Solving Enterprise Access to Disparate LRS/GIS Data

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BRINGING IT TOGETHER.

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Mapping and GIS Solutions

Introduction

GIST 2001 VIRGINIA

Objectives

- Define important terms
- Identify the problem
- Identify the challenges
- Describe the solution
- Show the solution
- Conclusion

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Definitions

Transportation Enterprise – **The holistic collection of stakeholders, data and procedures pertinent to accessing and creating decision support information**

Enterprise Database – **A unified database for all spatial and fiscal data that support application development**

Enterprise Stakeholders

Maintenance

Finance

IT

GIS

Engineering

Planning

The Problem

Disparate data across the enterprise

- Each department has their own data
- Everyone wants access to each other's data
- Need to make informed decisions
- Need to view and analyze all data together
- No one wants to give up ownership of their data
- Need integration of data across the enterprise
- But how?

Integration Challenges

Organizational Structure

- Who owns the LRS?
- Who owns the GIS?
- Who owns the Transportation Events?
  - Accidents, Pavement, ADT, Construction, Bridges, etc.
- What level of cooperation is there among the disparate groups in the organization?

Integration Challenges

Operational Constraints

- Are there plans for a single enterprise database?
- If so, what's the time-line?
- Across the enterprise how many referencing methods are used?
- Are proprietary technologies being used?

Enterprise

Maintenance

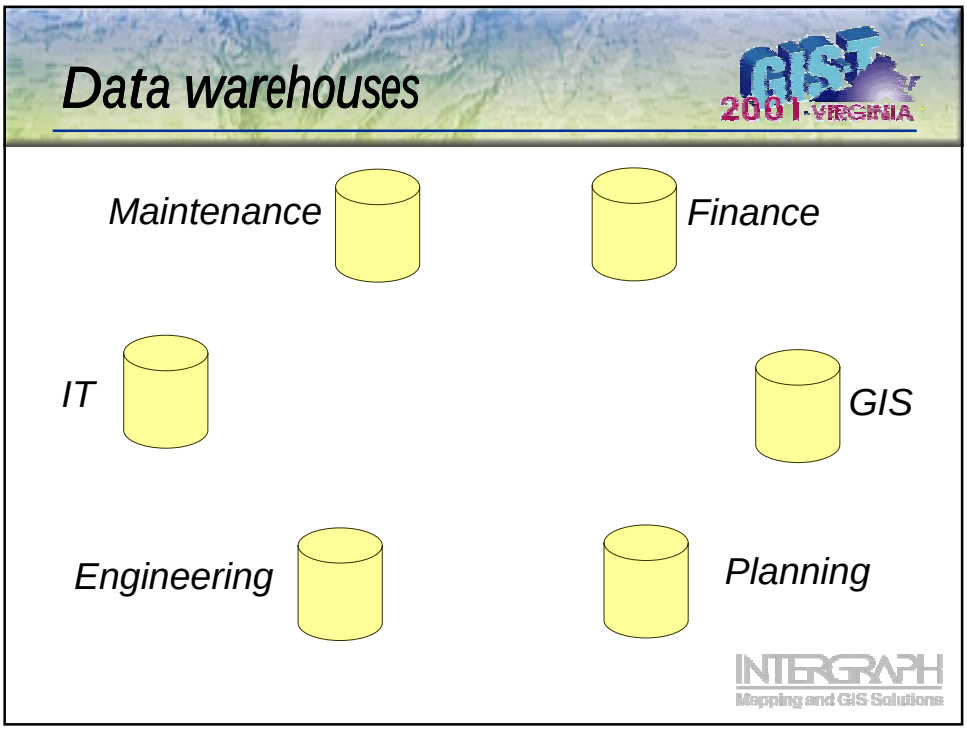
Finance

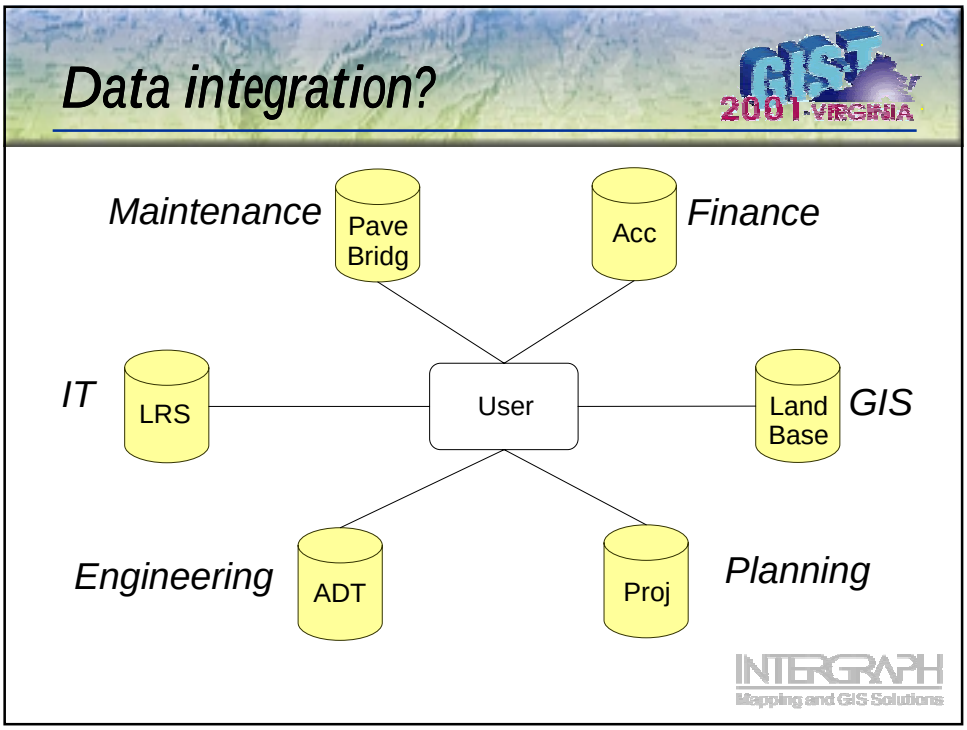
IT

GIS

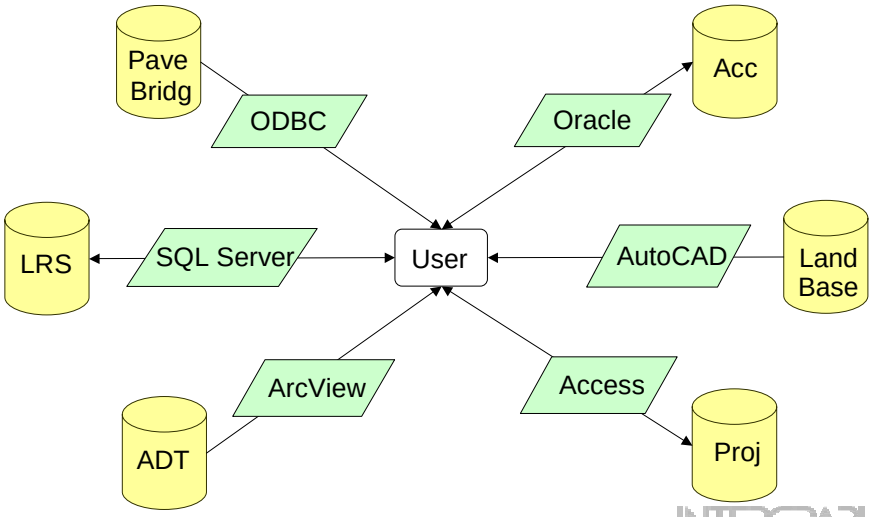
Engineering

Planning


Data warehouses
Maintenance
Finance
IT
GIS
Engineering
Planning


Data integration?
Maintenance
Pave
Bridg
Acc
Finance
IT
LRS
User
Land
Base
GIS
Engineering
ADT
Proj
Planning

Data servers



Data servers

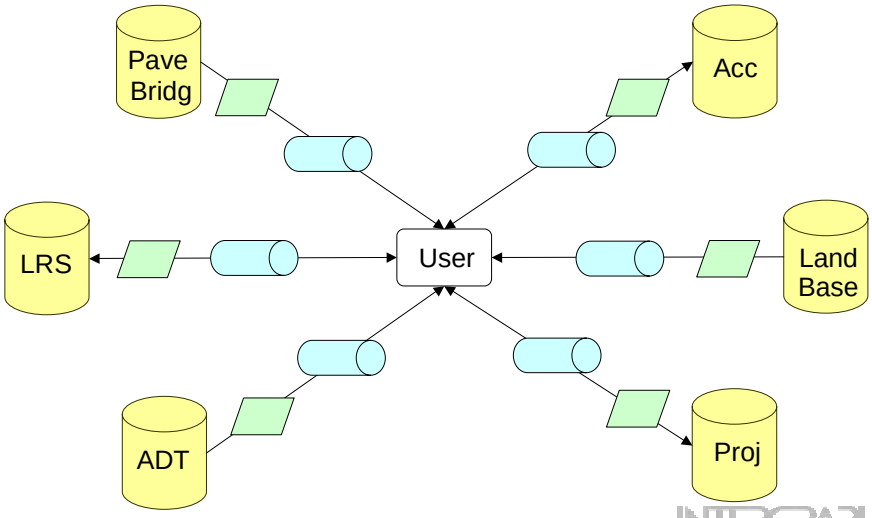
- **Understand native data format**
- **Read-only or read-write**
- **Transform native data to a common format**
- **Serve up data to variety of applications**
- **Applications only need to understand the common format**
- **Used by desktop or web applications**

Common data format

Recordsets

- Consist of records and fields
- Can be thought of as database tables in memory
- Can contain attribute data: character, integer, float, date, blob, etc.
- Can contain geometry: points, lines, areas, etc.

Pipes

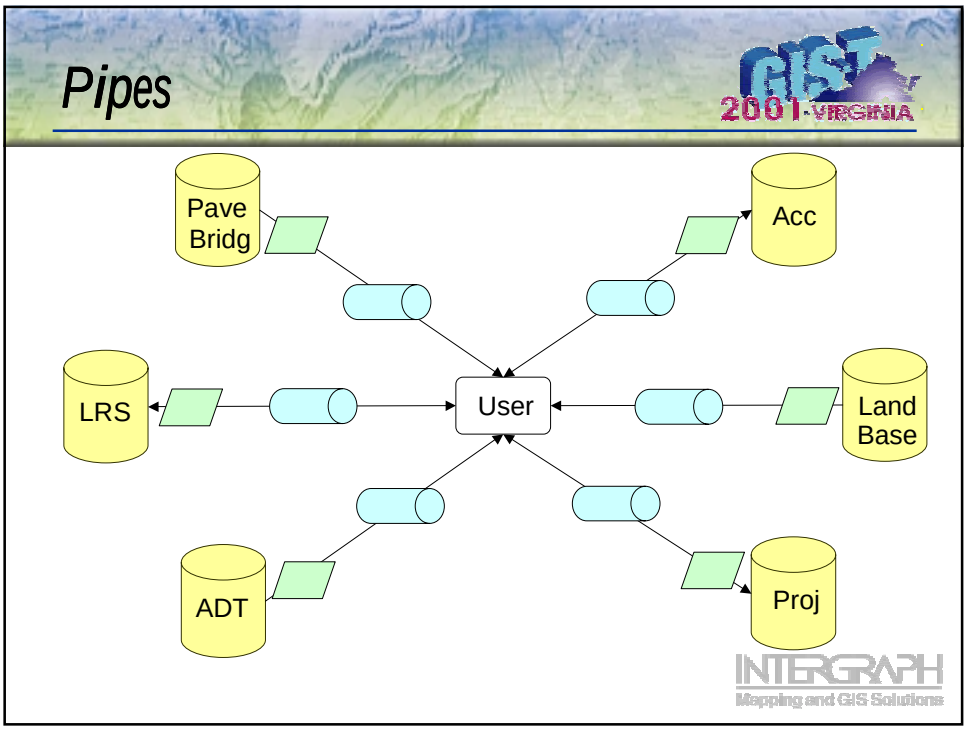


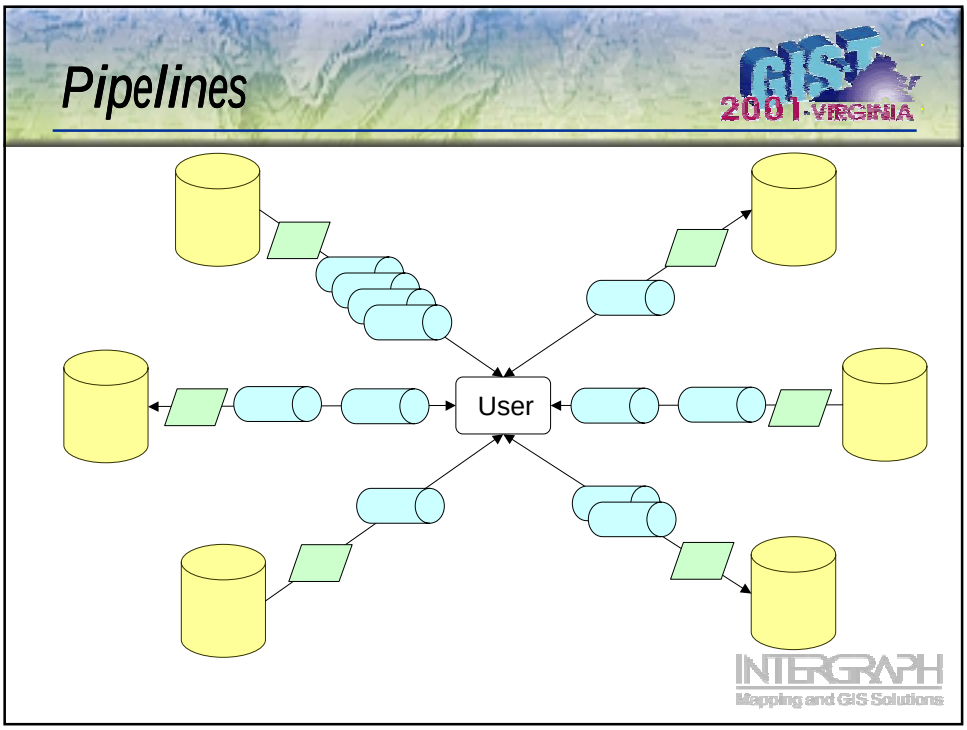
Pipes

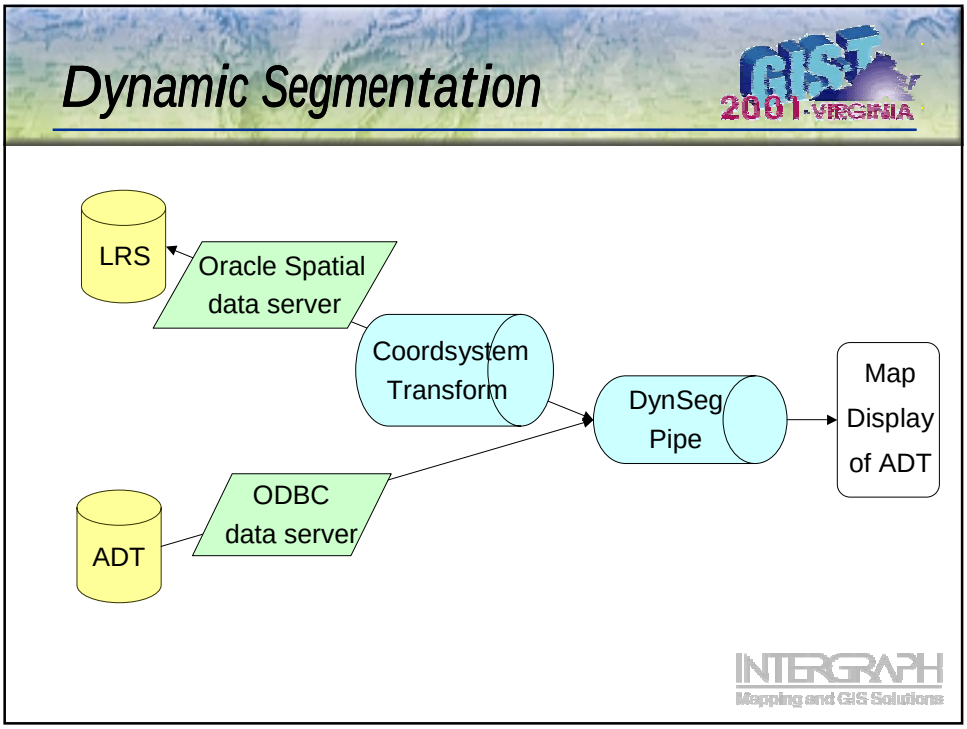
- Software components
- Understand the common format
- Perform some specialized function on data
- Produce data in the common format
- Can be used in any application that understands the common format

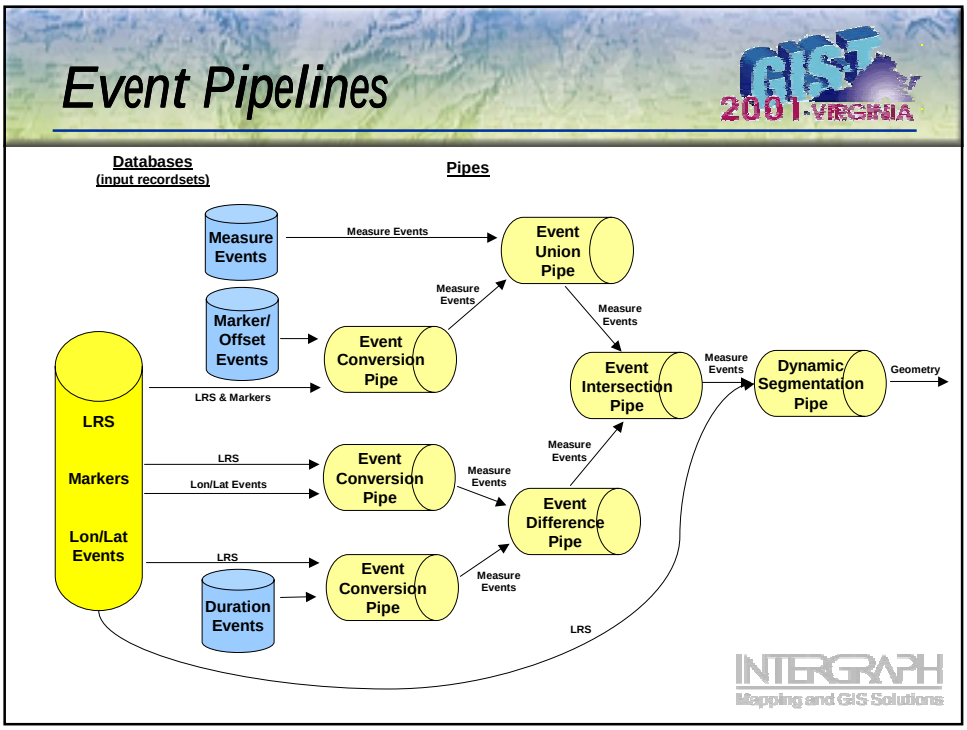
Examples of Pipes

- Coordinate system transformations
- Filter records by attribute values
- Spatial intersection of two recordsets
- Dynamic Segmentation
- Event Overlay
- Event Conversion


Pipes
2001 VIRGINIA
Pave
Bridg
Acc
LRS
User
Land
Base
ADT
Proj
INTERGRAPH
Mapping and GIS Solutions


Pipelines
2001 VIRGINIA
User
INTERGRAPH
Mapping and GIS Solutions


Dynamic Segmentation
GIST 2001 VIRGINIA
LRS
Oracle Spatial data server
Coordsystem Transform
DynSeg Pipe
Map Display of ADT
ODBC data server
ADT
INTERGRAPH
Mapping and GIS Solutions


Event Pipelines
GIST 2001 VIRGINIA
Databases
(input recordsets)
Pipes
Measure Events
Marker/ Offset Events
LRS
Markers
Lon/Lat Events
Duration Events
Measure Events
Event Union Pipe
Measure Events
Event Conversion Pipe
LRS & Markers
Event Intersection Pipe
Measure Events
Dynamic Segmentation Pipe
Geometry
LRS
Lon/Lat Events
Event Conversion Pipe
Measure Events
Event Difference Pipe
Measure Events
LRS
Event Conversion Pipe
Measure Events
LRS
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Mapping and GIS Solutions

Actions and Solutions

Enterprise Database can:

- Unify application development efforts
- Centralize data
- Provide an impetus to implement an enterprise-wide LRM if desired
- Standardize training across the enterprise

Technology that:

- Accesses disparate data formats (i.e. ODBC connectivity)
- Exploits different referencing methods
- Allows "Business as Usual" during migration

Conclusion

Enterprise database or not, technology can help solve the problems of

- Disparate data storage
- Disparate data formats
- Disparate referencing methods

when analyzing business data.

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IT TOGETHER.

Transforming Between Linear Location Reference Methods

Tom Ries, GeoAnalytics, Inc.

GIS-T Symposium
Arlington, Virginia
March 10, 2001

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Presentation Outline

- **LLRM Overview**
- Transform Design Strategies
- Transform Requirements

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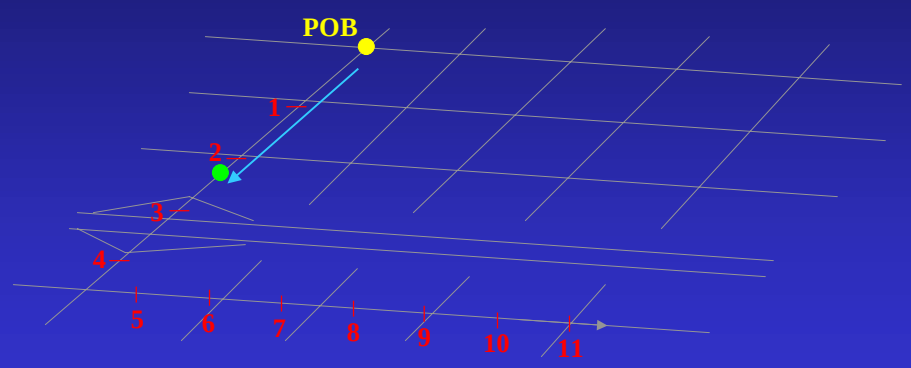
Accumulative LRM

milepoint, kmpoint, stationing



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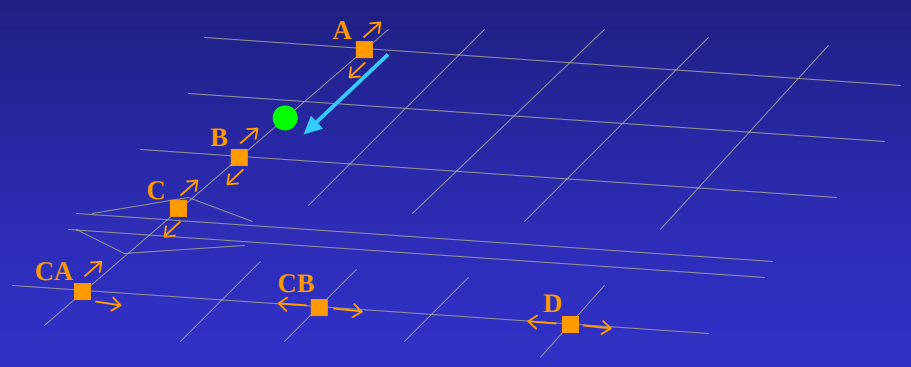
Reference Marker LRM

milepost, cross street, feature



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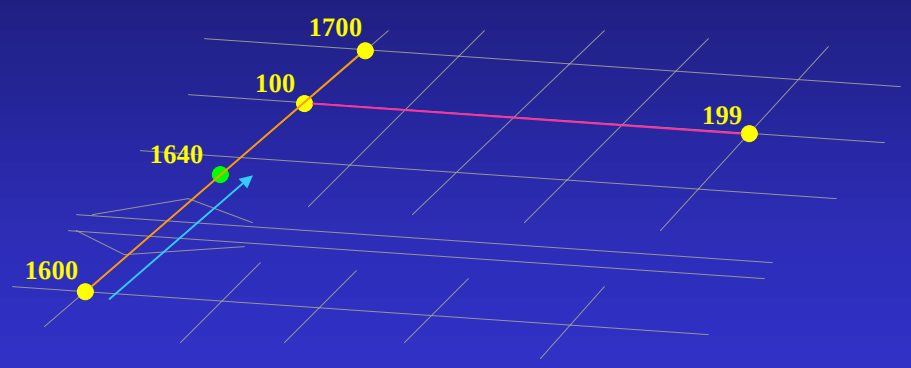
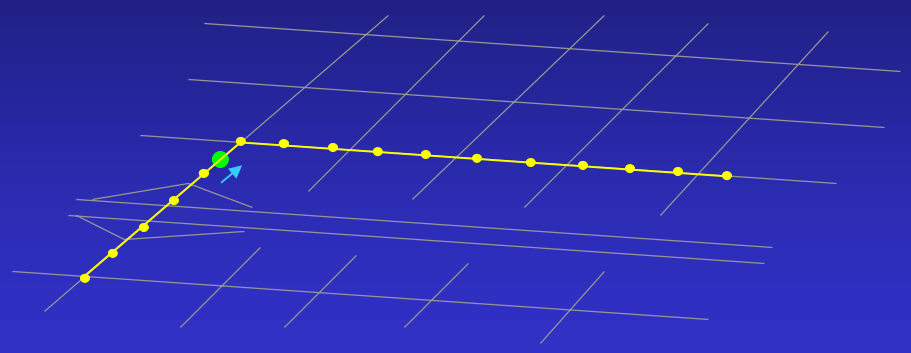
Interpolation LRM

address, stationing, milepoint



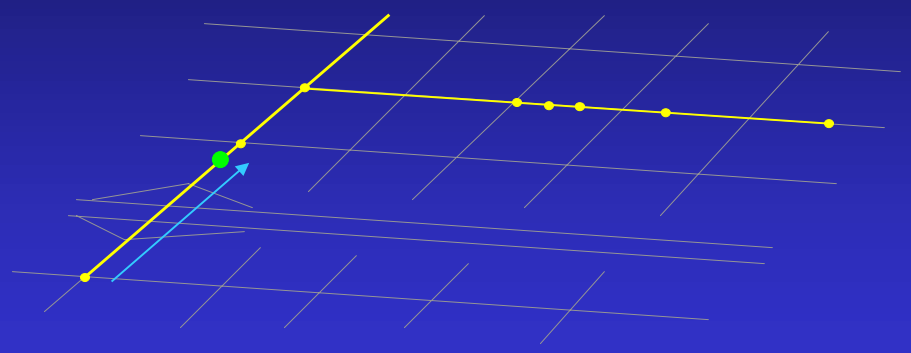
Control Section – Fixed

legacy systems (homogeneous values)



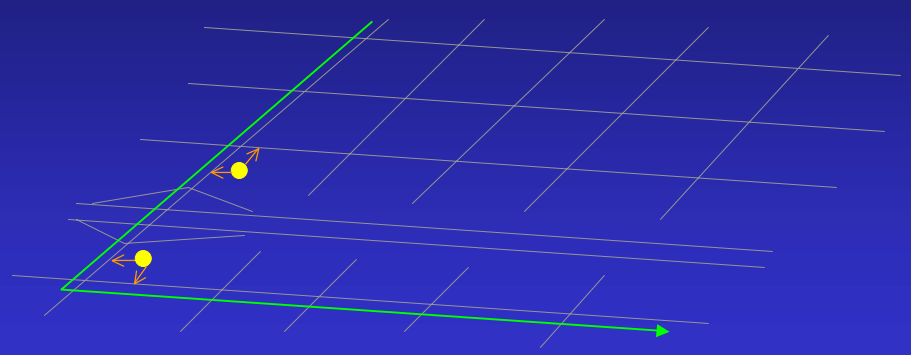
Control Section – Variable

legacy systems, performance, ?datum?
(homogeneous or offset values)



Coordinate Route Location Reference

GPS, cellular, maps



LLRM Overview
Conclusions

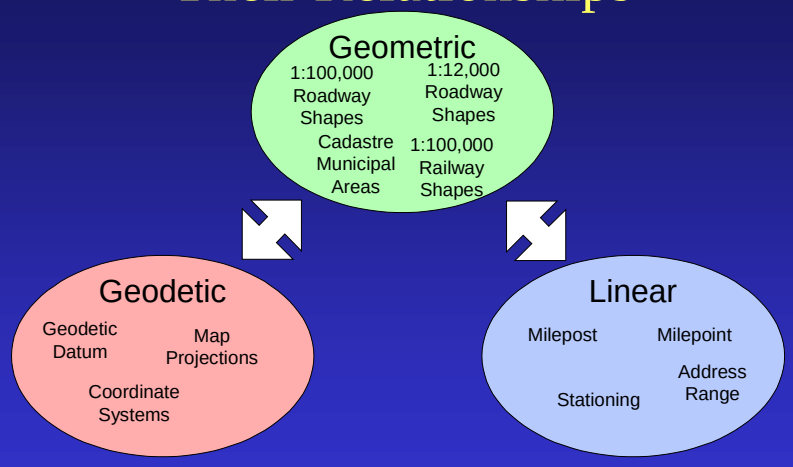
- Variety of LLRMs
- Each has advantages/disadvantages
- Most likely will have or need this variety

It's not about choosing one standard but how to apply a selected set of related standards.

