility may also be indicated. This statement is equivalent to a confidence interval in the sense that the facility is assumed to be at the centerline but could be anywhere between the marks. Any information, including markings placed as a result of detection or SUE "pothole" investigations should be regarded as valuable data to be recorded and archived. Otherwise, this data will be of no use and the effort will be duplicated at considerable expense. Of course, erroneous determinations are possible and the facility could in fact lie outside this zone.

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Alternatively, unidentified facilities may exist beneath the surface and not be located until an accident occurs.

Since many facilities are buried out of sight the answer to the location question is further subdivided:

> 1. How is the location specified? What coordinate frame has been utilized, as well as what is the accuracy and precision of the statement of location?

> 2. If the location of a facility is specified, what confidence is attached to this information?   How certain is it that it that the facility is actually present at that location or within some zone around that location.

> 3. What is the relationship between the location of a particular facility and the location of any other feature of interest (the roadway or another facility, for example)?

3.2 Cartography

The science of cartography is focused on the task of organizing and presenting geographic information.   Often this information is communicated by hard copy maps but also increasingly by digital transfer. Geodesy is the science of the determination of the shape of the geoid, defined as a gravitational equipotential surface (mean sea level). The geoid is used for a spatial reference in the presentation of geographical information. It is well known that the Earth is not a true sphere and over many years the methods of specification of location based on an understanding of the exact shape of the Earth along with the shape of the geoid has been developed.   The specification of location in this manner is in terms of latitude, longitude and relative elevation.   Methods of geodetic measurement include GPS and traditional surveying. While it is possible to speak of an "exact" location, in fact the location of any object must be measured which immediately brings to question the accuracy (determination of absolute value) and precision (resolution) of the measurement.   It must be accepted that any measurement is contaminated with error, due to both inherent error in the measurement technique and so-called "human" or operational error that includes faulty transcription of data.

Due to the complexity of making geodetic measurements and the associated problems of constructing a flat map to represent the location of objects relative to the surface of the earth, a number of ideas have been introduced as simplifications in the specification of location. While it is not the intent here to engage in an extended discussion of cartography, perhaps the most important of these ideas to mention is the State Plane representation for Florida [3.2]. This method enables a surveyor to work over limited and local areas of the surface of the Earth as if it were a planar area and to construct a local map (possibly

including elevation information).   It is essential that the map projection data be included as part of the survey information. The location of objects are then known to some degree of accuracy and precision but it must be remembered that now, in addition to measurement and transcription error, the result is not specified in the absolute sense but could be transformed or converted to geodetic coordinates or other reference frames. Finally, it is worth mentioning that maps are not restricted to hard copy diagrams since high resolution aerial photography (as well as other means) can also be used to create a functional diagram.

3.3 Accuracy and Errors

This section is devoted to a discussion of sources of error in reported spatial data and error propagation in coordinate transformation. Transportation modeling requires that both features and events can be placed accurately in space and time. Reference 3.3 is directly concerned with this problem (Location Referencing Systems are discussed later).

The following question illustrates the problem considered here. Suppose a measurement of position has been made by some means with respect to a well-defined datum.   What is the difference between that measurement once it is stored in the archive and the "true" position? Ideally, an absolutely accurate measurement is flawlessly transferred to an archive. This result is not possible due to ever-present error limitations. Analyses relating to the accuracy of measurement are widely available, but for the present elementary discussion the following terms will be utilized:

a) <u>Mapping error</u> - If a point is located with some technique with regard to some projection, what is the differential in position as established by this measurement and the actual "true" coordinates? This question is always a quandary because the true position cannot be measured with absolute accuracy, either. Measurements are always contaminated but the choice of referencing method may introduce additional error terms.

b) <u>Measurement limitation</u> – The inherent limitation of any measurement method or instrumentation.   The precision of an instrument refers to the best resolution of a measurement whereas the accuracy is the reported deviation from true value which might be encountered under normal conditions.

c) <u>Measurement error</u> - A human mistake during the measurement process or the error introduced as a result of instrument miscalibration.

d) <u>Transcription error</u> – An error made during the recording (archiving) of data -could include misdirection or omission for automatically recorded data

d) <u>Transformation error</u> – Sometimes it is necessary to manipulate coordinate data, as for example to transform from one coordinate frame to another. The mathematical process used for this transformation may introduce additional error into the record. Additionally any differential error already present is likewise transformed and in the worst case the transformation process may magnify this factor.

In all cases where two data sets are to be brought together, one of the most important points considered is the determination of intersection for two different data elements, one from each set, and the subsequent probability that these data elements are the same object. These questions will be considered further in the next chapter.

3.4 Technologies (locating, measuring and mapping)

Obviously there is yet another means of specifying the location of any object and that is by direct physical evidence.   This step can involve either placement of markers of various sorts or physical inspection and detection.   While location information obtained directly is generally high quality it is restricted in the sense that it applies only locally and does not always have immediate reference back to geodetic spatial coordinates, although this information could be provided with additional effort.   The extensive subject of location technology is partially reviewed in Reference 3.1. Recommendations from this report include:

- "Methods ideally should be able to identify utilities with a depth to diameter ratio of 30:1 or better, i.e. a 25 mm pipe or cable at 0.75 m depth or a 1 m diameter pipe at 30 m depth. "

- "Methods ideally should be able to resolve depth and horizontal position of utilities to within a depth to accuracy ratio of 20:1 or better, i.e. an error in depth or horizontal position of 50 mm at 1 m depth or 1 m at 20 m depth. "

- "Methods or combinations of methods are more desirable if they are able to improve detection of all kinds of pipe or cable in all soil conditions but the cost of multi-sensor technologies must remain realistic."

- "Methods capable of greater depths are better but the following depth ranges are most important."

    - Cables: up to 2 m (larger depths becoming more important as trenchless technologies are more widely used)
    - Pipes: up to 5 m most common, up to 10 m important, over 10 m uncommon

Regarding utility locates:

> "Although many existing methods can give more precise information under favorable conditions, the following information is considered the normal precision of utility location information (not including mis-locates):
>
> > Typical Surface-only Utility "Locates"
> > > Horizontal location within 24 inches either side of location markings
> > > Vertical location not provided
> >
> > Typical Surface Survey with Vacuum Excavation Potholes for confirmation (Subsurface Utility Engineering (SUE) provider
> > > Horizontal location within 0.5 ft.
> > > Vertical location within 0.05 ft."

Additionally this report includes an excellent summary of underground utility types and materials, as well as a discussion of methods and accuracy. For Florida, the utility marking process is explained in Reference 3.4. It is noted that the marks actually fall within the definition of "as-built" information used here but are not currently recorded and archived.

The following technologies are currently in common use:

1. Physical markers/detection

Physical evidence of utility facilities includes the components of the network itself (aboveground facilities, access covers, utility poles, etc) as well as permanent markers (posts, signs, etc) placed to be visible from ground level. Virtually any electronic or acoustic signal can be utilized to detect pipes from the surface using sensitive information, however some materials (plastic for example) are difficult to detect even with sensitive instrumentation. Frequently, specifications for the installation of new underground facilities require the addition of marking tapes and electrical detection wires. A relatively recent innovation involves placing small electronic transponders in trenches as lines are being installed [3.5].

2. GPS/surveying

Once a marker associated with a facility has been identified, an accurate measurement of position of the mark (surface and elevation) must be recorded. Conventional surveying techniques may be used to accomplish this directly. The Global Positioning System (GPS) is a newer technology capable of establishing position relative to the surface of the Earth, utilizing satellites. The level of accuracy achieved is in part a function of the initial investment in equipment. The literature discussing GPS is vast

and will not be reviewed here. Of special interest is a recent report concerning the development of a GPS based method for monitoring and inspecting construction projects for progress payments has been published [3.6]. In this application, GPS is used for accurate measurements (objects, linear, area and volume).   The FDOT system for Continuously Operating Reference Stations (CORS) is discussed. Since this work is very new, it remains to be seen how this project will be incorporated into the business activities of FDOT, but much important information has been made available.   A similar project dealing with environmental discharge compliance was reported [3.7].

3. Subsurface Utilities Engineering (SUE)

Subsurface Utilities Engineering is a process that incorporates rapidly growing technology [3.8-3.11] aimed at site inspection and analysis with the goal of reducing accidents and delays. The ASCE Standard Guideline for the Collection and Depiction of Existing Subsurface Utility Data (CI/ASCE 32-02) [3.12] defines SUE as:

> "…a branch of engineering practice that involves managing certain risks associated with utility mapping at appropriate quality levels, utility coordination, utility relocation design and coordination, utility condition assessment, communication of utility data to concerned parties, utility relocation cost estimates, implementation of utility accommodation policies and utility design."

Briefly, four levels of information regarding location are identified:

> Level D: Maps plans, and recollections only
> Level C: Onsite verification of aboveground facilities, etc.
> Level B: Onsite detection by sensors
> Level A: Survey information, both horizontally and vertically including test hole inspection

SUE investigations result in independent data (ie specific location information, generally on a point by point basis and therefore isolated fragments).

4. Photographic methods

Aerial photography has long been used to gather information rapidly over large areas on the face of the Earth and very high resolution is currently available.   Orthorectification is the technique for correcting the camera view to correspond to actual physical coordinates, as spatial information can be distorted by view angle and surface elevation.   Corrected photographs can be used to provide raster information in GIS applications.

Stereophotography can be used to record vertical elevation information [3.13, 3.14] and here again the resulting information can be directly integrated into GIS. Within Florida an ongoing project conducted to develop a stereophotographic system has been reported, with an accuracy of 0.16 ft (5 cm). Florida county aerials may be found at Reference 3.15, which includes metadata information.

5. Light Detection and Ranging (LIDAR)

LIDAR is a laser based system [3.16] capable of measuring elevation aerially to about 6 inch accuracy. This type of system may have substantial application with regard to recording depth measurements from any open excavation (although increasingly trenchless methods are being employed for installation). Pattnaik, et al [3.17] have reported LIDAR measurements of pavement cross slope and curvature.

6. RADAR

For some time ground penetrating radar has been utilized to detect underground facilities. In order for this technique to work, it is necessary that the facility reflect the radar signal. Recently, radar arrays have been employed along with algorithms for tomographic reconstruction to produce three dimensional images of underground facilities [3.18]. A potential problem with this method arises due to the presence of above ground obstacles.

3.5 Location Referencing Systems

A location referencing system (LRS) is any method for specifying locations with respect to some known reference point. Many state departments of transportation and other transportation agencies make use of this concept. Due to the fundamental network characteristic of any roadway, it is natural to refer to distance "along the path" from a known point. For example, with respect to a roadway the position of an intersection with a cross street could be given as a distance along the road from some initial, well defined point. Furthermore, since many features are located at the side of the road rather than on the road itself, a secondary data specification is the offset, perhaps from the edge of the pavement or from the centerline. There are several ways of constructing an LRS, termed Linear Referencing Methods (LRM), including:

> a) milepost
> b) project stationing
> c) street address

FDOT utilizes each of these methods. Furthermore, by extension, the Straight Line Diagram (Chapter 2) is a simple, graphical version of an LRS. These topics

are the subject of a comprehensive report [3.19]. *Dynamic segmentation* describes the process by which a line can be broken into point components and is frequently employed with LRS to improve the ability to represent information locally in GIS [3.20].

It is often observed that there is no direct reference between geodetic coordinates and a location established by LRM. Interpolation can be utilized to provide associated reference, however. For example, suppose that a number of stations are established along a roadway such that the exact position of each is known. A polyline can be constructed joining each station. This process is functionally equivalent to linear interpolation, so that if the position of any particular object is stated in terms of a linear and horizontal offset from some station then a geodetic position can be calculated for this object.   This calculated position will necessarily include an error term because of the tacit assumption that a straight line connects two adjacent stations. Other interpolates (splines for example) could serve as models and tests could be performed to estimate accuracy, perhaps by using every other station and attempting to determine the position of the skipped stations.

An extended discussion of the representation of point features with linear referencing methods can be found in [3.21]. This report includes a discussion of accuracy and transformation of data. Considerable effort was exerted to provide a centerline location for the roadway.   The use of LRS in connection with transportation databases is discussed in Reference 2.68.

Clearly, if the positions of points along the roadway (e.g. centerline data) are recorded in some coordinate system then distance along the roadway, along with any offset can be utilized to specify the position of an object with respect to a known reference point, at least to some degree of accuracy.   If the absolute position of the roadway is unknown, the concept is still useful however the result is the unreferenced equivalent to a simple straight line diagram (SLD).   LRS and various LRMs have a long history and are in common use.   Some investigators have questioned the future of such systems given the rapid development of GIS/GPS and geodatabasing for data archives.   For the moment however, it appears that LRS will remain in practice and should be discussed as part of this investigation.

Since most facilities of interest are closely associated with the roadway itself, the spatial location of the centerline of the roadway is useful, perhaps essential information [3.21]. Not surprisingly several states have adopted and published centerline standards (Table 3.1). Of special interest is a project completed in Flordia FDOT District 3 [3.22].

Table 3.1: Centerline standards

STATE	REF.	URL
ARKANSAS	3.23	http://www.gis.state.ar.us/Documents/ACFstan.pdf
FLORIDA	3.24	http://www.ncgia.ucsb.edu/ncrst/meetings/clem2001/GayHamiltonSmith.ppt
IOWA	3.25	http://www.gis.dot.state.ia.us/downloads/
KENTUCKY	3.26	http://giac.ky.gov/giac_standards_centerline.htm
OREGON	3.27	http://www.oregon.gov/DAS/IRMD/GEO/standards/docs/OR_Trans_Standard_V4_0.pdf

Other examples of LRS examined include:

1. Iowa LRS

The State of Iowa has invested in an extensive LRS and made much of this research available for inspection [3.28]. This system is currently under development and incorporates both straight line type representations and GIS linear referencing system. The Iowa system is not intended for utilities but with some modifications it might be possible to develop a similar approach. Here the facilities information would be tied directly to the centerline coordinates, with linear/transverse offset coordinates.

