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Development and Maintenance of a Critical Application Geodatabase For DOT Use.

Executive Summary

This paper presents a description of the development and maintenance of a state-level database used by the Louisiana Department of Transportation and Development (LADOTD) and prepared by Geographic Data Technology (GDT).

The LADOTD implementation uses both ArcGIS and ArcSDE/DB2. The database is served to LADOTD from GDT using standard ArcGIS and ArcSDE/DB2 functionality. Some customized tools are provided by GDT for data editing and maintenance purposes.

The presentation will cover 4 key steps:
1. Requirements Analysis
2. Database Feature Modeling
3. Compiling Data From Multiple Sources
4. Long-term Data Maintenance

The paper is a high-level description, and is not intended to cover each item in the detail required to fully understand and implement it. For more detailed information please contact the authors.

Requirements Analysis

Regardless of the nature of any project, the first step in producing a successful GIS implementation is the accurate capture and interpretation of the requirements of the users. This can be summed up in the question, “What are you trying to do?”
Although it sounds simple, in practice it becomes very difficult to sort out the answers from some other “booby traps” that masquerade as requirements.

Examples:
“Create the best data on the planet” – nice goal but without knowing what the data is to be used for the definition of best is not achievable.

“Make everything as accurate as possible” – really great goal and without an understanding of the difference between accuracy and precision this one can drive you to the poor house. It is also multidimensional; spatial accuracy, attributes, and topology often conflict with each other for accuracy.

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"Build the perfectly functioning geodatabase that will enable all my application needs to be met simultaneously" – Intellectually stimulating for the database design folks, but is it practical?

Our approach to the requirements process begins with a "plain talk" interview that specifies routine tasks that the GIS will support. In this project, the main thrust was to integrate data used for the daily operations of the LADOTD into an ESRI-based GIS.

The following high-level list was developed to determine the uses of the GIS:

Public Information Disseminated Via The Internet

Location of construction projects
Location of maintenance projects
Location of road and lane closures

Intelligent Transportation Systems

Locating and reporting events
511
Dynamic Message Signs [DMS] operations

DOTD Operations

Truck routing and permitting
Dispatching work crews
Identifying and locating events
Emergency operations
Safety

Reporting

Federal and State level reports for future project planning and funding
- Accidents
- Surface Type Log
- Highway Performance Monitoring System
- Needs assessment for the legislature

It became clear that the major requirement we needed to focus on was the integration of Linear Referencing System (LRS) data and its role in the enterprise GIS applications at

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LADOTD. The LRS data are the physical locations of inventory items that LADOTD manages and maintains. The LRS data are typically calibrated to one-one thousandth of a mile increments (5.280 feet) and may have been collected using various instrumentation from a steel tape to a measuring wheel to the odometer of a truck to GPS devices. A further complication on the LRS data is that it represents the measure of the "true surface" of the road. The existing LRS and inventory data was stored in CADD formats and non-spatial databases.

In order to support the LRS integration into the GIS, a "land base" was required. The land base data would consist of a center-line feature for all classes of roads, water, rails, and boundaries. Polygonal features to define water, land cover, and various political and jurisdictional boundaries were specified. Point features to represent various event themes were also deemed important.

Maintaining one set of street feature center-lines to support multiple applications was stipulated as a major need. This was further expanded upon to include the requirement that the LRS, once it is defined on the center-line, will be linked to inventory data that are kept in tabular format. As the LRS is updated, all associated data are updated using a "waterfall" maintenance procedure.

On the application side, ArcGIS was deemed sufficient "out of the box" to meet the needs of LADOTD users. Arc IMS is also employed to distribute data over the State's intranet. Internal development of Dynamic Segmentation tools continues at LADOTD. A very important consideration for application development is that they are user driven. All development at LADOTD takes place on user demand, and currently the users are satisfied with existing ESRI tools.

A complete re-statement of the requirements analysis is beyond the scope of this paper. The requirements analysis process should be considered to be a critical path to success in all projects, be they government or private sector endeavors.

Database Feature Modeling & Database Design

The next step was to develop a textual and tabular model of the data to be built. For a State level database, this is a complex and detailed set of documents that encompass of 200 pages and 3 "E" size drawings. An attempt will be made to explain the high points.

Land Base Objects

The table below details the objects in the land base component of the LADOTD database.

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Note: Each object below may be specified to have behaviors, and behavioral constraints. We will not include details in the paper on the individual objects and behaviors, but it is important to remember that they are there.

