Employing Network Analyst to Optimize Field Operator Routes

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Problem

• Oil & Gas field operator routes require updating on a regular basis as new well, valve, pigging, and facility locations are added (and removed)

• Previous methods of updating routes often took 2-6 weeks and only included well and facility locations
Goals

• Improve safety by avoiding high-risk areas and school zones
• Improve efficiency of routes and minimize costs/wear to vehicles
• Quickly update routes as new locations are added or temporarily altered by road closures/delays caused by floods, traffic accidents, etc..
568 sites to be visited by 20 field operators from field office
Solution

• Implement a road network routing solution utilizing ESRI’s VRP capabilities within Network Analyst
Final routing to all 568 sites to be visited by 20 field operators
Data Requirements

• Needed to be updated by staff on a regular basis for the addition of new lease roads
  – Rules out any read-only data

• High accuracy needed for risk analysis
  – Stratmap – Outdated (2006), but highly accurate and already in use by staff
  – Map21 – Updated and highly accurate, though not available until Summer 2015
    * Both (will be) available at tnrис.org
<table>
<thead>
<tr>
<th>Data</th>
<th>Present?</th>
<th>Actions</th>
</tr>
</thead>
<tbody>
<tr>
<td>CFCC/FCC (Census Feature Class Code) fields detailing road types/descriptions</td>
<td>YES</td>
<td>FCC used to update some Speed and Surface fields. Also used for driving directions.</td>
</tr>
<tr>
<td>Hierarchy – Typically ranked 1-3, but can be 1-5 with 1 as most preferred route.</td>
<td>NO</td>
<td>Calculated using highway data. Updated after AADT, Speed, and Surface data was entered.</td>
</tr>
<tr>
<td>Elevation – Can utilize actual elevation values or represent levels ( 0 to 1, 1 to 1, 1 to 2, 1 to 0, etc..)</td>
<td>NO</td>
<td>F_ZLEV and T_ZLEV fields were added and manually updated utilizing TxDOT bridge layer marking locations of all overpasses.</td>
</tr>
<tr>
<td>Oneway – Uses From – To (FT), To – From (TF), or No Travel (N).</td>
<td>YES/NO</td>
<td>Oneway field present, but only marked N, E, S, W directions. Updated Oneway fields manually.</td>
</tr>
<tr>
<td>Speed – MPH/KPH</td>
<td>NO</td>
<td>Utilized TxDOT data to update fields for major roads. Minor roads utilized FCC code</td>
</tr>
<tr>
<td>Surface – Concrete, Asphalt, Gravel, None...</td>
<td>NO</td>
<td>Utilized highway data, local knowledge, and imagery - manually updated.</td>
</tr>
<tr>
<td>Restrictions – Elected to add a restrictions field to facilitate queries.</td>
<td>NO</td>
<td>All private roads, 3rd party lease roads, ranch roads, driveways, and trails marked as private (P) to exclude features from ND/VRP analysis.</td>
</tr>
<tr>
<td>Average Annual Daily Traffic (AADT) for pipeline-road crossing risk ranking.</td>
<td>NO</td>
<td>Utilized TxDOT data to update fields. Not all fields were updated with values.</td>
</tr>
<tr>
<td>Accuracy/Updated</td>
<td>YES/NO</td>
<td>Stratmap maintained high accuracy and detail, but needed updating since the data was 10 years old.</td>
</tr>
</tbody>
</table>
Final Preparation of Data for Network Dataset

• Added LENGTH field – Calculated length (Miles)
• Added MINUTES field – LENGTH/SPEED*60

*Both required for VRP build

*Minutes attribute can be added when creating Network Dataset
Building the Network Dataset

Adding Restrictions

- Restriction added to exclude all 3rd party lease roads, private roads, ranch roads, driveways, and trails from route generation and analysis
Building the Network Dataset

Setting the Evaluators

• 1. Type values set to “Field”
• 2. Evaluator Properties selected to add expression
Building the Network Dataset

Evaluator Expression

- Expression entered to restrict travel on private roads (P)
Building the Network Dataset

Verifying ND Attribute Values

1. Unit value changed to “Miles”
2. Evaluator Values changed to “LENGTH”
Building the Network Dataset

Other Options

- Add More Participating Feature Classes
- Model Turns
- Connectivity Settings
- Model Elevation
- Create Travel Mode(s)
- Establish Driving Directions
- Build Service Area Index
Populating Route Fields

- **Settings**
  - Max Order Count set to 35
    - General setting that may be changed in the future to accommodate more drivers
  - 60 minute breaks assigned to each driver. (Breaks Application)
    - To be taken within a 2 hour window
  - Max Total Time set to 480 minutes (8 hours)
    - Limits the driver to 7 hours of work in the field
    - 8th hour is accounted for in the break above
    - Leaves additional hour to be spent at office (meetings, preparation)
  - Specialties and Start/End Depot assigned
Populating Order & Depot Fields