2. Texas- TxDOT Geographic Information System (GIS) Architecture and Infrastructure Project (GAIP)

The GAIP system ties information (road surface conditions, etc) to a version of a straight line diagram with visualization as a BLOB (Binary Large Object, a file structure for databases, often used for images etc) [3.29].   This is not a system for utilities but with some modifications it might be possible to develop a similar approach, tying the utilities facilities information to the graphical display. Whether or not this approach could produce a useful and satisfactory end product in the case of utilities remains to be seen.

3. Florida-Traffic Management Data

Ries [3.30] has provided an interesting example of an enterprise system for integrating traffic management data based on an LRS system.   A principal objection to such an application is the lack of stability in the referencing method. LRS are fundamentally unstable since the marker points may move due to road relocation or similar events. Transformations between systems with accuracy and confidence become very difficult in this situation.

3.6 Data and Metadata Standards

A fundamental principle of database construction is that appropriate standards are chosen for the data formats and for the metadata information. Not surprisingly, more than one type of standard may usually be found, depending on

the particular application.   Standards for describing utilities facilities are currently being developed, but it is probably fair to say that this work is not yet complete. Data and metadata standards are topics often raised in reports related to the present research effort. The following is a brief review of several important discussions. Halfawy, et al [3.31] have provided an excellent discussion of several agencies which currently maintain data standards appropriate to this investigation. These are

> a) Federal Geographic Data Committee (FGDC) – maintains content standards (specifically utilities content standard and some modeling), transfer standards and metadata standards [3.32]. This committee promotes the nationwide development of geographic data and promotes the sharing of information by developing standards and metadata information.   This effort includes the National Spatial Data Infrastructure (NSDI).   More information may be obtained from the following sources regarding standards of interest here:

Table 3.2: URLs for FGDC Sites

FGDC SITE	URL
FGDC WEBSITE	http://www.fgdc.gov
FGDC STANDARDS	http://www.fgdc.gov/standards/standards.html
UTILITIES STANDARDS	www.fgdc.gov/standards/projects/FGDC-standards-projects/utilities/index_html
GEOSPATIAL ONE-STOP	http://www.geo-one-stop.gov/
METADATA INFORMATION	http://www.fgdc.gov/metadata/metadata.html
METADATA WORKBOOK	http://www.fgdc.gov/metadata/documents/workbook_0501_bmk.pdf
METADATA STANDARDS	http://www.fgdc.gov/metadata/geospatial-metadata-standards
METADATA QUICK GUIDE	http://www.fgdc.gov/metadata/documents/MetadataQuickGuide.pdf
FRAMEWORK HANDBOOK	http://www.fgdc.gov/framework/handbook/components
CLEARINGHOUSE	http://www.fgdc.gov/clearinghouse/clearinghouse.html

> b) GIS/CADD (SDSFIE) is oriented towards AM and infrastructure. The State of Arkansas is utilizing NCITS SDSFIE in the development of its geodatabase (Chapter 1) and SDSFIE was the standards basis for the development of the Conceptual Site Model described in Chapter 2 (standard NCDITS 353 [3.33]. SDSFIE tools are available at Reference 3.34.

> c) OGC Open GIS Consortium - in addition to standards this agency maintains a graphics markup language (GML) [3.35].

> d) ISO/TC 211- International Standardization Organization- this agency adopts some OCG standards, does referencing by coordinates and geographical identifiers [3.36].

The FDOT Central Planning Office maintains ARC/Info[©] coverage of the base map (Projection: UTM 17; Datum: NAD 83), (geodatabases and metadata).

Figure 3.1 contains the metadata for the Florida base map, from the Central Planning Office site [3.37].

BASEMAP

DESCRIPTION
DATA LAYER NAME:	Basemap (FDOT Roads/Linear Referencing System)
DESCRIPTION:	FDOT coverage of state roads
TYPE:	Dynamic segmentation (arcs and routes)
SCALE:	1: 24,000
DATUM:	NAD83
PROJECTION:	UTM 17
MAP UNITS:	meters
GENERAL AREA COVERED:	Florida
REPORT PREPARED BY:	Original report by Marc Cooper. Revised by Paul O'Rourke.
DATE OF PREPARATION:	Original: 04/16/1996. Revised: 12/15/1999; 1/17/2002; 10/7/2003; 8/18/2005

PROVIDING ORGANIZATION
AGENCY:	Florida Department of Transportation
CONTACT PERSON(S):	Michael Dancy, Paul O'Rourke, Mark Welsh.
PHONE NUMBER:	(850) 414-4848
AGENCY DATA NAME:	Basemap

DESCRIPTION OF SOURCE MATERIAL(S)
SOURCE TITLE(S):	-2004/1999/1994 Digital Ortho Quarter Quads (DOQQs).
	-Turnpike aerial photos provided periodically by the Turnpike office.
	-Sub-meter county aerial photos provided through FREAC from DOT/DOR.
	-7 1/2" USGS Quadrangle maps (before DOQQs were acquired).
SCALE:	1: 24,000
DATUM:	NAD1983
MAP PROJECTION:	UTM 17 (DOQQs).
	Lambert Cnfrml. Conic, Trnsvrs. Mrctr. Polyconic (quad maps).
MEDIA OF SOURCE:	TIF, JPG images (DOQQs); mylar and paper (quad maps).
CONDITION OF MEDIA:	Good (quad maps)
DATE OF SOURCE MATERIAL:	DOQQs – 2004/1999/1994.
	Aerial photos from Turnpike Office – 2001→.
	Other aerials – 2001→
	Quad maps – various dates.
UPDATE SCHEDULE:	We are currently acquiring available images through a research contract with FREAC.

CREATOR OF SOURCE OR DATA LAYER
AGENCY/ORGANIZATION:	USGS (creator of DOQQs); FREAC (distributor).
UNIT/SECTION:	
CONTACT PERSON:	Stephen Hodge, FREAC
TITLE:	
PHONE NUMBER:	FREAC: (850) 644-2882
WEB ADDRESS:	USGS: www.usgs.gov
	FREAC: www.labins.org

DERIVATION METHOD(S) FOR DATA

Figure 3.1: Illustrating the metadata format for the base map [3.37]

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A comprehensive package discussing the adoption of data standards and metadata format is available for Oregon's "navigatOR" project [1.10].

3.7 Summary

It has been previously argued that the usefulness of a UIMS in supporting utility business practice at FDOT depends on the integration of all available information relevant to utility placement in an area of interest. The quality of this information, especially location accuracy is paramount. In this chapter consideration has been given to the methods by which actual location of utilities facilities can be measured and specified. Accuracy of measurement and accuracy possible within the system used for specification of location are separate but equally important issues.   A number of techniques for making measurements have been reviewed.   Thus any as-built data is unlikely to be error free for the reasons discussed above and also the processes of transferring data introduce new errors, due principally to round-off, and computational errors associated with transformations made to the original data.

As stated earlier, a goal for reporting accuracy for the UIMS is 0.5 ft. The FGDC standards for military installations range from 0.1 to 0.5 ft typically in both horizontal and vertical directions [3.38]. By comparison, field location and marking of facilities allows for a zone of uncertainty of up to 1.5-2 ft on either side of a buried conduit.   SUE investigations have a target accuracy of 0.5 horizontal and 0.05 vertical.   Milepost accuracy of 5.28 ft (in conjunction with the RCI) was reported by Dove [2.20]. In contrast, three dimensional spatial information obtained with high performance GPS can be accurate to 0.1-0.4 ft. [3.3]

Base maps are presented at different scales, often with resolutions much less than the accuracy expectation given above.   For military installations, mapping accuracies of 40 ft/inch are expected.   A slightly larger 50 ft/inch is expected for SDSFIE standards.   Orthophotography resolution of 2 ft resolution are reported, however the stereophotography claims of 0.16 ft. are made. For raster maps 1 ft per pixel is expected [2.26].

Based on these comparisons and the expectation that technology will improve with time, accuracy levels of 0.5 ft for the UIMS seem realistic.   However, older data, especially paper-based information cannot be expected to have this resolution. Furthermore, the transformation of any data between various coordinate systems will likely increase the error to some extent. Placing utilities data accurately on a base map to the accuracies desired would be difficult.

There are several reasons for interest in LRS within the context of the present report.   One possibility to consider is to connect the UIMS data directly to an LRS/LRM scheme (discussed more fully in Chapter 5). Secondly, because of the popularity and familiarity of LRS with transportation agencies, LRS may be a realistic technique for locating regions of interest.   Many currently existing

databases utilize some form of LRM to designate spatial location, even though these systems tend to be unstable in time due to changes in the position of the roadway.   There are several disadvantages to LRS, including the difficulty in including three-dimensional information.   Another concern is for the long term viability of such systems.   It seems likely that even if absolute coordinate systems become the method of choice, LRS will be used for many years to come and should be at least included in UIMS capabilities.

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Chapter 4: Challenges to the development of a UIMS

This chapter is concerned with the capabilities of the UIMS to represent and report data to the user, in light of the earlier discussions in this report. The association of graphical capabilities with the UIMS (as with GIS) is appealing, due to the very nature of facility organization in the R/W. This point is made elsewhere:

> "The greatest advantage of GIS can be attributed to the superior graphic image obtained which is much easier to interpret than tabular data, and greatly enhances the speed of decision-making." [1.4]

Once an area of interest is identified and all available information regarding the area is retrieved, a graphic display can help to provide a rapid understanding of spatial relationships among the various data elements. This function might be described as a graphical presentation of a data inventory. Corresponding attribute data should be available in text/graphic form.. The second task of a UIMS is to depict (and possibly improve) the overall spatial information. A visual presentation may help to reveal possible errors or misalignments in the data.

The challenge of the graphical display is closely tied to the problem of overlaying information discussed earlier. Utility facilities typically consist of linear (pipelines) and point features (valves, junctions) along with a few solid objects (boxes). The representation of facilities in maps, photos and CADD files, is quite different, consisting of coordinate information, pixels or line segment specifications, for instance. Does the requirement for a graphical presentation include the ability to manipulate individual objects and components of a utility network or simply to view a map, photo or CADD file? No matter how information is presented, it should be remembered that multiple levels of accuracy may be present in feature locations represented and also that a very large amount of information is incomplete or missing entirely.

Four factors contribute to making a UIMS a more complex entity than typical governmental geodatabases; 1) to be useful facility location information requires a high level of accuracy, 2) it is important to be able to understand the utility network topology, 3) a critical component of location is the vertical position of facilities, and 4) not only are the sources of information regarding facilities diverse but in general this information is not complete. An important question has been raised in previous chapters: given that information regarding facilities location is likely to come from a variety of sources, employing different coordinate systems and having different levels of accuracy and confidence, how is this information to be integrated within a UIMS for purposes of presentation and analysis?

To recap, the following is a summary of some of the types of information that could be available in a UIMS archive:

Location and attributes of point features

- Physical Markers (both above and below ground)
- SUE reports (includes also depth)
- Above-ground facilities (GPS, or other coordinate information)
- Open underground site- (GPS, or other coordinate information during excavation)

Location and attributes of line features

- Plan and profile data from CADD records
- Network data (arc data)
- Boring logs
- Straight Line Diagrams
- Markup plans
- One call marks (captured and recorded)

Location and attributes of area features

- CADD files
- Hard copy drawings and records, including manual markings
- Aerial photography or LIDAR
- Background raster information
- Topological Maps
- Other map types

Textual information

- Scanned records
- Text files (including existing database records)

4.1 Problems associated with graphical representations for the UIMS

Several problems relating to graphical displays have already been uncovered but in the interest of illustration and in order to obtain a better understanding of these issues, consider the following examples. It should be noted that while realistic, these examples are highly simplified and not necessarily closely related to actual circumstances.

A proposal has been made to install a new domestic waterline along a section of roadway, consisting of a main with lateral connections and other ancillary equipment. An engineer working on the planning phase is interested in underground conditions at a proposed work site and has good reason to believe

that a buried electrical conduit passes through this area, since an associated above ground facility has been located (Figure 4.1).
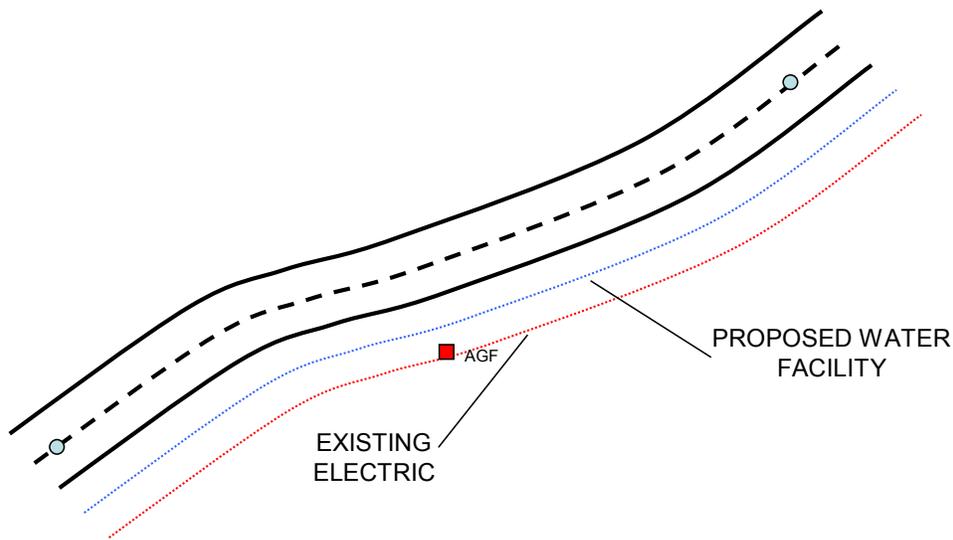

Figure 4.1: Site for proposed new water line.

The starting point to locate and describe this part of the system would usually be to request locate markings and any retained maps, mark-ups or plans relating to the previous installations. Information about the system, covering at least the mapped portion, would be available from plans annotation, system specifications and other legacy data from a variety of sources. In this case, several "as-built" CADD plans were found to be available. These plans were stored by referencing the site location relative to the mile post along the roadway.

