ORACLE

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CSX Rail: Implementation of Oracle's Spatial Routing, Geocoding, LRS and NDM in an Enterprise Rail Network

CSX Rail:
An Enterprise Rail Network Implementation

OVERVIEW

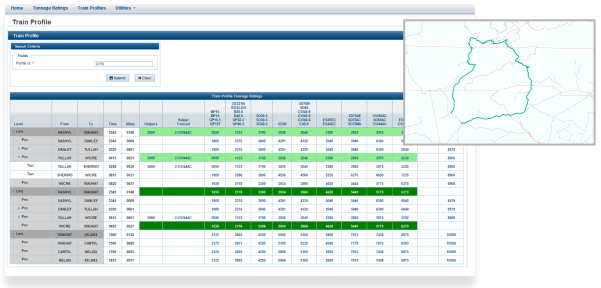
- Network Data Model use for Locomotive Tonnage ratings
- Linear Referencing System integration of Track Engineering information with GIS
- Routing and Geocoding web services use

CHALLENGES / OPPORTUNITIES

- Improve locomotive usage through more accurate routing
- Spatial integration of disparate systems
- Replacing legacy systems
- Improving operating efficiency through effective use of spatial technologies

SOLUTIONS

- Oracle Database 11g Release Enterprise Edition
- Oracle Spatial and Graph Option with
  - Network Data Model Graph and the NDM Load On Demand API
  - Routing engine and Geocoder web services
  - Linear Referencing System (LRS)



RESULTS

- Replaced an unsupported system with a well documented supported system
- Met modernization goals
- Standard, shared network data model provides consistent and trusted information
- Excellent Routing and Geocoding performance
- More efficient powering of trains (fuel savings)
- Improved on time placement of trains (increased operating efficiency)

Program Agenda

- Overview of current CSX environment
- Discussion of business drivers
- Discussion of Applications using Oracle's spatial technologies
  - Custom Rail Network Data Model
  - Deployment and use of Oracle's Spatial Geocoder and Routing Engine Webservices
  - Linear Referencing System integration of Track Engineering data

CSX Transportation

- Provides rail, intermodal and rail-to-truck transload services.
- Rail network spans approximately 21,000 miles
  - Service to 23 eastern states, the District of Columbia and two Canadian provinces.
  - CSX's network connects more than 240 short line and regional railroads and more than 70 ocean, river, and lake ports
- Over 3500 locomotives, 30k employees

CSX Technology Environment

- Approximately 500 Oracle databases, primarily 11.2.0.2
- Extensive use of RAC & ASM
- GIS
  - Dev & UAT are 2 node RAC systems running on Red Hat Linux OS
  - Production runs a 3 node RAC on Red Hat Linux OS

Locomotive Tonnage

- Business case for Locomotive Tonnage
  - Replace legacy network model
    - Princeton Data Model
    - Information is out of date
    - Proprietary
  - Improve Efficiency
    - Improves locomotive usage by applying the correct power to a train
    - **Reduce** fuel consumption
    - Correct power to trains improves service
  - In house support
    - Trusted data
    - Trusted results

Technical Solution

- Locomotive Tonnage
  - Network Data Model (NDM) Graph (feature of Oracle Spatial and Graph option)
  - Performance
    - Considerably faster than other platforms available to CSX
      - 100 route calculations in 6 seconds (through a web service)
    - Load on Demand API
      - Efficient and tunable
  - Standard platform
    - Oracle database servers are the corporate standard
    - Java is the standard development language
    - Oracle Spatial already used in several production locomotive systems
    - Oracle Spatial Routing Engine/Server is in use
  - Customizable
    - API / data model is flexible

Database Structures

- Building the Network Data Model

- Use the SDO_NET procedure to build the structures used in the Oracle Spatial and Graph NDM
  - SDO_NET.CREATE_SDO_NETWORK('NDM_CSX_TRACK',1,FALSE,'NDM_CSX_TRACK_NODE$','GEOM','COST','NDM_CSX_TRACK_LINK$','GEOM','COST','NDM_CSX_TRACK_PATH$','GEOM','NDM_CSX_TRACK_PLINK$','NDM_CSX_TRACK_SUBPATH$','GEOM');
  - Yields the following tables:

```
TNAME                          TABTYPE
------------------------------ -------
NDM_CSX_TRACK_SUBPATH$         TABLE
NDM_CSX_TRACK_PLINK$           TABLE
NDM_CSX_TRACK_PATH$            TABLE
NDM_CSX_TRACK_NODE$            TABLE
NDM_CSX_TRACK_LINK$            TABLE
```

