SNOW AND ICE ROUTE OPTIMIZATION IN KENTUCKY

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AGENDA

- Background
- Objectives
- Literature search
- Approach
- Setting up the data
- Analysis
- Obstacles
- Results

BACKGROUND

- KYTC typically expends between $40-$80 million/year
  - $75 million in 2014
- Currently, routes are largely county-based, with each county having a designated number of trucks and facilities available to address the county's needs
- Additionally, these routes are prioritized into categories according to several factors, with Average Annual Daily Traffic (AADT) being the most influential
- Interstates receive the highest priority

BACKGROUND

- The currently used snow and ice removal system has been in place for some time and functioned effectively
- GIS-based analytical tools could be used to further optimize the system
- System optimization could potentially improve mobility and safety by clearing roads more efficiently
- If this potential is realized, KYTC could also save considerable time and money through system optimizations

OBJECTIVES

- This research will utilize ArcGIS to analyze the current system of snow and ice
- Determine if any optimizations to the system are possible
- This analysis will include the following factors:
  - Routes
    - Priority
    - Lanes
  - Location of salt and brine facilities
  - Distribution and type of trucks
  - Time required for road clearance
    - Optimize

LITERATURE REVIEW

- FHWA recommends AADT as a measure for priority
- Consideration should be given to equalizing the number of routes per truck
- Time is typically the variable that is minimized
- Some agencies developed their own software, used existing GIS software, or developed mathematical models
- An interactive approach is preferred; local knowledge

APPROACH

- Tried ESRI's Vehicle Routing Problem VRP – too many setbacks
- Investigated using other states' software – too old
- Looked into developing mathematical models – was becoming too time consuming

- Went back to ESRI's VRP!

SETTING UP THE DATA

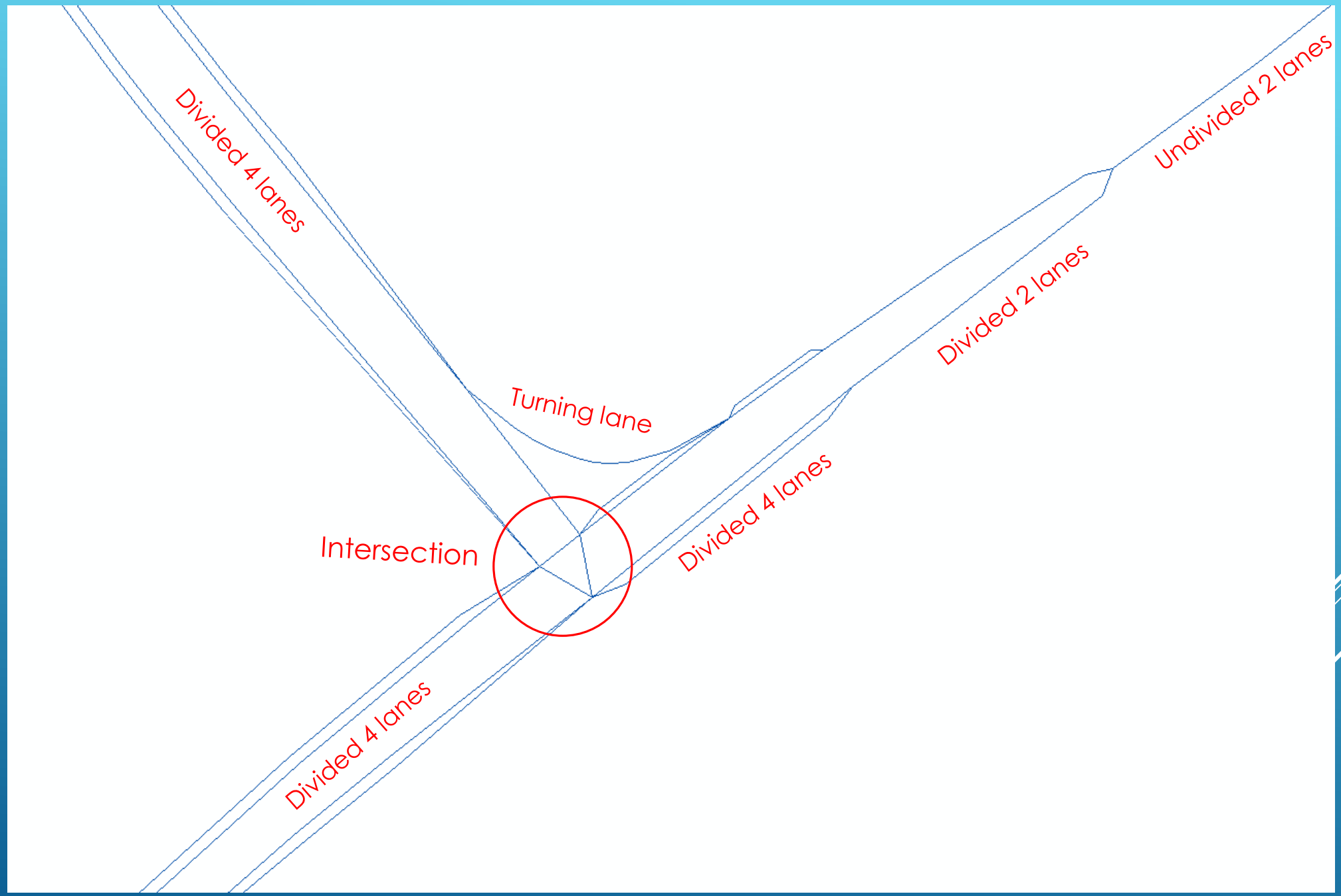
- Kentucky's SNIC roads needed tweaking to be used for network analyst
- Several additional roadway attributes were required:
  - Number of lanes, traffic volume, oneway/twoway, route type, speed limit
- These datasets are contained in separate assets
- Route overlay was used to combine these assets and create a new segmentation
- For divided highways, data from the mainline counterpart was used (data are only reflected on the mainline)