A subsequent SUE investigation reveals the electrical conduit, although not in exactly the offset position from the roadway as shown on the plans (Figure 4.2). Thus the "as-built" plans are suspect and may in fact have been simply original construction drawings. Nevertheless, the error is small and it is tempting to conclude that the electric facility runs from the SUE location to the above-ground feature (AGF) parallel to the roadway. However, as shown in Figure 4.3, if a deviation of the installed line occurred to avoid a rock or other obstruction and this information was not recorded properly then a claim for true as-built diagrams cannot be made.
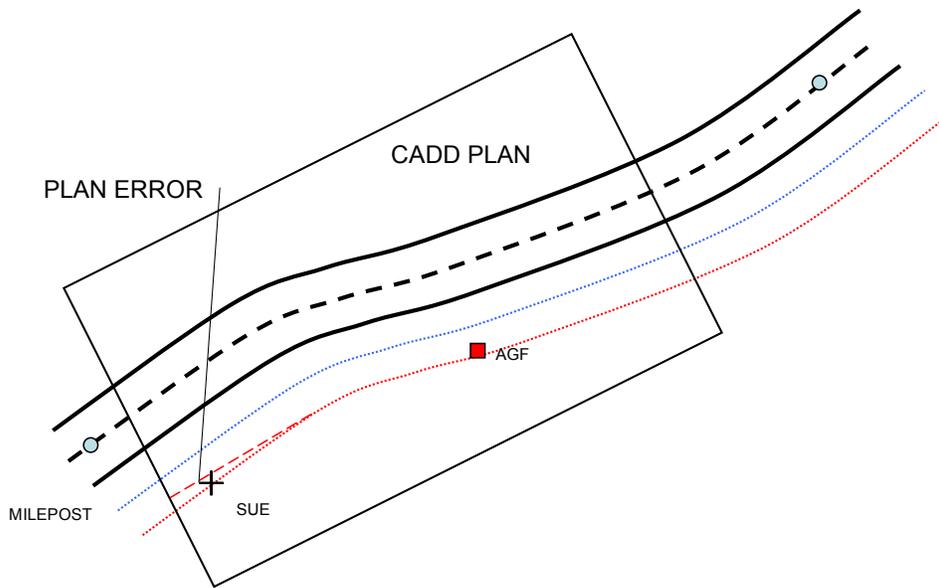
Figure 4.2: Illustrating plan error relative to SUE investigation.
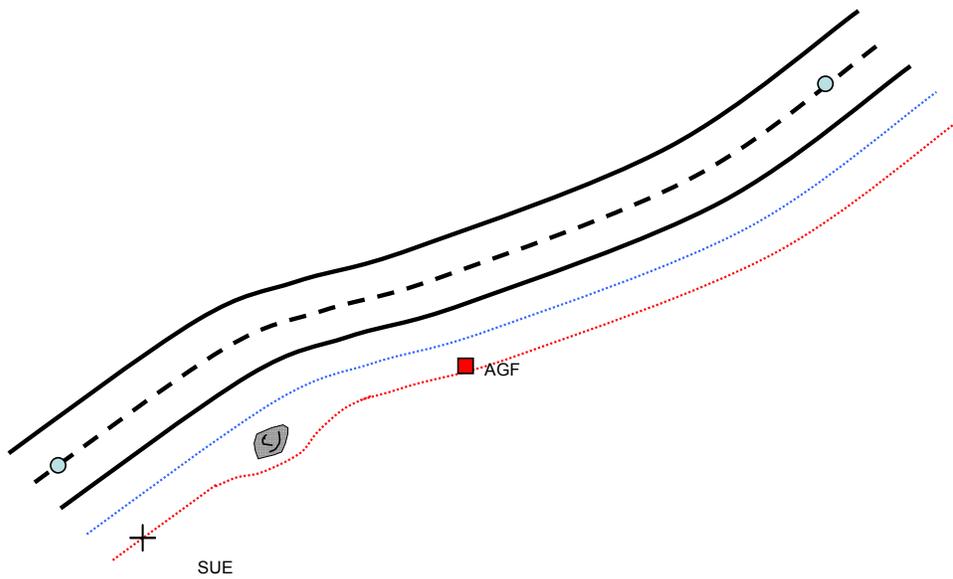
Figure 4.3: Interpolation error due to buried obstruction.

Suppose now that several sets of plans (from different time periods) were located, each covering a portion of the region of interest. Intuitively it is obvious that at the borders of the plan the lines continue and connect to other parts of the extended system. In situations where plans overlap two problems may occur. First, if the plans are overlain according to the best spatial reference available, poor alignment may result at the borders (Figure 4.4). Unless other information is available it is not possible to determine which plan is the more accurate. Secondly, if an object such as the AGF shown here occurs on both plans and does not exactly match (Figure 4.5), again it is not easy to determine which position is correct. Furthermore if the object is shown on a photographic image or a scanned plan, it is impossible to determine whether or not it may belong to an unsuspected utility facility and is positioned at nearly the same position. In other words, how can it be determined whether two images are actually the same object?

Figure 4.4: Misalignment at plan borders (exaggerated).

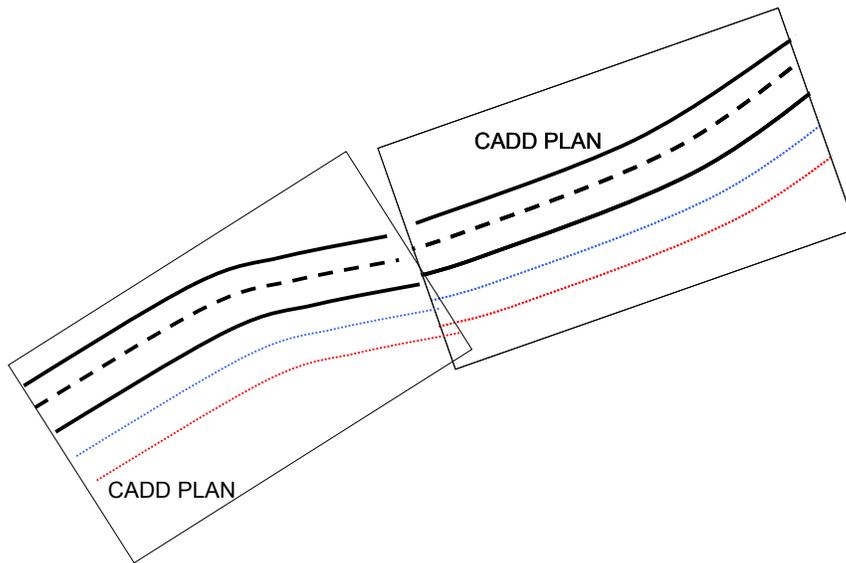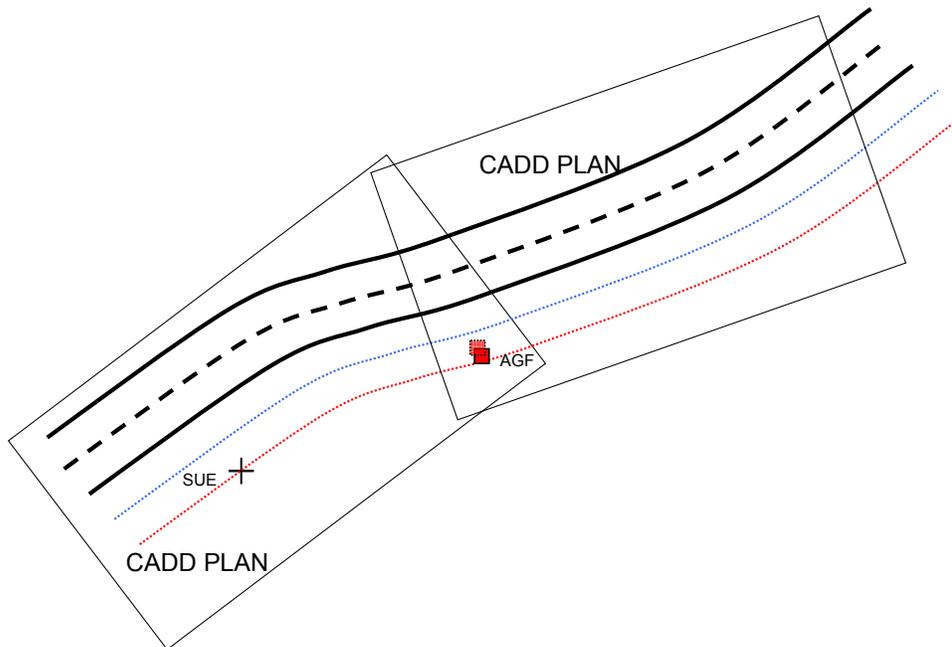**Figure 4.5:** Two sets of overlapping plans showing discrepancy in location of an above ground facility.

The purpose of establishing a UIMS is then to provide the user/client (here the engineer) with a means to obtain all available information regarding the proposed site so that underground conditions may be determined, including possible conflicts.   The challenge is to gather all this information, which is likely to be in different formats and of different quality, and to present one unified summary of conditions in this area.   In light of previous discussions, a graphic presentation coupled with access to related textual documentation is considered to be most appropriate.   How exactly to accomplish this task effectively is a major part of this investigation as initially stated.   The following issues and obstacles can be summarized:

> a) The plans documents are most likely in CADD format, or possibly hard copy drawings.   Thus the data content (the spatial data pertaining to the location of system components) is not generally directly compatible with GIS, and may require conversion if the overall graphic is managed by a GIS program, depending on how the UIMS is structured.

> b) The annotation of the drawings, text files of specifications, and other legacy information sources also frequently lack a geospatial reference. Additionally these types of information need to be linked to the plans information.

c) Complete understanding of existing facilities requires that all plans documents pertaining to these systems need to be integrated in some manner. In the example chosen here, this action would require obtaining component diagrams of systems adjacent to the original plan, resolving the matching conditions at the borders of plans, and then validating the connectivity of each individual system.

Several methods and concepts are directly related to this task:

Feature extraction-The process of recovering an object from an image in a program-recognizable form is feature extraction, a task that may involve substantial manual effort. For instance, consider four types of graphic representations: vector images constructed using GIS software, digitized paper diagrams (raster), CADD format drawings, and aerial orthophotography (raster). Geodatabases store objects with spatial location as features. Thus, for a water utility all fire hydrants in the system could be stored in a corresponding feature class (hydrant) with a unique identifier and attributes (manufacture, age, material, etc). If the object is represented as a point only then that point is georeferenced but if the object is represented by a polygon shape, a single point inside the area is georeferenced.   It is likely that a particular fire hydrant may be found on any other type of map or diagram.   For example, an orthophotograph or a digitized plan drawn some years ago may show the fire hydrant, but a scanned visual image has no vector representation in the same way as a GIS polygon does. Furthermore the part of the image representing the hydrant is not spatially referenced except that it should be possible to tie the location to the plan reference and scale, if these exist.

Conflation-The case of a CADD drawing is somewhat different since the file that contains the drawing is in a sense a vector description, but the information required to identify a hydrant as a distinct object may not exist. In fact a common problem is that an object occupying an area may look like a polygon but actually be represented as an unclosed group of line segments (similar problems occur if symbols are used instead).   In GIS terminology conflation is the operation by which two independent "coverages" (collections of features) are merged and treated as a single coverage.   GIS and CADD are not directly compatible in this regard, since the CADD file has an entirely different set of characteristics.   It is possible in some circumstances to overlay CADD representations on GIS visual images. Furthermore, there exists some commercial software to assist in transforming CADD formats to GIS representations [4.1- 4.6].

Interoperability- The situation encountered working with CADD and GIS exemplify the larger issue of interoperability, the desirable capability of any IT system to work seamlessly with other programs and file structures (often generated by products of different vendors) [4.7].

Scrubbing-Another problem concerns the manner in which information may be found in annotations placed on the diagram.   For example, the word "hydrant" might be lettered directly beside the hydrant on a pencil drawing along with important descriptive information describing size and material of construction.   Although digitized as an image, this information is not available as an attribute (without additional manual intervention or applications software).   By analogy, a text document scanned into a document management system cannot be read or searched automatically, unless first subjected to character recognition software and even then success is not usually assured.   Digitized diagrams and CADD plans must be "scrubbed", a process which removes or corrects extraneous marks and information on the sheet as a preliminary step in transferring digitized information into a geodatabase. In any case a decision to extract features from the diagram has to be made.   If this step is not taken then the best that can be accomplished is to store the digitized image as a background layer.   It is possible that a substantial volume of information (especially older data) may require manual conversion to an acceptable format for the UIMS.

If feature extraction is not completed (so that a GIS representation can be constructed) then the problem of overlaying two different plans must be resolved. For example, will it be possible to overlay a base map in GIS with a CADD plan? Will the representation of an object in one plan line up with the corresponding representation on the second plan? How will the UIMS understand this equivalence? While it is easy to envision a transparent overlay or adding a series of CADD representations on top of a GIS graphic, it is important to remember that the CADD plan may not be constructed to the same projection or cover the described area with the same boundaries.   More than one plan sheet may be required to describe an area of interest, requiring matching at plan borders, as discussed above.