Database Structures

- Building the Network Data Model

- Load network geometries and create an Oracle Spatial Topology
  - Use GIS (ESRI) tools to create the base network
  - Load network into Oracle using the SDO_GEOMETRY for storage
  - Create a Topology from the data
- Move data to the Network Data Model
  - Load the Topology nodes and links into the Network Data Model
  - Add node and link information as needed
  - Add userdata
  - Create partitions and partition blobs

Database Structures

- Additional steps

- Register with SDE
  - Enable visual verification of generated routes
  - QA of final network
  - Integration with Web mapping tools

Mid-Tier Tasks

- Overview of Routing tasks
  - What are routes used for?
    - Transportation Mile Post (*TMP*) to Transportation Mile Post directions
      - Results delivered in an ordered list
      - Distance given for overall route
      - Distance given for each link in the route
    - Alternate routes
      - 1 to n alternate routes can be requested
      - Alternates are returned in order of distance
      - Max difference in distance between routes

Mid-Tier Tasks

- Webservice Development

- Development Platform
  - IBM Rational
- Web Server
  - Websphere

Mid-Tier Tasks

- Web Service Development

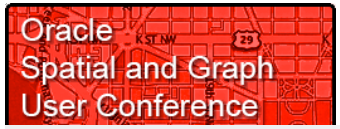
- Development approach
  - Bottom up….web service from POJO's
- SDONM API
  - Implemented LOD model
  - Used partition blobs
  - TMP names stored in userdata
  - Implements *KShortestPath* method

Mid-Tier Tasks

- Output

- Web Service Output
  - Turn by turn directions

Start TMP:QT 5 -- Stop TMP:QT 4 -- Path Distance:14.1177573572099
Start TMP:QT 4 -- Stop TMP:QT 0 -- Path Distance:917.172971666816
Start TMP:QT 0 -- Stop TMP:CTT 16 -- Path Distance:97.5923301481173
Start TMP:CTT 16 -- Stop TMP:CTT 17 -- Path Distance:48.9275776150029
Start TMP:CTT 17 -- Stop TMP:CTT 19 -- Path Distance:325.190283724741
Start TMP:CTT 19 -- Stop TMP:junction -- Path Distance:16.2986503525199
Start TMP:junction -- Stop TMP:CTT 38 -- Path Distance:82.0477769392928



End Use

Home | Tonnage Ratings | Train Profiles | Utilities

Train Profile

Train Profile

Search Criteria

Fields

Profile Id: * Q158

Submit | Clear

Train Profile Tonnage Ratings

Level	From	To	Time	Miles	Helpers	Helper Consist	MP15 MP15 GP15-1 GP15T	3GS21B RDSLUG B20-8 B40-8 GP38-2 GP40-2	SD50-2 SD50-3 SD40-2	SD50	SD70M SD60 CW44-9 CW40-9 CW40-8 C40-8	ES40DC ES44DC	SD70AE SD70AC SD70MA	CW60AC SD80AC CW44AC	ES44AH CW44AH	Proj Tons	80% Hist Tons
Lms	NASHVL	WAUHAT	2345	0148	5900	2-CW44AC	0850	1122	1700	2026	2040	2380	2805	2975	3230		8906
Pro	NASHVL	DANLEY	2345	0009			1800	2376	3600	4291	4320	5040	5940	6300	6840		9579
Pro	DANLEY	TULLAH	0230	0061			1800	2376	3600	4291	4320	5040	5940	6300	6840		9579
Pro	TULLAH	WICRE	0615	0051	5900	2-CW44AC	0850	1122	1700	2026	2040	2380	2805	2975	3230		8906
Ton	TULLAH	SHERWO	0559	0030	5900	2-CW44AC	0850	1122	1700	2026	2040	2380	2805	2975	3230		8906
Ton	SHERWO	WICRE	0615	0021			1900	2508	3800	4530	4560	5320	6270	6650	7220		8906
Pro	WICRE	WAUHAT	0830	0027			1650	2178	3300	3934	3960	4620	5445	5775	6270		8906
Lms	NASHVL	WAUHAT	2345	0148			1650	2178	3300	3934	3960	4620	5445	5775	6270		
Pro	NASHVL	DANLEY	2345	0009			1800	2376	3600	4291	4320	5040	5940	6300	6840		9579
Pro	DANLEY	TULLAH	0230	0061			1800	2376	3600	4291	4320	5040	5940	6300	6840		9579