Presentation Outline

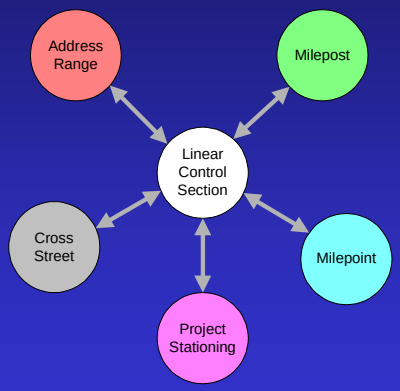
- LLRM Overview
- Transform Design Strategies
- Transform Requirements

Location Reference Groups and Their Relationships

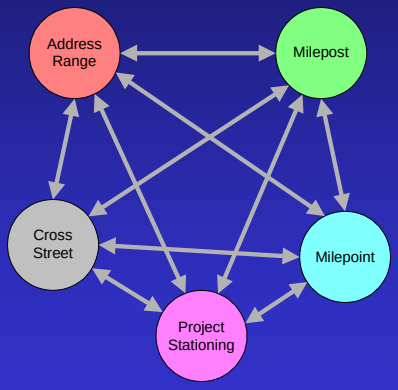


Transform Approach

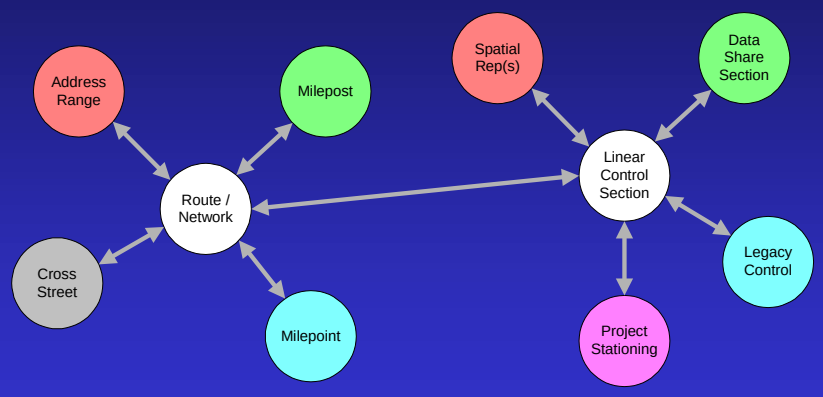
Indirect



Direct



Transform Approach
(combination)



Transform Design Strategies
Conclusions

- Indirect "by-product" of Normalized Databases
- Indirect for Integrated or Interoperable LRMs
- Decision Influences Commercial Software Selection or Custom Code Development

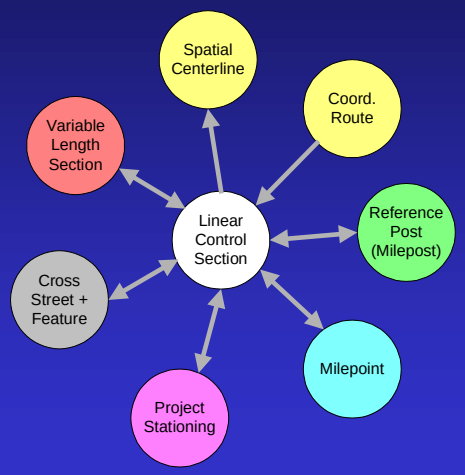
Indirect seems like more effective strategy but decision ultimately based on investment term and "Circle of Influence".

Presentation Outline

- LLRM Overview
- Transform Design Strategies
- Transform Requirements

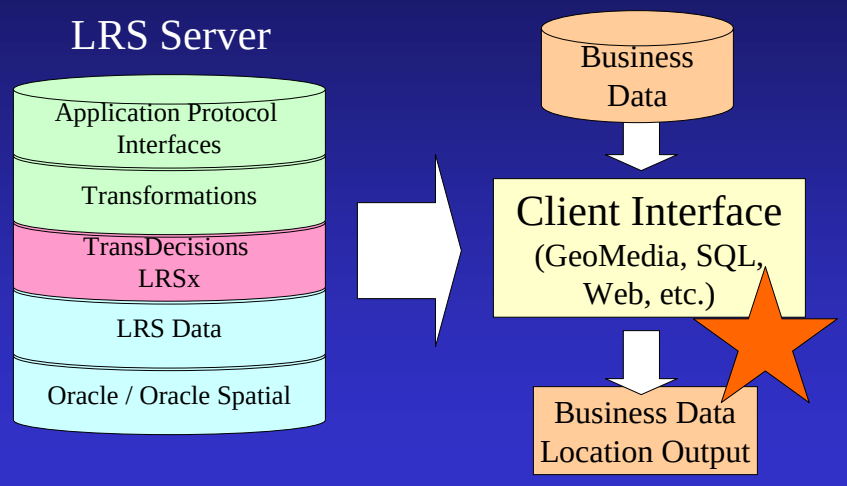
Iowa DOT

6 "LLRMs", Indirect Transform Method



Actual Design Based on NCHRP 20-27(2)

Iowa DOT Approach



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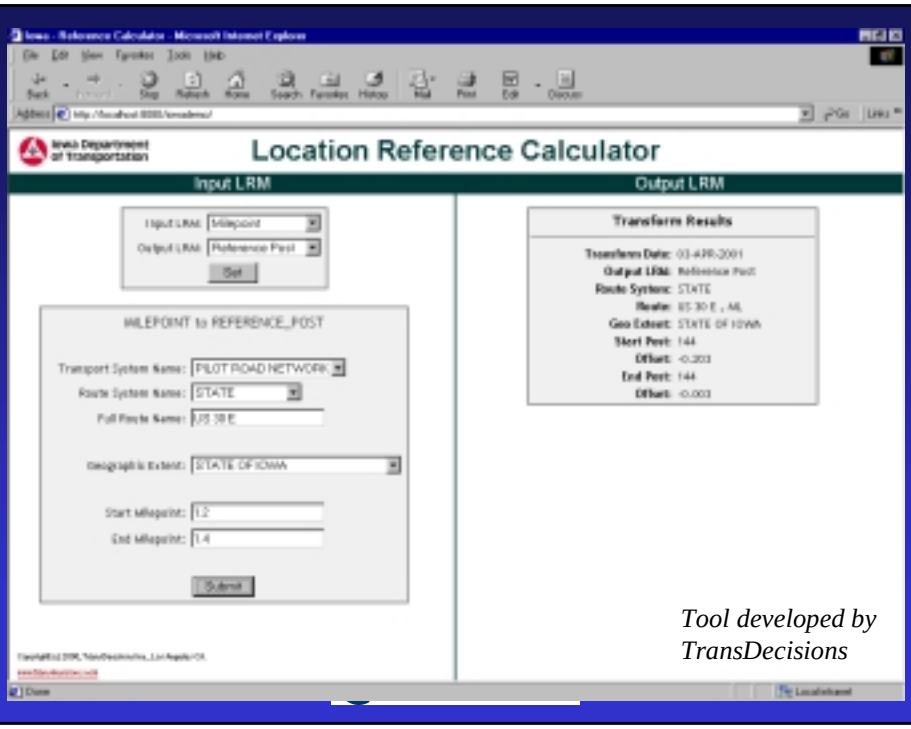
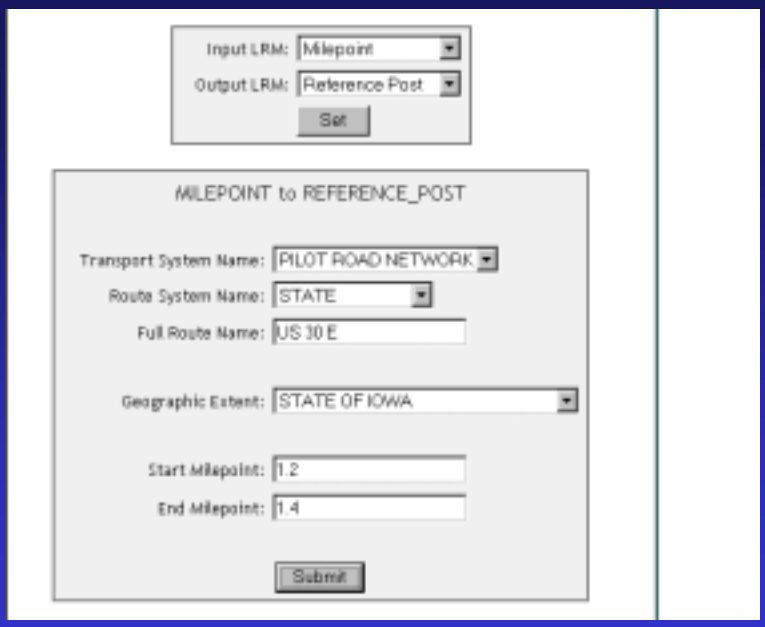
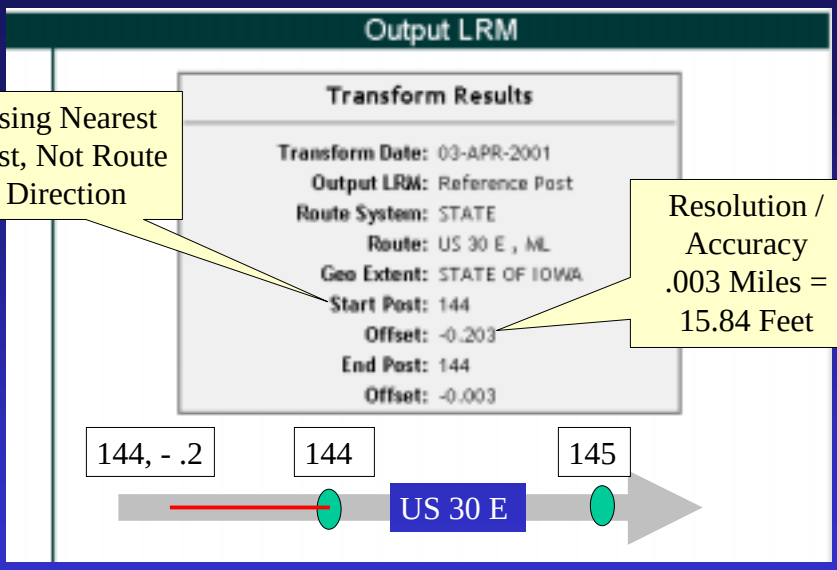


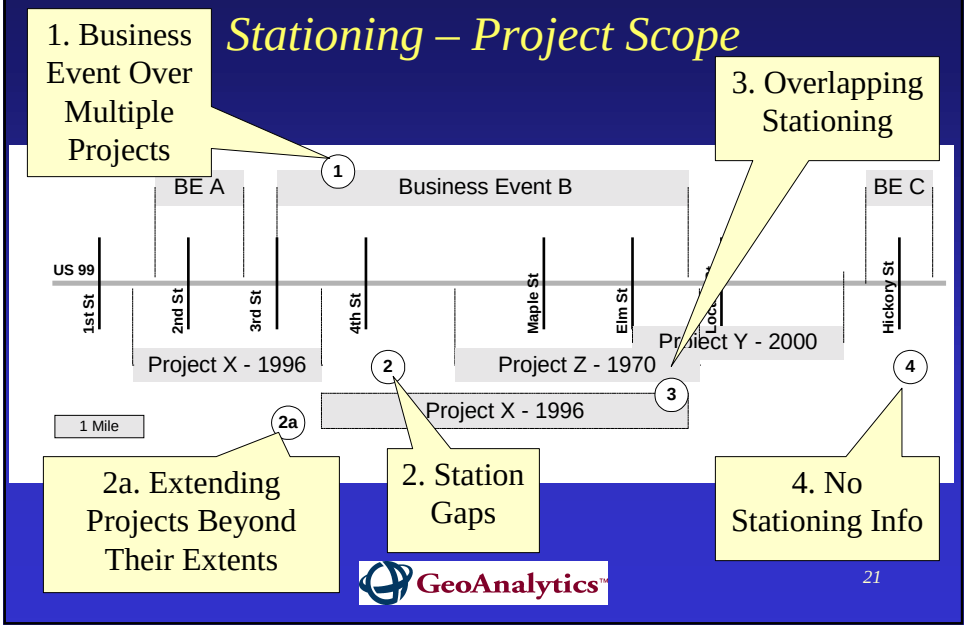
Tool developed by TransDecisions


Input LRM: Milepoint
Output LRM: Reference Post
Set
MILEPOINT to REFERENCE_POST
Transport System Name: PILOT ROAD NETWORK
Route System Name: STATE
Full Route Name: US 30 E
Geographic Extent: STATE OF IOWA
Start Milepoint: 1.2
End Milepoint: 1.4
Submit


Output LRM
Transform Results
Transform Date: 03-APR-2001
Output LRM: Reference Post
Route System: STATE
Route: US 30 E , ML
Geo Extent: STATE OF IOWA
Start Post: 144
Offset: -0.203
End Post: 144
Offset: -0.003
Using Nearest Post, Not Route Direction
Resolution / Accuracy .003 Miles = 15.84 Feet
144, - .2
144
145
US 30 E

Business Data and LLRM Extents

Stationing – Project Scope



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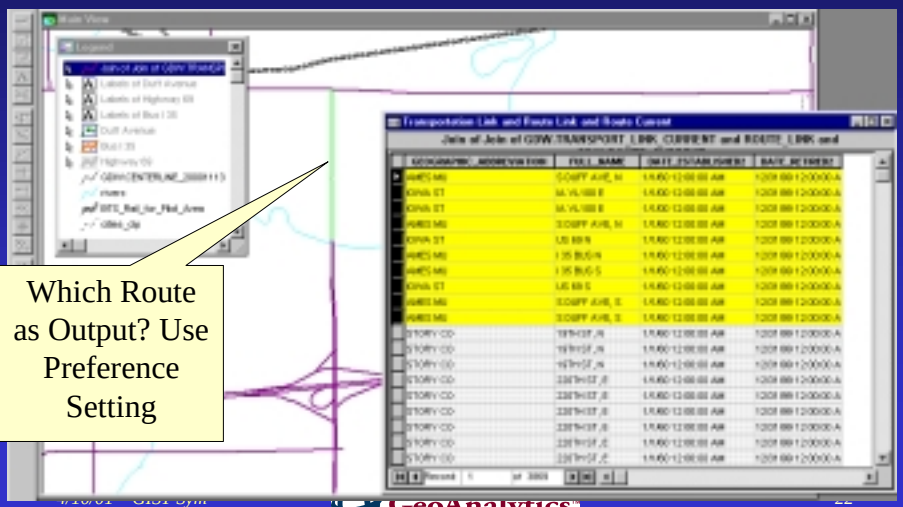
21

Intra-LLRM Overlap

Traversal Concurrencies



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Data Quality Consistency

Applying LLRM Business Rules

segmental.LST - Notepad

File Edit Search Help

```
--*****************************************************************************
SQL> -- Datum to LRS (Anchorsection 1000)
SQL> SELECT lineartransform.datum_to_segmental(1000, 2000, 4000,1002) from dual;

LINEARTRANSFORM.DATUM_TO_SEGMENTAL(1000,2000,4000,1002)
-------------------------------------------------------
SM({17-MAR-2001}, GIMS, 256737, 256736, 256743)

SQL>
SQL> --LRS to datum  (Anchorsection 1000)
SQL> SELECT lineartransform.segmental_to_datum(1002,256737) from d

LINEARTRANSFORM.SEGMENTAL_TO_DATUM(1002,256737)
-----------------------------------------------------------------------------
DT({17-MAR-2001}, {1000, 3,210.946, 2,426.002})

SQL>
```

Control Section with Homogeneous Attribution

Can Integrate with Other Specific Locations

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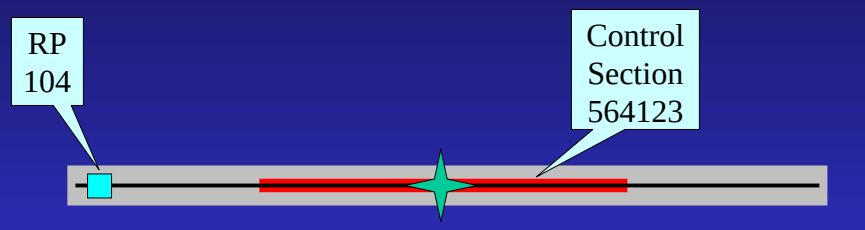
Illogical Transforms

Education, Education, Education, Smart Tools



US 30E RP 104+.20 → 564123 → US 30E RP 104+.15
RP 104+.25

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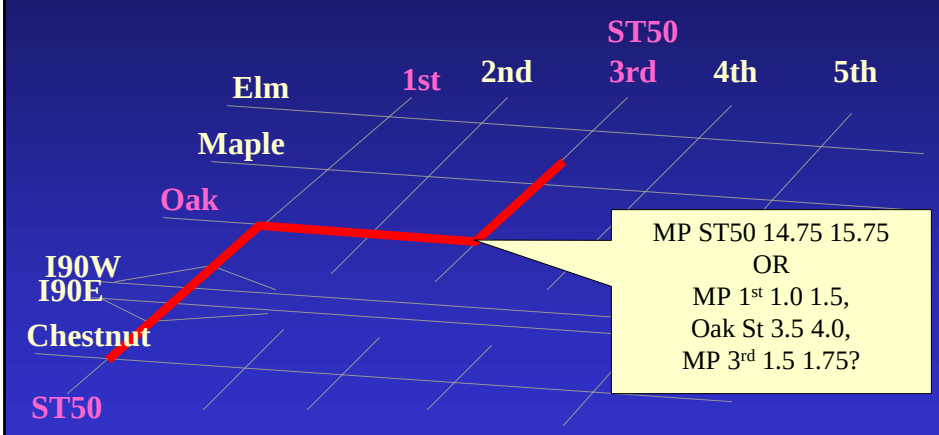
Multiple Location Output



MP ST50 14.75 15.75
OR
MP 1st 1.0 1.5,
Oak St 3.5 4.0,
MP 3rd 1.5 1.75?

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Multiple Output Management

segmental.LST - Notepad

File Edit Search Help

```
SQL>
SQL> -- Datum to LRS (Anchorsection 1229)
SQL> SELECT linearTransform.datum_to_segmental(1229, 6878.022, 8878.022,1002) from dual;

LINEARTRANSFORM.DATUM_TO_SEGMENTAL(1229,6878.022,8878.022,1002)
--------------------------------------------------------------------------------
<LinearReference><Date>17-MAR-2001</Date><SegmentalReference><Type>GIMS</Type><C
ontrolSectionList><Size>3</Size><ControlSection><SectionID>255748</SectionID></C
ontrolSection><ControlSection><SectionID>255747</SectionID></ControlSection><Con
trolSection><SectionID>255749</SectionID></ControlSection></ControlSectionList><
/SegmentalReference></LinearReference>


SQL>
SQL> --LRS to datum  (Anchorsection 1229)
SQL> SELECT linearTransform.segmental_to_datum(1002,255703)

LINEARTRANSFORM.SEGMENTAL_TO_DATUM(1002,255703)
--------------------------------------------------------------------------------
<LinearReference><Date>17-MAR-2001</Date><DatumReference><DatumSequence><Size>1<
/Size><DatumExtent><AnchorSection>1229</AnchorSection><StartOffset>1399.890</Sta
rtOffset><EndOffset>1570.179</EndOffset></DatumExtent></DatumSequence></DatumRef
erence></LinearReference>
```

How to Store a location that goes from one record to many? XML is one strategy.

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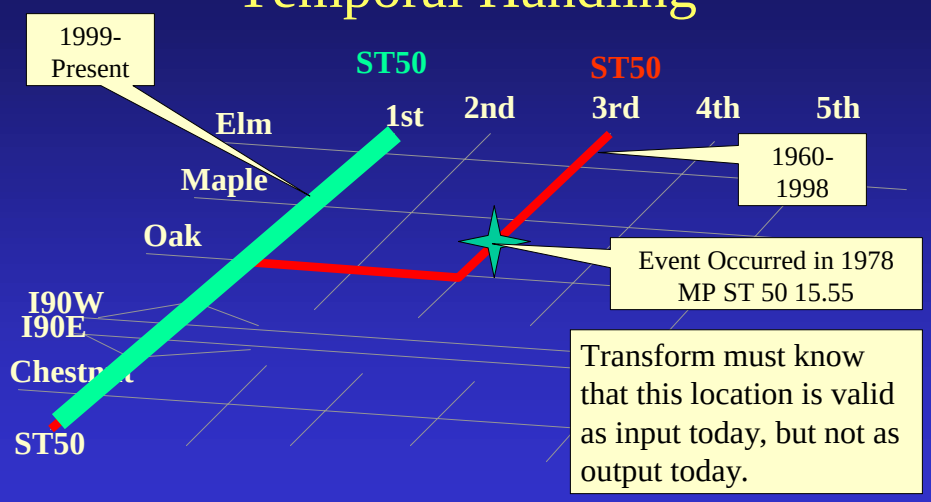
Temporal Handling



Transform Requirements
Conclusions

- Indirect Transform Assumes "From" Ignorance
  - Explicitly review all transform combinations
  - May need more info than you expect (preferences)
- Take the Time to Develop and Test Cases:
  - Point and Linear Events
  - Middle, End, Crossing Intersections/Linear Control
  - Simple / Complex Roadway Patterns

Transform Requirements
Conclusions

- Preference Setting for Output Transforms Gives Users much more flexibility
  - Specific Route Name (input)
  - Route Hierarchy (output)
  - Route Direction (output)
  - Stationing Project (output)
  - Temporal (processing)
  - Resolution (processing and output)

Transform Requirements
Conclusions

- Have Ways of Processing Legacy Data Formats
- Include Ability to Reduce Number of Output Locations
- Handle the Temporal Component

➡ Take the Time to Design
Test, then Deploy

Thanks!

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Dynamic Segmentation: From Spatial to Spatiotemporal

GIS for Transportation Symposium

April 9-11, 2001, Crystal City, VA

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&

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School of Engineering

University of Kansas, Lawrence, KS

MCDOT

2/13/02 11:23:32 AM

Acknowledgement

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in the

MCDOT Infrastructure Technology Center

Special Thanks to:

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George Stupski, Larry Wolfson,

Will Gardner, Jim Nelson, Tony Renaud

&Terry Peterson

MCDOT

Background

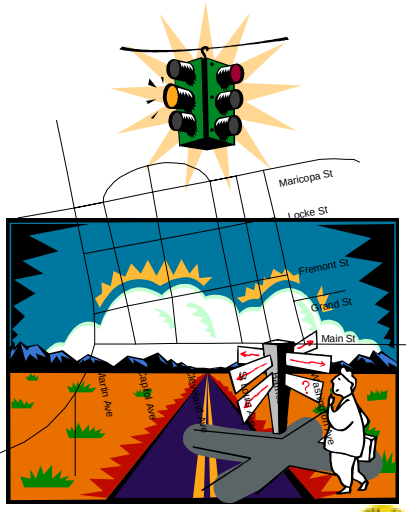
- Based on time-in-database and time-in-space researches
- Based on my research with the University of Kansas and practice at Maricopa County DOT in Arizona.
  - Feature-based Linear Data Model
  - Temporal Dynamic Segmentation
  - RoadRunner Version 1.2 in Production at Maricopa County DOT

Presentation Outline

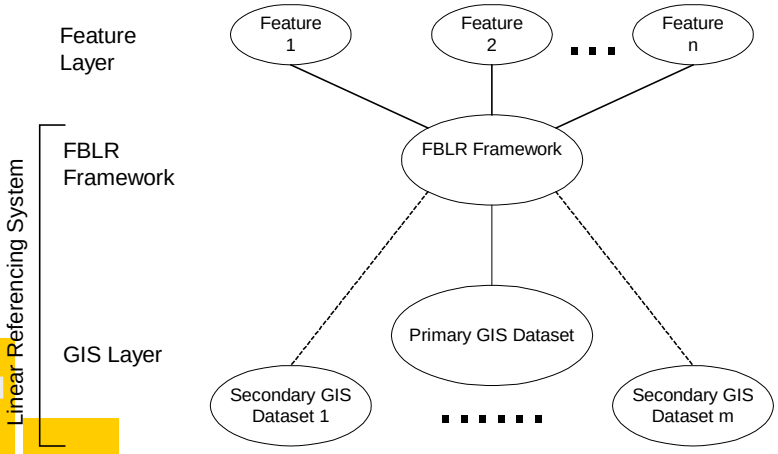
- Slide Presentation – 15 minutes
  - Concepts:
    - Key Terminology, FBLD Architecture, Network Hierarchy
  - Scope of Dynamic Segmentation:
    - Linear Network Versioning
    - Linear Data Processing
  - Temporal Assumptions in Classic Dynamic Segmentation
  - Segmentation Fundamentals
    - Spatiotemporal Segment Definition
    - Spatiotemporal Segment Topology
    - Spatiotemporal Segment Operations
  - Temporal Dynamic Segmentation
- Application Demo – 10 minutes
- Questions & Answer – 5 minutes

Feature Versus Object

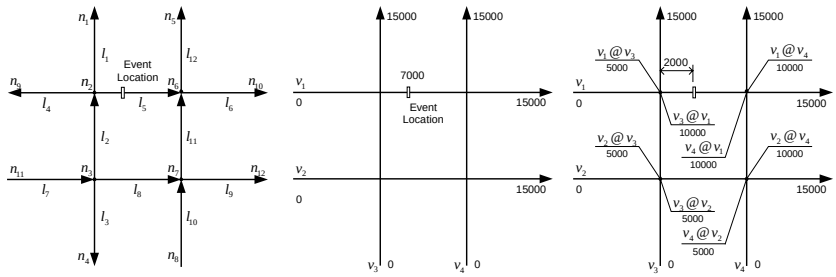
- Feature
  - Attribute of, or phenomenon related to, road network
  - Its geometry and location are represented by objects
- Object
  - Digital representation of road network
  - Geometry and location
- Location-based Approach
  - Object as modeling units
- Feature-based Approach
  - Features as modeling units



FBLD Layer Architecture



Network Hierarchy



Link-node Traversal Traversal-reference

GIS Datasets

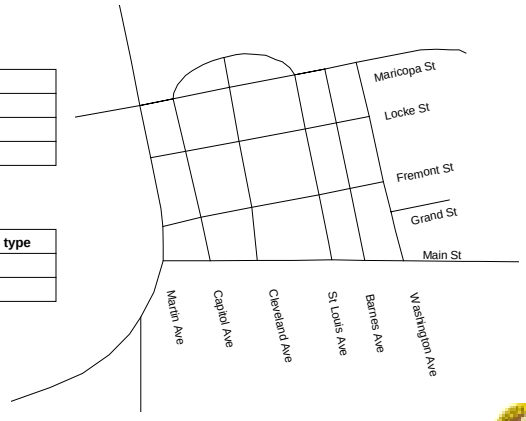
FBLR Framework

Dynamic Segmentation Characteristics

- Feature-feature Independence
- Feature-network Independence

Road	From-mp	To-mp	PCR
Main St	0.0	1.0	80
Main St	1.0	2.0	93
Main St	2.0	2.8	76

Road	From-mp	To-mp	Pavement type
Main St	0.0	1.5	Asp
Main St	1.5	2.8	Con



Dynamic Segmentation Scope

- Linear Network Maintenance and Versioning
  - Tools to build and maintain traversal network
- Linear Data (Feature) Processing
  - Geocoding
    - As a result of feature-network independence
  - Overlay
    - As a result of feature-feature independence
  - Maintenance
    - Spatiality or spatiotemporality is decomposable