Before leaving this section, there is yet one more problem that must be discussed.   The introduction to this example indicated that plans recording previous installations near the site of interest were found by describing a distance along the road from a milepost, a common method of attaching the description of the location of the plan to a location referencing system (LRS).   The use of such methods to find information may introduce a new complication into the UIMS process, as follows.   Consider a new example, similar to the last but with the addition of a cross road (Figure 4.6) including a telecommunication line and AGF running parallel to it.   Suppose the site of interest is near the intersection. Proceeding as before and asking for all information in a region specified in terms of a distance from the mile post along the main road would produce a plan recording work associated with this reference, but as shown in the figure not necessarily another plan showing the telecommunications line which is located by referencing the crossroad.   Especially if the telecommunications project was completed after the electric installation the existence of the former facility would not show up without a dual search process.
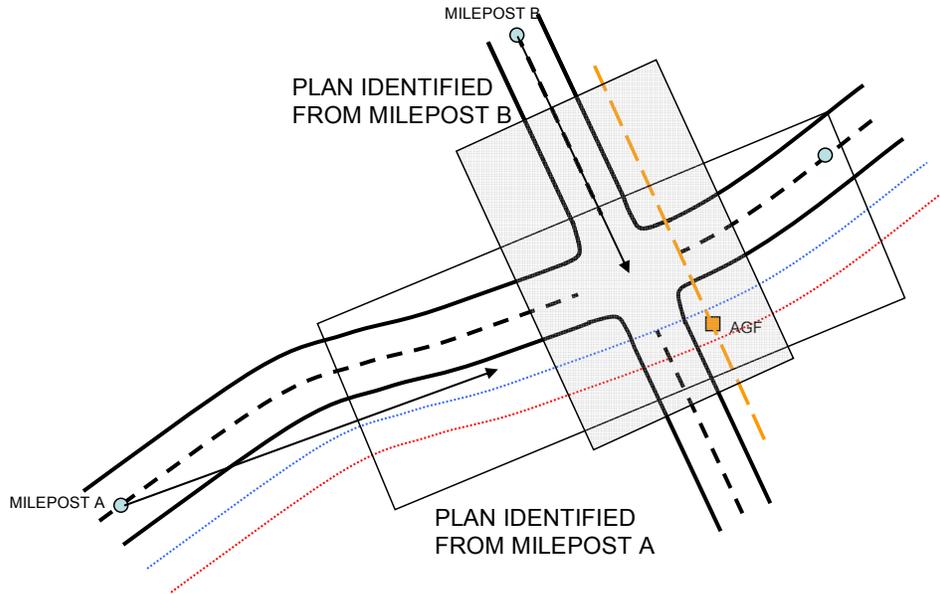
Figure 4.6: Illustrating the problem of locating intersecting facilities using an LRS to file plans.   Here if the telecommunications line running parallel to the cross road was installed after the electric facility, the telecommunications line will not show up in the plans referenced from Milepost A.

4.2 Prototypes and model systems

The literature review conducted as part of this investigation has identified several good examples of systems which actually accomplish one or more of the tasks anticipated as possible capabilities for the UIMS. Each of these systems is examined below, in light of the foregoing discussion, to determine what lessons might be learned for the present study.

1. TxDOT - Utilities in the ROW

Quiroga and co-workers have presented a series of papers [4.9-4.11] proposing to construct a system to acquire and store utility information in a database structure. The heaviest emphasis is on identifying utility installations as line and point features. Spatial information is discussed primarily in terms of GPS data from the field although there is some indication that information from digitized plans or electronic files are also considered. Accuracy is a prime concern. There is recognition that integration of data from different facilities at the same spatial

location will have to be considered. The relationship of this method to AM/FM systems (mentioned in Chapter 1) is discussed along with the consequences of the fact that utility companies are not required to submit as-built documentation to TxDOT.   A comprehensive logical data structure to store utility information is presented. Also noteworthy is the inclusion of temporal events. Most concern is shown for identifying utility installations as primarily represented by line and point features. Spatial information is discussed primarily in terms of GPS data from the field although some information from digitized plans or electronic files was also considered and future work in this direction is mentioned.   It appears this effort is currently being expanded. Also it is noted that TxDOT is currently funding a related study [4.12] concerning data for utilities infrastructure, however there are no available reports concerning this effort at present.

2. TxDOT Intelligent Transportation System Spatial Data modeling

A recent paper [4.13] is concerned with a GIS based prototype for Intelligent Transportation Systems, to handle incident management along a section of roadway.   A part of this effort is involved with the display of particular sections of roadway of interest and including various sensors and other features. The paper includes a demonstration of the problems associated with bringing CADD plans into a GIS and rectifying the alignment of the plans. A significant part of this work is the use of transformations (scale, rotation, translation) to align images. Furthermore, the project was tied to the Texas GAIP linear referencing system (discussed in Chapter 3). Aerial photographs with 0.5 foot resolution were obtained and utilized. Feature extraction and the scaling of features are discussed.

3. Philadelphia Water Department

In a project conducted for the Philadelphia Water Department [4.14], diagrams of the water system were first transformed to digitized format, then individual features contained in the images were given unique identification and attribute information was provided from other sources. The total effort will involve 250,000 diagrams and hard copy diagrams covering over 6600 miles of linear infrastructure (pipelines, etc). Automated tools were employed for the bulk of the processing work with manual intervention as needed. The problem of correctly identifying features as well as edge matching and rectification was considered. Once feature extraction was completed, and archived in the geodatabase, legacy data (maintenance records, etc) were linked to the feature dataset. Considerable effort was expended on connectivity and network validation. The combination of automated processing with manual intervention still left a substantial amount of data unreferenced. Reporting for this project contains little information concerning overall accuracy of transformation and three dimensional aspects of the data do not seem to be treated.

4. <u>Tucson, AZ</u>

In the period around 1999 Tucson Water undertook a water system data management project in ArcSDE Geodatabase©. This project has been ongoing for some time and fortunately there exists a large body of reports of progress, including the GIS strategic plan [4.15-4.19]. This report was included in the present discussion because the subject was primarily a prototype conversion project of older data (1600 paper based maps) into a geodatabase format. The steps involving the conversion methodology including manual manipulation of paper drawings ("data scrubbing") are discussed.   The author of the paper was contacted by the research team and provided answers to a number of questions of interest here.   Several interesting observations about the overall process were made, including commentary on overall reduction in staff requirements, the elimination of "pockets of knowledge" (a common theme, repeated elsewhere), and conversion methodology for paper based documents which included some automated checking. Although this system was intended for a municipality, in many ways it could serve as a prototype for the conversion of existing paper-based documentation to a UIMS format.

5. <u>NASA Langley Research Center</u>

This paper [4.20] reports an asset management study conducted for underground utilities at NASA Langley.   The primary issue was interoperability between GIS (which was to be used for archiving and graphical file processing) and CADD the original format for much of the layout of the utilities. The choice between utilizing only one system and alternatively transforming the CADD data into GIS was examined. A study of the literature points to the underlying problem of inaccuracies in as-built records. The value of less accurate legacy data is likewise considered. As in many other studies inherent incompatibilities between CADD and GIS are observed. Along with many other researchers, the author draws the conclusion that a CADD system is the best choice for engineering construction. Three methods for working simultaneously with the two systems are identified (some commercial software is available). Paraphrasing the author:

- File translation (a conversion with possible loss of data)
- Direct read (CADD is overlay or background)
- Shared access (both types can be present in a session)

Each method functions only if corresponding standards for data have been adopted (addressing the issue of interoperability).

This particular reference is especially timely and relevant to the present effort. In using CADD files within GIS this author recommends that maps have accurate

edge alignment with adjacent maps, including continuous lines and closed polygons. Metafiles should be a part of the contractual obligations and submitted along with the final plans delivery. As in other references, substantial problems were encountered with alignment and registration of features.

6. <u>EPA- Conceptual Site Modeling</u>

The technique of conceptual site modeling (CSM) has been explored in a recent paper [4.21]. CSM represents a unique idea which may be quite useful in developing methods of visually displaying three dimensional and cross sectional information. While the paper is concerned primarily with environmental/geotech issues, something similar might be an interesting approach for a UIMS, especially as a means to combine and interpret information from several sources.

The importance of this paper is that it demonstrates the idea of accessing information via a planar map, then redisplaying in cross section (stratigraphic visualization, boring logs, wells), generated from for example 3-D Analyst[©] (which performs some data interpolation), GMS[©] or Earth Vision[©]. For this reason, the system is referred to as a CSM. A software "bridge", WNDGIS was developed to aid in retrieving and displaying data. Such a step is important also as an application programmer interface (API). The authors state:

> "WNDGIS is unique because it queries the database directly based on selection of a locid by the user on a base map and generates the selected visualization"

The term "locid" apparently refers to location identification. This application makes use of the an extended discussion of Spatial Data Standard for Facilities Infrastructure and Environment (SDSFIE) NCITS353 ANSI standard, discussed elsewhere [3.33, 3.34].

4.3 Graphical capabilities for UIMS

Several desirable graphical characteristics for the UIMS are considered in this section. Continuing the example started in the first section of this chapter, Figure 4.7 shows a small, straight section of the transportation R/W after installation of water line, so two buried utility facilities that generally parallel the pavement (the original electric and the new potable) are indicated. The question is, how can the two utilities now buried along side the roadway be adequately represented to a new client? The following information is available:

> a) There are two mile post markers recorded on the State Map and referenced to the State Plane coordinates to modest accuracy (thus, there is some error with respect to high accuracy GPS, latitude/longitude as discussed in Chapter 3). These mile posts could also be the basis of a straight line diagram or other linear referencing method (LRM).

b) From previous work, there exists a new CADD plan for a subsection of the R/W, as shown (dotted rectangle), with both facilities indicated.   This electronic diagram has been referenced to the map coordinates but since it was originally a local project reference there exist some alignment error. Furthermore this diagram is not a true as-built but rather the original plans. Note that the CADD plan shows that the potable line is slightly offset from the map indication of the line location as a result.   No quality statement can be attached to the vertical but because only two lines exist an assumption (from specifications) that the lines were placed at a depth of three feet is realistic and the best available information.

c) There are two additional SUE reports of investigations of the potable waterline (blue) recorded as GPS latitude/longitude (high accuracy) data. Note that these locations which are equivalent to very good as-built point data differ from both the map location and the CADD document. Vertical information for this data is considered to be excellent.

d) There is an above ground facility (AGF) associated with the underground electric recorded by the utility asset management system. Note that here again the mapped position of the AGF and the actual line are not quite in agreement. The AGF is recorded by accurate GPS.

As an advanced capability the UIMS should be able to construct this presentation for the new UIMS user (recall that the original spatial accuracy proposed for the UIMS was +/- 0.5 ft).

In the discussions of prototype systems summarized in the previous section the problem of combining overlapping data is frequently identified as a serious concern [4.13, 4.20].   Several solutions are possible but in fact, the best choice among alternatives depends strongly on the structure of the UIMS chosen. A considerable amount of manual intervention effort may be required to resolve conflicts and discrepancies.   Possible alternatives making use of automation include:

a) Bring all data to a single reference, keeping track of transformations and not worrying about alignment.

b) Overlay by matching reference points then apply "rubber sheeting" to force alignment.

c) Feature matching and alignment by common description (requires tools).
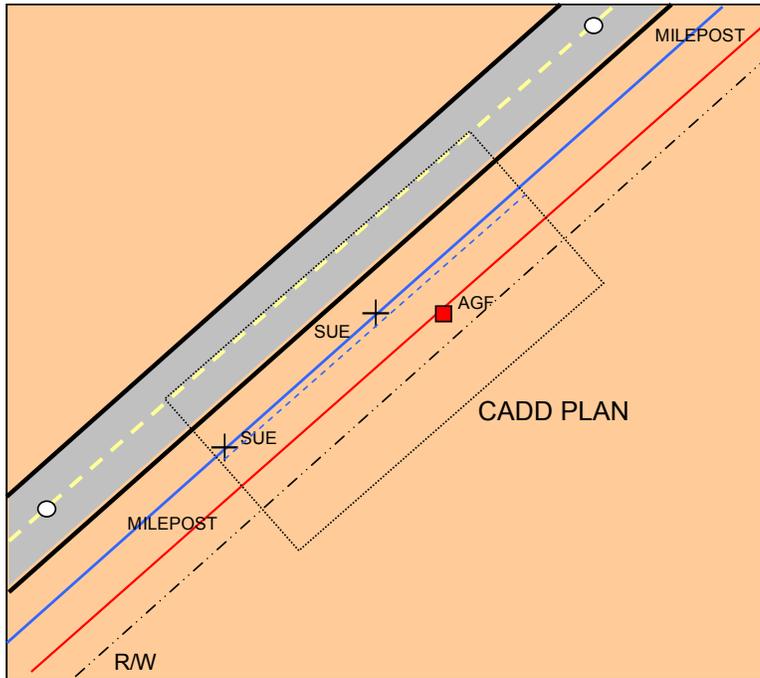
Figure 4.7: Composite view integrating data for region of interest from several sources.

As defined earlier, in GIS terminology the combining of information from two different shape files is known as conflation. Provisions must be made to bring all available data to the same reference but in the process it is likely that error will prevent proper georectification (registration) of mapped features. For example, will above ground facilities from one diagram align with the corresponding features obtained from another plan. A similar problem is encountered when attempting to match the edges of two adjacent plans. Will a continuous pipe actually line up across the edge? Notice that these questions are very similar to those raised in the first section.

Thus it is essential to consider the aggregation or disaggregation of local installation information into meaningful elements. How are these elements (portions of the roadway, AGFs, SUE reports, etc) to be correctly referenced to a

spatial location? For example, does a user of the UIMS want a simple presentation of a network or individual objects?   How will users of the database query the system in an efficient and productive manner? What graphical interfaces will be most useful? These questions, along with a consideration of the requirements that are likely to be put forth point to the selection of a GIS system in view of the many tools included.   On the other hand the underlying problems associated with bringing all data to the GIS format suggest that maintaining a type of graphical data warehouse approach may be a more suitable structure for the UIMS.