Oracle Enterprise Geocoding & Routing

- Business case for Routeserver and Geocoder webservice
  - Jobtrax application
    - Place bids on jobs and add, change, remove or prioritize bids during a bid cycle
      - This important requirement requires a route from the employees location to the job site
- Business case for server side geocoding
  - Locomotive start/stop event reverse geocoding
    - Determine patterns in start/start stop events

Enterprise Geocoding & Routing with Oracle Spatial and Graph

- Webservice deployment using Oracle Spatial and Graph's built-in engines
  - Geocoder
  - Routing engine
    - Tuning mid-tier JVM for performance
- Geocoding within the database
  - Parallel batch geocoding for performance

Geocoding and Routing web service

- Purchase and deploy third party data
  - Tom Tom was the vendor
  - Purchased both Geocoding and Routing data
- Deployment environment
  - IBM Websphere

Geocoding and Routing

Functions and Applications

- Job Trax Application
  - Match employees to Jobs by distance
    - Input address of employee and job location
      - Single and Batch Geocoding or Routing to job
      - Route could be between any 2 points
- Locomotive start/stop event reverse geocoding
  - Nightly batch job
  - Processes GPS information transmitted from Locomotives
  - Determines nearest address to a locomotive stop

Oracle Spatial and Graph Routing Engine

Route generation time

- Tuning Routeserver JVM
  - Partitions in memory = faster performance
  - More memory = more Partitions
    - Do not size the max_partition parameter too high
  - Performance increase is not linear
  - More partitions = more consistent response

Average response time (seconds) for route generation. Test size is 650 routes.

Partitions	Avg Response
150	2.549391253
150	2.758800236
150	2.488332151
200	3.287419622
200	3.414976359
450	1.742868794
450	1.639865248
650	1.776641844
650	1.7241974
1300	1.227327423
1300	1.219875887

Parallel Geocoding

- Batch Parallel processing
  - Stats are for reverse geocoding
  - Near linear increase in performance
  - 8 core Linux system used
    - 2 node RAC used for testing
    - Parallel processing limited to one node

Parallel	Rows Geocoded	Minutes	Seconds
1	51,118	119	22
3	51,118	38	16
6	51,118	29	36
10	51,118	22	15
14	51,188	15	37

Oracle Spatial and Graph LRS use for Rail Network Data Integration

- Business case for LRS (Linear Referencing System)
  - Visualize Engineering data on a map
  - Improve (reduce) operating cost through better understanding of rail conditions
    - Slow orders
    - Track time
    - Rail Defects
    - Track Curfews

Oracle Spatial LRS use for Rail Network Data Integration

- Using LRS to integrate track information with GIS
  - Connecting to existing non-spatial engineering systems
  - Using dynamic segmentation for events
  - Turning the end results into web map layers
- Automation of creating new dynseg events (layers)
  - Using APEX and stored procedures
  - Layers used in MapCSX ESRI web mapping application

Oracle Spatial LRS use for Rail Network Data Integration

- Biggest Challenges
  - Integration of disparate systems
    - GIS and Engineering are separate databases
    - Matching data between systems
      - No consistent primary keys
    - Data quality