SETTING UP THE DATA

- Simplifying the network
  - Two speeds for SNIC trucks established:
    - For interstates, parkways, highways, truck speed set at 30 mph
    - For rural roads and congested areas, truck speed set at 15 mph
  - Dissolve road layer according to the following fields:
    - SNIC_PRIORITY, LANES, TYPEROAD, ONEWAY, SPEED
  - Create points at all intersections (Intersect tool)
  - Convert multipoint feature to point feature (the newly created intersections)
  - Split dissolved road layer at intersection points
  - Calculate geometry for length in miles

SETTING UP THE DATA

- Accounting for multiple lanes
  - Need to account for either multiple trucks or the same truck on multiple passes treating each lane along roadway segments
  - Edit Features, Select roads by number of lanes, Copy Parallel, offset 12'
    - For "FT" segments, copy to the right, for "TF" segments, copy to the left. Two-way segments can be copied to either side
  - ET GeoWizards: Global Snap Polylines
    - Snaps endpoints of newly created parallels to nodes (already created intersection points)


Divided 4 lanes
Undivided 2 lanes
Turning lane
Divided 2 lanes
Intersection
Divided 4 lanes
Divided 4 lanes

SETTING UP THE DATA

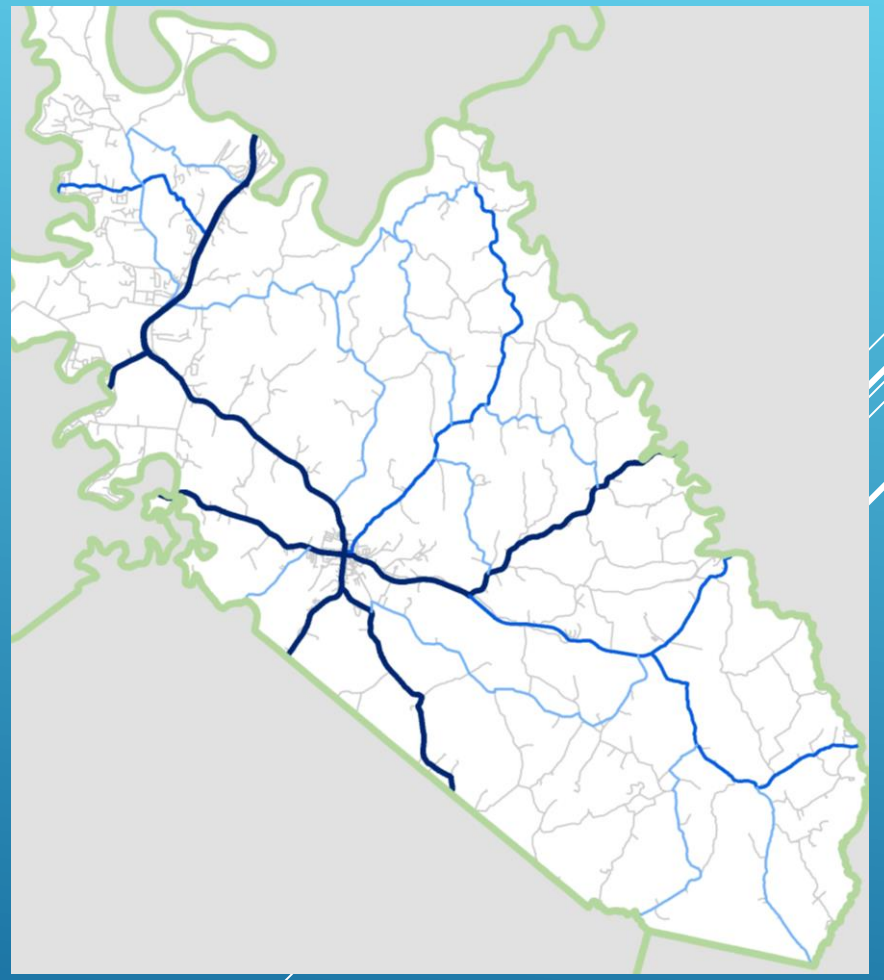
- Parameters for the network dataset
  - Road data is the only layer needed
  - Global turns
  - Connectivity at endpoints, No elevation field
  - Attributes:
    - Length: miles
    - Minutes: time required for a truck to travel the segment length according to the SNIC speed limit
    - Oneway: “FT”, “TF”, or “”