4.4 Three dimensional representations

The fact that facilities location data is actually three dimensional in nature has not yet been adequately considered. In view of the foregoing discussion, does the requirement for graphic capability describe just simple (planimetric) visual display, or highly accurate, three dimensional depictions of facilities?   The most practical outcomes for visual interpretation of corridor occupancy, simple planimetric views of installed facilities, are not totally satisfying. Current practice dictates the use of plan and profile diagrams to partially represent the three dimensional nature of the facility installation. Even profile views, if available, do
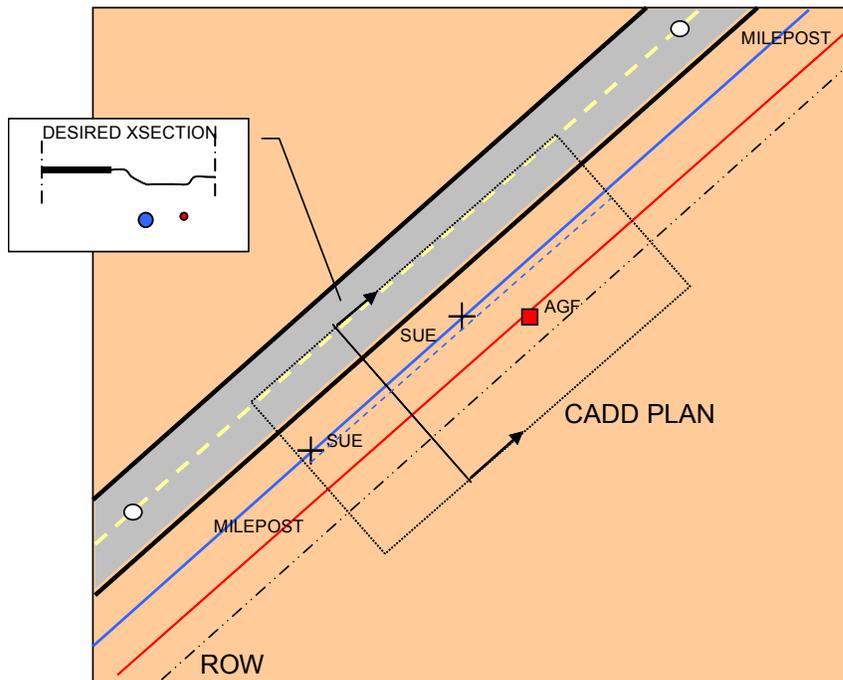

Figure 4.8: Cross sectional display of corridor occupancy combined with planimetric view.

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not convey organization of the corridor completely. There are several ways in which three dimensional data retrieved from a UIMS might be presented to the user. The elevational data might be simply attached to graphic elements as an attribute. Another alternative is the wire frame representation commonly used for surfaces.

From a conceptual standpoint, the ability to generate cross sectional views of the transportation corridor may be particularly useful, having the advantage of depicting depth information visually wherever constructed.   This concept, closely related to the ideas presented in Reference 4.21, is shown as additional capability for the type of planimetric display just explained.

Finally, an advanced concept for the presentation of visual information is suggested.   An extension of the idea behind Figure 4.8 is the generation of a sequence of cross sectional images for the visualization of corridor occupancy. Assuming a satisfactory method of interpolating missing information can be found, the construction of a cross section of the corridor with every known facility positioned on the diagram could be achieved.   A conceptual version of this type of presentation is shown in Figure 4.9, below.
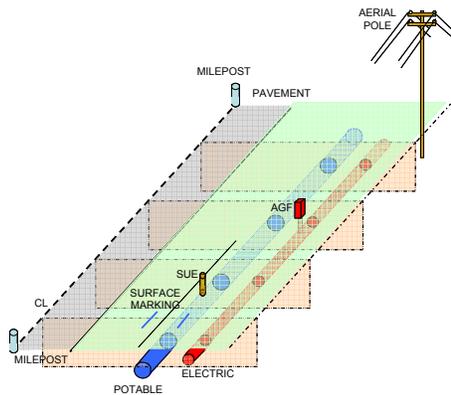
Figure 4.9: Advanced three dimensional depiction (conceptual).

While the software effort involved in providing the means to generate cross sectional data would be substantial, the value of such a presentation for a user of the UIMS would be very large. Certainly the three dimensional depiction is desirable, the final decision regarding display lies in the availability of appropriate technology, the quality of available data and the investment cost to obtaining such a display.

4.5 Other desirable application tools for the UIMS

Graphical capabilities are not limited to just the visual presentation of data but include graphical user interfaces (GUI) for the various applications tools envisioned for the UIMS.   For example, the initial step that a user might take is to identify an "area of interest", a task (alluded to previously) which can easily be accomplished given a base map along with point and click as a means of specifying a search region within the available databases.

It is obvious that at least some important differences between various schemes for construction of a database lie with the development or utilization of various application packages to perform various specialized tasks. With regard to access and retrieval of information archived in the proposed UIMS, several additional means of explaining and visualizing the location of utility facilities might be considered. Some possible applications that may be required or perhaps just serve as useful capabilities include:

1. Conversion to/from various spatial representations (for example, generation of linearly referenced data, straight line diagrams, etc).

2. Means to perform network analysis and checking for consistent connectivity.

3. Tools for data "improvement", including interpolation or insertion of projected data to fill in information gaps.

4. Incorporation of depth information including data from SUE investigations, LIDAR and stereo photos.

5. Specific search and analysis capabilities for collecting and reporting status information.

6. Accessing relevant information from sources other than the UIMS at the time of query, as for example the RCS or the Five year work plan.

4.6 Summary

This chapter is concerned with the graphic presentation of information about utilities facilities location.   For purposes of discussion it is convenient to imagine two levels of display. The first is a simple retrieval function that permits the viewing of individual plans, maps and other forms of images. A more complex system constructs a composite image of the entire body of facilities data in an area of interest.   This operation is accomplished by a combination of conversion to common coordinates, merging of data sets and overlay of images (possibly in different formats).   Bringing diverse data together in this manner multiplies the

benefits of a UIMS for the user, since a comprehensive and informative view results.   At the same time serious challenges for implementation are presented.

Specifically, feature extraction and adjustment emerge as particularly difficult aspects to providing common views of data. Fortunately, there are a number of reports by various groups who have attempted to accomplish these tasks and who have made their instructive commentary available, particularly with respect to the problem of interoperability between CADD and GIS. A cross sectional viewing capability would be highly desirable. The final decision regarding graphic display is likely to be a compromise between the costs and technologies for providing an accurate and integrated view.

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Chapter 5: Requirements for the establishment and maintenance of a UIMS

Before a UIMS can be implemented, a number of alternative possibilities should be weighed and decisions must be made. The purpose of this chapter is to present a list of functional requirements for the UIMS and identify criteria for successful implementation and system operation.   Four model systems are proposed for consideration.

5.1 Functional requirements for the UIMS

It will be beneficial at this stage to construct and review a set of functional requirements for a UIMS. The statements below are based on the original scope envisioned for this project supplemented by other requirements which have arisen.

1. *The system adopted should contain as-built location information, with attributes regarding accuracy and provenance.* As-built information (temporal as well as spatial) is interpreted broadly, i.e. any information that can help to determine what facilities have been installed and where they have been placed, along with the current operational status (characteristics, ownership, etc). In order to be useful records must be spatially accurate, complete and sufficiently detailed.

The usefulness of as-built information is apparent in the planning and execution of facilities installation (particularly underground), so that conflict and damage can be avoided. Moreover, positional accuracy of installation is extremely important to ensure optimal utilization of scarce resources in the R/W.   The requirements for positional accuracy are generally more stringent for a UIMS than for other comparable systems, as emphasized by the desire for high quality, as-built information.

2. *The system adopted should be graphic in nature.* A graphic display might be as simple as bringing up an approximate representation for visualization to a system that constructs a highly detailed and precise representation in several views. While the benefits of simply visualizing the data available cannot be overlooked, it is highly desirable that specific functions should be facilitated by graphics, including

- identification of conflicts between facilities
- indications of proximity and associations with related features
- topological representation of utility networks (connectivity, etc)
- overlay of information from various sources
- rectification with regard to a spatial reference
- ability to handle different accuracy levels and different scales
- provisions for dealing with incomplete information

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Plan views of facility placement tend to minimize the three dimensional aspects of a facility configuration. A high degree of accuracy in all three coordinates is required if a useful system for an UIMS is to be developed. Unfortunately much information currently available concerning utility locations is in the form of CADD electronic files. Such files may be difficult to present and correlate with other means of representing spatial locations.   It is likely that specialized tools for utilizing information retrieved from the UIMS will be required.

3. *The system adopted should have a formal, geographically enabled structure.* A principal requirement for any UIMS is the ability to connect features, files, images, etc. to spatial locations.   This requirement includes detecting proximity to associated structures and overlaying various data in the neighborhood of a specific location.   In considering the UIMS model, the question of how data is spatially referenced is critical.

4. *The capabilities of the UIMS should reflect the business activities that FDOT conducts regarding utilities.* In addition to spatial information this requirement includes recognition of the temporal nature of some data and the ability to work with other systems in a manner transparent to the user.

5. *The UIMS requires the capability to connect to other databases containing utility related information.*   The integration and sharing of information among a group of state maintained databases is essential. These include the EDMS, the RCI, the 5 year Work Program and the FGDL, for example.

6. *Requirements regarding data ownership, data stewardship and data standards should be clearly articulated.*

- Data ownership refers to the group or entity that originally develops or collects the data and by extension, "owns" it.   In general, data may be considered to be public (open) or private, and the latter term might apply to data which is held secure (ie not public, but owned by a governmental agency) and also proprietary data (for example that owned by a private corporation and kept confidential).

- Data stewardship applies to the entity charged with archiving and maintaining data.   By extension, the element of quality assurance regarding the retention of data is implied.

- Data standards (discussed previously) refers to the format for retaining information as well as the content.

7. *Effective measures to ensure quality of archived data must be implemented.* In addition to data stewardship, a means ("best practices") to ensure quality and consistency of data introduced into the UIMS should be present [5.1-5.3].

8. *Security of the UIMS (access and data content) must be resolved.* Security concerns are often raised as an issue in any discussion of database development. With regard to the present discussion, the two principal questions are who will have access to sensitive information and whether utilities and other agencies will invoke security as a reason to decline to provide location information about facilities. These concerns are discussed as a part of the National Infrastructure Protection Plan (NIPP) [5.4]. See also for example, the procedures for the FDOT Right of Way Management System security [5.5] and Reference 5.6.

The Best Practices Committee of the CGA approved the following (4/8/2003) regarding homeland security [2.62]:

"Many of the recommended practices contained within the CGA's Best Practices Manual require the sharing of critical infrastructure information. This sharing is an important aspect of ensuring that parties involved with the identification of, the excavation around, and the general protection of underground facilities have adequate information to protect underground infrastructures. However, in the interest of Homeland Security, all parties must ensure that such information is only shared with individuals who truly require this critical information. To this end, parties who employ or contract with individuals that may have access to such information, should ensure that those individuals or contractors have the appropriate credentials to ensure that the information is not obtained by individuals or groups that may intend to damage, alter or destroy the infrastructure in question."

It should be apparent that the above functional requirements parallel the discussion of the original scope of research. A decision as to which are essential and which are desirable – and eventually as to which are economically justified will be required. Recommendations are presented in the next chapter. It is expected that the list of functional requirements will be refined and expanded, beyond the scope of the present investigation.

5.2 Application tool set

Along with functional requirements it is essential to develop specifications for a tool set available for the users, to facilitate operations and provide support for the UIMS. It is likely some of the items listed below may be commercially available, but others are very specialized and will require an investment of time and effort.

User Tools

- Association (how to relate all data content near a spatial point or area of interest).

- Alignment (how to rectify a CADD drawing to a GIS diagram).

- Data improvement, including interpolation or insertion of information to fill in gaps or missing knowledge.

- Generation of linear referenced presentations and other alterative views of the area of interest.

- Feature extraction from sources (CADD, Orthophotography, etc.).

- Transformations to/from geodetic specifications (and LRS methods).

- Accessing relevant information from sources other than the UIMS at the time of database query (RCI, R/W easements, Work plan, for example).

- Assistance for data mining/reporting functions (metadata access including ownership, legacy, etc).

- Capability to understand network topology, including junctions, and conflicts (including a means to distinguish out-of-service from active facilities)

- Interpretation of installation methods including vaults, common trenching etc

5.3 Performance goals and assessment

An established UIMS will be successful if the following goals are met. At least some of these items can be directly measured. Regular review, including surveying users and clients is essential for assessment and system improvement.

1. Easy to use and graphic (all users are able to recover and interpret comprehensive utility data regarding a specific location).

2. Measurable improvement in efficiency during the planning and permitting process – improved quality control.

3. Reduction in duplicate expenditures for SUE.

4. Reduction in utility cuts.

5. Reduction in claims during construction.

6. New information is not lost or isolated (archiving and storing new information).

5. Data is easily manipulated for common tasks.

6. Other partners/stakeholders are involved and contributing as-built information.

7. Integration and interoperability with other similar GIS functions at the state level is achieved.

8. The system is flexible with regard to change. UIMS data is easily migrated upward as technology improves.

5.4 Models for the structure of the UIMS

During the course of this investigation four options for the construction of the UIMS were explored.   It should be recognized that these options have been drawn along somewhat arbitrary lines, meaning that the concepts are not unique and some mixing of capabilities are possible. Recommendations are deferred until Chapter 6. The choice of methods and the availability of techniques for performing the tasks described above will strongly influence the overall architecture chosen for a UIMS.

Option 1: Document management

An *electronic document management system (analogous to the EDMS or an "*electronic file drawer"*). The emphasis here would be on a central repository of all data, facilitating retrieval in a useful form. Queries could be handled by conventional database software (ORACLE$^©$).   Spatial referencing of all documents would be required in order to make useful queries. Graphic presentation would be limited to display of stored images.

The ability to examine the content of any object would be limited by the data format. In other words, graphical documents could be viewed providing suitable software is available but no graphical linking between images would be possible. A scanned text document would have to be recalled and processed by optical

character recognition to interpret content.   Similar restrictions would apply to scanned graphical documents.

As a minimum, the following requirements are necessary for a UIMS structured as a document management system:

- data objects must be spatially referenced
- standards must be selected for data objects
- a metadata format must be selected
- quality control and assurance must be in place to minimize errors

Option 2: Attach data to LRS system

A linear referencing system (LRS), which many states utilize in various embodiments to record information about roadways could serve as the basis for a UIMS (including FDOT SLD). LRS methods use a reference or anchor point and then describe a position along the roadway to a feature (linear offset). Such methods are "natural" for use with roadways which are characteristically long and narrow.   In many instances the basic structure is already present and it may be possible to attach a UIMS to this structure. For example, an above ground facility feature known accurately from GPS could be referenced to the centerline coordinates of the road plus an offset dimension in the normal direction.   This step would require a coordinate transformation algorithm.

A simplified version of this concept could utilize a generated straight line diagram for the presentation of all available data, instead of a State map. As discussed elsewhere, there exists an inherent error as a result of interpreting a roadway plot as a straight line diagram. The principal advantage of SLD is that it is relatively easy to represent data that is long and narrow in shape, with relatively gentle curvatures. Furthermore, this method is closely tied to other applications used by FDOT and has the advantage of familiarity.