Road	From-mp	To-mp	Pavement type
Main St	0.0	1.5	Asphalt
Main St	1.5	2.8	PCC

Asphalt *Concrete*

Road	From-mp	To-mp	Pavement type
Main St	0.0	15	Asphalt
Main St	1.5	1.9	PCC
Main St	1.9	2.4	Compsite
Main St	2.4	2.8	PCC

Asphalt *Composite* *Concrete* *Concrete*

Classic Dynamic Segmentation

- Feature Classification
  - Point feature & Linear feature
- Temporal Assumptions
  - Feature data and target network share the temporal existence
  - History data is discarded once replaced by the current data
    - In both network maintenance and in feature data maintenance
  - Overlaying feature data share the temporal existence

Road	At-mp	Date	Severity
Main St	0.2	2000.1.5	INJ
Main St	0.25	1975.3.5	PO
Main St	1.5	1985.8.3	PO
Main St	2.0	1995.6.7	FT

Road	From-mp	To-mp	Pavement type
Main St	0.0	15	Asphalt
Main St	1.5	1.9	PCC
Main St	1.9	2.4	Compsite
Main St	2.4	2.8	PCC

Spatiotemporal Segment Definition

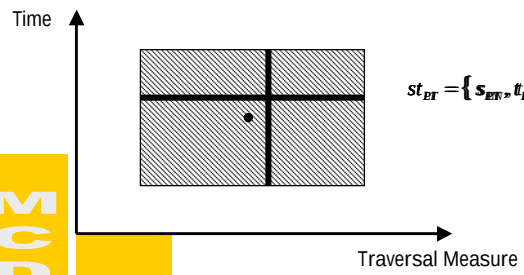
- A segment can be mapped in a Traversal-Time space
  - Linear Term: pavement type
  - Linear Instant: sweeping activities
  - Point Term: traffic signs
  - Point Instant: accidents

$$t_{PER} = \{ [t_i, t_j) \mid t_i, t_j \in dom(T), t_i \le t_j \}$$

$$s_{LN} = \{ v, [m_i^v, m_j^v) \mid v \in dom(V),\ m_i^v, m_j^v \in dom(M^v),\ m_i^v \le m_j^v \}$$

$$t_{INS} = \{ t_i \mid t_i \in dom(T) \}$$

$$s_{PT} = \{ v, m^v \mid v \in dom(V),\ m^v \in dom(M^v) \}$$

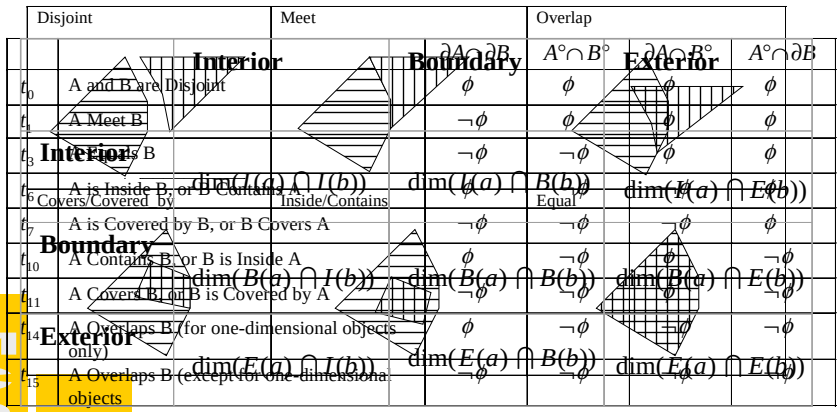


$$st_{PT} = \{ s_{PTV}, t_{INSR} \mid s_{PTV} \in dom(S_{PTV}), t_{INSR} \in dom(T_{INSR}) \}$$

Segment Topological Relationships(I)

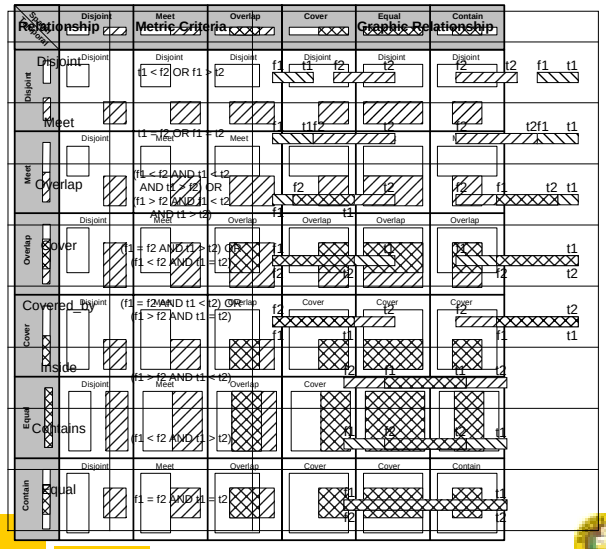
- Egonhofer's General Topological Relationship Framework
- The DE-9IM ([OGC 1999])

	Disjoint	Meet		Overlap		
		$\partial A \cap \partial B$	$A^\circ \cap B^\circ$	$\partial A \cap B^\circ$	$A^\circ \cap \partial B$
t_0	A and B are Disjoint	ϕ	ϕ	ϕ	ϕ
t_1	A Meet B	$\neg\phi$	ϕ	ϕ	ϕ
t_3	A Equals B	$\neg\phi$	$\neg\phi$	ϕ	ϕ
t_6	A is Inside B, or B Contains A	ϕ	$\neg\phi$	ϕ	ϕ
t_7	A is Covered by B, or B Covers A	$\neg\phi$	$\neg\phi$	$\neg\phi$	ϕ
t_{10}	A Contains B, or B is Inside A	ϕ	$\neg\phi$	ϕ	$\neg\phi$
t_{11}	A Covers B, or B is Covered by A	$\neg\phi$	$\neg\phi$	ϕ	$\neg\phi$
t_{14}	A Overlaps B (for one-dimensional objects only)	ϕ	$\neg\phi$	$\neg\phi$	$\neg\phi$
t_{15}	A Overlaps B (except for one-dimensional objects	$\neg\phi$	$\neg\phi$	$\neg\phi$	$\neg\phi$



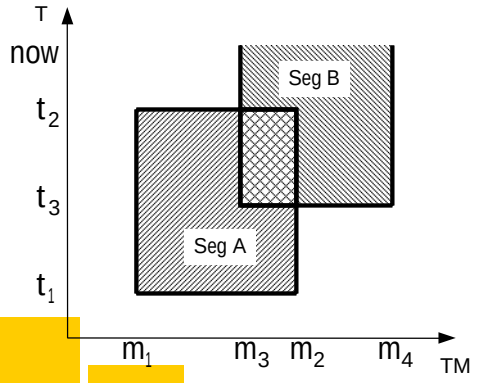
Segment Topological Relationships(II)

2-D Segment Relationships



Basic Segment Operations

- The set operations construct the basic segment operations
  - Set Intersection
  - Set Difference
  - Set Union



$A \ominus B$

Spatiotemporal Segment Join Operation

$R_i = \{K_i, A_{i1}, \ldots, A_{im}, S, T\}$ be a schema for spatiotemporal segments

$S = \{V, M_B^V, M_E^V\}$ for linear sub-schema, or

$S = \{V, M_A^V\}$ for point sub-schema

$T = \{T_B, T_E\}$ for a term sub-schema, or

$T = \{T_A\}$ for an instant sub-schema

$R_i^{'} = R_i - T - S$ as the non-spatiotemporal sub-schema of R_i

$r_i(R_i)$ a relation on schema R_i

x_i a tuple in relation r_i

$x_i(\ )$ projection of x_i on given attribute(s)

ϕ denotes the value of null

$x_i(S)$ defines a spatial location (linear or point) for tuple x_i

$x_i(T)$ defines a time (term or instant) for tuple x_i

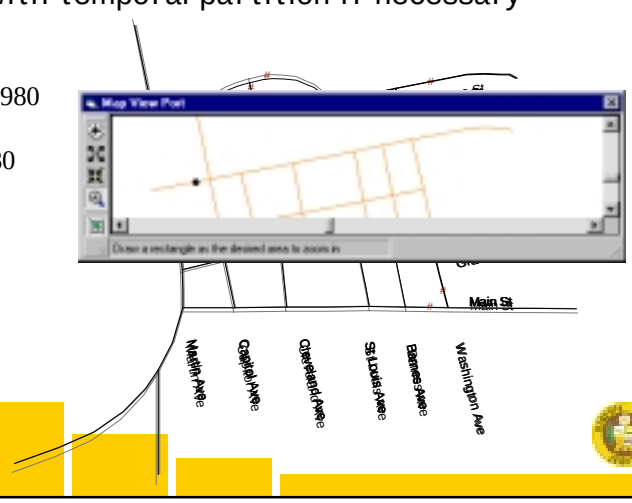
$$
\begin{aligned}
r_1\ ST-Join\ r_2 = \{\, x_3 \mid\ & x_3(R_1^{'}) = x_1(R_1^{'}) \wedge \\
& x_3(R_2^{'}) = x_2(R_2^{'}) \wedge \\
& x_3(S) = x_1(S) \cap x_2(S) \wedge \\
& x_3(T) = x_1(T) \cap x_2(T) \wedge \\
& x_1(S) \cap x_2(S) \neq \phi \wedge \\
& x_1(T) \cap x_2(T) \neq \phi \ \}
\end{aligned}
$$

Temporal DynSeg - Network Versioning

- Composite versioning approach for basic network
- Composite versioning approach for traversal network with temporal partition if necessary

Prior to 1/1/1980

After 1/1/1980

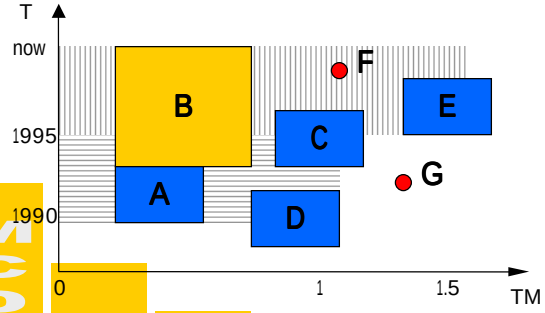


Temporal DynSeg – Segment Geocoding

Configuration	State	Example
Mappable	One-to-one	A, F
	One-to-many	B
Partially mappable	One-to-one	D, E
	One-to-many	C
un-mappable	NA	G

Main St: New alignment since 1995

Main St: Alignment from 1990 to 1995

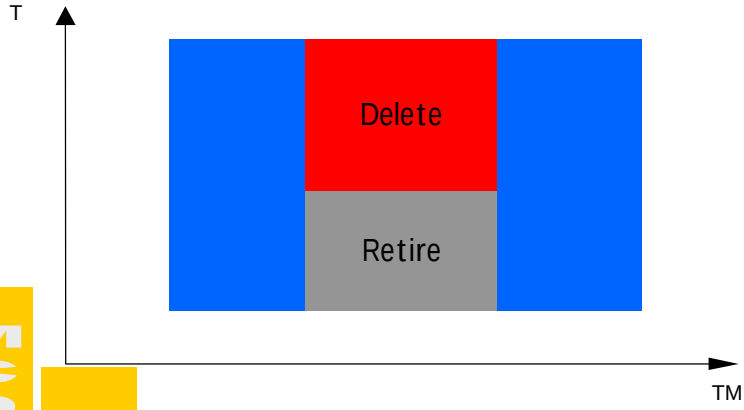


G: Collision occurred on Main St at 1.3 mi. on July 13th 1992.

1993.

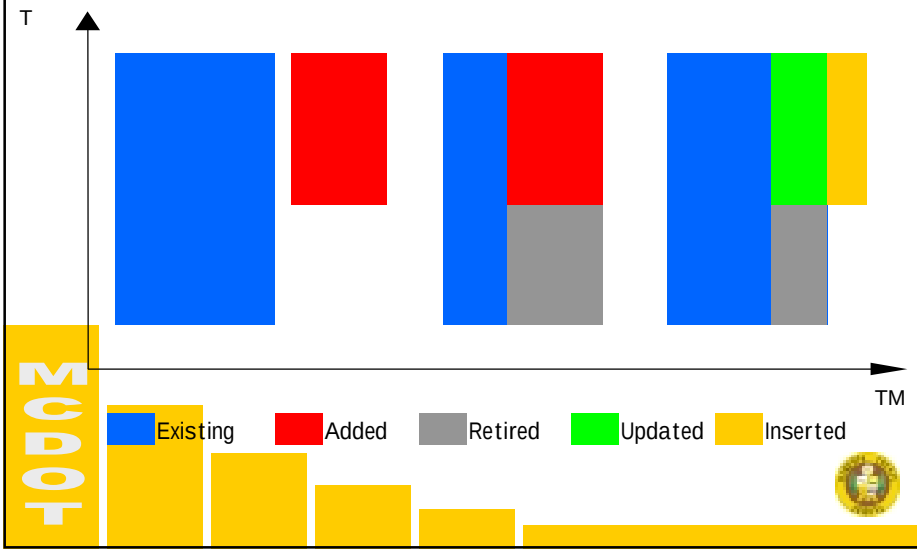
Temporal DynSeg – Maintenance (I)

- Insert, Update, Delete



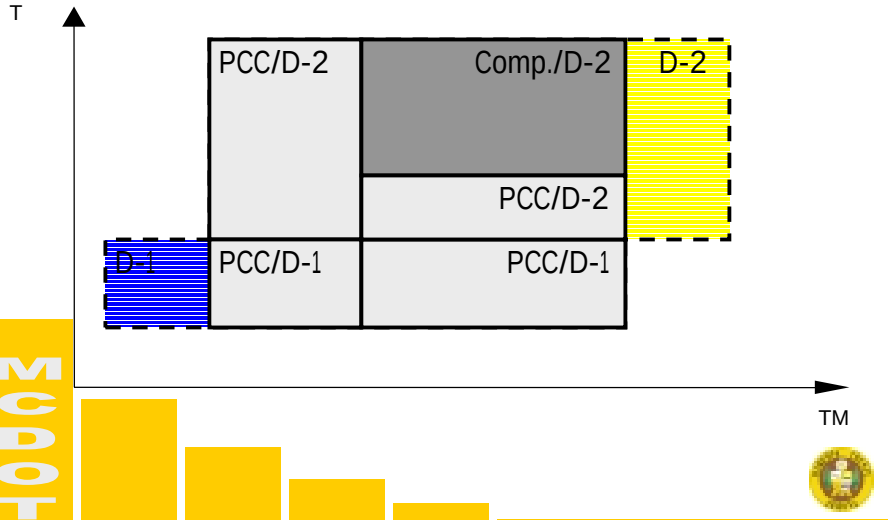
Temporal DynSeg – Maintenance (II)

- Topological Relationship and Maintenance Operations



Temporal DynSeg – Overlay

- Pavement Type overlays on Maintenance District



Georgia Department of Transportation

Partnerships for Centerline Maintenance

The Challenges of Maintaining State Transportation Basemaps

GIS-T 2001

Overview

- GIS @ GDOT
- Partnership Model
- Phase I - Public Org Partnership
- Maintenance Components

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GIS @ GDOT

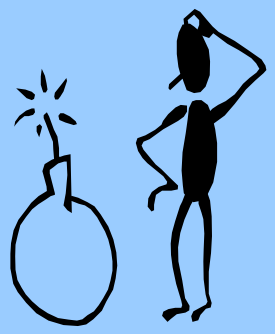
- **5 Year Development Effort**
  - Mylar Conversion
  - Digital Line Graph Feature (DLG-F)
  - Corrected to 1993 DOQQ's
  - 1:12,000 National Map Accuracy Standards
  - Transportation Framework

"Seamless" GIS Presentation

- Clean Representation
  - Uniform scale
  - One projection
  - Vertical Integration
- Flexible Mapping

Planned Development

- Addressing & Route Enhancements
- Roadway Facilities
- Transit, Rail, Airports, Ports
- Environmental Features
- Photolog
- Elevation Models



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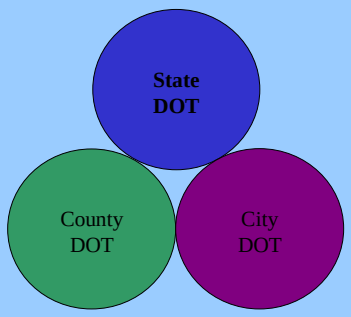
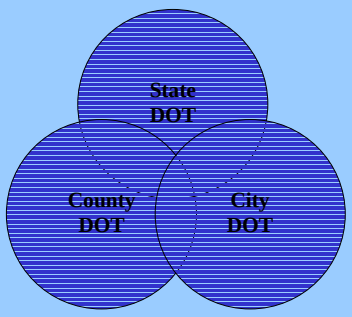
Georgia Transportation Data

Old World



New World



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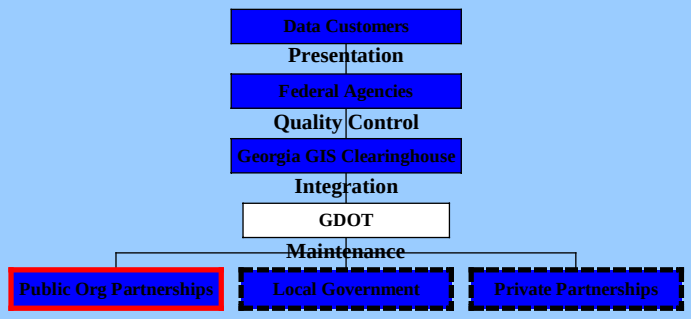
Partnership Model

1. **Data is only as good as the source**
2. **Better sources and development opportunities exist at national and local levels**
3. **Standardization enhances the ability to take advantage of those opportunities**
4. **Successful maintenance incorporates each opportunity into an overall support strategy**

Critical Success Factors

- Relationship with the "data source"
- Knowledge of Opportunities
- Understanding Standards
- Support Resources
  - Technical Oversight
  - Financial
  - Tools

Partnership Architecture



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Best Practices

- Understand your limitations
- Develop a sustainable architecture
- Be cost effective
- Start small
- Field test in-house
- Always pilot
- Plan implementation
- Actively monitor
- Control implementation

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Regional Development Centers

- Maintain GIS for local governments to support planning
- Provide GIS support services
- Maintain strong working local relationships

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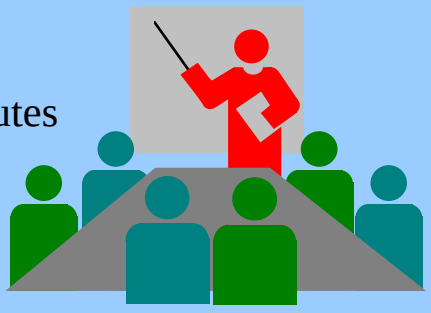
Objectives

- Identify roads
- Collect centerlines
- Collect basic attributes
- Quality control
- Processing
- Metadata



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Materials

- Trimble - ProXRS
- Satellite DGPS
- Trimble Pathfinder Office
- ESRI - ArcView & ArcInfo
- RTSE - SMMS

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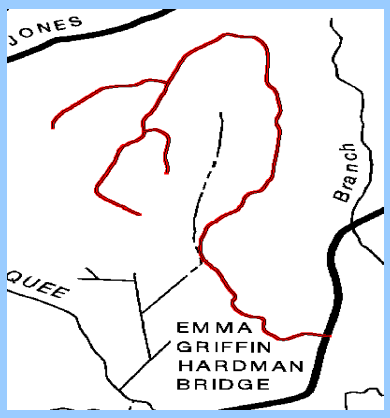
Maintenance Components

Consistency

Completeness

Accuracy

Currency



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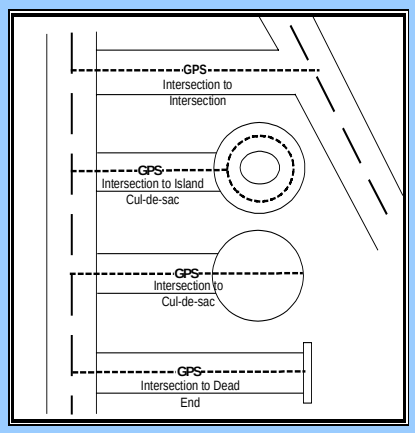
Consistency

- ***Data Collection Standards***
  - Data Dictionary
  - Equipment Parameters
  - Common Scenarios
- ***Processing Standards***
  - Software Settings
  - QA/QC
  - Metadata
- ***Delivery Standards***
  - Formats
  - Data Transfer



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Completeness

- All roads not on the “map”
- Divided Highways
- Non-field verified roads
- Work with GDOT Road Inventory Crews
- Involve locals
- Data without metadata is incomplete

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Accuracy

- Starts with the Equipment
  - Use 12 Channels
  - Set the Collection Parameters
  - Over-sample
- Satellite DGPS
  - Post-Processing?
- Depends on the Collector
  - Stamp the Data

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Currency

- Version Control
- Automated Workflow Processing
- Annual Updates to Instant Updates

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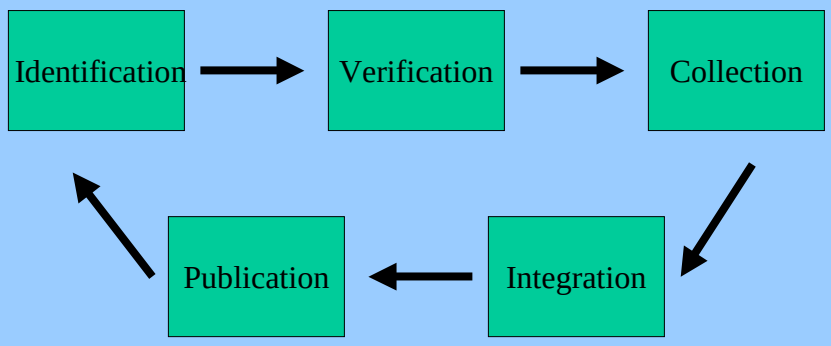
Maintenance Process



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Georgia Department of Transportation

Questions?

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(404) 463 - 2840

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Developing A Statewide Transportation Dataset

Serving Both

Texas DOT's Linear Measurement System

and the GIS Community

Key Points

- StratMap transportation data layer integrates multiple data sources to create a single road network for Texas
- New Texas Linear Measurement System requirements drove the StratMap network specifications
- Incorporates a robust data model designed to meet TxDOT's requirements for spatial and temporal queries of transportation data

Texas StratMap Program

- Legislative Mandated Program
- Multi - Year
- Cost - Sharing
- 75% Funded by Federal Government and State of Texas

Texas, Digitally Remastered

- Digital Orthophotos
- Digital Elevation Models
- Hydrography
- Soils
- Contours
- Boundaries
- Transportation

Integrating Data From So Many Sources

- County Road GPS Data
- Digital Orthophotos
- Large Scale Local Data
- TxDOT CAD/GIS Data
- 1:24,000 USGS DRG Data
- TxDOT County Map Books and Sheets

StratMap Transportation Layer

Data Model

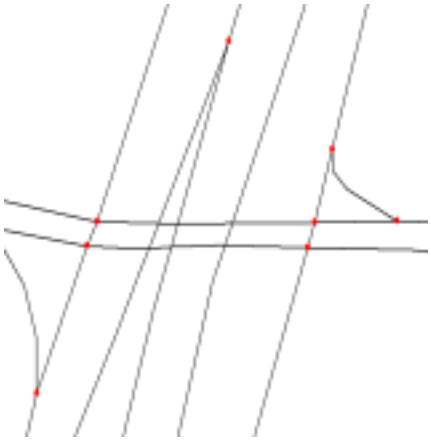
Goals of the Data Model

- Single data set for State and local roads
- Facilitate the integration of transportation networks from several sources
- Support TxDOT's existing and future LRS (TLMS)

Integrating Networks from Different Sources

- "Railroad" Network
- Intersection Points (IPs)
- StratMap Unique Identifier Scheme
- 5 Table Database structure

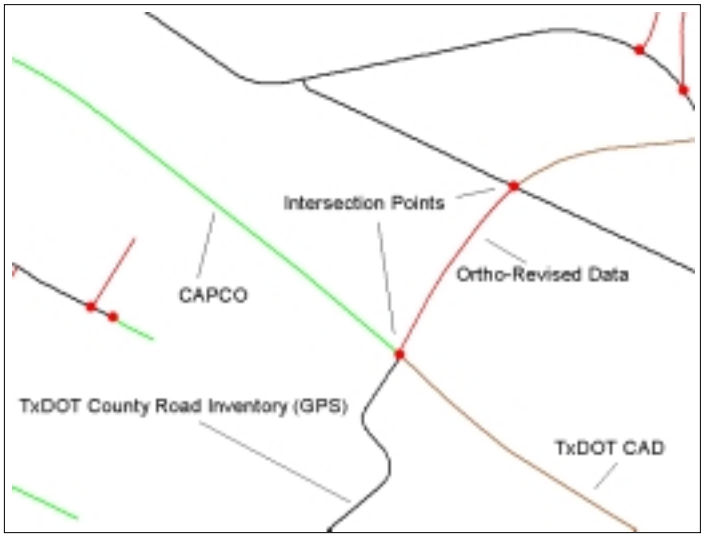
“Railroad” Centerline Network



- Nodes only at physical intersections
- No connectivity at overpasses
- Exception- Nodes required at source boundaries to facilitate network updates

Intersection Points

- Intersection points occur at nodes but only a subset of nodes are intersection points
- Provide unambiguous point of connection between two or more network data sets or tiles
- Collected from orthophotos or GPS
- Attribution contains ID of connecting segments



Intersection Point Table

Field	Type & Domain	Description	Example
IP_ID	CHAR(16)	Intersection Point Identifier. ID is the concatenation of latitude & longitude of the IP location.	3312345@10012345
Category	CHAR(4)	Describes type of IP. IPs can be between TxDOT on- and off-system network, between counties, between county and city, etc.	ONCO, ONOF, ONPR, etc.
Road1	CHAR(10)	10 character StratMap ID of one of the road features sharing the IP	
Road2	CHAR(10)	10 character StratMap ID of the other road feature sharing the IP.	

StratMap IDs

- 10 digit UID
- JJJNNNNNNN Where:
  - JJJ – Jurisdiction code to allow for creation of UIDs at the local jurisdiction.
  - NNNNNNN – sequential number generated for each feature
- Features that cross tile boundaries get a new ID each time they cross

Database Structure

- Feature Attribute Table – All Segments
- Intersection Point Table
- On-System Segment Table
- On-System Ramp and Connector Table
- Off-System Segment Table (required because of the non-standard nature of Off-System attributes)

Segment Tables with Significant Fields

Feature Attribute Table – All Features

StratMapID	CHAR(10)	0250000001
F_Type	CHAR(4)	ONSS, ONSR, OFSS, etc.
Source	Char(3)	
LocalID	VARCHAR (20)	

Off-Sys Segment Table

StratMapID	CHAR(10)	StratMap Unique Identifier	0120012345
FullStName	VARCHAR(40)	Redefined primary street	W Guadalupe St
Category	NUMBER(4)	Off-system roadway feature classification	1000, 2000, etc.