ANALYSIS

- Rules for Snow and Ice Clearance

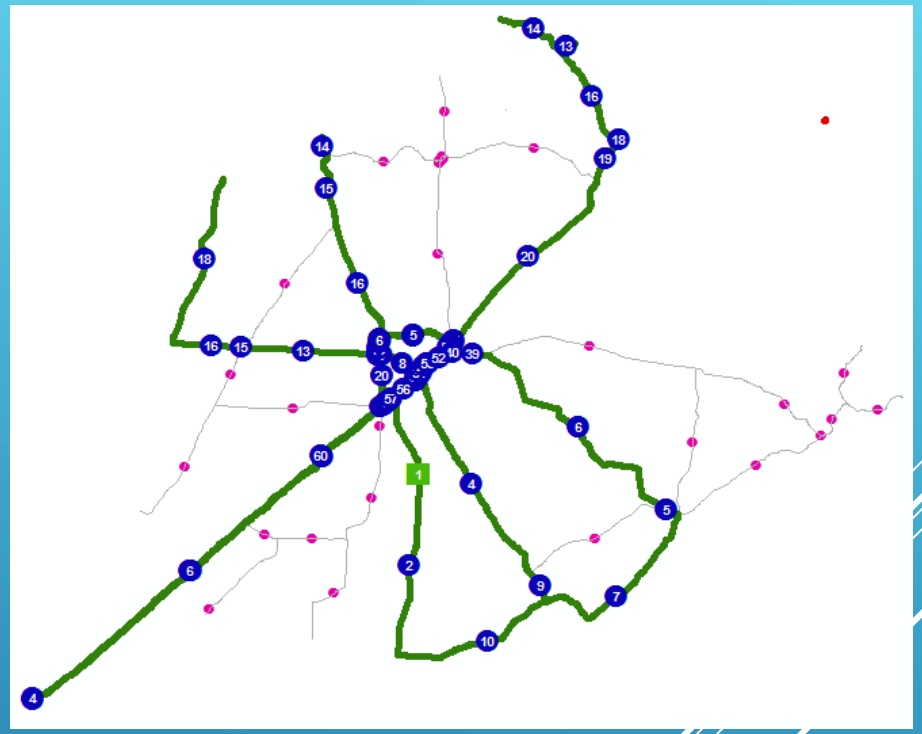
  During a ‘typical’ winter storm (1” snow):

  - Interstates and parkways should be treated during a routine winter storm with a goal of a one-hour turnaround
  - All other Priority A routes should be treated with a goal of a two-hour turnaround
  - Priority B routes should be treated with a goal of a four-hour turnaround
  - Priority C routes should be treated with a goal of an eight-hour turnaround