Layer	Type	Source	Tile
LADP Streets	line	Custom LADOTD	Parish
Address Points	point	Assessors Parcel Records	Parish
Placeholders	point	GDT	Parish
Highways	line	Multiple Sources	Parish
LADOTD Custom Highways	line	Multiple Sources	
Exits	point	Multiple Sources	Parish
Railroads	line	Multiple Sources	Parish
Water segments	line	Compiled	Parish
Water polygons	poly	Multiple Sources	Parish
Major Water polygons	poly	Multiple Sources	Parish
Parks	poly	Multiple Sources	Parish
Large Area Landmarks	poly	Dynamap/ Transportation	Parish
Airports	poly	Dynamap/ Transportation	Parish
Recreational Areas	point	Dynamap/ Transportation	Parish
Transportation Terminals	point	Dynamap/ Transportation	Parish
Institutions	point	Dynamap/ Transportation	Parish
Major Retail Centers	point	Dynamap/ Transportation	Parish
ZIP Code Boundary and Inventory	poly/point	Dynamap/ZIP Codes	State
Parish Boundary and Inventory	poly/point	Dynamap/Census Boundaries	State
Tract Boundary and Inventory	poly/point	Dynamap/Census Boundaries	State
BlockGroup Boundary and Inventory	poly/point	Dynamap/Census Boundaries	State
Place Boundary and Inventory	poly/point	Dynamap/Census Boundaries	State
MCD Boundary and Inventory	poly/point	Dynamap/Census Boundaries	State
Othophotography	raster	Multiple Sources	¼ Quad

For each layer, the features are defined as to subtypes (objects) and given a specific Feature Classification Code that defines the use of the subtypes. Rules are developed for the capture and representation of each object as compared to its “authoritative input source”. The definitions and rules are documented and published for use in quality control sampling and data acceptance.

DOTD Objects

The table below details the objects in the DOTD component of the LADOTD database
Note: It is an over-simplification to call each of the items below an “object”. They are really separate TABLES, some of which contain subtypes that are themselves “objects”.

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For the sake of brevity we will stick with the "object" nomenclature. Some of the DOTD objects are non-spatial, and it is anticipated that the identification of spatial locations of all the DOTD objects will be an ongoing process.

Type	Surface Type Log (STL) – Inventory of State Maintained Highway System
ID	Control section, route, subsection
Use	Pavement Inventory of events.
Type	Local Roads City Street File – Inventory of non-State maintained roads.
	Parish, City and Route number (non spatial)
ID	unknown
Use	Local road names if no other source is available
Type	Othophotography – "The Homeland Security Imagery"
ID	Spatial registration file (.tfw or .jfw)
Use	Horizontal control and feature identification
Type	Lidar
ID	X,Y,Z coordinate
Use	Vertical control
Type	HPMS – Highway Performance Monitoring System
ID	Control section – contains sub-segments
Use	Inventory of State and Local Roads for Federal Highway reporting
Type	Highway Needs File
Use	Inventory of State Maintained Roads – Copy of STL with different attributes, segmented differently
Type	Parcel Data
Owner	Parish Assessors offices
Use	Identifying features not on imagery, establishing rights-of-way
Type	DOTD Control Section Database
ID	Control section
Use	Source for conflation of control sections to Dynamap Geometry.
Type	Parish & Urban Boundary file
ID	FIPS
Use	Parish and Municipal Boundaries (Regionalized)
Type	District Boundaries File
ID	District Number (char)
Use	DOTD Districts

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Type	Jefferson Parish Local Data
ID	ID as per individual object
Use	Local source data for Jefferson Parish
Type	Video Logs
ID	X,Y coordinates of points
Use	Identification of inventory events along highways

Relationships

In order to make use of the power of the geodatabase, relationships between objects are specified. The relationships and behaviors are then enabled to provide functionality in the application.

An example might be the relationship between a Street object, a River object, and a Parish Boundary object. The relationships that they have to each other spatially can enable an Emergency Evacuation System to start automatically calling residents of the Parish contained in the boundary and telling them to find high ground.

Another example is a Structure or Parcel Address Point. The Point has a relationship to the Street that can be used for Waterfall Geocoding and point-to-point routing to a specific location. Objects are often joined or related in the software using unique ID's or Primary Keys.