Ramp and Connector Table

StratMapID: CHAR(10)	0120012345
Prefix CHAR(2)	{XX}
From: VARCHAR(35)	USF-183 N/S, IHM-90 E/W
To: VARCHAR(35)	IHF-183 N/S, USM-90 E/W

On-Sys Segment Table

StratMapID: CHAR(10)	StratMap Segment Unique Identifier
Prefix CHAR(2)	Designated roadway type.
Roadbed: CHAR(1)	Roadbed type. Only TxDOT options are included.
Road #: NUMBER(4)	Designated highway number
Suffix: CHAR(1)	Split designation for single highway (e.g. IH-35 E/W)
Dir: CHAR(1)	Posted direction of travel
Direction: CHAR(1)	Directionality of roadbed
Status: CHAR(1)	Represents the current status of the segment in transportation terms
Inventory: DATE	Date segment inventoried
Method: NUMBER(2)	Method used to collect segment geometry
Sigma: NUMBER(3)	Two standard deviation estimate of centerline location confidence

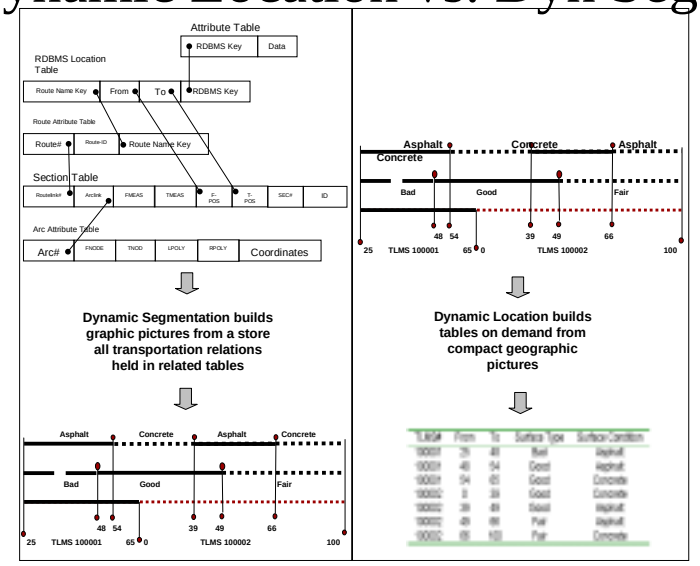
LRS Support

- The Texas Linear Measurement System (TLMS) was developed to overcome drawbacks of traditional LRS with dynamic segmentation
- Based on Anchor Points and Dynamic Location Objects (DLO) – AP is separate entity to intersection points
- On-System Tables come straight from the TLMS design

TLMS

- “Railroad network” is segmented by anchor points at 12-15 km intervals
- “Anchor Sections” are stored in SDE or geodatabase as measured objects (polyline M) and become the “ruler” for linear measurements.
- Transportation “events” are stored as BLOBS
- Temporal control through check-in and check-out dates

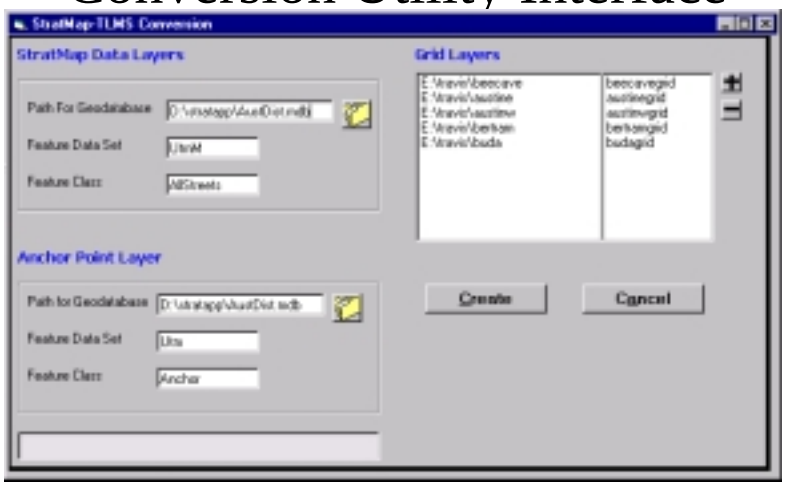
Dynamic Location vs. Dyn Seg



StratMap to TLMS Conversion Utility

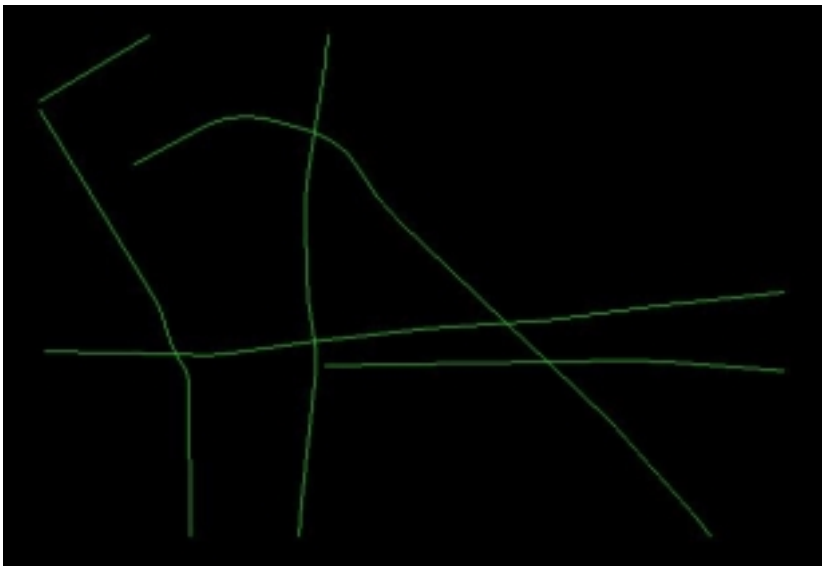
- Developed in VBA for ArcInfo 8 Geodatabase
- Uses “Railroad Network”, Anchor Point layer and USGS DEMs (in GRID format) as input to create TLMS DLO ruler
- Measures derived by overlaying vectors over GRID to get true 3D distances
- Easily modified to create other rulers (mile point, control section, reference marker)

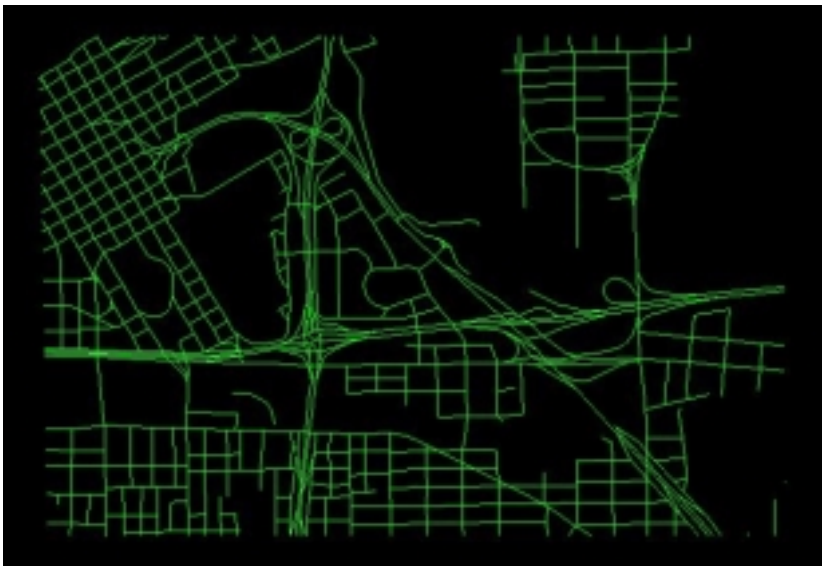
Conversion Utility Interface



StratMap Transportation Layer

Data Collection





Feature Attributes

Feature	No. Attributes
Intersection Point	4
ON-System Segment	11
ON-System Ramp & Connector	9
Off-System Segment	14

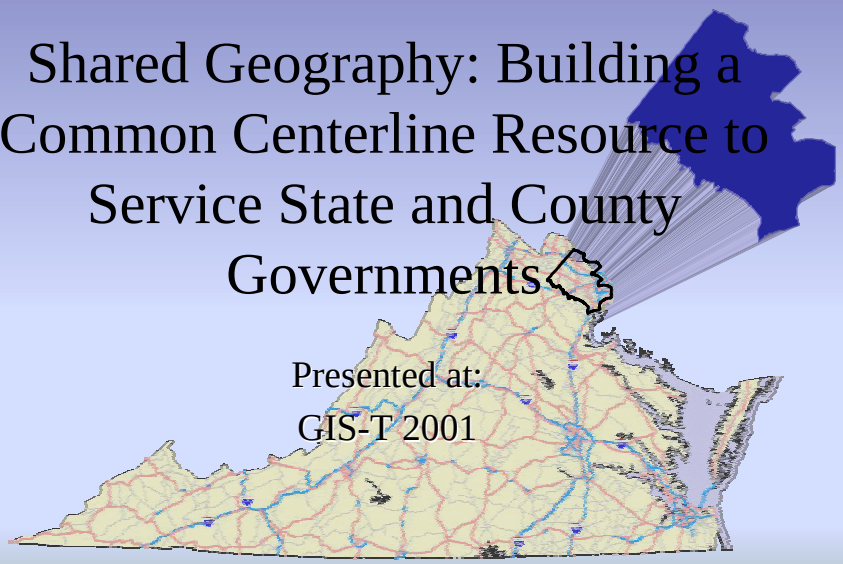
Conclusion

- Transportation data layer designed for multiple users
- Data model developed first to meet TxDOT requirements
- Data integration techniques follow data model specifications
- Result – a single transportation data layer for the whole of Texas
- TLMS built on the enhanced On-System network

Shared Geography: Building a Common Centerline Resource to Service State and County Governments

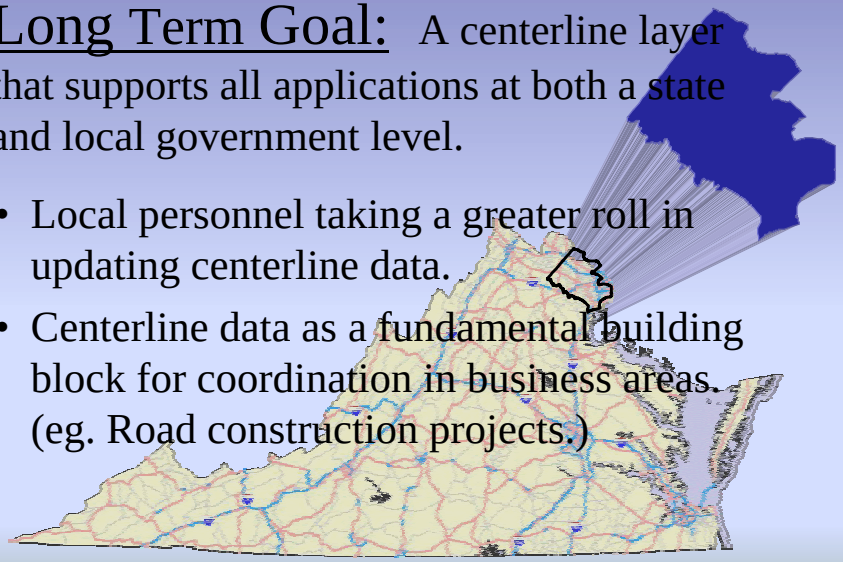
Presented at:

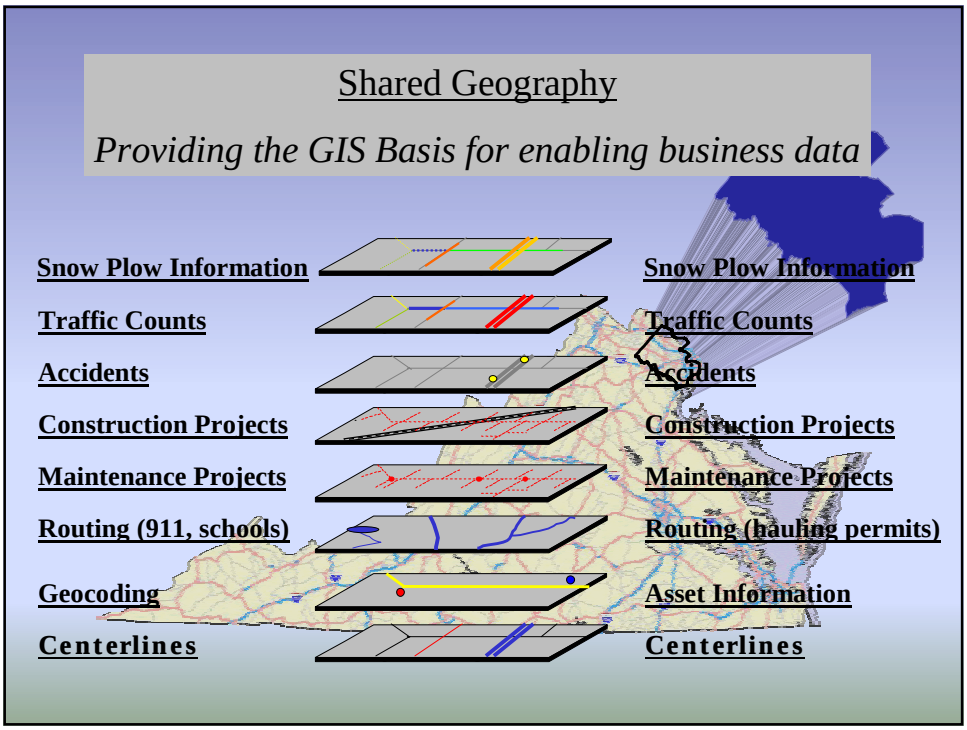
GIS-T 2001

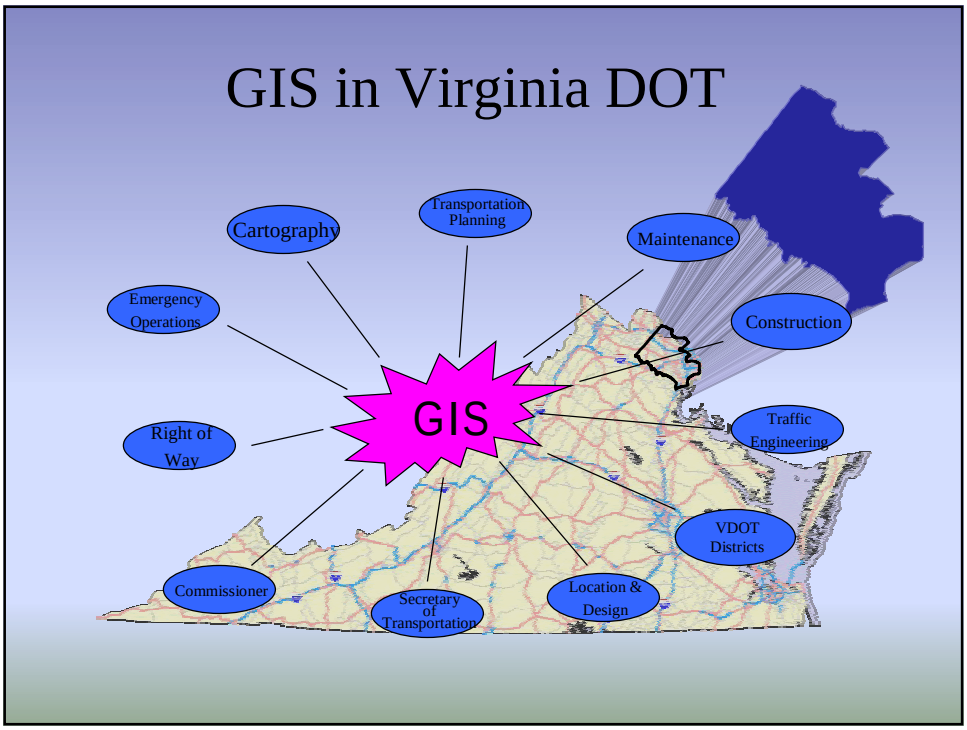


Long Term Goal: A centerline layer that supports all applications at both a state and local government level.

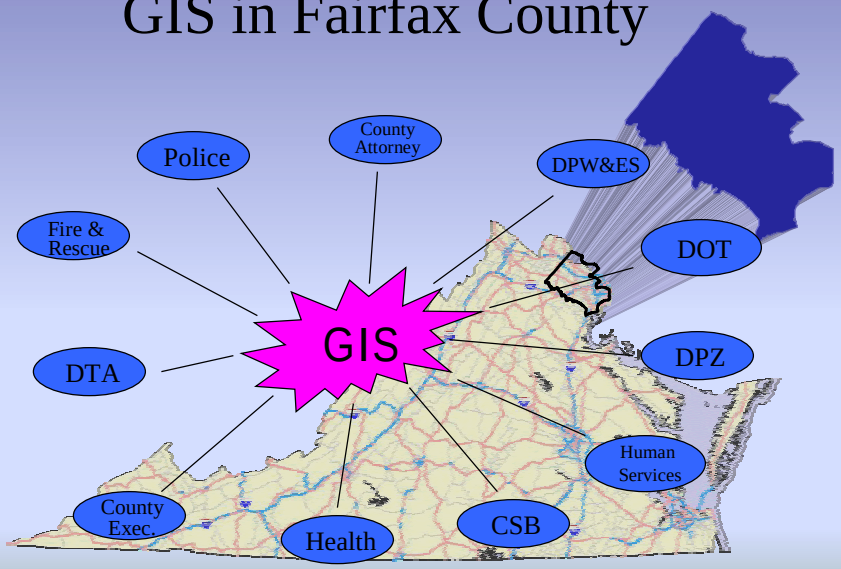
- Local personnel taking a greater roll in updating centerline data.
- Centerline data as a fundamental building block for coordination in business areas. (eg. Road construction projects.)



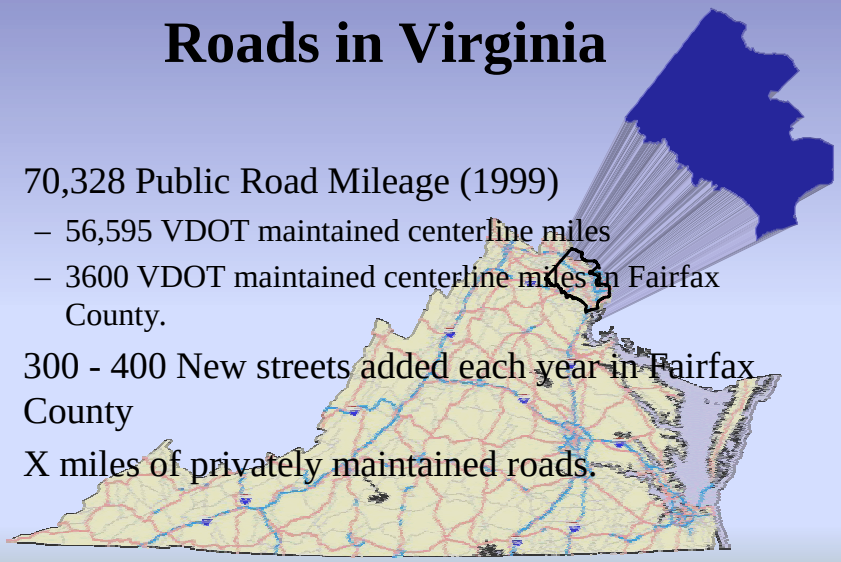

Shared Geography
Providing the GIS Basis for enabling business data
Snow Plow Information
Traffic Counts
Accidents
Construction Projects
Maintenance Projects
Routing (911, schools)
Geocoding
Centerlines
Snow Plow Information
Traffic Counts
Accidents
Construction Projects
Maintenance Projects
Routing (hauling permits)
Asset Information
Centerlines


GIS in Virginia DOT
GIS
Cartography
Transportation Planning
Maintenance
Emergency Operations
Construction
Right of Way
Traffic Engineering
VDOT Districts
Commissioner
Secretary of Transportation
Location & Design

GIS in Fairfax County



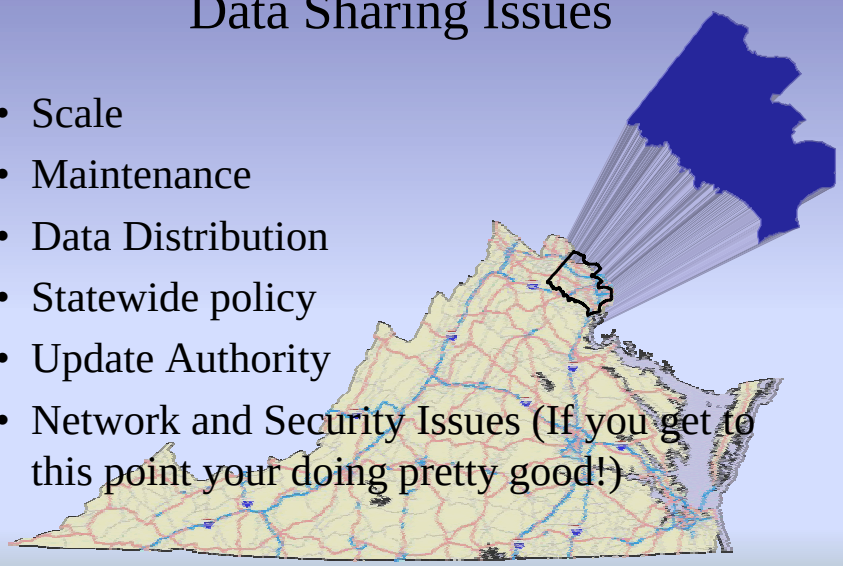
Roads in Virginia



- 70,328 Public Road Mileage (1999)
  - 56,595 VDOT maintained centerline miles
  - 3600 VDOT maintained centerline miles in Fairfax County.
- 300 - 400 New streets added each year in Fairfax County
- X miles of privately maintained roads.

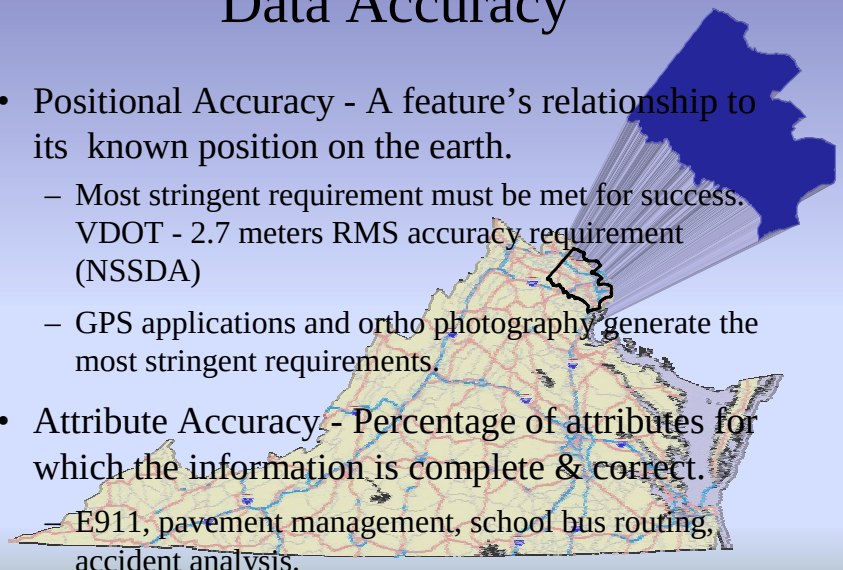
Data Sharing Issues

- Scale
- Maintenance
- Data Distribution
- Statewide policy
- Update Authority
- Network and Security Issues (If you get to this point your doing pretty good!)

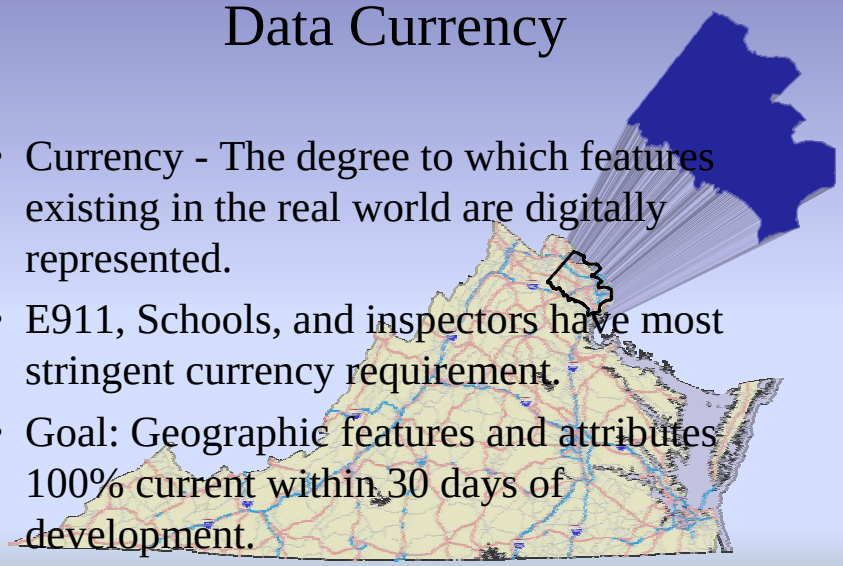


Data Accuracy

- Positional Accuracy - A feature's relationship to its known position on the earth.
  - Most stringent requirement must be met for success. VDOT - 2.7 meters RMS accuracy requirement (NSSDA)
  - GPS applications and ortho photography generate the most stringent requirements.
- Attribute Accuracy - Percentage of attributes for which the information is complete & correct.
  - E911, pavement management, school bus routing, accident analysis.

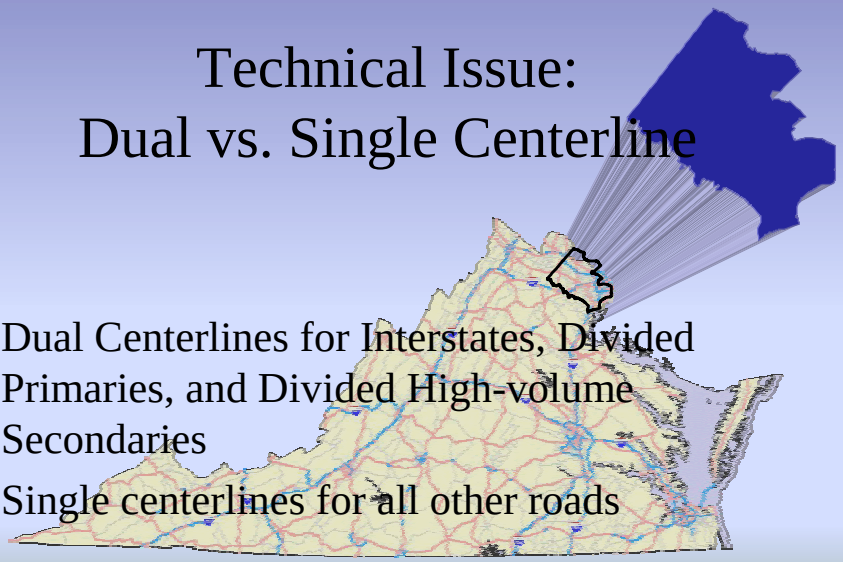


Data Currency



- Currency - The degree to which features existing in the real world are digitally represented.
- E911, Schools, and inspectors have most stringent currency requirement.
- Goal: Geographic features and attributes 100% current within 30 days of development.