APEX & LRS

Dynamic Dynseg Overview screen

Home | Dynseg Administration | Monitor

Dynamic Dynseg Control

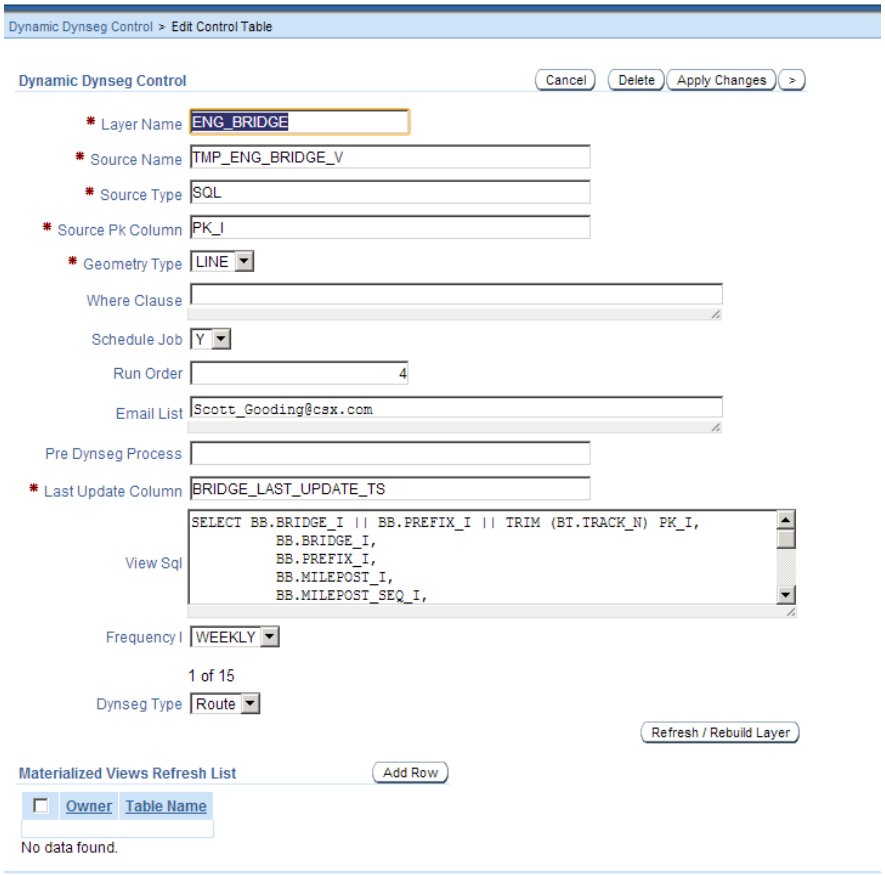
Go | Actions | Create New Layer

Rowid	Layer Name	Schedule Frequency	Source Name	Source Type	Source Pk Column	Geometry Type	Schedule Job	Run Order	Email List	Pre Dynseg Process	Last Update Column	Dynseg Type
	ENG_CULVERT	WEEKLY	TMP_ENG_CULVERT_V	SQL	PK_I	POINT	Y	1	Scott_Gooding@csx.com	-	CULVERT_LAST_UPDATE_D	ROUTE
	ENG_TURNOUT	WEEKLY	TMP_ENG_TURNOUT_V	SQL	PK_I	POINT	Y	2	Scott_Gooding@csx.com	-	LAST_UPDATE_D	ROUTE
	OEX_JOINT_FAC	WEEKLY	TMP_ENG_OEX_JOINT_FACILITIES_V	SQL	PK_I	Line	Y	11	scott_gooding@csx.com	-	LAST_UPDATE_D	ROUTE
	ENG_CURVE	WEEKLY	TMP_ENG_CURVE_V	SQL	PK_I	Line	Y	7	scott_gooding@csx.com	-	LAST_UPDATE_D	ROUTE
	RSFRAIL_DEFECT	WEEKLY	TMP_RSF_RAIL_DEFECT_V	SQL	PK_I	Point	Y	17	scott_gooding@csx.com	-	LAST_UPDATE_D	ROUTE
	OEX_MAINLINE	WEEKLY	TMP_ENG_OEX_MAINLINE_V	SQL	PK_I	Line	Y	13	SCOTT_GOODING@CSX.COM	-	LAST_UPDATE_D	ROUTE
	OEX_SIDINGS	WEEKLY	TMP_ENG_OEX_SIDINGS_V	SQL	PK_I	Line	Y	10	SCOTT_GOODING@CSX.COM	-	LAST_UPDATE_D	ROUTE
	ENG_TUNNEL	WEEKLY	TMP_ENG_TUNNEL_V	SQL	PK_I	LINE	Y	3	Scott_Gooding@csx.com	-	TUNNEL_LAST_UPDATE_D	ROUTE
	ENG_BRIDGE	WEEKLY	TMP_ENG_BRIDGE_V	SQL	PK_I	LINE	Y	4	Scott_Gooding@csx.com	-	BRIDGE_LAST_UPDATE_TS	ROUTE
	TCIS_YTD	Daily	TCIS_BASE_YTD	TABLE	PK_I	Point	Y	14	scott_gooding@csx.com	update_TCIS_data	INCIDENT_OPEN_TS	ROUTE
	TRACK_CURFEWS	Daily	TMP_OP_ENG_TRACK_CURFEWS_V	SQL	PK_I	LINE	Y	5	Scott_Gooding@csx.com	-	LAST_UPDATE_D	ROUTE
	TCIS_7DAY	Daily	TCIS_BASE_7DAY	TABLE	PK_I	Point	Y	15	scott_gooding@csx.com	-	INCIDENT_OPEN_TS	ROUTE
	TRACK_TIME	Hourly	TMP_TRACK_TIME_V	SQL	PK_I	Line	Y	16	SCOTT_GOODING@CSX.COM	-	LAST_UPDATE_D	PREFIX
	SLOW_ORDERS	15 Mins	SLOW_ORDERS_V	SQL	PK	Line	N	6	SCOTT_GOODING@CSX.COM	-	LAST_UPDATE_TS	ROUTE
	TRACK_WORK	15 Mins	TRACK_WORK_704_707_V	SQL	PK_I	Line	N	5	SCOTT_GOODING@CSX.COM	-	NTWMP_LAST_UPDATE_TS	ROUTE