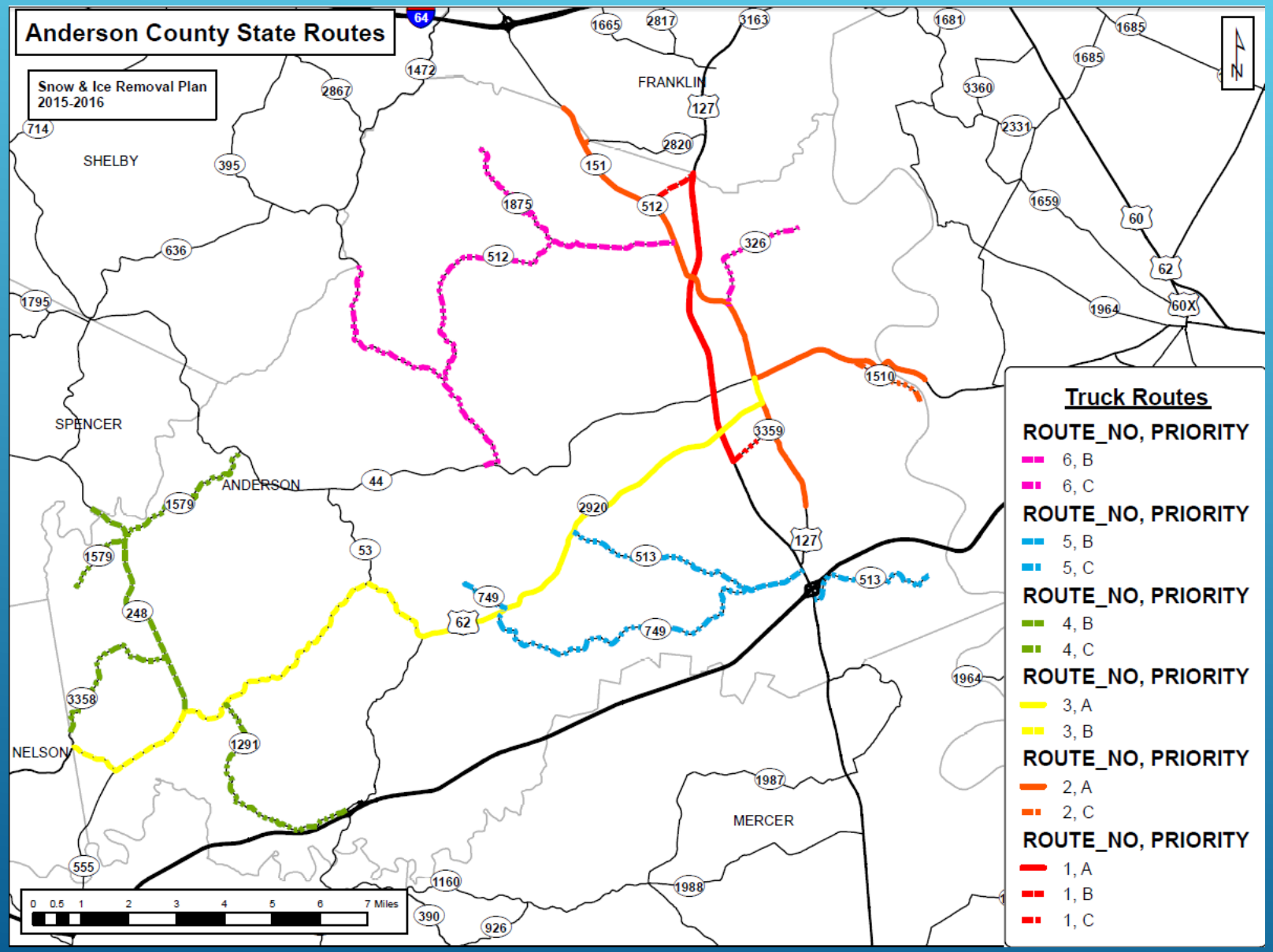


ANALYSIS

- ArcGIS Network Analyst: Vehicle Routing Problem
  - This solver finds the best routes for a fleet of vehicles to service many orders.
  - Can account for several constraints, such as vehicle capacities, time windows, delivery types, side of the road for delivery, route renewals
  - First, need to understand the current system and existing constraints



CURRENT ROUTES



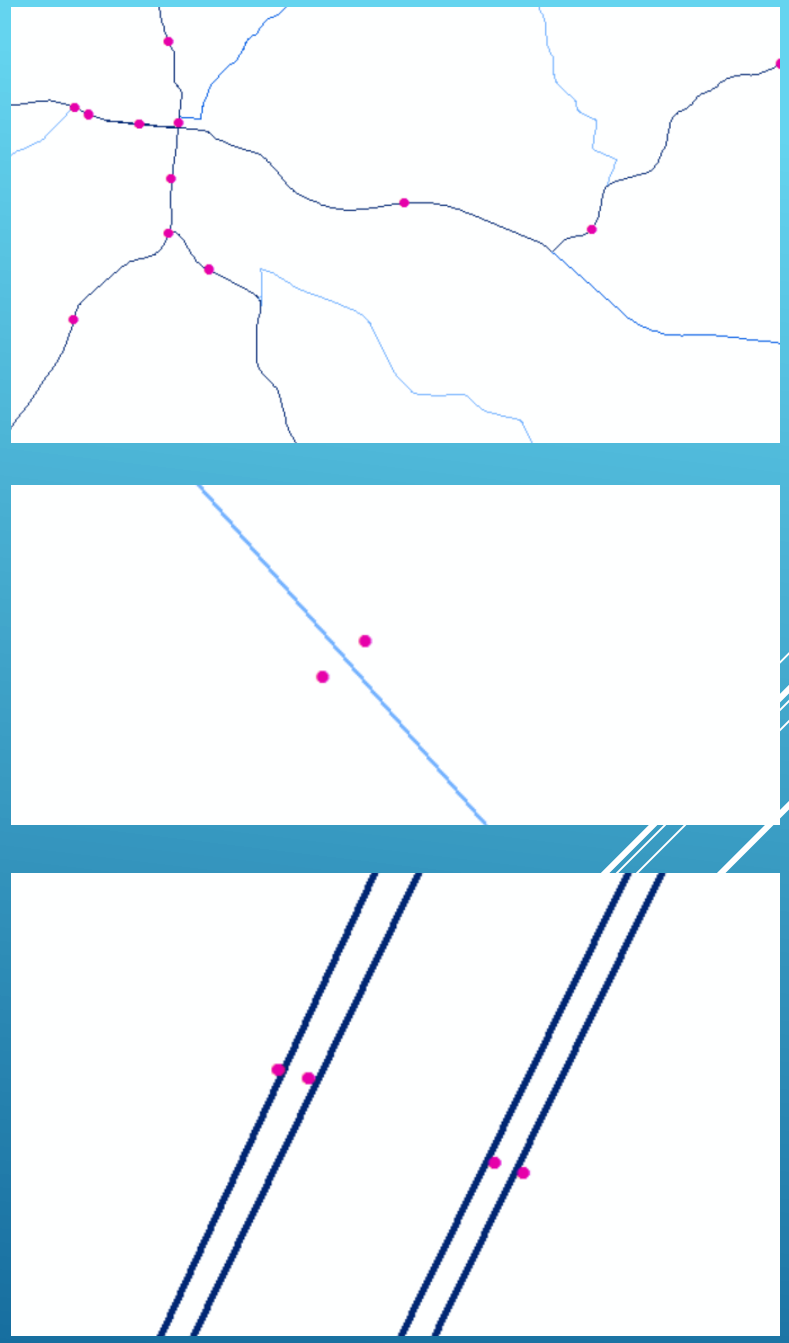
Anderson County		COUNTY PRIORITY SYSTEM
PRIORITY A - INTERSTATE (SINGLE LANE MILES)		71.354
PRIORITY A - OTHER ROUTES (TWO LANE MILES)		87.4
PRIORITY B -	(TWO LANE MILES)	59.7
PRIORITY C -	(TWO LANE MILES)	53.1
CONTRACTOR RESPONSIBLITIES		
PRIORITY A - INTERSTATE (SINGLE LANE MILES)		71.354
CONTRACTOR UNITS		6
CONTRACTOR MILES/CONTRACTOR UNITS		12
Anderson		COUNTY CREW RESPONSIBILITIES
PRIORITY A - INTERSTATE (SINGLE LANE MILES)		0
PRIORITY A - OTHER ROUTES (TWO LANE MILES)		73.4
PRIORITY B -	(TWO LANE MILES)	41.2
PRIORITY C -	(TWO LANE MILES)	50.5
NUMBER SALT SPREADERS		5
A & B MILES/SALT SPREADER	120.4/5	22.92
*CREW SIZE		12
AVAILABLE TRUCK OPERATORS		10
*A & B MILES/CREW SIZE	120.4/10	9.55