As a minimum, the following requirements are necessary for a UIMS structured as an LRS (assuming one or more location referencing method has been selected)

- spatial references for data objects must be transformed to match the LRM
- standards must be selected for data objects
- a metadata format must be selected
- quality control and assurance must be in place to minimize errors
- graphical display tools consistent with the LRM chosen

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Option 3: GIS geodatabase

A geospatial database, which incorporates GIS principles and utilizes a complete geospatial referencing system (latitude/longitude), has the principal advantage that all the software tools and power of GIS can be brought to bear on problems and tasks facing the user.   In principle this type of system would meet all functional requirements and have the advantage of good spatial organization. The largest problem likely to be encounter will be attempting to bring in accurate data from a variety of sources. Thus the geodatabase approach would appear to satisfy the requirement to bring all facilities in the area of interest together, with graphic visualization. An additional advantage would be that an LRS or roadway centerline diagram could be superposed in the same manner.

Representing the elements of a utility facility in a geodatabase would generally require feature extraction from digitized plans or CADD drawings. Examples of this type of effort have been discussed previously.   The advantages of this approach include the ability to manipulate individual parts of larger systems since these components are now independent features with their own attributes.   The full power of GIS (visual, analysis, etc) can be utilized in these operations.

As a minimum, the following requirements are necessary for a UIMS structured as a geodatabase.

- features must be extracted, georeferenced and attributed
- standards must be selected for feature classes
- a metadata format must be selected
- quality control and assurance must be in place to minimize errors
- reconciliation of facility networking required

Option 4: Retain CADD functionality in parallel GIS/CADD system

A hybrid structure is proposed for this model, in an attempt to avoid expensive and potentially error prone feature extraction and transformation.   The "engineering" advantages of CADD are retained. Any CADD drawing, construction plan or map providing sufficient detail and reference location could be used to generate a presentation diagram showing utility location.   Profile drawings provide depth of burial information.   As shown in References 4.13 and 4.20, tools would be necessary to rectify CADD drawings for placement in GIS visual depictions. Some data, for example GPS coordinates of SUE investigations could be placed directly into the GIS.

- CADD plans must georeferenced and attributed
- Transformation tools to georectify and overlay plans are required
- standards must be selected for all data
- metadata formats must be selected

- quality control and assurance must be in place to minimize errors
- reconciliation of facility network requires special tools

It is noted that both Concept 3 and 4 could easily include LRS functionality as required.

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Chapter 6: Recommendations and implementation plan

Before making recommendations regarding the UIMS, several facts that emerged during the previous discussion should be reviewed and summarized. In many states and municipalities the case for implementing geodatabases to store and access spatial information has been justified. In some states (including Florida) the developmental effort is at least partially complete. While the inclusion of utilities facilities is often considered, there has been only minimal progress in this direction and often the result is simply a representation of major pipe lines or local services with a relatively low level of positional accuracy. As the results of the literature review show, accurate synthesis of existing information regarding facilities within a particular area of interest is a specialized and complex problem, much more advanced than anticipated for the broader based geodatabases currently under consideration or construction. At present there exist some tools, methods and techniques to bring about a fully functional UIMS, but much more work remains to complete this task.

The positive side of this observation is that the adoption of a UIMS at the present is timely. Even with some limitations, a management system will prove useful, and even providing simple capabilities to archive and retrieve information will be extremely productive. With a well planned start, advances in technology will permit the FDOT to develop and grow such a system into the future.

Before constructing and implementing a UIMS it will be essential to seek a mandate and to secure the authority to proceed. Legislative action may be required. A second step is to secure the funding necessary to complete a system capable of attaining realistic performance levels. The remainder of this chapter is devoted to recommendations for UIMS and a plan for implementation.

6.1 Implementation strategies used elsewhere

While considering the implementation of a UMIS for FDOT, it will be worthwhile to examine the implementation strategies for various types of systems adopted by other agencies (the current FDOT Enterprise Information System was discussed earlier in Chapter 3). Utilities are often mentioned as an important theme for developing geodatabases, but the underlying message in most cases is that this area will likely lag other themes such as roadway, environment and hydrology. Most of these studies have at least some focus on infrastructure themes so that studying the approach and lessons learned in each case will prove useful. Implementation of such systems usually represents a significant investment of resources but may not be successful unless well planned and executed. Tomlinson [6.1], Parkey [6.2] and others have discussed the necessary steps leading to implementation of an effective system. Quoting from Parkey's discussion of Tomlinson's methods, these steps are:

1. Consider the strategic purpose
2. Plan for the planning
3. Conduct a technology seminar
4. Describe the information products
5. Define the system scope
6. Create a data design
7. Chose a logical data model
8. Determine system requirements
9. Perform benefit-cost, migration, and risk analyses
10. Make an implementation plan

With respect to the immediate concerns of this investigation, the approaches of several states and municipalities are considered:

1. West Virginia WVDOT GIS implementation strategy

In 2002 the West Virginia DOT sponsored a study of a proposal to implement a transportation GIS system [6.3]. The importance to the present work is the summary of many aspects that bear on the smaller implementation regarding utilities being considered here. It is probably fair to say the WVDOT was behind Florida (and the efforts in many other states) regarding GIS at the time of the report and in fact there is an extended discussion of the Florida system as a possible model. The WVDOT implementation strategy report is quite extensive and provides a framework for how the current database proposal to retain utility information might be structured and integrated into current FDOT record keeping. Although the basis of this report is primarily to build a case for moving WVDOT documentation to a GIS process, still many points are very relevant to the present study.

> "Although maps are the most visible product of a successful GIS implementation, it is the ability to extract useful knowledge from tables of interrelated spatial data that defines a successfully implemented GIS."

Utilities are mentioned as a possible application theme, but there is little insight as to how this addition might proceed.   Rock and soil boring logs are also considered, and appropriate methods here might serve as an analogy.

The difficult relationship between CADD and GIS is addressed.   The conclusion of the West Virginia report is that although there is some overlap it is unlikely that the two functions will merge. The report also refers to the management of large numbers of paper drawings, which will need to be absorbed into the system adopted.   A distinction is drawn between "linear" data (remaining with project) and "repository" data (archived and accessible).   It is noted that:

> "Most applications can be considered either a mapping application or an analysis application. A mapping application takes spatial data and

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displays the data on a base map. An analysis application, on the other hand, performs a higher level of spatial analysis/computation on one or more related data sets and then displays the results on a base map.

Final recommendations favor a data warehouse model (which seems to be artificially differentiated from an enterprise system).

> "Two approaches to data sharing available to the WVDOT are the enterprise approach and the data warehouse approach. The enterprise approach combines all corporate databases into a single central relational database management system. Some transportation agencies have decided against translating the large volume of existing data into a common data format under a single database management system. The replacement of extensive legacy systems to maintain and query the data often is a cost and/or effort prohibitive process. The data warehouse approach permits data to reside in its existing data management system for maintenance but provides a new central database management system for GIS applications."

Goals and criteria for a successful system are presented.

2. <u>New Jersey</u>

The system under adoption by New Jersey consists of a group of management tools for application to a database of scanned documents (referenced to geographical location) [6.4, 6.5]. The user can identify from a visual image an area to search and the system will retrieve all related documents. A portion of the retrieved documents are scanned. The system is based on Intergraph$^©$ and Microstation$^©$ software but the basis is general and other software could be substituted.   A GIS program is used to link the user input to a geographic location based on the state roadway map. A database management system is used to retrieve the scanned roadway plans.

The overall goal of this system is to provide efficient access to the data sources concerning New Jersey roads. This system includes several capabilities of direct interest to the present study. Specifically,

- Integrating data from a variety of sources
- Develop a visual interface from which to make requests
- Provide access to a large amount of available data
- Provide other useful applications with GIS

A document management program, "Falcon" manages the database of roadway plans-making the connection to geographical road. Areas of interest are referenced in terms of route information.   The user brings up a map and clicks

on a location which links to milepost information. Dynamic segmentation is required to break these sections into smaller parts. A Visual Basic$^©$ query writes the location to a text file in Falcon protocol and a list of available files are then returned. The size of the file structure is some concern. The problems of image registration or georectification are not discussed.

3. Oregon

As mentioned in Chapter1, the State of Oregon is in the process of adopting an extensive enterprise geodatabase involving many state data resources. A strong business case has been presented for this course of action. Utilities are listed as a theme but have not yet been absorbed into the effort. To avoid confusion, readers should note that Oregon refers to the entire GIS implementation itself as a "utility" (the name of the system is "navigatOR"). At present the system is under development and a series of reports to the State from an outside consultant are available from the central web page [1.14]. A comprehensive plan for the implementation of the GIS Utility project is available and much of this plan is relevant to the present study [5.2, 6.6-6.10]. The Oregon Geospatial Enterprise Office maintains an extensive site, including map projection information [6.11].

A current focus is the adoption of metadata standards. Other state efforts are included in the Oregon review. A strong message from these reports is the advantage of enterprise systems and the incorporation of smaller units into the framework of a larger system. Information regarding the Framework Implementation Team (FIT) may be found at Reference 6.12. The work of this group includes the utilities framework [6.13] and the GIS data standards [6.14].

The research team found few examples of enterprise systems for which so much documentation was readily available. Although the present investigation was not tasked with designing a final version of a UIMS, the Oregon documentation was examined to help determine how such a system might be constructed and in order to better understand the benefits and pitfalls of adoption. The Conceptual design report [6.9] could easily serve as a starting point for the UIMS and the Implementation plan as a guide for the steps to adoption [6.6].

4. Arkansas

The State of Arkansas is developing some GIS standards related to utility facilities [6.15]. The state appears to be headed for adoption of the Spatial Data Facilities Standard for Infrastructure and Environment (SDSFIE) introduced by the Federal government. In particular there is a draft outline of a database structure for piping is in place based on the SDSFIE. With regard to repository data it is stated that,

"As-built survey drawings or hard copy maps that have been field verified can be registered to proper geographic coordinates, utilizing base map information that has a known accuracy that exceeds 10 meters horizontal accuracy at a 95% confidence level per the National Spatial Data Accuracy Standards (NSSDA).

Computer Aided Design (CAD) drawings may also be used as a source of mapping and/or attribute data if the drawings have a reference to the earth's surface such as a Public Land Survey System (PLSS) township, section, and range layer, or any other standard grid for referencing data to the earth's surface. Mapping (GIS) products derived from CAD and/or hardcopy files can be scaled and rotated to base map information that has a known accuracy that exceeds 10 meters horizontal accuracy at a 95% confidence level per the National Spatial Data Accuracy Standards (NSSDA).

Attribute data will need to be cross-walked into the standard database or relational database management system (RDBMS)."

Also noteworthy is the adoption of centerline standards for roadway representation (Chapter 3).

5. <u>City of Tampa</u>

In 2004 the Strategic Planning and Technology Department produced a report for The City of Tampa concerned with the adoption of a GIS implementation plan for the city [6.16].   The central theme for this report is to lay out planning for a central repository for geographical data in the form of an enterprise geodatabase. Various issues including a staffing assessment, a consideration of access availability, implementation costs and expectations are discussed.   The retention of as-built diagram records (in a central repository) is considered.

The overall problem is summarized as follows:

"There is no central repository of the geo-spatial enterprise data that is able to store geo-spatial data and its associated attribute information in a format that is readily interchangeable. Existing infrastructure asset information is cataloged as generic inventory database files, AutoCAD[©] data files or hard copy as-built record drawings. This information is not currently tied to a spatial reference system, such as the state plane coordinate system."

As part of the solution, the report recommends:

"2. Migrate to an Enterprise GIS Database:
	a. Procure and customize an enterprise GIS Data Model.

b. Develop a central GIS database for spatially enabling enterprise data.

c. Establish citywide GIS Data Standards to support citywide GIS requirements. Begin in the CAD area as the Utility Pilot is implemented.

d. Develop and implement a software/hardware architecture that adheres to open GIS standards.

e. Develop policy that enforces adherence to open GIS standards.

3. Implement a pilot to evaluate central relational database options:

a. Identify and implement application tools to spatially reference utility asset data.

b. Develop and refine appropriate data layers."

The report includes a proposal to begin a utility pilot project as part of the implementation plan.

"The Utility pilot is a way to take some quick steps to initiate a proof of concept of the central GIS relational database. It involves setting up a server to hold a base layer of the 'right-of-way' map that will allow utility asset infrastructure to be incorporated as additional layers in the database. The Oracle$^©$ database will allow both AutoCAD$^©$ and MapInfo$^©$ users to add and retrieve data to and from this database in a format common to both. Additionally, Munsys$^©$ software will assist in adding asset information into the database in an accurate and efficient way. If this approach proves successful, this system and approach can be expanded to the rest of the City as appropriate. This will provide a quick start toward enterprise level GIS capability."

Appendix J of this report includes a utility prototype.

Several important issues are raised in the report including

- Who should have access to this database - the utility companies?
- How is the system linked to the county?
- What are the skilled staff requirements?
- What authority does the city have to implement the system?

6. City of Suffolk, VA

A report (prepared by a consultant in 2002) details an updated GIS Database design for the municipality of Suffolk, VA [6.17, 6.18]. The theme of utilities infrastructure is included to the extent that above ground features will be spatially referenced. At least a portion of the repository information is anticipated to be in non-electronic form and so must be transferred in electronic form for integration. Some planning and effort estimation for this task as well as a system for feature capture from aerial photography are discussed. Elevation data is mentioned as a

possible attribute. Of special interest is the concern for system security and potential liability incurred by the city as a result of use of the system by outside stakeholders.

7. City of Regina, Saskatchewan, Canada

The City of Regina originally adopted a GIS system which has been applied to many municipal tasks [6.19]. As the system evolved duplication of effort and isolation of functions were encountered. To counter these problems an enterprise GIS system (REGIS) was constructed and implemented [6.20]. REGIS incorporates a data warehouse approach. Some of this effort has been directed at the storm and sanitary sewer system and a data model has been suggested. Part of this effort involved conversion from CAD formats to GIS. Functionality includes network topology and consistency checking.