Technical Issue: Dual vs. Single Centerline

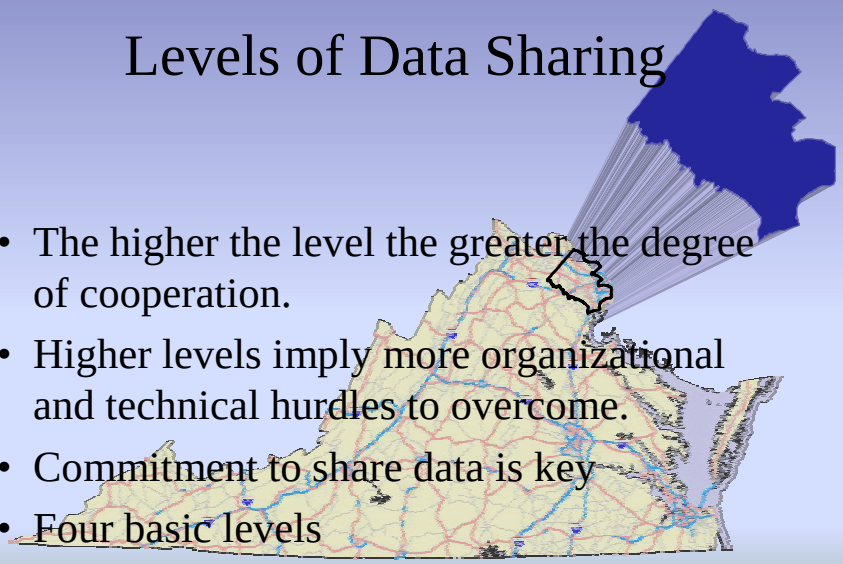


- Dual Centerlines for Interstates, Divided Primaries, and Divided High-volume Secondaries
- Single centerlines for all other roads

Dual vs. Single Centerline

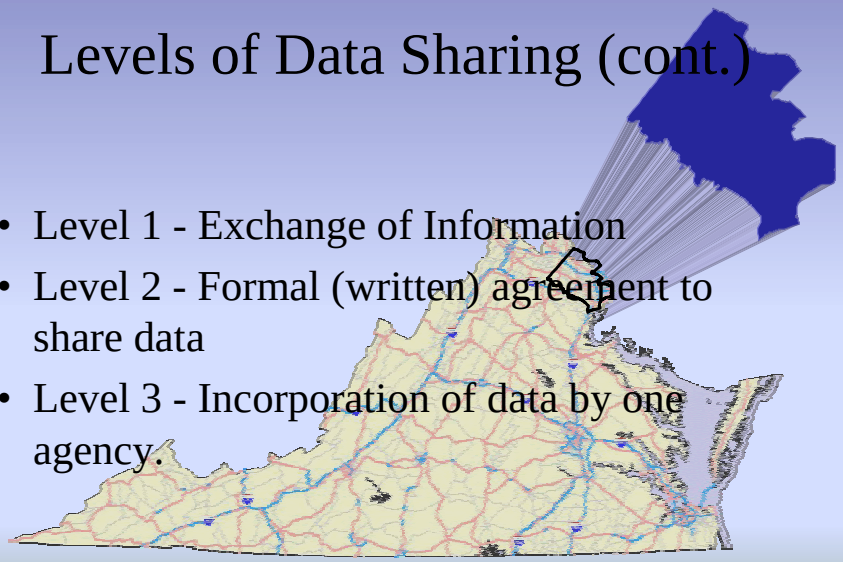
Dual Centerline Placement

Levels of Data Sharing



- The higher the level the greater the degree of cooperation.
- Higher levels imply more organizational and technical hurdles to overcome.
- Commitment to share data is key
- Four basic levels

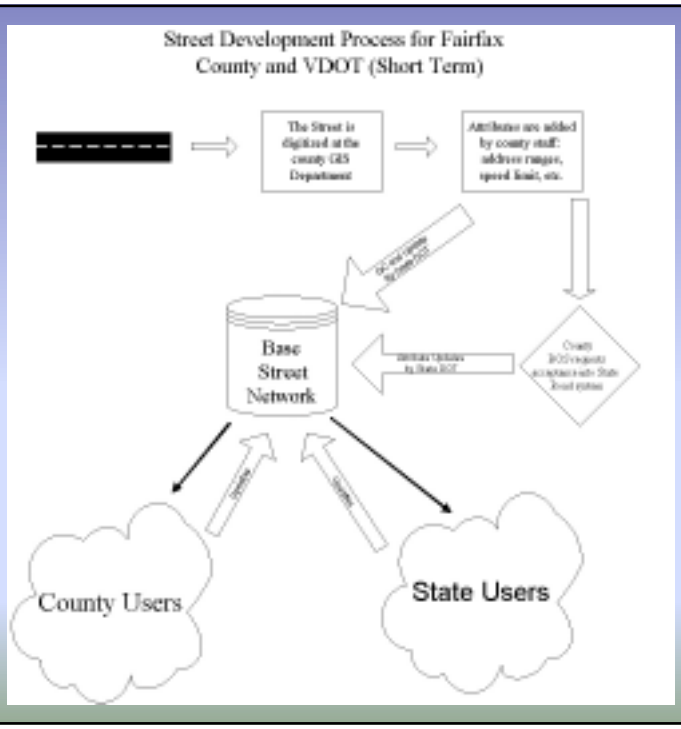
Levels of Data Sharing (cont.)



- Level 1 - Exchange of Information
- Level 2 - Formal (written) agreement to share data
- Level 3 - Incorporation of data by one agency.

Level 4
Dual Updates to Common Base

- Single data set that serves multiple organizations.
- Different elements updated by each organization.
- Easy user access to all transportation related information. (ex. Accident locations)
- Facilitates inter-agency cooperation.
- Taxpayers save $$$.



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Virginia Department of Transportation

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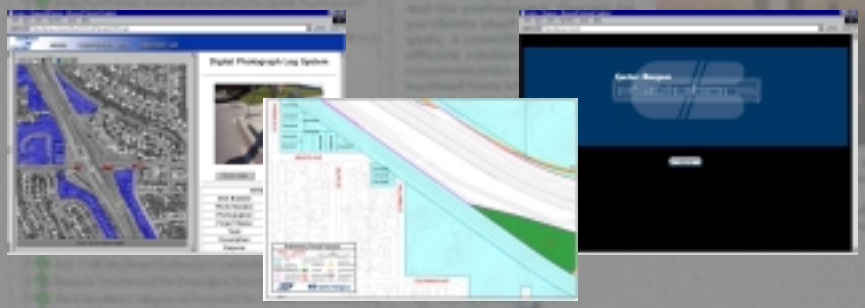
widner_dk@vdot.state.va.us

Design and Deployment of Internet-Based GIS Tools for the Southeast Corridor Parcel Acquisition and Right-of-Way Management



Matt Erker, Ken Carlson and Philip Lidov

Carter=Burgess

Outline

- Project Description
- Problem Statement
- Requirements
- Solution
- Future Development
- Summary

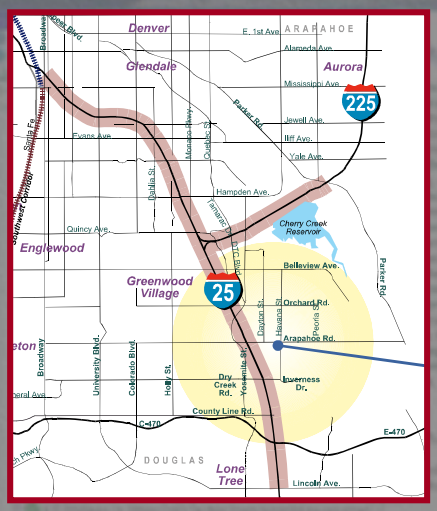
Carter=Burgess

Project Description

- Purpose
  - Combines highway and transit elements
  - LRT along I-25 and I-225
  - Additional highway lanes and improvements on I-25 and I-225
  - Links two regional employment centers

Carter & Burgess

Project Description



- Purpose
- Limit

Carter & Burgess

Project Description

- Purpose
- Limit
- Project Team
  - Carter & Burgess
  - RTD
  - CDOT
  - FHWA
  - FTA
  - Cities and Counties
  - Design/Builders

Carter=Burgess

Project Description

- Purpose
- Limit
- Project Team
- Schedule
  - NTP by summer 2001
  - ROW acquisition is critical path

Carter=Burgess

Project Description

- Purpose
- Limit
- Project Team
- Schedule
- Critical Elements
  - 19 miles long
  - 900 adjoining properties
  - Design/Build
  - ROW Acquisition

Carter & Burgess

Objective

To ensure the successful completion of the project, the Carter & Burgess Survey Unit needed to establish a procedure that integrated an expedited acquisition process with the design/build approach.

Carter & Burgess

Requirements

- Data
  - Complex spatial and relational data
  - Longevity
  - Progressive accuracy
  - Live updates
- Users
  - Accessible to extended project team
  - User friendly/technically complete
  - Secure
- Output
  - Integrated with project schedule
  - Flexible/Customizable
  - Map-based

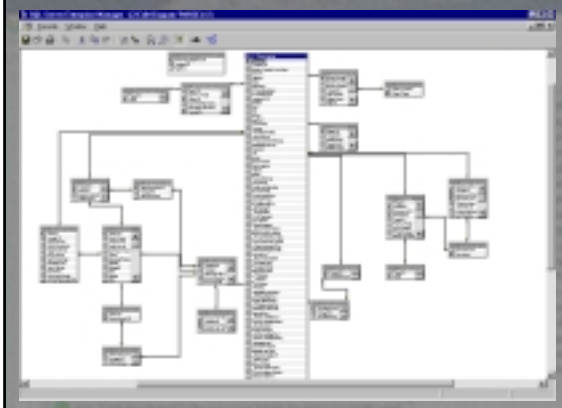
Carter=Burgess

Requirements

	Technical Approach
• Data	
– Complex spatial and relational data	Relational DB and GIS
– Longevity	Relational DB
– Progressive accuracy	GIS
– Live updates	Relational DB
• Users	
– Accessible to extended project team	Web-based
– User friendly/technically complete	Custom application
– Secure	Custom application
• Output	
– Integrated with project schedule	Custom application
– Flexible/Customizable	Custom application
– Map-based	Mapping Tools

Carter=Burgess

Solution



- Relational Database
  - MS SQL Server 7.0
  - Relational table structure
    - Users
    - Projects
    - Parcels
    - Parties (Owners)
    - ROEs
    - Titles
    - Appraisals
  - Stored Procedures

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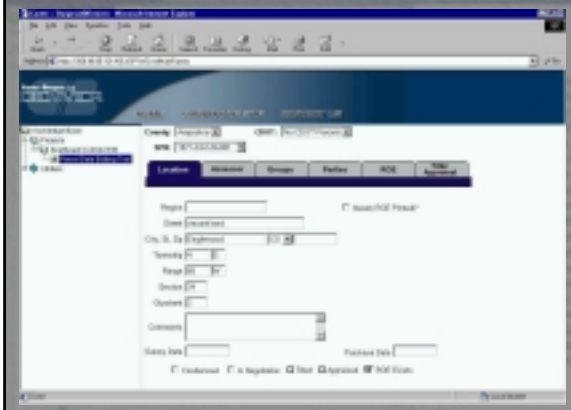
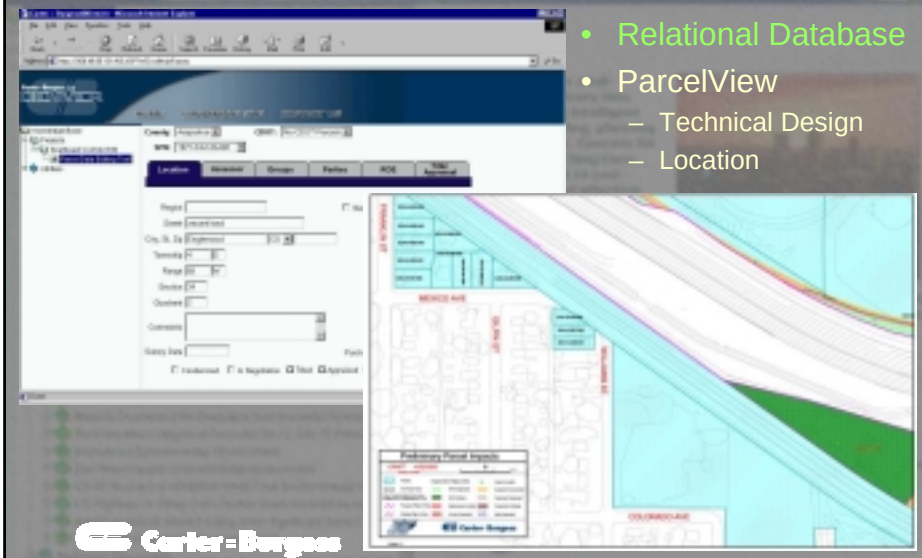
Solution



- Relational Database
- ParcelView
  - Technical Design
    - VB Webclass
    - Stateless
    - Data Environment Designer
    - HTML Forms
    - Microsoft Transaction Server

Carter=Burgess

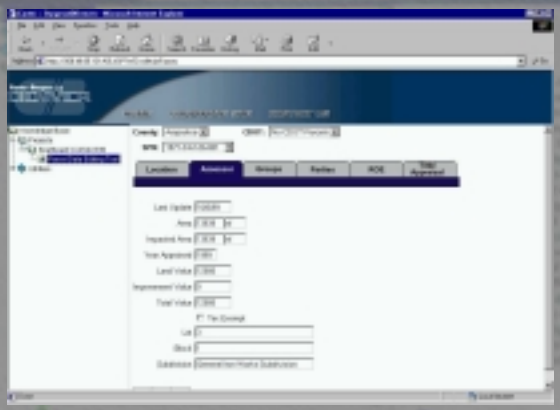
Solution



- Relational Database
- ParcelView
  - Technical Design
  - Location

Carter=Burgess

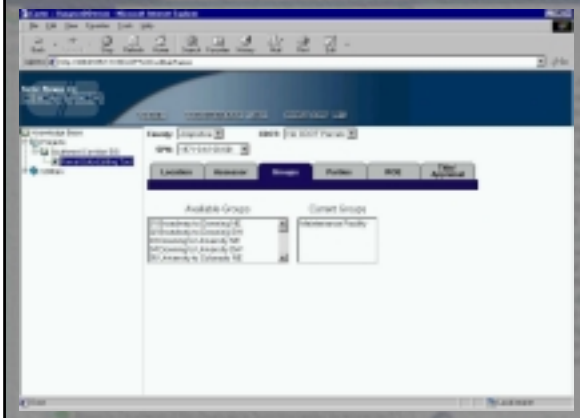
Solution



- Relational Database
- ParcelView
  - Technical Design
  - Location
  - Assessor

Carter=Burgess

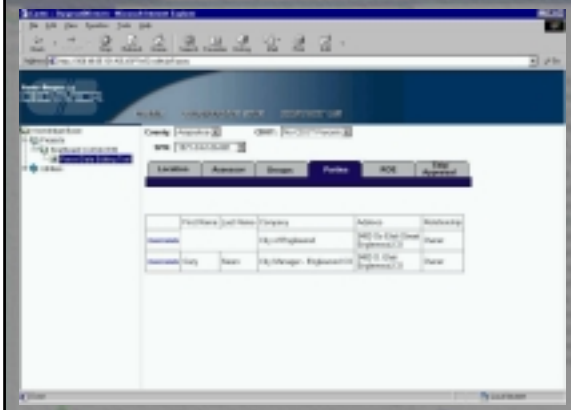
Solution



- Relational Database
- ParcelView
  - Technical Design
  - Location
  - Assessor
  - Groups

Carter=Burgess

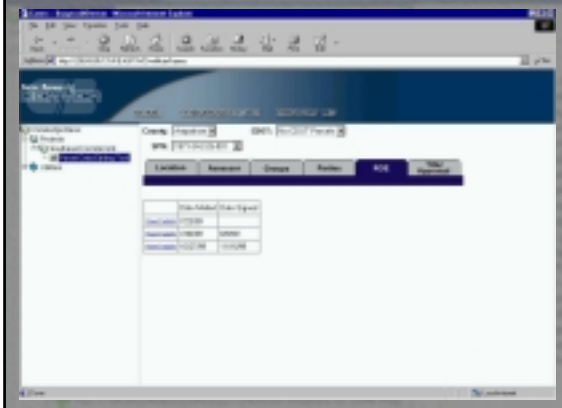
Solution



- Relational Database
- ParcelView
  - Technical Design
  - Location
  - Assessor
  - Groups
  - Parties

Carter=Burgess

Solution



- Relational Database
- ParcelView
  - Technical Design
  - Location
  - Assessor
  - Groups
  - Parties
  - ROE

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Solution

- Relational Database
- ParcelView
  - Technical Design
  - Location
  - Assessor
  - Groups
  - Parties
  - ROE

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Solution

- Relational Database
- ParcelView
  - Technical Design
  - Location
  - Assessor
  - Groups
  - Parties
  - ROE
  - Title/Appraisal

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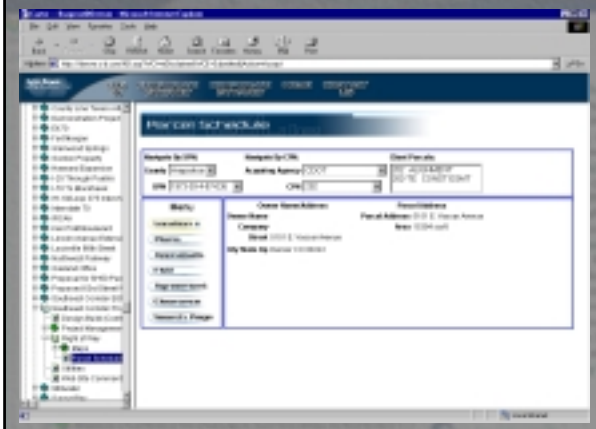
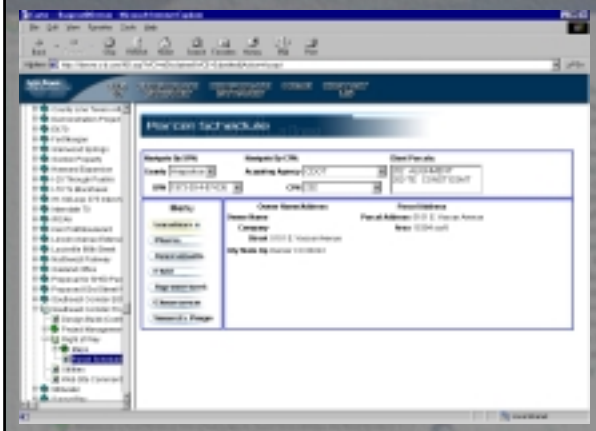
Solution



- Relational Database
- ParcelView
- Parcel Scheduler
  - Technical Design

Carter=Burgess

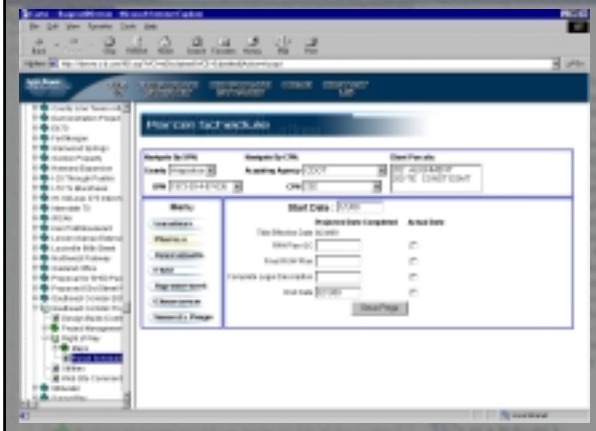
Solution



- Relational Database
- ParcelView
- Parcel Scheduler
  - Technical Design
  - Location

Carter=Burgess

Solution



- Relational Database
- ParcelView
- Parcel Scheduler
  - Technical Design
  - Location
  - Plans

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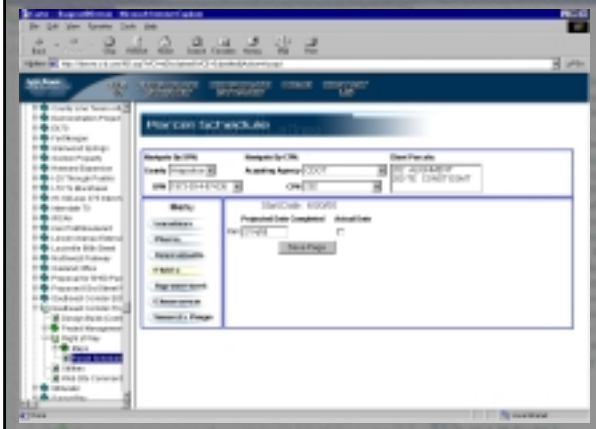
Solution

- Relational Database
- ParcelView
- Parcel Scheduler
  - Technical Design
  - Location
  - Plans
  - Appraisals

Carter=Burgess

Solution



- Relational Database
- ParcelView
- Parcel Scheduler
  - Technical Design
  - Location
  - Plans
  - Appraisals
  - Fair Market Value

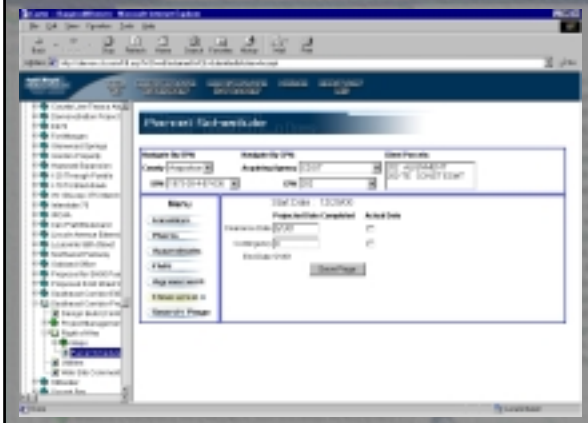
Carter=Burgess

Solution

- Relational Database
- ParcelView
- Parcel Scheduler
  - Technical Design
  - Location
  - Plans
  - Appraisals
  - Fair Market Value
  - Agreement

Carter=Burgess

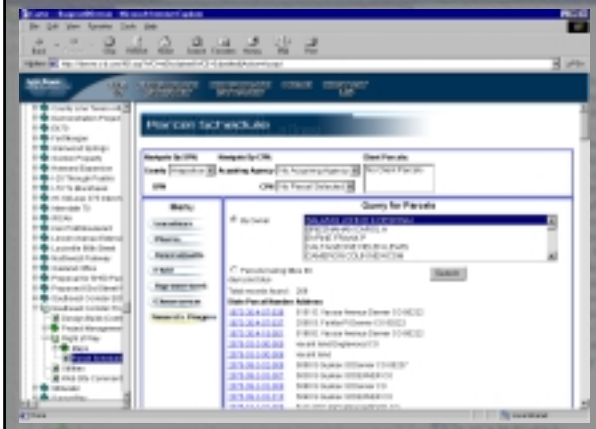
Solution



- Relational Database
- ParcelView
- Parcel Scheduler
  - Technical Design
  - Location
  - Plans
  - Appraisals
  - Fair Market Value
  - Agreement
  - Clearance

Carter=Burgess

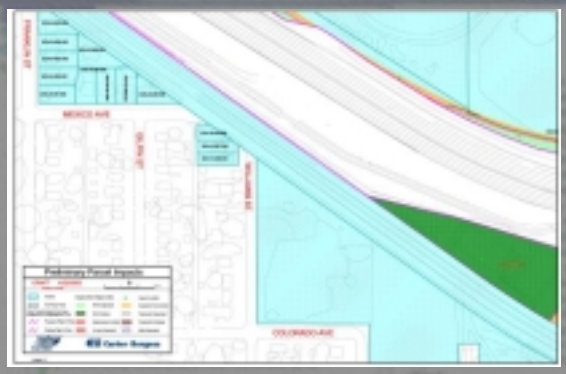
Solution



- Relational Database
- ParcelView
- Parcel Scheduler
  - Technical Design
  - Location
  - Plans
  - Appraisals
  - Fair Market Value
  - Agreement
  - Clearance
  - Search

Carter=Burgess

Solution



- Relational Database
- ParcelView
- Parcel Scheduler
- Impact Maps
  - Arc/Info polygon coverage
    - State Parcel Number
  - Project limits polygon coverage
    - Project feature
  - Arc/Info for analysis
  - ArcView for mapping

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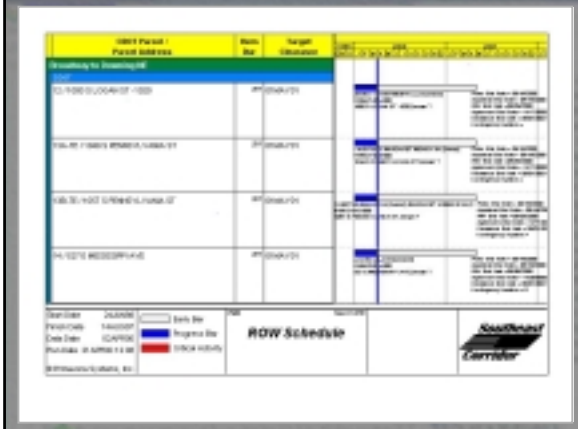
Solution



- Relational Database
- ParcelView
- Parcel Scheduler
- Impact Maps
- Project Schedule
  - Export tabular data to P3

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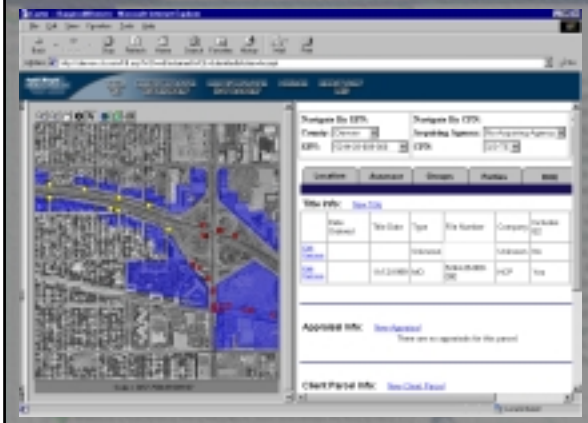
Solution



- Relational Database
- ParcelView
- Parcel Scheduler
- Impact Maps
- Project Schedule
- Web-based Maps
  - VB Application
    - Map Objects IMS
    - Database driven
  - Java Application
  - HTML Form

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Future Development

- Tighter coupling between GIS and database
  - Links from database to Microstation for increased spatial accuracy
  - Geodatabase/SDE
- ArcIMS
- GIS analysis tools

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Summary

- Integration of survey team and technologists provides an innovative approach to complex problem
- Efficiency gains, better teamwork, and shortened schedule offset cost of development
- Reuseable

Carter & Burgess

Contact Information
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Visualizations for I-81/I-77 Location Study

Marissa Gagné & Dr. Randy Dymond
Dept. of Civil & Environmental Engineering
Virginia Tech

14th Annual GIS-T Symposium

April 10th, 2001

Parties Involved in Full Location Study

Virginia Tech:

- Center for Public Administration and Policy (CPAP)
- Dept. of Civil & Environmental Engineering (CEE) (Visualization)
- Urban Affairs and Planning (UAP)
- Dept. of Agricultural and Applied Economics
- Virginia Tech Transportation Institute (VTTI)

- Virginia Center for Innovative Technology (CIT)
- Town of Wytheville
- Virginia Dept. of Transportation (VDOT)
- Hayes, Seay, Mattern, & Mattern (HSMM)

Visualization Project Goal:

- To create 3-D visualizations of existing conditions and proposed routes for the new I-81/I-77 corridor in through Wythe County that can be presented to all parties involved, including the people of the Wytheville community.

** Constraints **

PC-based and low-budget

Project Location

Local Map:

AVI movie at
http://cegis.ce.vt.edu/projectwebs/wytheville/
under Animated Visualizations

Project Background

- I-81/I-77 Interchange and Corridor
  - 8-mile overlap of the two interstates.
  - Near town of Wytheville
- VDOT believes redesign is necessary for safety.
  - Significant increase in truck traffic (from 15% to 40%)
  - 58,000 vehicles/day
  - High accident rate

Key Concerns

- Any re-alignment of the roadways will have direct economic and developmental effects on the town of Wytheville and the surrounding areas.
  - Desire to maximize local development and minimize the negative economic impacts.
- Many citizens are concerned about new zoning and construction effects.

*Public needs to be involved in decisions!

Need for Visualizations

- Typically, topographic maps and survey or construction plans have been used in the past.
  - Difficult to understand for public or clients with non-engineering background.
- 3D visualizations facilitate the communication of existing and proposed conditions to the “layman”.

Available Data Types

- Elevation Data
- Survey Data
- Imagery

Elevation and Survey Data

- Planimetrics, contours, survey points and breaklines for interstate corridor (Microstation .dgn format) from VDOT.
- Planimetrics and Contours for the town of Wytheville (AutoCAD .dwg format) from the town engineer.
- LIDAR data (points and breaklines in Microstation .dgn format) and planimetrics for the interstate corridor from VDOT.
- USGS 30m DEM data.

Imagery Data

- Black and White Aerial Photos (.tif and .hmr formats) of the interstate corridor from VDOT.
- Black and White Aerial Photos (.tif format) of the town of Wytheville from the town engineer.
- Landsat 7 imagery of the area.
- Color-infrared Digital Ortho Quarter Quads (DOQQs).

Software Packages

1. ArcView GIS 3.2 3-D Analyst by ESRI, Inc.
2. ERDAS Imagine 8.4 Virtual GIS by ERDAS, Inc.
3. AutoCAD Land Development Desktop by Autodesk, Inc.
4. World Construction Set 5 by 3DNature, LLC.
5. EDGE Viewer by Autometric, Inc.

ArcView GIS – 3D Analyst Visualizations

Using LIDAR points and breaklines with planimetric overlays

Other screen captures at
http://cegis.ce.vt.edu/projectwebs/wytheville/
under Still Visualizations - ArcView

AutoCAD LDD Visualizations

Using AutoCAD contours and planimetrics for the town of Wytheville.

Interchange near Wytheville where I-81 and I-77 come together

Other screen captures at http://cegis.ce.vt.edu/projectwebs/wytheville/ under Still Visualizations - AutoCAD

World Construction Set Visualizations

Using AutoCAD contours and planimetrics for the town of Wytheville.

Other screen captures at http://cegis.ce.vt.edu/projectwebs/wytheville/ under Still Visualizations – World Construction Set

ERDAS Imagine Virtual GIS Flythrough

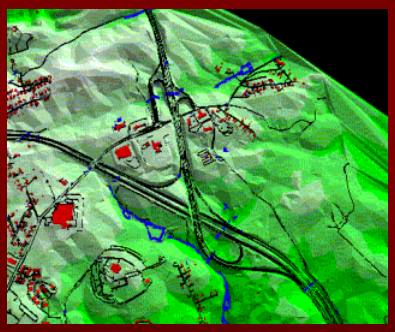
Using USGS DEMs overlaid with Digital Ortho Quarter Quads

- Starting at the easternmost intersection of the corridor.
- Traveling west toward the town of Wytheville.