ANALYSIS

- Assessing Current SNIC Routes
  - All current routes created using Network Analyst Routes
  - Points to define the routes added manually to network according to current KYTC SNIC book
  - Time required for these routes calculated through Network Analyst, total time tallied for all routes
  - This total time serves as the baseline for analysis: to what extent can this optimization routine improve upon the time needed to treat all routes within all the constraints

ANALYSIS

- ‘Delivery’ Points
  - Snow and ice treatment as a “delivery” optimization problem
  - Midpoints created for all road segments, offset to the right of the driving direction
    - ET Geowizards: Points along polylines, Midpoints, Offset 3’
  - Points represent “deliveries” of salt



ANALYSIS

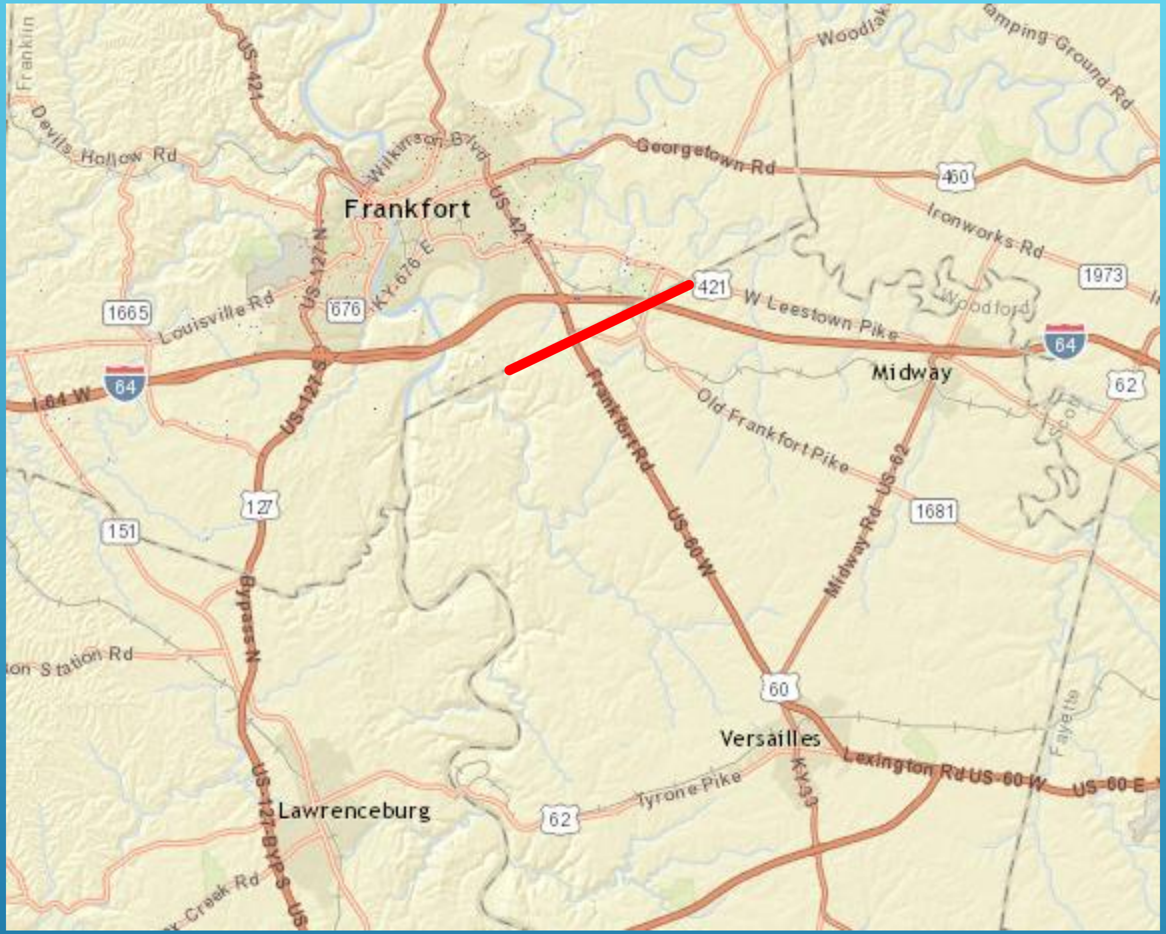
- ‘Point feature class contains the following data fields:
  - Delivery Quantities: The length of the road segment for which the point represents
  - SpecialtyNames: SNIC priority, i.e. ‘A’, ‘B’, ‘C’
  - CurbApproach = 1 (right side of the road approach only)
  - TimeWindowStart: 8:00 AM
  - TimeWindowEnd: corresponds to the Specialty Name
    - A priority – 10:00 AM, B priority – 12:00 PM, C priority – 4:00 PM