Keys

In order to relate objects between tables, the objects need a way to be identified uniquely. In many cases the relationships between objects will be many-to-one, and one-to-many, but regardless each object needs to be able to be uniquely identified. For the Land Base features, the key is the Dynamap ID. It is a unique number, created once for each object. If the object changes its location, it gets a new ID.

For the DOTD objects, in most cases the ID is the Control Section ID. Because the control section ID can span multiple segments in the streets layer, there is an additional attribute named "Log mile" that is joined to the Control section. The unique key for each section becomes a "Control Section Log Mile".

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To allow the Streets objects to relate to the DOTD objects a conflation activity is performed. The conflation process appends the appropriate "Control Section Log Mile" to each segment in the streets table. The user can then relate the street objects in the GIS to the non-spatial objects in the DOTD tabular data using ArcGIS.

Compiling Data From Multiple Sources

One the database design and quality standards are set, data compilation activities begin. Compilation activities vary, but it is safe to say that hundreds of separate editing steps are undertaken over tens of thousands of objects. High-level descriptions of these operations are:

Feature Extraction and Photo Revision – The creation and modification of vector data using photography for feature detection and location.

Spatial Conflation – The modification of vector features using software that relates them spatially and performs bundled adjustments and transformations to improve spatial accuracy and content.

Attribute Conflation – Appending attributes from one data set to another by the use of conflation technology.

Attribute Changes – Addition, deletion, or modification of attributes associated with an object.

Spatial Data Analysis

There are an unlimited number of potential source data for a database that is this complicated. Because the database is constrained by quality guidelines, not every potential source data is desirable. There is always a consideration for cost-effectiveness in any endeavor.

During the requirements phase, guidelines were adopted to show the "window of acceptability" for allowable sources.

For the initial compilation it was understood that several input data would have to be used "as-is" due to the fact that the State had been using these sources and needed to

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continue to do so. An example of this is the Log-Mile value. In some sources the values were collected with a measuring wheel, in some cases an odometer on a truck, in some cases using GPS. Multiple values for the same Control Section are collected in different tables. Metadata for collection methods are incomplete or unavailable.

For the street objects, input sources come from GDT, the State, and Parish GIS data. Horizontal control comes from aerial imagery, planimetric data, and GPS collection.

For the purpose of compiling the database, each source is identified, cataloged, analyzed, and prepared for compilation as needed. For each street object, the table below is used to store segment level metadata for the edited street objects.

Street Level Metadata Record Layout

Layer	Field Name	Type	Length	Description
Street	NAME_SRCE	C	30	Street name source
Street	ADDR_SRCE	C	30	Address source
Street	GEOM_SRCE	C	30	Geometry source, Sid
Street	GEOM_ACC	C	1	Geometry accurate <= 12 M
Street	LADOTD_SRCE	C	20	LRS Source

Format Conversions

The various inputs come into the process in different data formats and coordinate systems. ArcGIS interoperability tools are used to bring everything into a common format (ArcSDE/DB2) and reference system (Geographic, NAD83, Meters). If other reference systems are required, the data can be re-projected as needed.

It is important to mention that we do not favor the use of the automated re-projection of data in the view. Prior to editing all reference systems are explicitly defined.

Compilation activities typically take place on a county tile for detailed areas and a state tile for the highway network (no off-system roads).

Data Maintenance

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The successfully completed compilation efforts are the database equivalent of a photograph. The data are frozen in time, and doomed to decay and become irrelevant over time. Data will continue being collected by multiple sources. Users will continue to need a common reference source to update for operational reasons.

The maintenance process operates using a central database for Land objects, and periodic updates of the conflation operations and attribute updates. Cycle time per object/attribute combination is determined based on the criticality of the object and the temporal constraints for the input data. An example of this is the existence of a new street vs the addition or correction of an attribute on an existing object.

If you don't have the street, then the address update is impossible to make. On the application side the corollary is that you can't geocode to the location if the feature you are geocoding to isn't there. This sets us up to work on a priority of actions:

1. Something is usually better than nothing. Capture new objects regularly.
2. Small, continuous, change packets are preferable to large periodic change packets
3. Encourage the creation of an owner for each object/attribute and work on authoritative source agreements.
4. Technical capability for identifying change between multiple inputs and object level metadata tracking.