AVI flythrough at
http://cegis.ce.vt.edu/projectwebs/wytheville/
under Animated Visualizations - ERDAS

ArcView GIS – 3D Analyst Flythroughs

Using AutoCAD contours and planimetrics for the town of Wytheville. (Left model draped with B&W orthophotos)



AVI flythroughs at
http://cegis.ce.vt.edu/projectwebs/wytheville/ under Animated Visualizations - ArcView

Westernmost intersection of the corridor. I-77 enters from the north and I-81 enters from the west. The northern interchange is where I-77 meets the main street of Wytheville

Problems Encountered

Realism difficult to achieve with data and software available.

- World Construction Set
  - Can import grid points but terrain is generated using a TIN and must have a certain projection and coordinate system.
  - If resolution is low, roads and other vectors are crossed with TIN lines.
  - Cannot extrude building outlines so difficult to add buildings.
- ArcView 3-D Analyst
  - Good navigation tools but no rendering capabilities.

Problems Encountered (Cont.)

Realism difficult to achieve with data and software available.

- AutoCAD Land Development Desktop
  - Difficult to handle large amounts of data.
  - Relatively little rendering capabilities.
- ERDAS Imagine Virtual GIS
  - Cannot extrude buildings.
  - No rendering capabilities.

Problems Encountered (Cont.)

Realism difficult to achieve with data and software available.

- LIDAR data extremely large
  - Could not work with entire corridor
  - Difficult to break up ground cover layers into smaller areas due to large ASCII file format.
- USGS DEM data contained a 1-pixel gap between the two sections.

Future Work

- Find more funding.
- Purchase additional software (Bentley, Multigen,…).
- Acquire additional data sets (imagery, RADAR,…).
- Improve the realism of these visualizations.
- Export visualizations to VRML for use on the web.
- When specific design information is provided for the proposed alternatives, new models will be created.
- Final group of models will be shown at committee meetings, etc. For public involvement and input.

Using GIS as a Decision Support Tool for Transportation Feasibility Studies

Phil Lidov
Carter & Burgess, Inc.

GIS-T 2001, Virginia

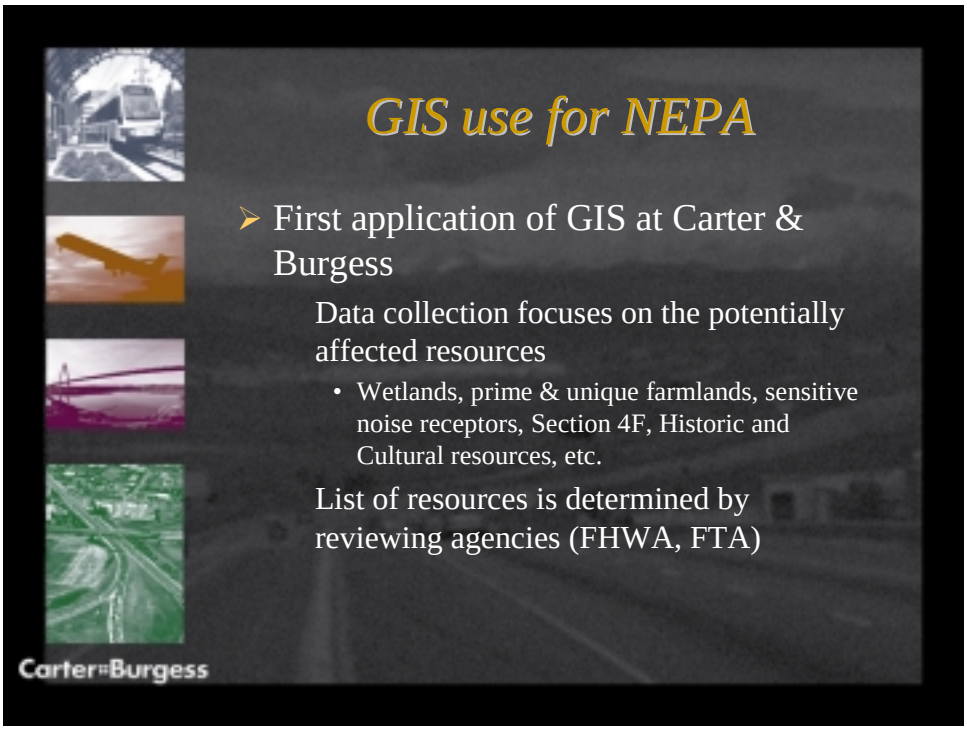
Carter&Burgess

Outline

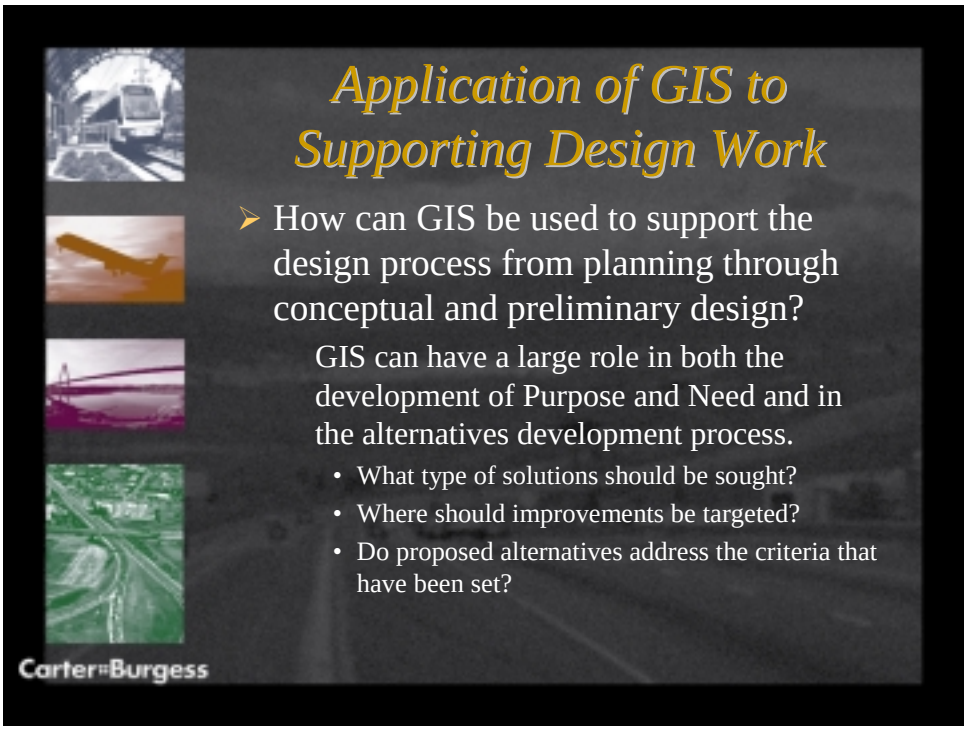
- Working from the Consultant's Perspective
- Using GIS to Support Decision Making
  - Procedural Role in NEPA
  - Decision support role for the design process
- Expanding GIS Applications in Transportation
  - US 285 Feasibility Study
    - Project overview
    - Database design and data collection
  - Toolkit outline & examples
- Conclusions

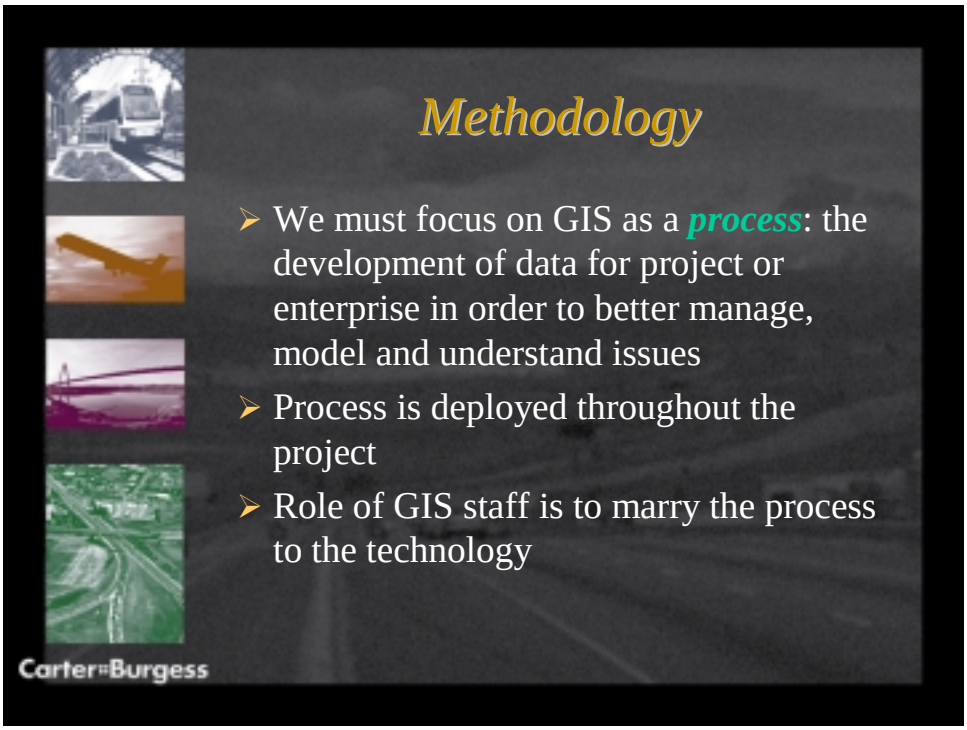
Carter&Burgess

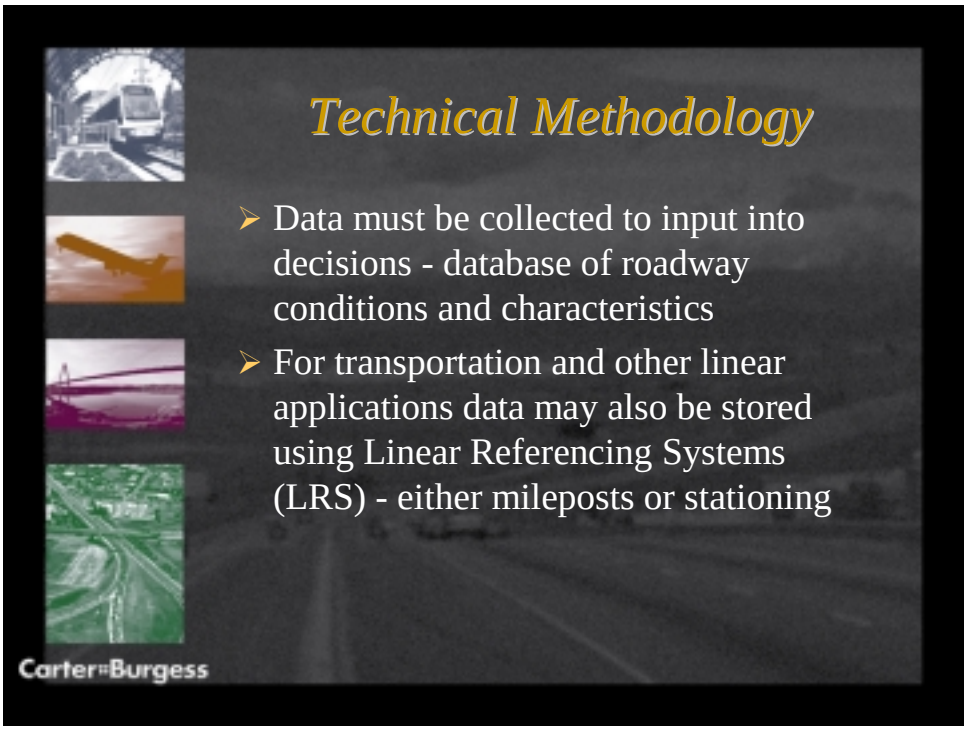
Using GIS as a Consultant
Perspective of GIS program leader for environmental, planning and design consultant
GIS program began with Environmental Planning 6 years ago
Use of GIS is project specific
Currently part of Infrastructure (design) group
Focus on supporting all Transportation programs
Carter&Burgess


GIS use for NEPA
First application of GIS at Carter & Burgess
Data collection focuses on the potentially affected resources
Wetlands, prime & unique farmlands, sensitive noise receptors, Section 4F, Historic and Cultural resources, etc.
List of resources is determined by reviewing agencies (FHWA, FTA)
Carter&Burgess

GIS Methodology for NEPA
Conventional GIS –
"study areas"
overlays to produce new information
Baseline Resource
Projected Development
Carter:Burgess

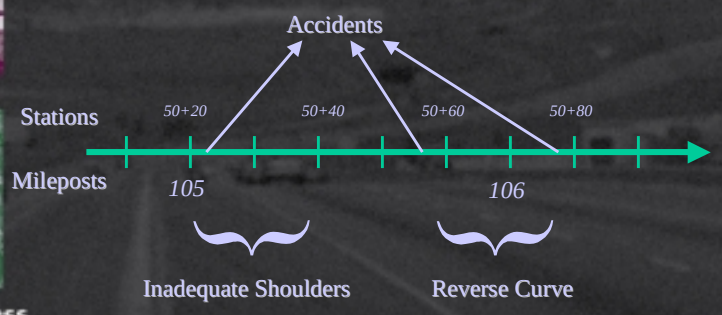

Application of GIS to Supporting Design Work
How can GIS be used to support the design process from planning through conceptual and preliminary design?
GIS can have a large role in both the development of Purpose and Need and in the alternatives development process.
What type of solutions should be sought?
Where should improvements be targeted?
Do proposed alternatives address the criteria that have been set?
Carter:Burgess


Methodology
We must focus on GIS as a process: the development of data for project or enterprise in order to better manage, model and understand issues
Process is deployed throughout the project
Role of GIS staff is to marry the process to the technology
Carter:Burgess


Technical Methodology
Data must be collected to input into decisions - database of roadway conditions and characteristics
For transportation and other linear applications data may also be stored using Linear Referencing Systems (LRS) - either mileposts or stationing
Carter:Burgess

Linear Referencing/Dynamic Segmentation

- GIS for Transportation
  - Map the connections between places
  - Create events along a route

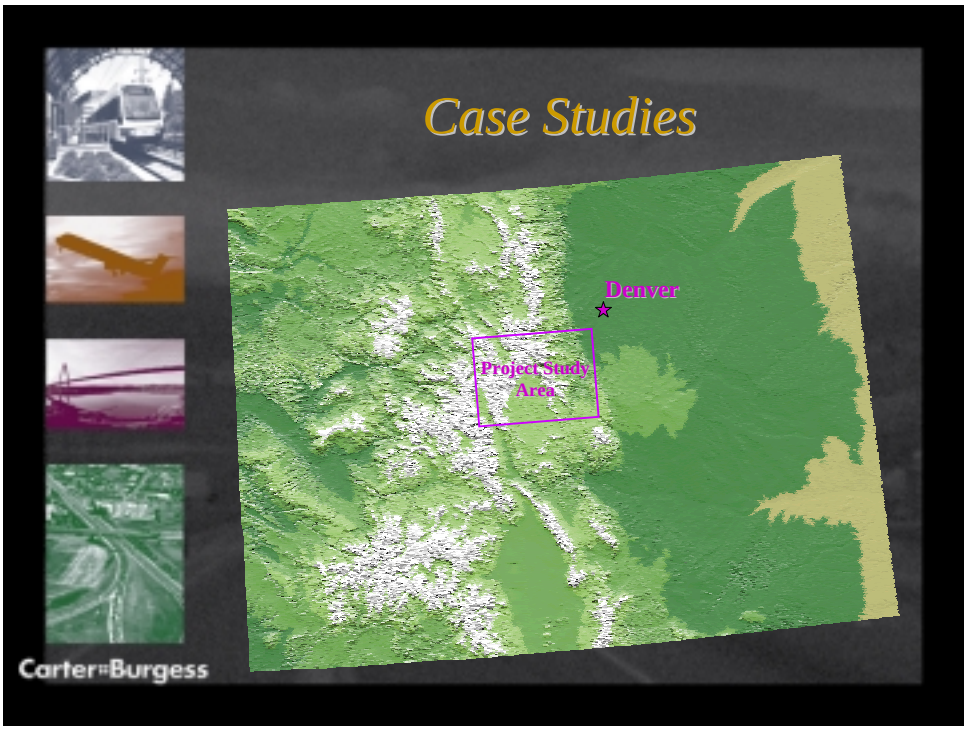


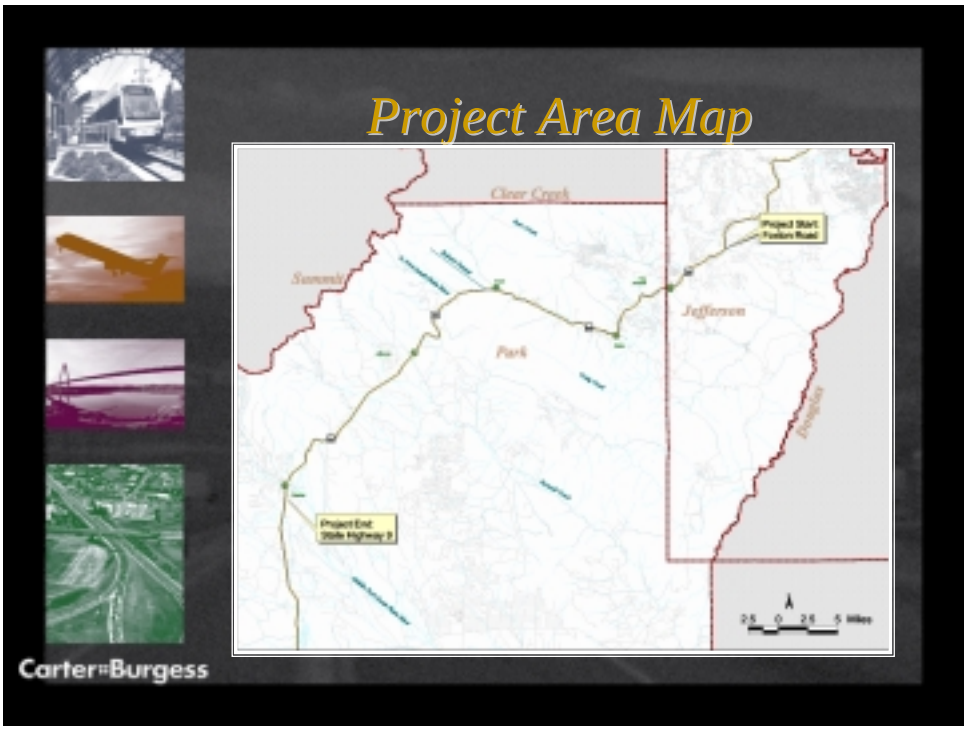
Carter&Burgess

Case Study: US 285 Feasibility study

- 52-mile highway feasibility study currently underway provides examples for how GIS can contribute to initial design decision-making
- Large study area with little available data
- GIS used to develop database of roadway conditions, document environmental issues, manage property information along corridor, and to help develop and screen conceptual level alternatives

Carter&Burgess


Case Studies
Denver
Project Study Area
Carter=Burgess


Project Area Map
Clear Creek
Summit
Park
Jefferson
Douglas
Carter=Burgess

Carter:Burgess

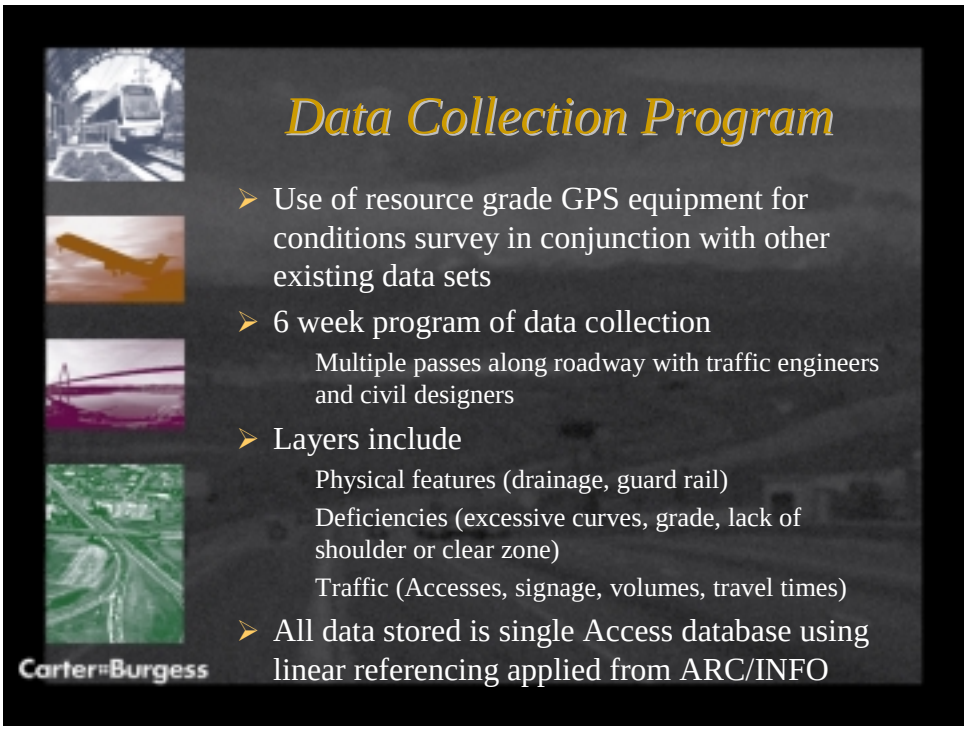
Carter:Burgess

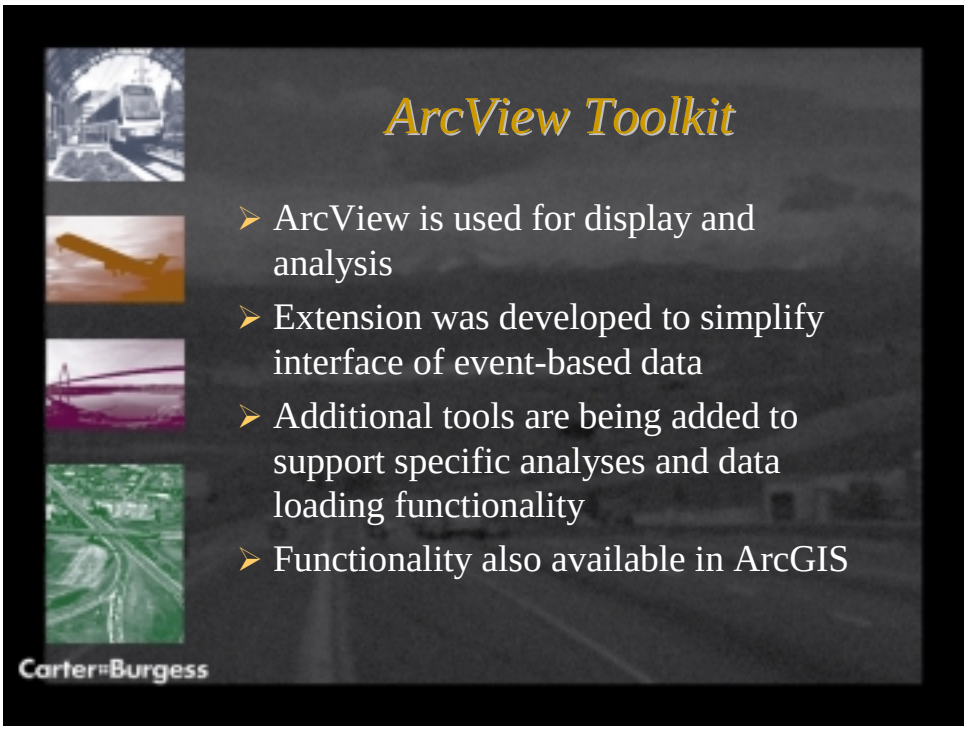
Carter&Burgess

US 285 Feasibility Study

- Objective: Need to develop clear purpose for future projects
  - Many potential long-term projects
  - Limited budget
  - DOT would like early action
- Solution
  - GIS database of roadway conditions from GPS
  - ArcView toolkit for analysis

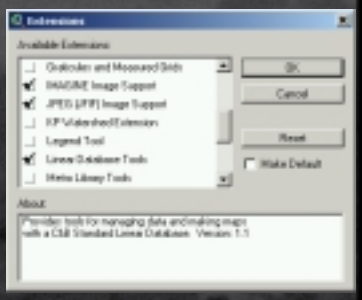
Carter&Burgess


Data Collection Program
Use of resource grade GPS equipment for conditions survey in conjunction with other existing data sets
6 week program of data collection
Multiple passes along roadway with traffic engineers and civil designers
Layers include
Physical features (drainage, guard rail)
Deficiencies (excessive curves, grade, lack of shoulder or clear zone)
Traffic (Accesses, signage, volumes, travel times)
All data stored is single Access database using linear referencing applied from ARC/INFO
Carter&Burgess


ArcView Toolkit
ArcView is used for display and analysis
Extension was developed to simplify interface of event-based data
Additional tools are being added to support specific analyses and data loading functionality
Functionality also available in ArcGIS
Carter&Burgess

Tool Kit

- Written as an ArcView extension in Avenue
- Reads event based data from Access database - can be any ODBC compliant database
- Eliminates requirement for user to understand the procedures for creating event based data