ANALYSIS

- **Setting Up the Vehicle Routing Problem**
  - Orders: The salt delivery points, i.e. midpoint of road segment
  - Depot: County maintenance facility containing SNIC equipment and salt dome
  - Specialties: Used to restrict certain types of trucks to certain types of routes
  - Routes: Number and type of truck available for the county
    - Capacities: route should require about 80% of the truck's salt
    - KYTC trucks, contract trucks
    - Single axle trucks, tandem trucks
  - Route Renewals
    - Enables trucks to return to the facilities and reload on salt
  - VRP layer properties
    - Time Attribute and Distance Attribute
    - U-Turns at Junctions option to "Allowed only at intersections and dead ends"

OBSTACLES

- Routing issues
  - Desire for most efficient routes?
  - Or desire for most realistic/efficient routes?
  - Interstate ramps, multi-lane highways, divided highway turnarounds
  - "Tricking" the solver to provide more realistic routes
- Iterative process: altering the constraints a little can lead to very different results
  - Time violations (H, M, L), Excess transit (H, M, L)
  - Altering start time according to SNIC priority
  - Grouping routes according to SNIC priority


Frankfort
Midway
Versailles
Lawrenceburg
Georgetown Rd
Devils Hollow Rd
Wilkinson Blvd
Louisville Rd
W Leestown Pike
Ironworks Rd
Old Frankfort Pike
Frankfort Rd
Midway Rd
Tyrone Pike
Lexington Rd
I-64 W
US-421
US-60 W
US-62
US-127-S
Bypass N
KY-676 E
460
1973
421
64
62
1665
676
127
151
1681
60