1 - 15

APEX & LRS

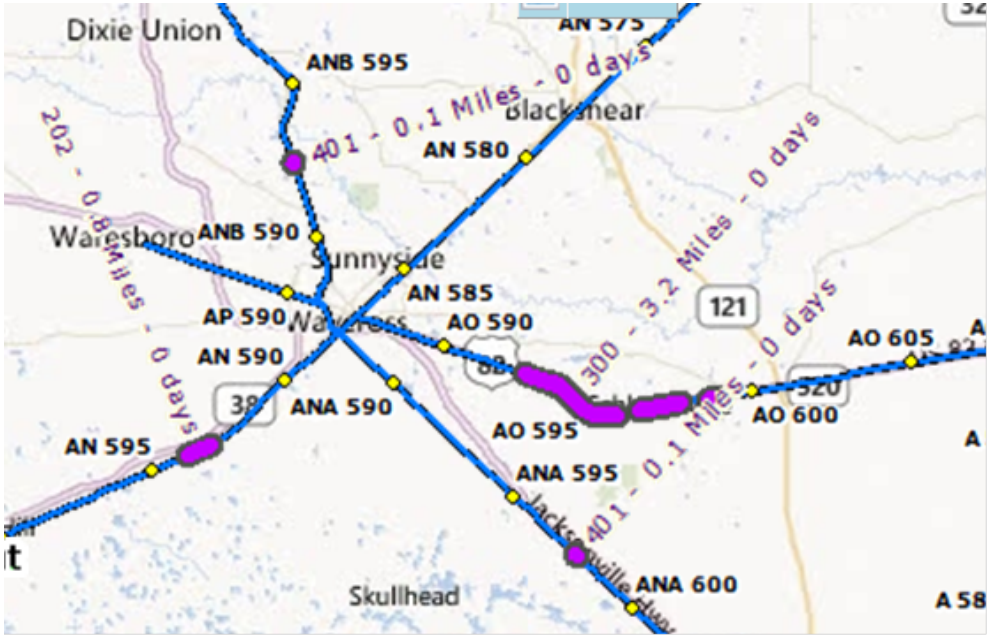
Dynamic Dynseg edit screen



LRS Integration

- End Result

- Using LRS to visualize track information
- Slow order example
  - Major metric is avg train speed
  - Slow Orders require Trains to slow for track work
  - ESRI software used for visualization



Q&A