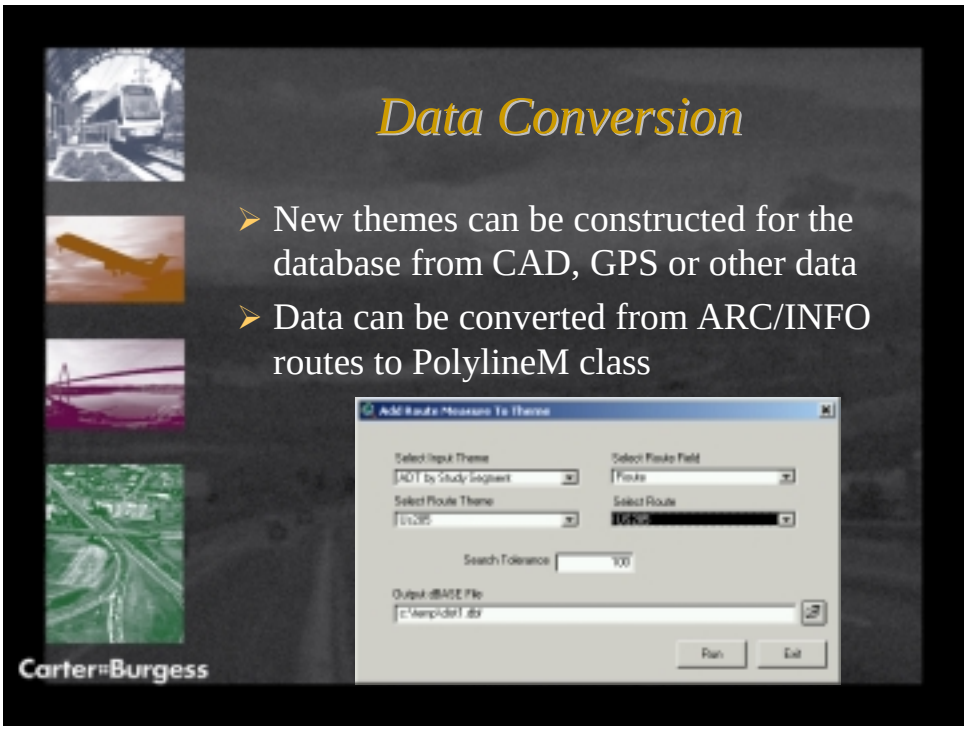


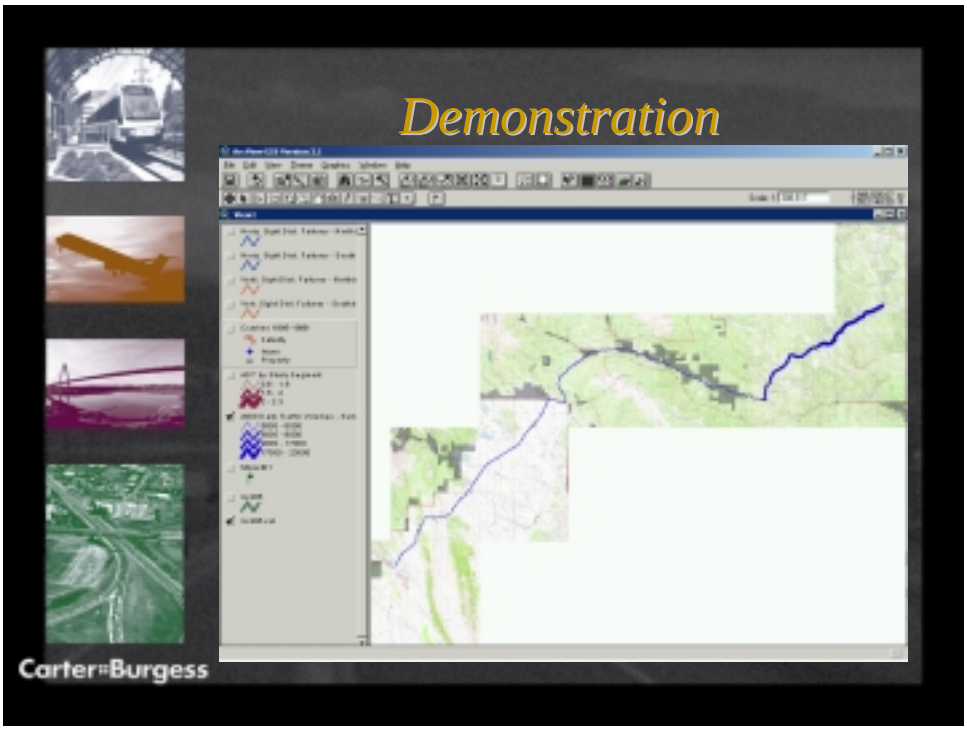
Carter&Burgess

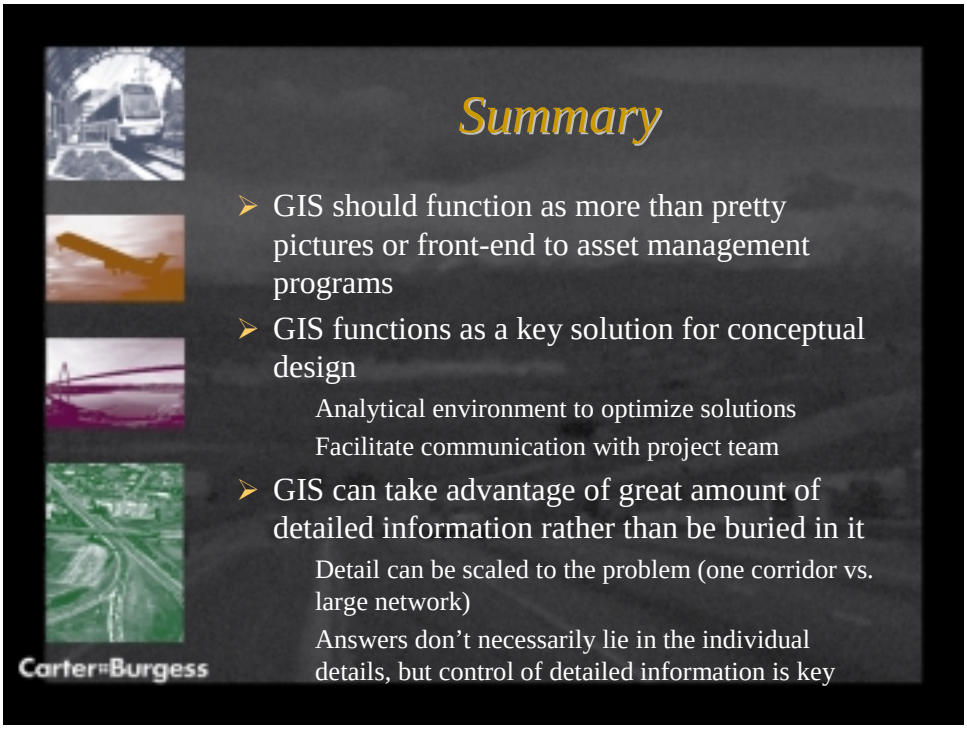
Analysis

- Cartographic display and queries
- Point-on-line overlays
  - Relies on spatial joins available in Avenue
  - Line-on-line overlays require ARC/INFO dynamic segmentation functions
- Specific tools are being coded around these capabilities

Carter&Burgess


Data Conversion
New themes can be constructed for the database from CAD, GPS or other data
Data can be converted from ARC/INFO routes to PolylineM class
Add Route Measure To Theme
Select Input Theme
ADT by Study Segment
Select Route Field
Route
Select Route Theme
Select Route
Search Tolerance
100
Output dBASE File
Run
Exit
Carter:Burgess


Demonstration
Carter:Burgess


Summary
GIS should function as more than pretty pictures or front-end to asset management programs
GIS functions as a key solution for conceptual design
Analytical environment to optimize solutions
Facilitate communication with project team
GIS can take advantage of great amount of detailed information rather than be buried in it
Detail can be scaled to the problem (one corridor vs. large network)
Answers don't necessarily lie in the individual details, but control of detailed information is key
Carter&Burgess

GIS In Human Service Transportation Planning and Coordination

Mark Agee
Brian Smith
University of Virginia
Smart Travel Lab
Department of Civil Engineering.

Outline

- Project overview.
- Use of GIS.
  - Why use GIS?
  - Data collection and entry.
  - Data analysis.
  - Observations.
- Future directions
- Questions

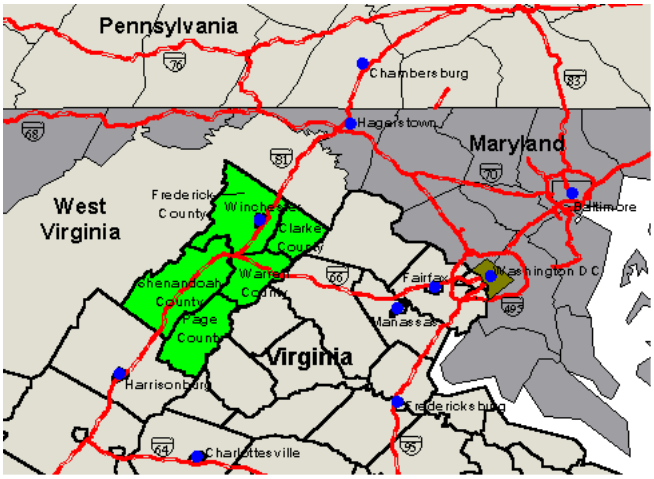
Northern Shenandoah Valley Public Mobility Project

- GIS as an evaluation tool.
- Effort to help people who are unable to provide their own transportation.
- Sponsored by VDOT and VDRPT.

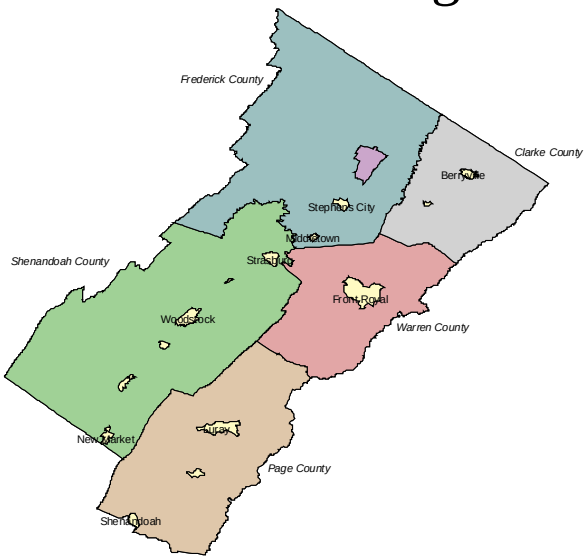
Organizations Involved

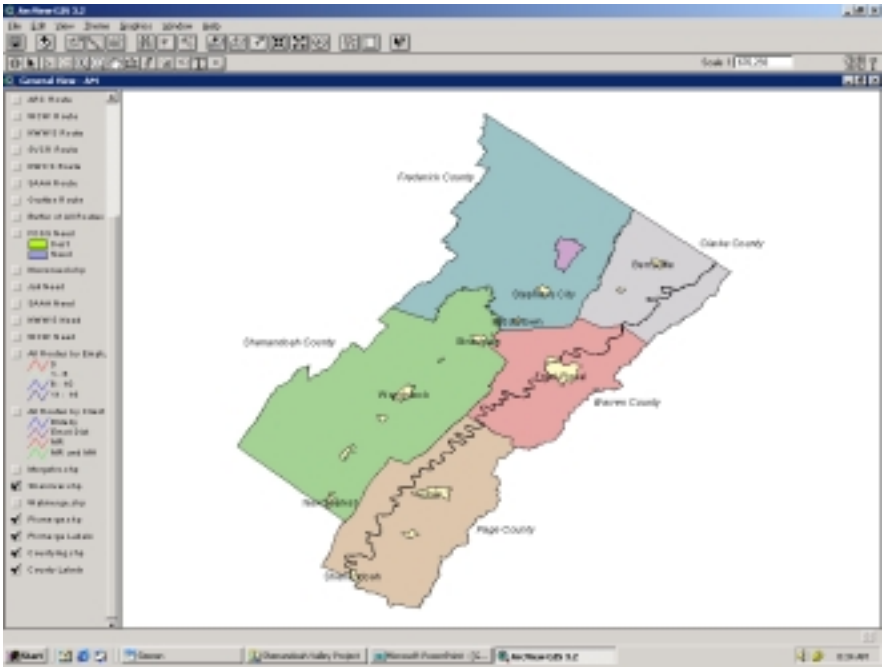
- Northwestern Community Services
- Northwestern Workshop
- Shenandoah Area Agency on Aging
- Shen-Paco Industries
- Shenandoah Valley Community Residence
- Frederick Dept. of Social Services
- Clark/Frederick/Winchester Jail
- Access Independence
- Wincester/Frederick Red Cross
- Winchester Public Transit

Lord Fairfax Planning District



Lord Fairfax Planning District





Project Vision

- To provide improved transportation service by coordinating efforts with the help of technology.
- Scheduling and dispatching software with enhanced networking capability.

Why use GIS?

- Data with spatial nature as well as associated attributes.
- Visualization of routes and service areas.
- Feasibility of coordination.

GIS Tools Used

- ArcView 3.2
- Network Analyst Extension
- TIGER data for base map and street net

Data Collection

- Location of each stop.
- Time stop made.
- Number of passenger picked up and dropped off.
- Vehicle capacity.

Agency: Vehicle #:

"Stop #" indicates the order in which the stops are made.
"Time" indicates the time that the vehicle reaches that location. Indicate range if exact not known.
"Action" indicates what takes place at that location:
- "Depart" for departing location with no passengers (beginning a route).
- "PU" for picking up passengers.
- "Drop" for dropping off passengers.
- "Return" for returning with no passengers (end of a route).

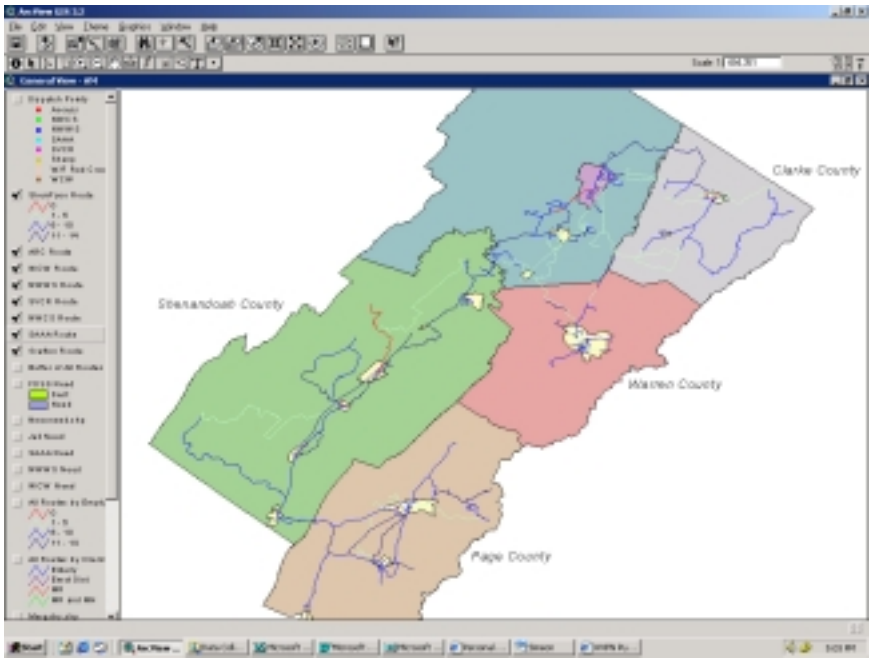
"Address," "City," "Zip" indicate the present location of the vehicle (where the action is performed.
"# PU/Drop" indicates the number of passengers either picked up or dropped off.

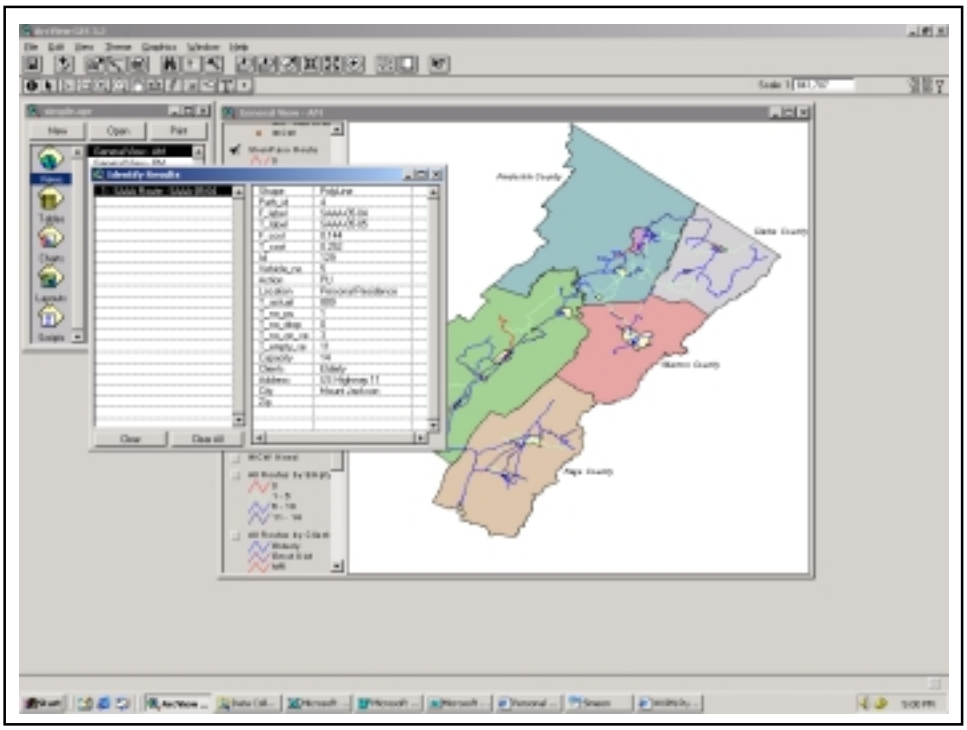
Day of week:						
Stop #	Time (am/pm)	Action	Address	City	Zip	# PU/Drop
1						
2						
3						
4						
5						
6						
7						
8						
9						
10						
11						
12						
13						
14						
15						
16						
17						
18						
19						
20						
21						
22						
23						
24						
25						

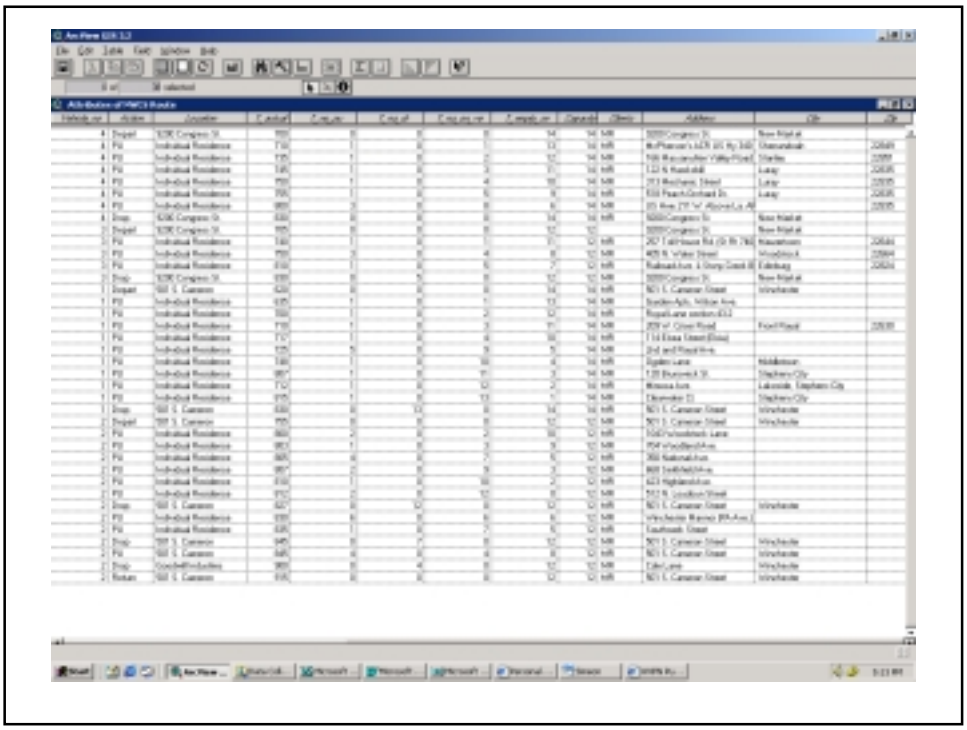
On the back, please note times when the vehicle is idle and whether the driver is available or unavailable during those times.
Also indicate if the vehicle is used sporadically during that idle time in its regular route.

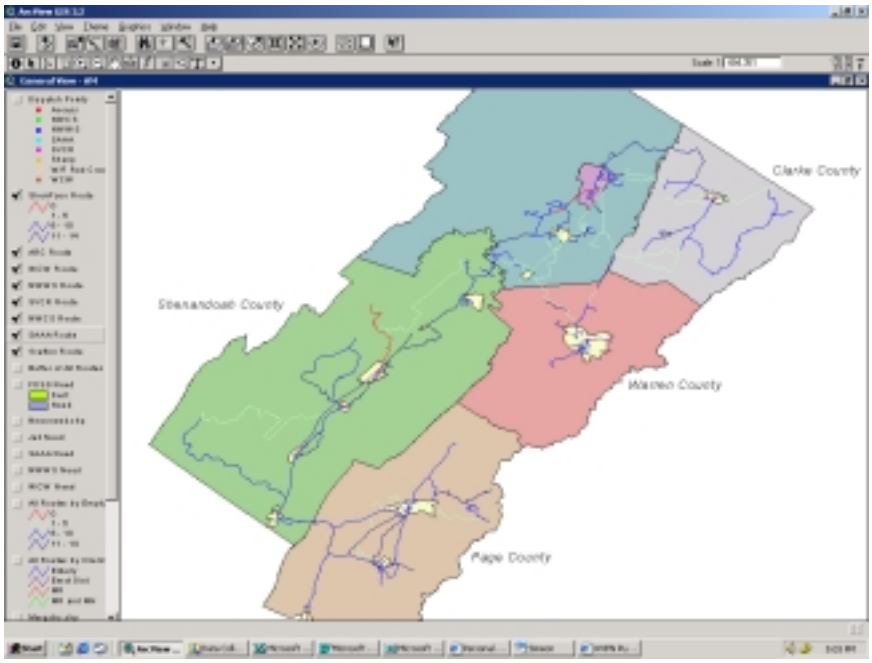
Data Entry

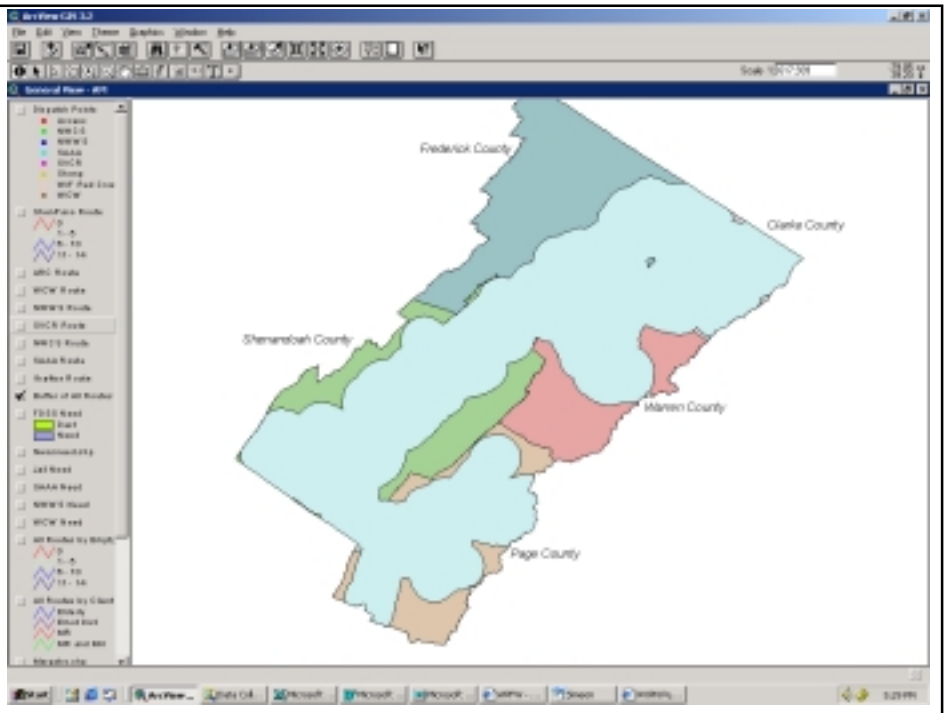
- Entered attribute data in Excel then saved as a .dbf file to open in Arcview.
- Geocoded stop locations.
- Network Analyst to produce reasonable routes.
- Joined stop table to Route Table generated by Network Analyst.

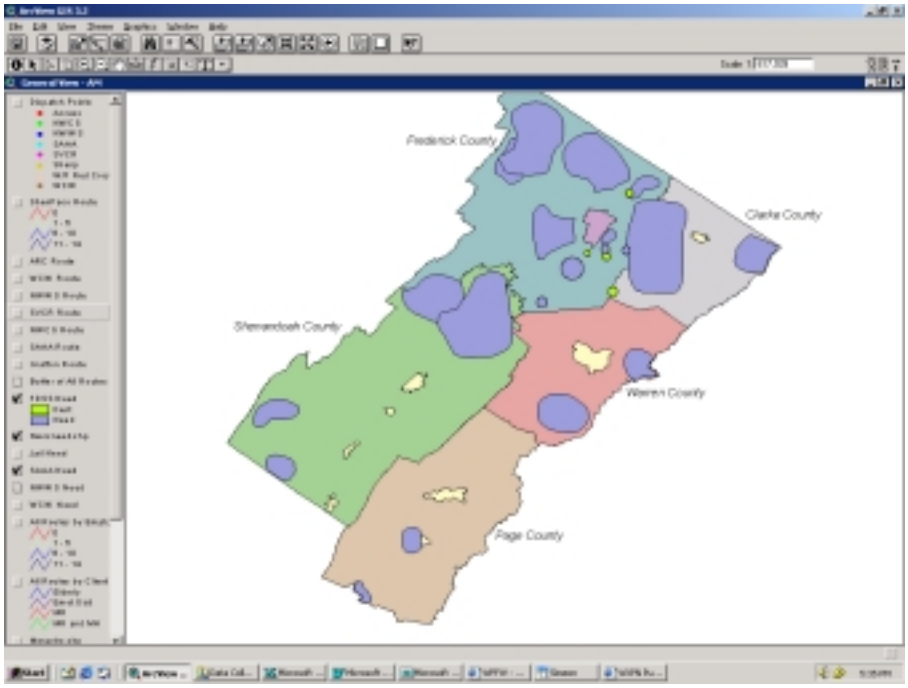


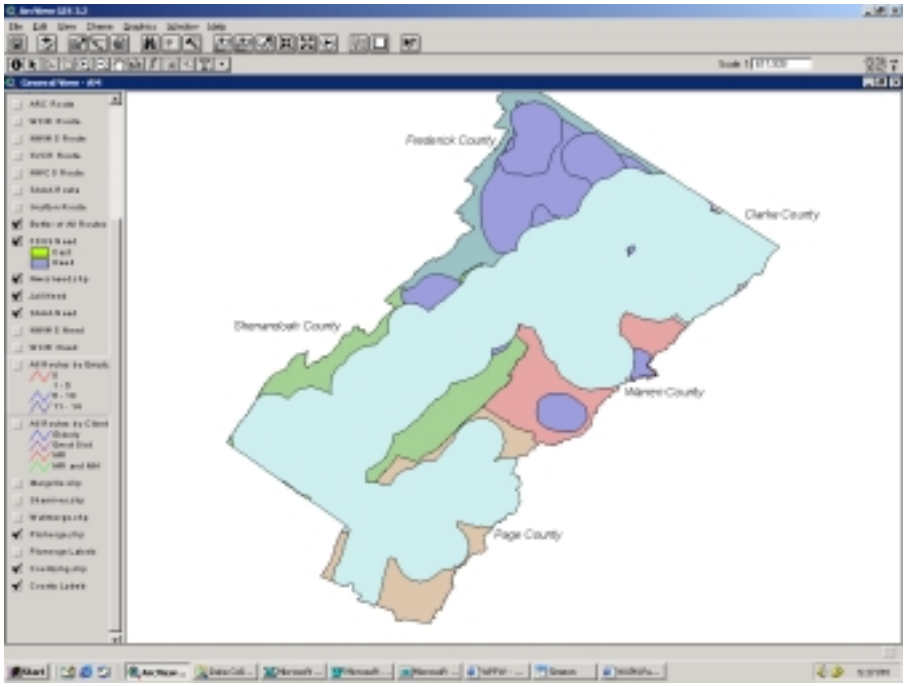





Clarke County
Shenandoah County
Warren County
Page County


Frederick County
Clarke County
Shenandoah County
Warren County
Page County


Frederick County
Clarke County
Shenandoah County
Warren County
Page County


Frederick County
Clarke County
Shenandoah County
Warren County
Page County

Difficulties

- Data collection
- Geocoding
- How do you deal with map features that change as a function of time?
  - Location of a vehicle along a route.
  - Direction of travel.

Results and Future Directions

- Scheduling and coordinating software purchase.
- To what extent will GIS be a part of the solution? Unclear.

Conclusions

- GIS was an excellent tool for this project.
- Difficulties
- Rural areas pose particular problems for people who cannot provide their own transportation because there is typically little public transportation.