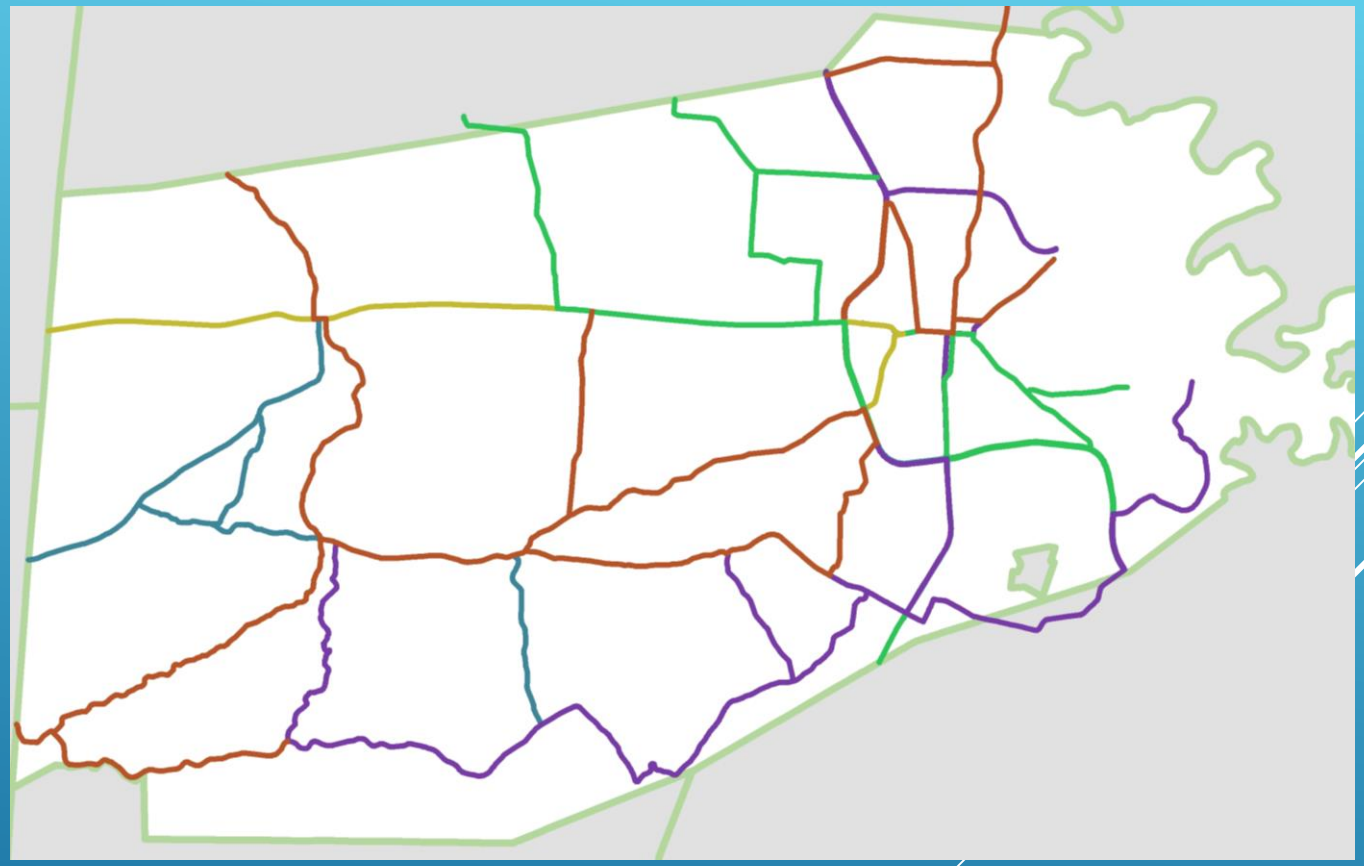
OBSTACLES

OBSTACLES

- Desire to script the iterative process
  - Would improve upon the time needed to solve for a county (currently ~ 1 day)
- …but, need to continually quality check network dataset
  - Even the smallest network connectivity error can lead to major problems
  - Divided highway connections
  - Geometry anomalies

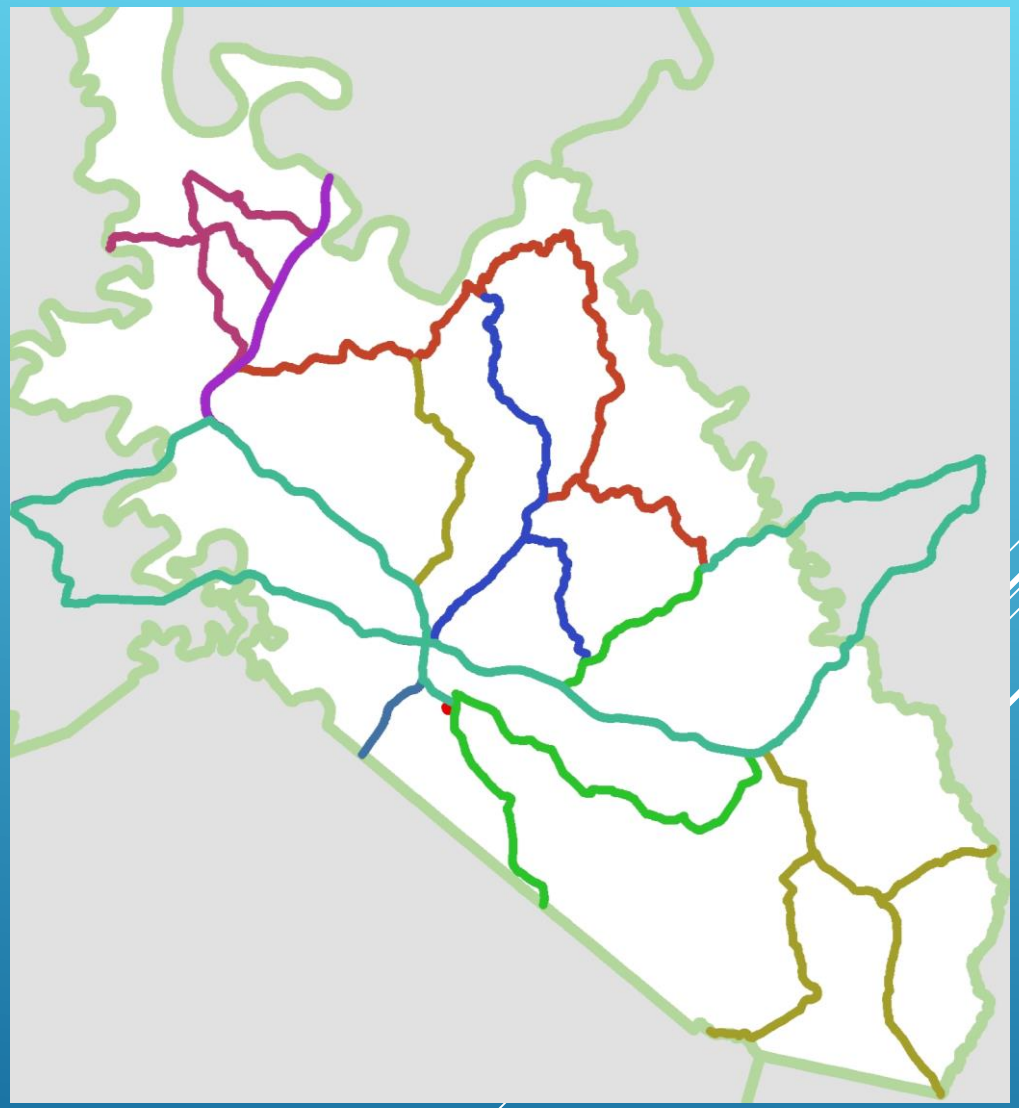
RESULTS

- Boyle County
  - 2 Contract trucks, 1 KYTC tandem trucks, 3 KYTC single-axle trucks
  - Current routes: 926 minutes
  - Optimized routes: 892 minutes
  - 3.67% improvement