8. City of Richmond – British Columbia, Canada

This application [6.21] concentrates on management of municipal infrastructure. A "point and click" access function is included and a good example of a data dictionary is provided. Quality control was successfully introduced into the system. Most important to this investigation is the effort to involve other stakeholders (utility companies).   Data partnering was successful and the utility companies were convinced to share information in exchange for access to the system.

6.2 Recommendations for establishing a UIMS

The following recommendations are based on the findings of this investigation:

> 1. Establish "ownership" and an oversight committee responsible for the developmental direction and maintenance of a UIMS. The committee should carefully monitor trends and new developments in all related areas (GIS, GPS, SUE, etc). The committee should also provide liaison with the state-wide GIS enterprise system. Until such time as other private and public utilities can be integrated into the system, FDOT owned facilities should be managed by the UIMS.

> 2. Adopt a structure for the UIMS based on a GIS geodetic reference system (latitude-longitude coordinates). For the present however, maintain a CADD based overlay procedure that avoids feature extraction. Acquire applications software to accomplish transformation of data to appropriate formats. Linearly referenced coordinates for plans, etc. should be available, for convenience.   This recommendation (Option 4) would lead to a georeference for all data that is consistent and stable, while at the same time coordinates for other referencing methods can be

Comment [SK1]: This entire section has been changed to be identical with the recommendations found in the Executive Summary.

generated. This recommendation also anticipates the further development of extremely accurate GPS data acquisition.

3. For visual presentation to the user, adopt an "area of interest" concept so that all available data around a specific site is accessible via a point and click visual interface.

4. For textual materials and some other document types, a direct link to the EDMS system is essential; however in all cases a geospatial attribute for relevant data contained in the EDMS will be required.   Several other important information sources are available and need to be accessible by the UIMS.   For example, from other FDOT databases, the Five Year work plan, data from the Roadside Characteristics Inventory, State maps, etc. should be easily obtained during routine operations.

5. Adopt robust data standards and metadata format.   Ensure that data stored at the present will easily migrate to future systems.

6. Inventory and evaluate all available data concerning utility facilities (to be an ongoing process). A clear chain of data stewardship should be established. The approach needed to incorporate old data into a UIMS is quite different than information being currently developed (see next recommendation). Recognize that, the older the data is, the more difficult it may be to bring this information into a UIMS in a cost effective manner (for example, paper based plans and documents).

7. Include quality control for all data archived in the UIMS. Attach to each data set an attribute indicating the relative accuracy (in the same manner that SUE information is rated D, C, B, A).   For example,

Level I: Paper maps, plans, and recollections only
Level II: Onsite verification of aboveground facilities, markings etc.
Level III: Onsite detection by sensors, with GPS spatial reference
Level IV: Survey or SUE information; sealed plans document

8. Initiate a program to archive newly developed data from current and planned projects in a suitable form for incorporation into a UIMS as soon as possible. While the establishment of a final system structure is being implemented, it is very important not to lose the value of this incoming data stream. At the very least, all new data should conform to proposed standards and textual data should be georeferenced (Option 1).

9. Make policy changes to improve as-built quality. Avoid loss of any useful information including capturing raw data at sites (utility marks, photographs of open excavations, etc). Require as-built documents from contractors in machine readable formats. The importance of high quality

as-built information cannot be overemphasized. Consider changes in law to require utilities to release information regarding facilities. Implementation of this recommendation for FDOT owned facilities should be relatively straightforward.

10. Merge or attach the UIMS to existing enterprise GIS efforts in the State. Linking the UIMS activity to major ongoing efforts will build on experience and other data sources, to make the transition period smoother, save money and help to deflect resistance to the adoption of a "new" system. Regarding overall adoption, it is recommended that the UIMS be phased in gradually, rather than an instantaneous changeover, to minimize transitional problems.

11. Provide a prototype UIMS for adoption by each district but maintain a decentralized structure (rather than a centralized system).   Most utility installations and relocations are confined to one district and are best handled at the local level. Projects crossing FDOT District boundaries can be treated by facilitating communications between the districts. The intent of this recommendation is that the Central Office would provide the system protocols and the UIMS software (to be implemented without deviation) but leave the operation of the UIMS to the Districts.

12. The use of commercial software for GIS applications and other data operations is strongly recommended. Any software adopted should conform to standards chosen and also be totally compatible with existing software.

13. Defer extensive feature extraction (especially from older documents) until commercial software capabilities improve. It is unlikely that GIS will replace CADD for the generation of engineering plans.   In time, merging information from different sources will synthesize virtual as-built documents for locations of interest.

14. Consider a strategy of data integration and improvement "on the fly", as opposed to a massive project to incorporate all older data in the UIMS. In this approach, available older information would be examined and integrated into the UIMS in an area of interest at the onset of a new project, when there is a strong motivation to obtain the most complete data inventory possible. If implemented, this method would focus attention on those areas with the most current interest and avoid wasting or duplicating effort on areas not immediately needed. Furthermore, projects in the future could presumably take advantage of improvements in technology.

15. Begin with a pilot study., perhaps a single district or a distinct region. If integration of public and private utility information proves to be initially unmanageable, consider as a first effort just FDOT owned facilities. A pilot study could offer several benefits and many important lessons could be learned. For example, a realistic measure of the effort involved to incorporate older data would be obtained and the cost of developing and maintaining a UIMS could be gauged. Once the system is functional, user feedback and experience would be invaluable for system improvement.

16. Actively search for data partners (who will often also be potential users). The utility companies themselves represent the largest of this group. Other stakeholders include SSOCOF as well as county and municipal utility coordinators. Obviously, many obstacles to obtaining this important data remain (communication, data ownership, security, standards, etc).

17. Consider web based and wireless access for remote users of the system (consistent with security concerns). Provide for onsite acquisition of GPS data for utilities facilities mapping, with direct downloading capabilities to the UIMS. Consider direct capture of raw data such as open excavation photographs and utility markings at worksites. A small additional investment will likely enable a much broader use factor for the UIMS.

18. Establish an ongoing training and education program to introduce and explain the UIMS to potential users and data partners.

19. Regarding overall UIMS adoption, it is recommended that the UIMS functionalities be phased in gradually (possibly a few functionalities at a time), rather than a complete instantaneous change-over, to minimize transitional problems.

6.3 Limiting factors identified

A number of issues have thus far been identified which could potentially reduce the effectiveness of a UIMS.

1. Verified, as-built information is difficult to obtain. To build a competent archive, aggressive action may be required to force delivery and retention of accurate as-built plans.

2. If data archived in the UIMS is to be used for planning at close tolerances, a high degree of accuracy must be ensured and documented. This means that some older data, perhaps most of the data currently

available in paper format, may not be particularly useful in this regard. Also, the scale of some information may limit usefulness.

3. Similarly, data archived must be precisely georeferenced for projects requiring high degrees of accuracy. Transformation and conversion of plans to overlay all relevant data in some area of interest with accurate registration will require substantial effort. Again, older data may not be worth the investment of manual labor.

4. Feature extraction from electronic CADD files is likely to be a substantial task.

5. The incorporation of (absolute) depth information along with horizontal position is essential but difficult.

6. Sophisticated application software will be required in the future to integrate and correct existing information.

7. An appropriate choice of standards for data and metadata is essential if flexibility of the UIMS is to be assured. Migration of data in the future to other system structures is likely.

8. Unless adequate quality control measures are in place, it will be difficult to evaluate the importance of some types of data.

9. Significant issues regarding record keeping requirements [6.22], liability and security need to be resolved. Additionally, at least one referenced document has raised questions regarding the requirement for a licensed surveyor if data is placed on maps of Florida (Statute 472).

6.4 Roadmap to implementation

A proposed timetable for the implementation of a UIMS as recommended above is as follows:

1. Designate a responsible group within Utilities at FDOT including Central Office and District representation to manage the decision making, liaison activities and implementation regarding the UIMS. Establish "ownership" of the system.

2. Decide upon a set of preliminary functional requirements for the UIMS and seek a mandate to proceed with implementation from the appropriate authority. Address preliminary funding needs.

3. Establish a liaison with the ongoing enterprise effort at FDOT, with a goal of integrating the UIMS into this ongoing effort. Coordinate further study and development of Option 3 as part of this step.

4. As soon as possible, set a goal of having at least the simplest configuration (Option 1) for the UIMS in place and operational. Implement immediate changes in the retention of existing data to avoid future loss Set minimum standards for the submission of all future utility location data.

5. Establish a pilot project in one district or geographic area at the Option 4 level for a period of one to two years. A set of goals and an evaluation procedure must be in place and functioning. From the results of this study develop a benefit cost ratio evaluation.

6. Assuming positive results from Step 5, seek authority and funding to proceed with the implementation of Option 4 for all districts. This step will require finalizing the framework for the UIMS, based on the results for the pilot study, and may also require policy or rules changes to improve the quality of as-built submissions.

7. Prior to adoption of the UIMS in final form, develop training and personnel requirements to ensure adequate staffing. A decision regarding system access and security will also be required.

8. As an ongoing research effort to be included as soon as practical develop a process for integrating all data into a true geodatabases (including feature extraction, as discussed for Option 3). This step will include dealing with older records requiring manual interaction (paper based, etc). The oversight group will need to be especially alert to changes in technology during this period to take advantage of new developments.

The interval for this timetable will be in part established by the group responsible for development of the UIMS, but will also be governed by the funding provided. At the present, a period of five years to complete steps 1-8 above seems realistic and ample.

6.5 Summary

The focus of this chapter has been to present recommendations for the establishment of a UIMS. Immediate adoption of the most elementary system would constitute a very large step towards achieving the goals envisioned in this study. By archiving currently available information with geospatial attributes, and providing an application to retrieve this data, business processes regarding utility installations would be positively impacted. Developing a UIMS with capabilities of overlaying and integrating data from different formats should be an

intermediate term goal.   Scanned plans and other information are not nearly as useful as recovery of data in original formats. It should be recognized that at present there remain some issues related to interoperability of various software packages that will need to be resolved. The technology in this area is evolving rapidly enough that some solutions for these problems are likely to be available shortly.

It is strongly emphasized that the UIMS should be developed as an integral part of other GIS Enterprise activities within FDOT and not become a stand-alone system.   It is very important that access to other related sources of data be available to users. Several prototype systems currently being used can provide effective guidance for UIMS development. The importance of a pilot study, which will help to clarify potential problems and costs, as well as the benefits of a good training program are not to be underestimated.

Development of a data functionalities to inventory individual components of the facilities infrastructure within the R/W [4.9, 4.10, 6.19, 6.23], is not recommended at this time. Likewise the adoption of an AM/FM capability [3.31, 6.19, 6.20, 6.24,6.25] for the UIMS does not seem appropriate, given the original objectives of this study (it is noted that there may be some interest in pursuing this course if management of FDOT owned facilities is to be incorporated into the UIMS). Nevertheless, a considerable body of literature and methods in these areas exists. Some of these ideas and concepts could be potentially useful additions to the capabilities of the UIMS, so it is recommended that these areas be monitored as part of an ongoing effort.

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Chapter 7: Efficacy of a UIMS

Having described the UIMS as completely as possible at this stage of consideration, it remains to weigh the benefits against the costs, and to understand the risks involved in adopting such a system.

7.1 Benefits of a UIMS

Previous sections of this report have documented the rationale for a UIMS and presented an understanding of how an effective UIMS might be implemented. In this section, the advantages and benefits accrued from implementing and maintaining a UIMS are considered. Closely related systems have been instituted elsewhere and in many cases, an examination of these revealed lists of benefits that are expected to result from adoption. One of the best summaries of anticipated direct benefits may be found in Reference 3.11, regarding the application of SUE. Many of the anticipated benefits of a UIMS are virtually identical.

> "There are numerous benefits obtained when using SUE on highway projects. By using SUE, significant benefits are derived for the DOT, utility companies, SUE consultants, contractors, and the general public. Some of the benefits that have been obtained are as follows:
>
> Reduction in unforeseen utility conflicts and relocations;
> Reduction in project delays due to utility relocates;
> Reduction in claims and change orders;
> Reduction in delays due to utility cuts;
> Reduction in project contingency fees;
> Lower project bids;
> Reduction in costs caused by conflict redesign;
> Reduction in the cost of project design;
> Reduction in travel delays during construction to the motoring public;
> Improvement in contractor productivity and quality;
> Reduction in utility companies' cost to repair damaged facilities;
> Minimization of utility customers' loss of service;
> Minimization of damage to existing pavements;
> Minimization of traffic disruption, increasing DOT public credibility;
> Improvement in working relationships between DOT and utilities;
> Increased efficiency of surveying activities by elimination of duplicate surveys;
> Facilitation of electronic mapping accuracy;
> Minimization of the chance of environmental damage;
> Inducement of savings in risk management and insurance;
> Introduction of the concept of a comprehensive SUE process;
> Reduction in Right-of-Way acquisition costs."

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While this list is comprehensive, these items are <u>outcomes of successful</u> <u>implementation</u>; whether or not a system is genuinely effective can only be assessed after adoption. Likewise benefits are often intangible and cannot be directly translated for purposes of economic comparisons. Recognizing that the adoption of a particular approach is a very large undertaking and not without significant risks, it is perhaps wise to ask for more details- what new capabilities will be introduced that are not now available [1.8]?   Do the advantages of these increased capabilities justify the increased economic burden? To address these questions a more detailed consideration of several benefits is offered:

1. The UIMS capability for recovering and visually displaying information regarding site conditions will enable the client/user to better understand the situation at the project site, thus operations from plans production to construction and maintenance will be accelerated.

a) Improved speed of acquisition – avoids confusion and overlooking important material.

b) Provide quality statement to accompany data -minimize mistakes due to quality control issues

c) Improved compatibility and access with other sources of information - all relevant factors can be considered simultaneously

2. Data from ongoing projects will continue to accumulate, but is useless if not organized and readily available.

a) Avoid duplication of the effort to acquire information

b) Lost (or irretrievable) data is a wasted opportunity to improve future knowledge

3. Subsurface Utility Engineering represents a special case of the first two items and in fact provided one of the original motivations for the present study.   Utility projects frequently require the application of SUE (at considerable expense to FDOT), but these reports are not retained in a directly accessible spatially referenced format, so that SUE data cannot be easily reused.   It has been estimated that some utility facilities must be located by SUE techniques as many as five times over the life of the facility.   SUE benefits have been quantified [3.11].   Thus each reuse of existing SUE data multiplies this benefit.   Moreover, the quality of the SUE information will be enhanced through improved spatial referencing.