Contact

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Providing Real-Time Information to Transit Passengers Using Internet-Enabled GIS

Jian Zhou, Environmental Systems Research Institute
Marc Krätzschmar, Exor Corporation

Acknowledgements

- Lenny Kneller
- RTD Staff

Presentation Outline

- Introduction—Where's My Bus
- GIS Approach
- Implementation
- Conclusion

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Introduction – Where's My Bus

- Demand
  - ATIS
  - GIS
- Project background
  - RTD Initiatives
    - CAD/AVL
    - GIS
  - ArcIMS
- Our goal
  - Evaluate COTS GIS Technology for ATIS

A GIS Approach To ATIS

- Why GIS
  - Location Services
  - Network Data
  - The Internet

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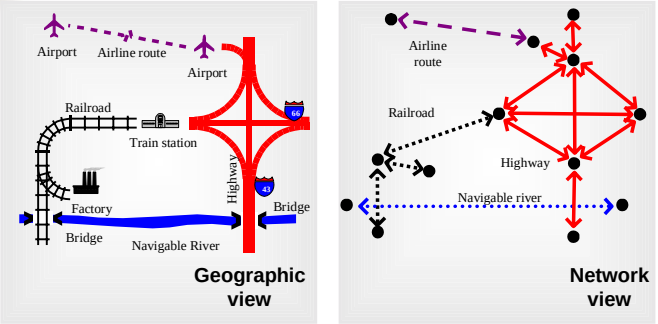
Location, Location, Location

- Vehicle Location On The Planet
- Location Relative To Landmarks
- Other Spatially Related Data
  - Traffic
  - Weather
- Commercially Available Data
  - Street Network, Weather, Traffic
- Operator-Specific Data
  - Routes, Stops

Networks

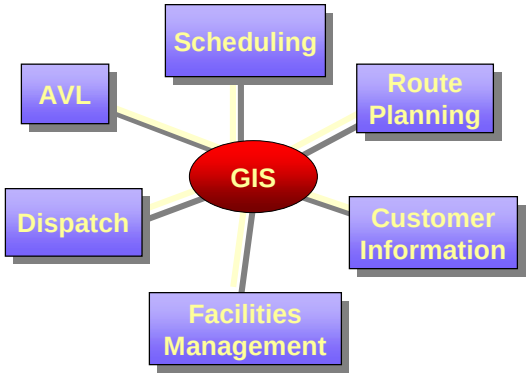


Geometry and Connectivity

The Internet

- Data Transfer Infrastructure
  - Kiosks
- Universal Web Browser
- Free Online Data and Applications
  - MapQuest
- COTS Internet Map Service Software

Broader Value of GIS



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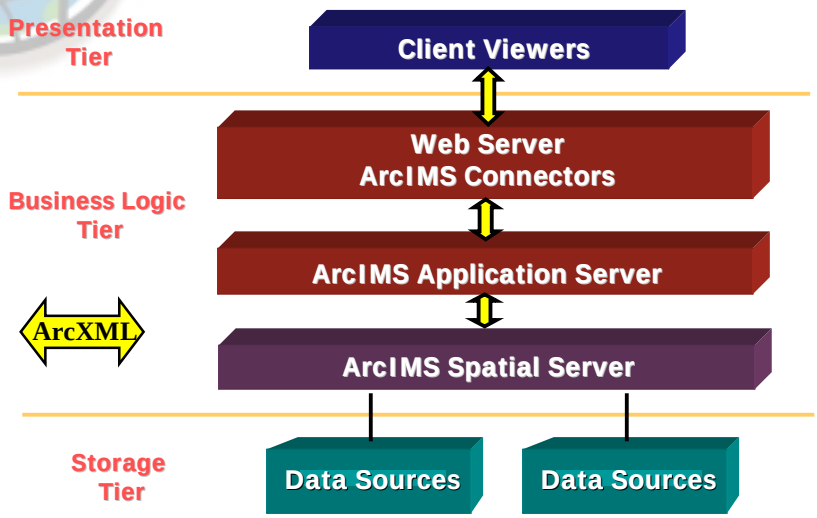
Implementation

- Internet Map Serving Technology
- Database design and data processing
- Application clients design
- Conclusion

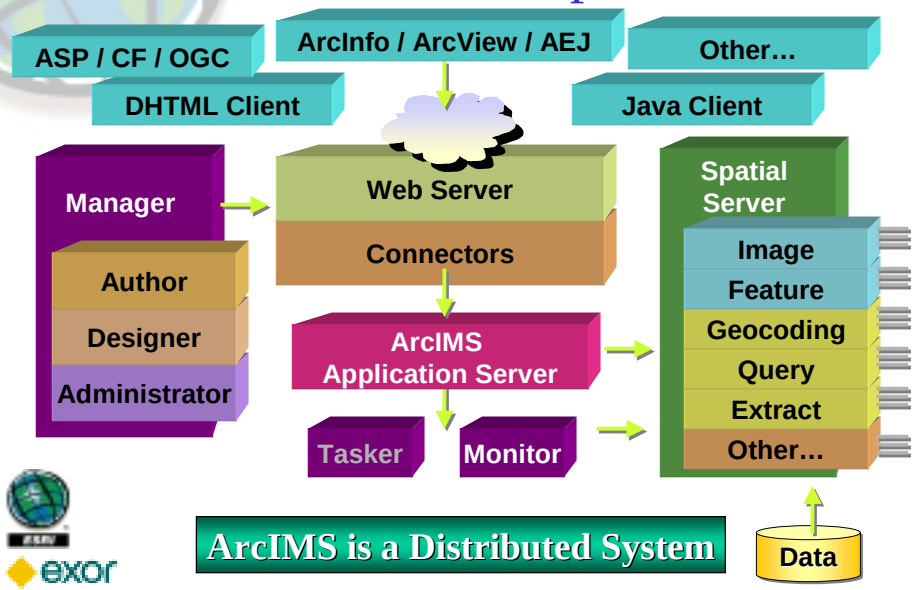
System Components

- Data collection
  - Denver RTD AVL/CAD system
  - Data is FTPed to ESRI Server
- Data loader
  - Gets the data from FTP
  - Inserts data into Oracle and ArcSDE
- Server
  - Windows NT Server 4.0
  - Web Server: Microsoft IIS, ServletExec 3.1
  - ArcIMS 3.0
- Client viewers
  - Customized HTML and Java viewer

ArcIMS is a Multi-Tier System



ArcIMS Components

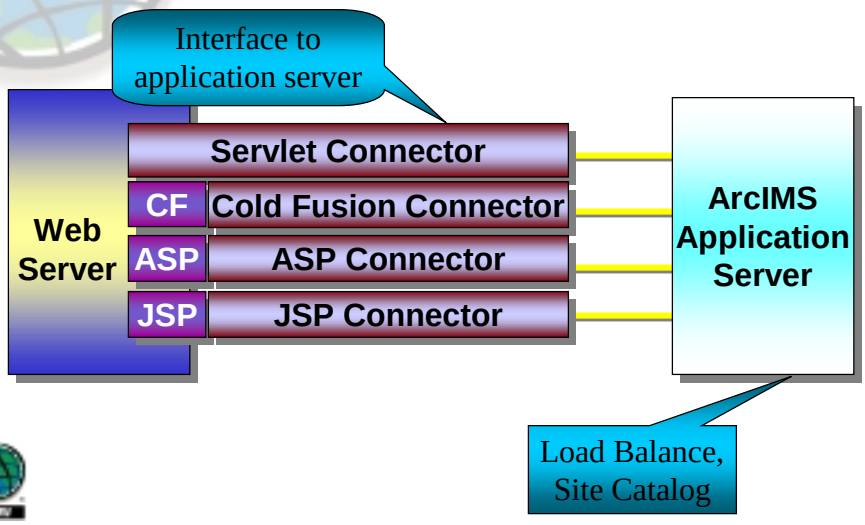


ArcIMS is a Distributed System

Web Servers

- Handle requests from a client using Hypertext Transfer Protocol (HTTP)
- Pass the request to the appropriate application
- Sends the response back to the requesting client

Connectors / Application Server



ArcIMS Spatial Server

- A container that holds the different server components
- Provides functional capabilities for accessing and bundling maps and data into the appropriate format

ArcIMS Spatial Server Support Components

- Weblink is communication link between the ArcIMS Application Server and Spatial Server
- XML parser parses ArcXML requests
- Data Access Manager provides links to the data

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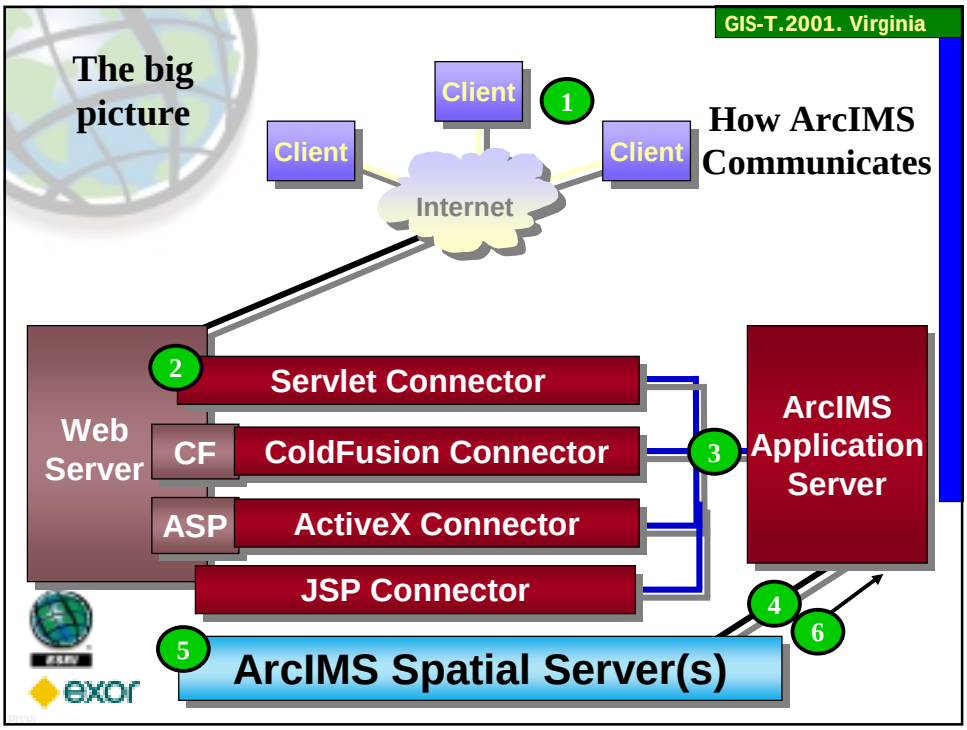
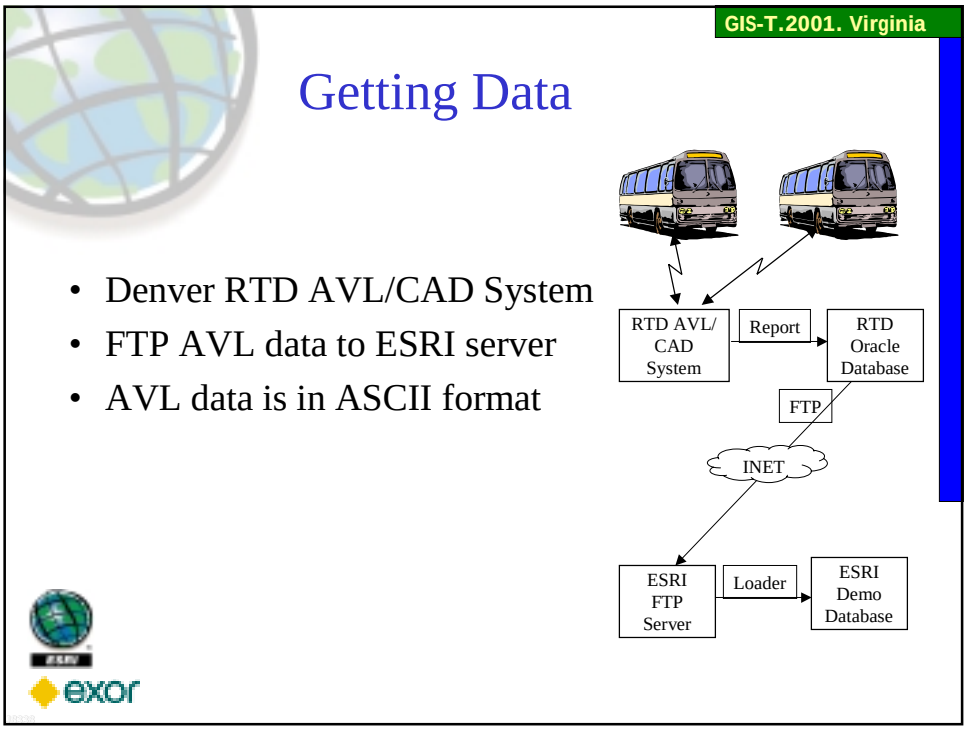
ArcIMS MapServices

- Processes that run on an ArcIMS Spatial Server
- Define how to display maps on the web
- Two types of MapServices
  - Image
  - Feature


GIS-T.2001. Virginia
The big picture
How ArcIMS Communicates
Client
Client
Client
1
Internet
Web Server
2
Servlet Connector
CF
ColdFusion Connector
ASP
ActiveX Connector
JSP Connector
3
ArcIMS Application Server
4
6
5
ArcIMS Spatial Server(s)
exor


GIS-T.2001. Virginia
Getting Data
• Denver RTD AVL/CAD System
• FTP AVL data to ESRI server
• AVL data is in ASCII format
RTD AVL/ CAD System
Report
RTD Oracle Database
FTP
INET
ESRI FTP Server
Loader
ESRI Demo Database
exor

AVL data in ASCII format

```
38  41    29-MAR-01 11:28:12   2172289 708743  W
12  9     29-MAR-01 11:26:26   2148358  694210  NNW
44  15    29-MAR-01 11:28:04   2101498 702595  WSW
18  3     29-MAR-01 11:25:04   2191681  682024  SSE
18 1      29-MAR-01 11:26:35   2178476  695122  WSW
```

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Database Design - Challenges

- The database needs to be constantly retrieved, mapped and updated
- Storing location data can represent a major cost in real-world tracking systems
  - Too many records to store
  - Performance considerations
- AVL data is in a different projection than the base street data from GDT

The Solution is Spatial Database

- ArcSDE stores and manages spatial data in relational database management system (RDBMS)
- ArcSDE supports multiuser GIS
- ArcIMS supports ArcSDE layers directly

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Database Design - Implementations

- Three programs running in parallel:
  - Loading Data into Oracle (written in Java)
    - Gets the AVL bus file from ESRI FTP server, parses the bus file and inserts the records in Oracle
    - Keeps only the most current position for each bus
    - Un-projects bus points to geographic coordinates
  - Creating ArcSDE layer (written in C)
  - Purging old data (written in Java)

Client Viewers - Requirements

- Defines the graphical look and functionality of the website
- Includes a map component and navigation tools
- Tracks the real-time bus locations
- Query by specific bus route and bus stop
- Combines traffic and weather data from other Internet sources

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Client Viewers – ArcIMS templates

- ArcIMS includes two types of client viewers:
  - ArcIMS HTML Viewer
    - A thin client written in HTML and JavaScript
    - Supports Image MapService
  - ArcIMS Java Viewer
    - A thicker client that requires a plug-in
    - Supports feature streaming
    - Supports data integration from other Internet sources

Client Viewers - Challenges

- Automatically repainting map when the database is updated
- Combining data from other Internet sources such as traffic and weather conditions
- Performance requirements

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Client Viewers – the First Prototype

- We used ArcIMS HTML client because it:
  - is a thinner client
  - supports both IE and Netscape browsers
  - is easy to customize
  - supports the concept of an “acetate layer”, which is ideal for tracking objects
- Drawback:
  - Can not integrate traffic, weather data from other Internet sources

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Client Viewer - Implementations

- Create a custom acetate layer to display bus locations
  - Sits on top of the map
  - Ideal for tracking objects that move in time
  - When objects move, only the acetate layer needs to be repainted

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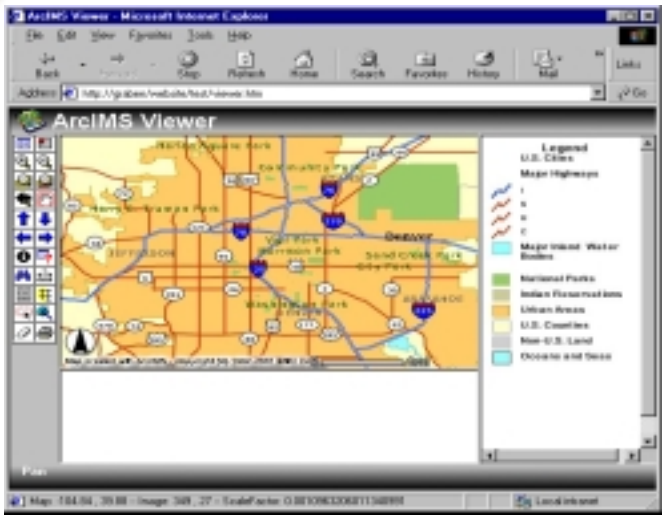
Client Viewer - Implementations

- A customized ASP program
  - Called by a hidden form on the client interface
  - Use ODBC to read Oracle directly
  - Read AVL data into arrays
- Customized JavaScript functions
  - Read elements in the arrays to construct a series of ArcXML requests to plot points in a acetate layer
  - Sent requests to server – use GET_IMAGE request
  - ArcIMS Spatial Server generates a new image with the bus points
- Use JavaScript function setInterval() to schedule the above functions at a two minutes interval

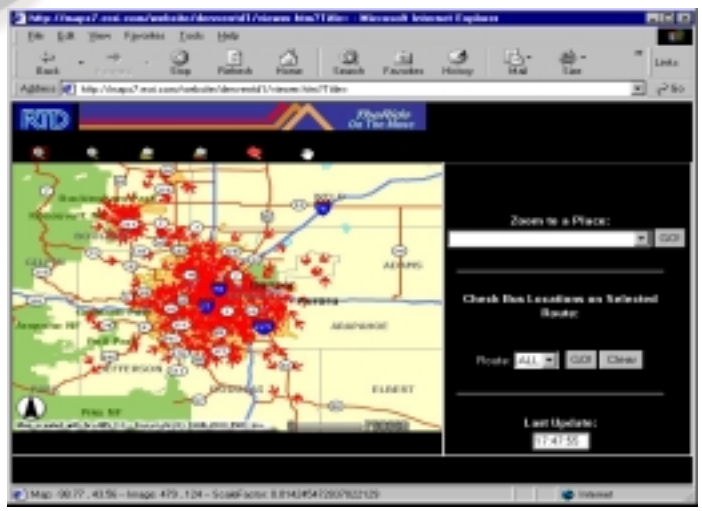
Default ArcIMS HTML Viewer



exor

GIS-T.2001. Virginia

Customized Client Interface



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User Experience

GIS-T.2001. Virginia

Client Viewers – Further Development

- A true ATIS should provide passengers with more information like traffic and weather conditions
- ArcIMS Java Viewer supports multiple MapServices to be combined
- Live traffic and weather conditions can be added from Geography Network – a collection of ArcIMS services provided by organizations around the world

Geography Network (www.geographynetwork.com)

- Multi-participant, open network for publishing, sharing, and using geographic information on the Internet
- Portal site for data, maps, and geoservices
- Data from various providers through one Web site
- Most of the services using ArcIMS as the delivery mechanism
- Querying Geography Network Explorer to find map services
- MapService can be added to ArcIMS Java Viewer directly

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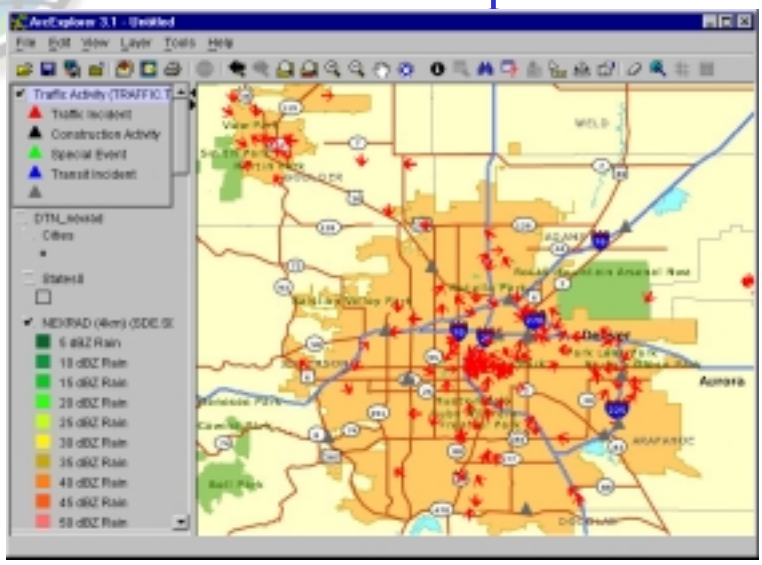
Java Viewer Still Under Development



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Afterthoughts
A better way?

- Direct access to RTD AVL system instead of using FTP
  - AVL data FTP to ESRI Server: 3-4 minutes old
  - Data Loader to Oracle: another 1-1.5 minutes
  - Data displayed in client viewer: 5-6 minutes old
- Create a custom Java Client that allows data integration and query functions
- Is automatically repainting the map screen really necessary?

Questions?

To Get Hold of The Presenters Later:

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Making GIS & Transit ITS Technology Work

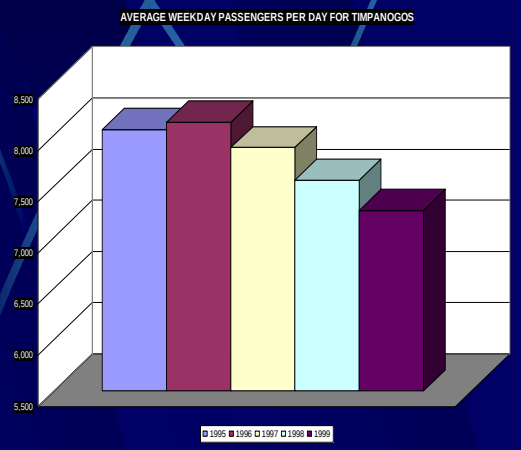
GIS and ITS in the Realignment of Utah County Bus Service

ITS Development at UTA

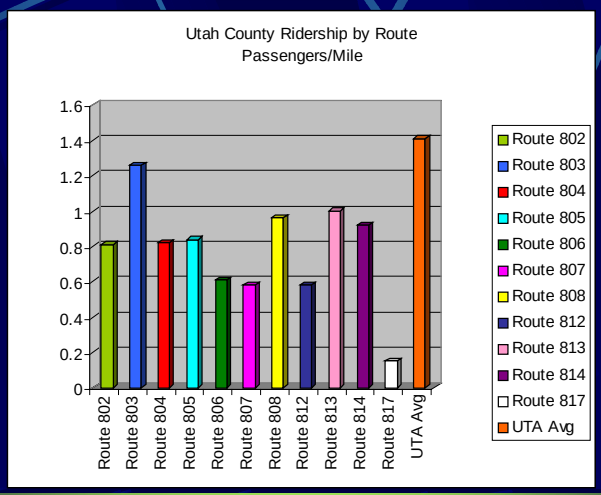
- Understanding practical uses
- Highest priority - automated passenger counters
- Biggest payoff for lowest cost
- 18 month test deployment of APCs
- 50 bus full deployment near completion

Utah County
Problem – Decreasing Ridership

- Ridership dropping
- System designed for coverage
- Rural areas difficult to serve
- Potential for county to withdraw from transit service district



Utah County
Problem - Poorly Performing Routes



Solution Strategy

- Preliminary analysis to understand the nature of the problem
  - What are the transit markets?
  - Where are our customer's origins?
  - What are their destinations?
  - What are the demographic profiles of the service area?

Solution Strategy

Three Phase Market Analysis

- Current ridership
  - Sample every trip
- Survey of current customers
  - 2 markets, local & express
  - Customer profiles
  - Trip purposes
- Market location
  - Demographic data and GIS

APC Process

- Three APCs used to gather all information
- Sample all trips at least three times
- Information to be reported at Service Development team meetings

APC Graphic Pre-Change Spatial Distribution

Survey Results

- Express Market - Commuters, Diverse Characteristics
- Local market
  - Students
  - Transit dependant
    - Lower income
    - Renters
    - Service industries

Utah County 2000 Transit Improvement Project

- **Local Market**
  - **University Students** **45%**
  - **Transit-Oriented Users** **48%**
  - **Other** **7%**

Utah County 2000 Transit Improvement Project

Of all local market trips,

students account for:

- **81% of school trips.**
- **24% of work trips.**
- **47% of shopping trips.**
- **47% of recreation trips.**
- **27% of medical trips**
- **29% of misc. reasons.**

transit-oriented users account for:

- **17% of school trips.**
- **65% of work trips.**
- **48% of shopping trips.**
- **50% of recreation trips.**
- **71% of medical trips**
- **63% of misc. reasons.**

Pre - Change Routes

•Designed for Coverage

•Created as various cities joined service district

•Long routes and low frequency

GIS

- Demographic Data
  - Claritas
  - Transit Oriented
    - Rental Housing

GIS

- Demographic Data
  - Transit Oriented
    - Household Income under $30,000/ Year

GIS

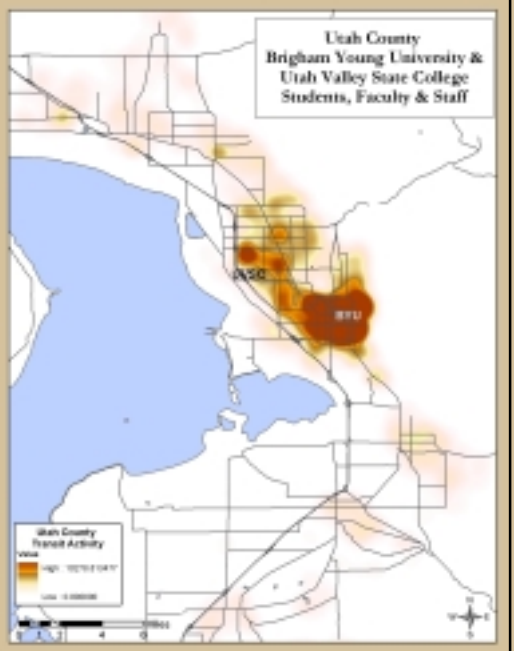
- Trip generators
  - License plate surveys
  - Major employer lists
  - Malls

GIS

- Universities
  - BYU & UVSC
  - Students
  - Faculty
  - Staff
- Spatial Analyst

GIS

•Density of Students, Faculty, Staff at BYU & UVSC



Analysis

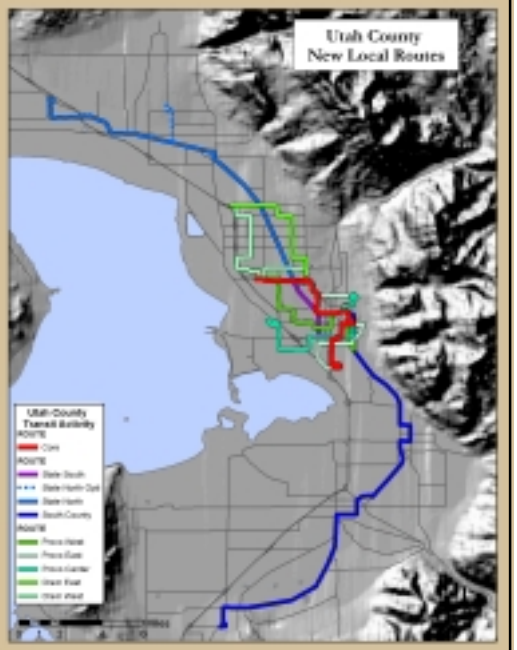
- GIS overlay
  - Buffer, Intersect, Proportional Sum
  - Walking access, Network Analyst
  - Optimum Path, Spatial Analyst
- Typical day - APC
- Density - Students & Population
- Paratransit Service Area Change
- Political Evaluation

Route Design

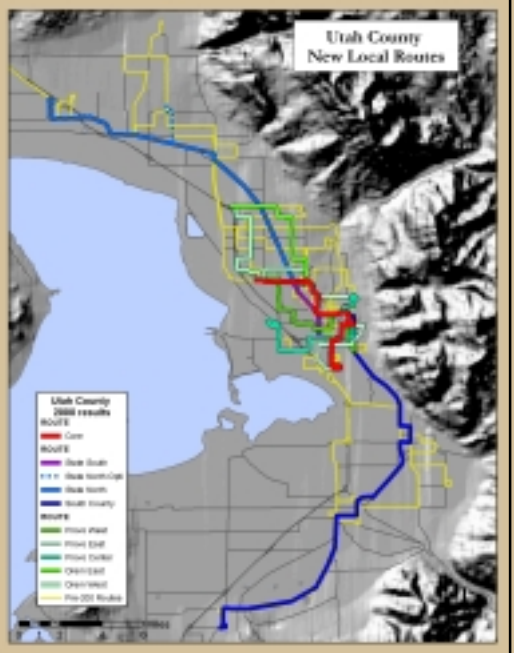
- Core route
- High frequency
- Good connectivity
- Increased potential trips
  - (Pop. within .25 mi) x (number of trips)
- Focus on market
- Improved opportunity

Route Design

- Local Routes
- Decrease coverage in areas w/o market density
- Coordinated connections at key transfer locations



Before & After



Results

- Implementation was August 2000
  - 6 months of data available on changes
  - Passengers/Day up 7.7%
  - Revenue Miles/Day down 13.7%
  - Revenue Hours/Day down 1.3%
  - Trips/Day up 44.1%
  - Passengers/Mile from .74 to .93 - up 25.7%
  - Passengers/Hour from 15.5 to 16.9 - up 8.9%
  - Passengers/Trip from 17.7 to 13.2 - down 25.5%

	Pass/Day	Rev.Mi/Day	Rev.Hrs/Day	Trips/Day	Pass/Day	Pass/Mile	Pass/hour	Pass/Trip
Before	7360	9846	474	415	7360	0.74	15.52	17.73
After	7927	8501	468	598	7927	0.93	16.9	13.2
% Change	7.7	-13.7	-1.3	44.1	7.7	25.7	8.9	-25.5