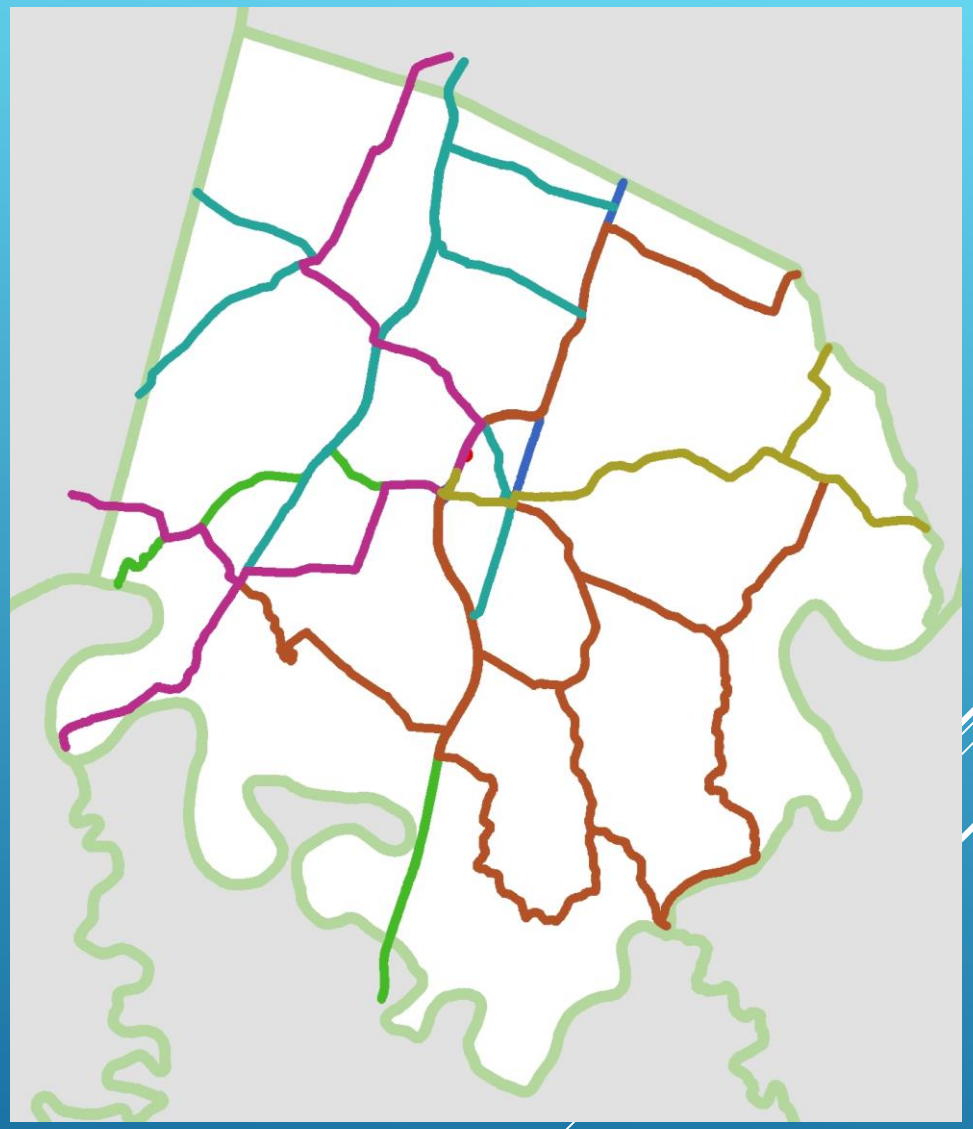
RESULTS

- Garrard County
  - 2 Contract trucks, 2 KYTC tandem trucks, 2 KYTC single-axle trucks
  - Current routes: 997 minutes
  - Optimized routes: 961 minutes
  - 3.61% improvement



RESULTS

- Jessamine County
  - 2 Contract trucks, 2 KYTC tandem trucks, 2 KYTC single-axle trucks
  - Current routes: 1050 minutes
  - Optimized routes: 925 minutes
  - 11.9% improvement



RESULTS

- Caveats
  - Preliminary results only
  - Optimizations expected to yield greater improvements when assessing at the District level as opposed to strictly at the county level
  - Not yet vetted by KYTC
  - District and county officials may have local knowledge or concerns that need to be incorporated into the routing
  - Kentucky's AVL data not included in this model

VRP LESSONS LEARNED

- **Vehicle Routing Problem can account for:**
  - Truck variables: Speed, Salt capacity, Type of truck
  - Road variables: SNIC priority, i.e. “A”, “B”, “C”; Number of lanes’ Road length; Time windows

- **Simplifying the network is key**
  - 100 feet vs midpoint
    - Limit truck turnaround
  - Greatly increased solver time (hours to seconds)
  - Simplified network does lose some roadway attributes

QUESTIONS?