• Orders - Settings
  – Service Time for each site set to 10 minutes
    • This is an average value
  – Specialties Added

• Depot - Settings
  – Time Window Start set to 6:30 am
  – Time Window End set to 5:00 pm
Solving the VRP

All **Orders** (Facility/Well Sites)
**Depot** (Office)
and **Routes** (Operator Trucks) added

Not in initial VRP solve
- Barriers
- Seed Points
- Route Zones
- Order Pairs
Resolving Unassigned Orders

• Unassigned Order – Unreachable
• Check Connectivity
Resolving Unassigned Orders

- Unassigned Order – Unreachable
- Lines do not meet at end point
- Split line
- Recalculate LENGTH and MINUTES
- (Re)Build network from catalog window
- Run VRP Solve again
Resolving Unassigned Orders

• Unassigned Order – Resolved

• Other Errors
  – Max Order Count exceeded
  – Capacities exceeded
  – Unmatched Specialty
  – Max Total Time exceeded

* See ArcGIS Help for more errors & descriptions
## Initial Results

<table>
<thead>
<tr>
<th>Name</th>
<th>Overtime Start Time</th>
<th>Overtime</th>
<th>Cost Per Unit</th>
<th>Max Order Count</th>
<th>Max Total Time</th>
<th>Order Count</th>
<th>Total Time</th>
<th>Total Order Service Time</th>
<th>Total Break Service Time</th>
<th>Total Travel Time</th>
<th>Start Time</th>
<th>End Time</th>
<th>Hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>Truck_03</td>
<td>&lt;Null&gt;</td>
<td>35</td>
<td>480</td>
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<td></td>
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</tbody>
</table>

**Lowest Value**

**Highest Value**
Balancing Route Times

• Route Durations
  – Shortest route – Truck 20 = 5.56 hours
  – Longest route – Truck 12 = 7.99 hours
    • Difference of 2.4 hours!

• The route durations need to be evenly distributed among the 20 field operators
Artificial Overtime

• Evenly distribute route durations by artificially inflating overtime costs

• Divide the sum of the Total Time field by the number of routes
  – Truck 01 + all other routes ≈ 9200 minutes
  – 9200 minutes / 20 routes ≈ 460 minutes
  – 460.5 minutes is entered for the value of the Overtime Start Time field for all routes
    (*0.5 minutes was added after another iteration)
## Final Results

<table>
<thead>
<tr>
<th>Name</th>
<th>Overtime Start Time</th>
<th>Cost Per Unit Overtime</th>
<th>Max Order Count</th>
<th>Max Total Time</th>
<th>Order Count</th>
<th>Total Time (Minutes)</th>
<th>Total Order Service Time</th>
<th>Total Break Service Time</th>
<th>Total Travel Time</th>
<th>Start Time</th>
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<th>Hours</th>
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<tbody>
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<td>6/25/2015 6:30</td>
<td>6/25/2015 14:11</td>
<td>7.70</td>
</tr>
</tbody>
</table>

**Lowest Value**

**Highest Value**
Routes Balanced

• The duration between the shortest route and longest route now only differs by 20 minutes

• The duration of each route ranges between 7 hours 40 minutes – 8 hours
Truck 18 Route and Stops
Truck 18
Driving Directions

• Turn-by-turn directions
  – Accumulated Distance
  – Time of Day
  – Total Drive Time
  – Total Mileage
  – Inset Maps

• Shared as .txt, .html, .xml files
Adding Specialties

• Order #15 (selection) on Truck 18’s route requires driver with skills to maintain special equipment
• Truck 20 operator has skills needed to service special equipment
Routes After Specialty Added

• Routes have been re-solved and updated for the addition of a specialty item to Truck 20’s route
• The re-solve has completely changed all routes in the area
• Option exists to preserve routes and sequence, if required (Orders table)
Route Barriers

• Flooding
  – Modeling flooding scenarios ready the operators for changes in routes due to impassible barriers

• Unreachable sites can quickly be identified

*In this scenario a polygon barrier is added to determine new, temporary routes
Present Routes – Flood Scenario

Flooded Areas (Outlined in Red)
New Routes – Flood Scenario

Flooded Areas (Outlined in Red)
Old Routes Traversed Flooded Areas
New Routes Avoid Flooded Areas
Inspector Routes

- Regularly inspectors will check equipment at one to two dozen sites
- Inspectors may not be familiar with the field
  - Driving Directions
  - Reorder/Optimize Routes
    - Traveling Salesman
Results

• Safer routes generated
• Ability to generate new routes in seconds saves thousands of dollars in employee hours with each new route creation
• Decrease in vehicle fuel and maintenance costs
• Inspector routes offer driving directions and optimized routing
Extending Capabilities of VRP & the Network Dataset

• Publish as a web service
  – Utilize vehicle GPS tracking

• Strive to further reduce costs
  – Utilize road surface conditions
  – Extract true elevation values to establish true length and factor in slope as a cost

• Add a “floating” operator
  – Useful for substitutions
Questions?
Contact Information

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