Schematic Diagram of Maintenance Activities Showing Multiple Users

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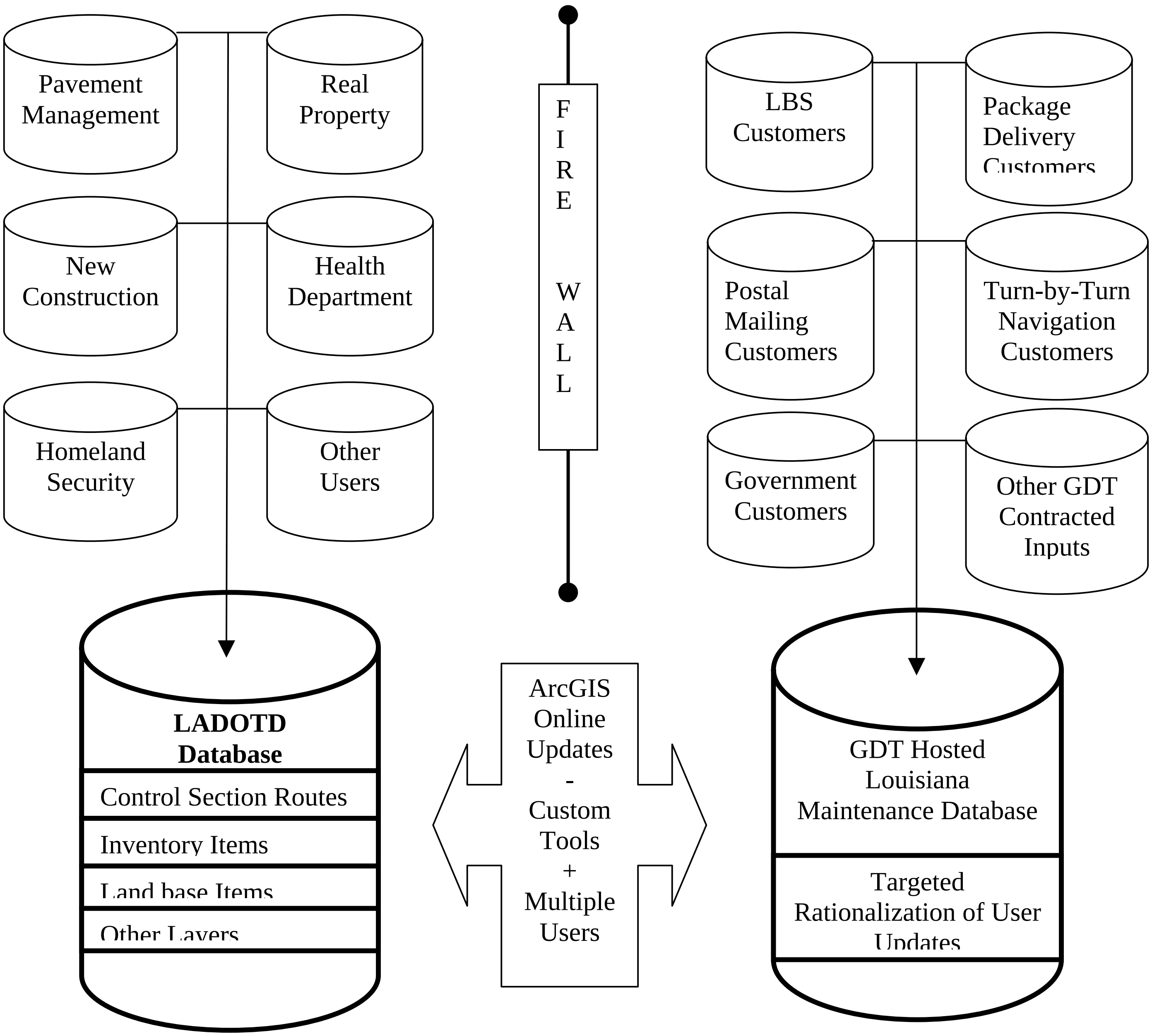

The maintenance system uses LADOTD, ArcGIS, Arc Server, and GDT proprietary technology. It is customized in as much as needed to meet the requirements as defined in section one, and to keep the qualities required for all the previous sections of this document.

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Conclusions

GIS implementations for use by Departments of Transportation can be developed to incorporate data from new systems and legacy systems to create a spatially enabled operating framework for State Level GIS.

Using best-of-breed ESRI software, GDT data building technology, requirements specification and direction from LADOTD, it was possible to build a system to convert the operations of LADOTD from several parallel, repeated operations to one State Level Enterprise GIS.

This GIS is now poised to be integral in the operations of multiple departments in the State of Louisiana.

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