4. The introduction of a UIMS offers a unique opportunity to capitalize on existing efforts.   The current mode of operation regarding planning for

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utilities installation involves a number of steps, many of which are manual, labor-intensive tasks. The processes related to the UIMS operation recommended here would capture and archive this work. Thus all the effort related to current planning could be reused effectively on future projects, avoiding wasteful duplication. In time, evolutionary growth in this fashion would lead to a much more complete UIMS with little additional effort.   The development and adoption of the UIMS does not have to be completed at one time, so that the impact of change over can be minimized.

5. FDOT is currently in the process of adopting an Enterprise Geographic Information System (EGIS) [2.51].   If the recommendation to attach the UIMS to this effort is adopted then the benefits associated with the EGIS will accrue additional leverage.

6. Future developments at FDOT will require a UIMS. For example, in Chapter 1 it was mentioned that an ongoing effort at FDOT was the development of a program for the optimal routing of utility facility installations.   In order to accomplish this objective for any particular project it will be necessary to accumulate a substantial amount of data about current site conditions, information that the UIMS (as recommended) could provide.

7.2 Costs associated with a UIMS

In this section, the costs of implementing and maintaining a UIMS are considered. These items may be broken down as follows:

1. Additional personnel will be required and these individuals will need sufficient background in database, GIS and CADD software. Most additional staff effort would be devoted to transferring information to the UIMS.   Depending on the level of UIMS functionality adopted, digitizing and other manual effort would also be required (it may not be realistic to archive some types of older data). The total time spent in these activities would be in part offset by the reduction in staff time required to research poorly archived data, and general improvement in the overall work effort, and therefore the information transfer effort can be in part accomplished by current workforce.

2. Realistically, there will be an increase in cost associated with acquiring high quality, verified as-built information.   It is noted that this increase may be marginal, since this data is already being collected. What will be required is to put the information in machine-readable form instead of hand annotation. Most of this effort will come from outside FDOT workforce and will result in increased prices for effort.

3. There will be some associated increase in computer hardware, particularly in storage capacity.   The impact of equipment should be marginal however, since FDOT has an established computational infrastructure and especially if the UIMS is tied to the enterprise effort. Furthermore, much client access will be from existing desktop PCs.

4. Most major software required to support the UIMS is already in place at FDOT. It is anticipated that some bridging applications packages will be required, however.

5. Additional research/planning effort will be required to formally structure the UIMS and to specify additional software requirements mentioned previously. Logically, a certain level of ongoing assessment and examination of improvement would be lumped under the research effort also.

6. As with any project of this scope, the UIMS will require a certain level of management and administration. Once initiated this effort would likely be only fractional effort for one person at each District and at the Central office assuming reasonable levels of technical assistance would be available (already in place).

7. A component of training for all personnel involved in the UIMS should be planned as both an initial and ongoing activity. Furthermore, to maximize the benefits of the system, training for all potential clients (both inside and outside FDOT) should be planned.

8. Just as some benefits are intangible, there are intangible costs associated with not pursuing a course of action, which might be referred to as the value of lost benefits or opportunities. This category includes items such as reduction in claims, reduction in damage due to utility cuts, reduction in traffic delays, all of which have economic impact which will not be fully realized if the UIMS approach is not adopted.

7.3 Preliminary benefit/cost analysis

The concept of systems similar to the UIMS described in this report is very new; consequently there are few models in place upon which to base the costs of adoption and the economic value of the benefits. Nevertheless, as pointed out above, the ratios associated with SUE can assist in developing estimates. For example, a widely quoted return for SUE is $4.62 per $1.00 invested. Repeating SUE investigations of the same facilities obviously reduces this ratio. Five investigations would effectively reduce the ratio to about 1:1.   It seems likely that the cost of archiving and reusing this data in a UIMS would constitute only a small fraction of the cost of the test itself, so that if data were available for reuse, the initial expectation of the value of SUE would be retained. Quantifying the

savings could be stated in several ways, but perhaps the easiest is to point out that the benefits of SUE could be worth close to $30 million (annually) but are reduced by the fraction of sites explored that have been previously examined, as well as the number of repeat visits. A savings of several million dollars in SUE costs is then to be expected.

The first option for UIMS structure (discussed in Chapter 5) would require software capable of storing and recovering information based on geospatial coordinates. Currently it is expected that this operation could be handled by ESRI© software already licensed to FDOT. Assuming that geospatial coordinates are known for SUE investigations (and other documents) placing data in the UIMS is a straightforward task, unlikely to require more than the current effort to store similar data in the EDMS. Thus, the largest cost component for the first option is likely to be the effort involved in formal adoption and training.

A more complex structure, such as that envisioned in Option 4, will require additional personnel (perhaps one person per district) and additional software. Suitable application software is currently being developed and competitively marketed. It is noted however that these statements do not account for the effort to bring older data into the UIMS. Scanning, scrubbing and manually aligning older plans could easily involve several full time individuals in each district, or these services would have to be contracted.

In a similar fashion, an understanding of the investment ratios associated with infrastructure Enterprise GIS can provide further guidance to the economics of a UIMS. For example, a study [7.1] concludes:

> "Despite all the difficulties in quantifying major GIS benefits, there is a particularly useful study that presented examples of the productivity improvements and cost savings produced by GIS -- the Joint Nordic Project Report. This report presented information on costs, benefits, and applications of 16 well established GIS projects in North America and two in Italy. This study is considered by many authors as the best single reference for detailed Benefit/Cost ratio data.(Korte, 49) The project findings were:

>> If a system is used only for computer-aided mapping and updating, it gives a full return on investment (B/C 1:1).

>> If the system also is used for planning and engineering purposes, the investment will be doubled (B/C 2:1).The ratio would rise to 4:1 where all commonly used data sets have been automated.

>> Research reports publish in Norway and Sweden show that the B/C ratio for automating conventional maps is greater than 3:1.

If a common system is created in which information can be shared among different relevant organizations, the investment will come back four times (B/C 4:1).

For organizations with a poor system for manual map production, the automated system has given B/C ratios up to 7:1.(49)"

Thus, the benefit/cost expected for GIS (like SUE) is usually quite positive. The system adopted in Tucson (discussed earlier, [4.15-4.19]) projected a return of 2.5 to 3 times investment [7.2] based on the work of Tomlinson and others. There exist many similar studies and furthermore some governmental agencies have added their own conclusions to this discussion. Only a few examples will be introduced here [7.3-7.6], as representative of these efforts   USGS offers an on-line training course "GIS Implementation". Chapter 3: User Requirement Analysis presents the elements of a cost benefit study [7.7].

Benefits obtained through other types of leveraging are much more difficult to quantify:

1. If the recommendations of this report are followed, the UIMS would become yet another advantage to a larger system like the Enterprise GIS already contemplated for FDOT. Benefits realized would accrue to the larger project.

2. If suitable partners can be found, the potential for outside investment may be obtained. It is interesting to note that the Oregon system [1.14] (much larger than the UIMS) discussed earlier is anticipated to cost a total of $200 million, but the state expects to request only $30 million [7.5].

7.4 Cautions and risks

Certainly the adoption of any major system such as the UIMS can have many negative aspects, especially including certain risks that may arise during implementation. Below, a number of possible risk factors for the UIMS are catalogued and while some are common problems for many systems, some are specific to the UIMS.   Related discussions in References 1.8, 2.48 5.2, and 6.3 are noted and should be of interest regarding risk factors.

Large risks involving costly mistakes

1. Picking the wrong plan for the UIMS initially, including data and metadata standards. This item is not intended to suggest that changes are not possible and indeed, lack of flexibility during the development and growth phase would be very negative.

2. Scope creep- the risk of developing a system while having unrealistic and growing expectations for performance including accuracy, registration and presentation.

3. Failure to define performance expectations and a means of assessing outcomes early in the timetable.

4. Underestimating the importance of developing a mandate and acquiring a champion within the administration. A related problem is underestimating hostile political agendas.

5. Underfunding the ongoing program to the extent that the effort is not on track either with respect to a timetable or system capabilities.

6.   Lack of qualified support staff and failure to provide adequate training for the users.   These two items will influence the development of an enthusiastic constituency, which in turn will pressure the continuation and expansion of the system.

7. Failure to anticipate the problem of interoperability as related to CADD and GIS, including feature extraction, manual intervention and the problems associated with bringing older data into the UIMS.

Risks with smaller impact and modest financial consequences

1. Choice regarding a centralized or decentralized UIMS: Although a decentralized system is recommended here, either of these choices could work and the decision is not irreversible. Reference 6.3 discusses the pros and cons of the centralized/decentralized choice.

2. The format of graphical output.   Many choices could be acceptable, thus the only consequence is relatively small development and installation costs.

3. Demanding high levels of accuracy improves the value of the available data, but adds dramatically to the cost.   This risk factor can be minimized by careful study of data accuracy needs.

4. Premature adoption of commercial off-the-shelf software (COTS): It is not likely that any software package will satisfy all needs and some bridging applications will be necessary. Software evolves rapidly to suit needs. As long as selections are made that do not conflict with existing software currently adopted by FDOT this risk is judged to be small.

There is one risk factor for which the economic consequences are difficult to assess. Due to the delivery of information to a client/user which is of either a surveying or and engineering nature there is a certain risk of liability not only for guarantees of accuracy but also for the preparation and dispensing of this information.   It is suggested that this issue be reviewed before proceeding.

7.5 Summary

In this chapter an analysis of the benefits, costs and risks associated with the adoption of a UIMS has been presented. Because no decision as to how the system will finally be structured and implemented has been made, it is virtually impossible to develop an overall cost estimate for adoption.   However, several relevant observations can be made:

- Information systems are expensive in the early stages of adoption, but the benefits of having the system occur in the future [6.3, 7.5].

- The introduction of an information management system often requires the investment of more staff effort in initial data handling, but the return on this investment is dramatic as information is effectively reused.

- Many benefits are hard to quantify economically, or are intangible (for example improvements in workflow efficiency).

- A large portion of the benefits of a system accrue from very simple and relatively inexpensive changes (Option 1, for example), but as the system capabilities increase in complexity, more expense is incurred for marginal improvements.

The recommended pilot study should be scalable and therefore a good predictor of the overall cost of the UIMS. Inspection of SUE and Enterprise GIS studies indicate that similar, positive benefit/cost ratios should be attainable, justifying the adoption of a UIMS.   However, it is also recognized that the future may bring new developments in location technology as well as software appropriate for a UIMS. Thus, a well planned system should be flexible and mid-course corrections should be easy to make.

7.6 References

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Chapter 8: Conclusions

Because utilities share the crowded transportation right-of-way, it is essential that high quality information regarding placement of these facilities be maintained, to reduce uncertainty in decision making for construction and maintenance projects. The principal task reported here has been a study of the efficacy of a utilities information management system (UIMS), intended to serve as a database for the retention and graphical presentation for information regarding the location of utilities facilities. In order to accomplish this task the following items were completed.

> a) The rationale for instituting a UIMS has been investigated by studying similar systems elsewhere. It was concluded that the benefits and advantages of implementing even a minimal system are likely to be very positive.

> b) Resources available for a UIMS (data sources, current software and methods) both inside and outside the FDOT have been examined.   These resources were compared to anticipated system requirements.

> c) Several possible UIMS options have been described in terms of organization and capabilities. Advantages and disadvantages of these concepts have been studied.   It is recommended that at least a minimal system be introduced as soon as possible to preserve current information. This step should be followed by the development and implementation of a hybrid GIS/CADD graphical system. Several prototype systems currently being utilized elsewhere have been identified from a literature review and these can serve as examples.

> d) While estimates of investment return ratios were determined, it was found that a complete and detailed examination of system costs is not possible at present due to lack of specific detailed planning (beyond the current scope of effort). To assist in developing projected costs however, a pilot program was recommended. It is a conclusion of this research that expenditures associated with a UIMS will scale directly with the size of the system, thus minimizing the chances that costs will spiral in time, especially if careful choices regarding the structure of a UIMS are made.

A common observation regarding the implementation of engineering systems is that a very large portion of the overall benefits are obtained with only a modest expenditure of funds. The capabilities of a system implemented using current technology may not meet all goals established, but many desirable benefits will still be obtained. At this point in time, the FDOT is not really behind in the adoption of a UIMS, but the risk of being overwhelmed by information is increasing rapidly.

The conclusions of this investigation may greatly influence how information is gathered and stored in the future, which is a different problem entirely from the development of a unified archive of currently existing information. It is therefore highly desirable that the UIMS developed can easily adapt to future change. Conversely, a strong recommendation has been made to change the current manner of information gathering and reporting.

8.1 Recommendations for future research

In addition to the overall recommendations made in this report, it is further suggested that a continuing program of research be established in conjunction with development efforts. The purpose of such a program would be to

a) Investigate methods to move the UIMS towards a highly structured geodatabases (Option 3).

b) Review literature for and maintain contact with parallel efforts being developed elsewhere.

c) Take advantage of newly developing methods for improving information management systems.

8.2 Issues identified but unresolved

During this research, several questions were uncovered for which no adequate answer could be provided at this time. These include the following:

a) A somewhat bothersome issue that poses a potential negative factor for the maintenance of a UIMS is Florida Statute 472, which may limit the acquisition of spatial information for inclusion into maps for individuals who are not licensed surveyors. It is unknown at this time how such restrictions might affect the UIMS.

b) Delivery of surveying or engineering information to a client/user poses a certain risk of liability, not only for guarantees of accuracy but also for the preparation and dispensing of this information. The economic consequences for the UIMS are difficult to assess. It is suggested that this issue be reviewed carefully before proceeding.

c) A minor issue relates to the possibility of charging for UIMS access for interested users who are outside the FDOT. This issue will be left open at this time pending a complete cost study, except to note that the value in obtaining stakeholder involvement and valuable data sharing through free access may exceed potential revenues.