

# Automating Work Orders for Winter Weather Operations Using GPS Tracks

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20210131, WO #20848885, Activity #2660 - Patrolling (mil - Miles Veh #63100 - Multi-purpose Tandem Axle Dump Truck

Vaiting to be deployed" or "On the way to work zone

(Gray) N/A: 1.2 h, 2.2 mil U35: 8.0 h, 206.5

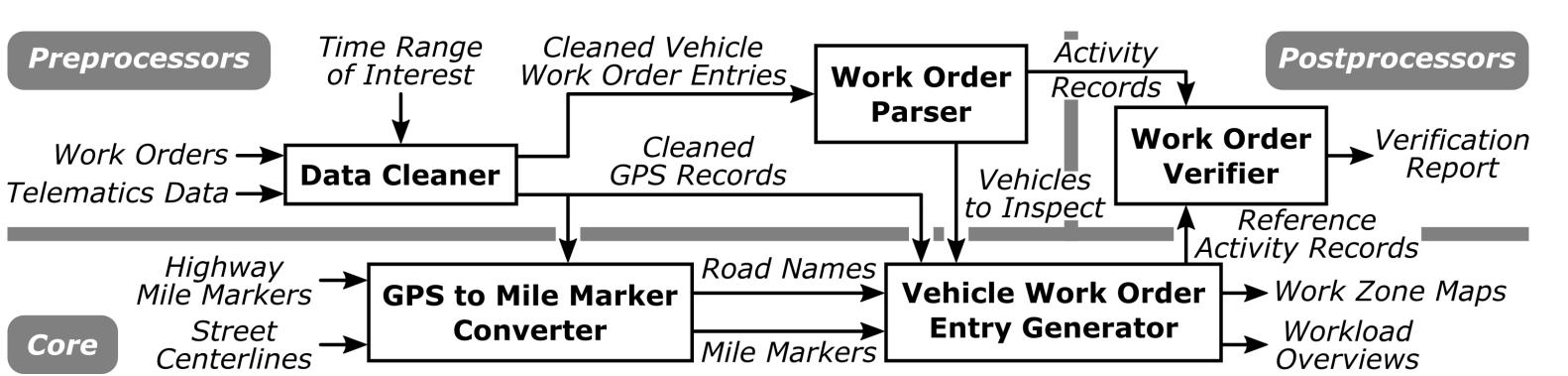
## Motivation

- > Snow and ice can decrease transportation efficiency and cause deadly threats to drivers on >70% of U.S. roadways.
- > INDOT's number one priority during the winter is snow and ice removal.
  - More than 29,000 lane miles of interstate highways, U.S. routes and state roads
- More than 1,000 snowplows to work alternating 12hour shifts, 7 days per week, if needed
- Significant record keeping burden on operators/managers
- Need automated work order verification and generation



Work order record verification is

- fully automated based on GPS data.
- Furthermore, extra details revealed
- can enhance existing/future records.



20210131, WO #20848885, Activity #2660 - Patrolling (mil - Mile:

Veh #63100 - Multi-purpose Tandem Axle Dump Truck rted Hours: 8.0. Detected Hours: 8.0. Detected Miles: 206 **Fully Automated Work Order Verification** 

- Implemented in Matlab R2021b
- > Only requires the date and vehicle of interest
- > Key steps
  - Extract GPS points of interest Ο
  - Label samples by road names and mile markers Ο
- Group records on highways Ο
- Generate work order records for comparison Ο

HOME PLOTS	APPS	Search De S	ocumentation	🔎 🜻 Yaguang		
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	Git	Command Window	Workspace	Value		
<ul> <li>.git</li> <li>1_ExploreGpsData</li> <li>2_GroupTracks</li> <li>3_MatchWorkOrdersWithGps</li> <li>lib</li> <li>tests</li> <li>.gitignore</li> <li>LICENSE</li> <li>progressbar_1966.txt</li> <li>README.md</li> <li>setPath.m</li> </ul>		<pre>matchWorkOrdersWithGps</pre>	<ul> <li>ch ABS_PATH 'C:\Python39\pyt</li> <li>ch ABS_PATH 'D:\One Drive - Pi</li> <li>ch ABS_PATH 'D:\One Drive - Pi</li> <li>ch absHomePa '/home/coverage</li> <li>ch absHomePa '/home/coverage</li> <li>ch absHomePa 'D:\One Drive - Pi</li> <li>ch absPathToC 'D:\One Drive - Pi</li> <li>ch absPythonP '/usr/bin/python3</li> <li>ch absPythonP 'C:\Python39\pyt</li> <li>v boolsIndot 'X602714 logical</li> <li>colorGrey</li> <li>D:000,0.5000,0.5</li> </ul>			
README.md (MD File)	~	<pre>Pre-processing: Found indotRoads in the current workspace. Pre-processing: No need to load it again. [2022/09/18 15:43:12] Filtering out non-highway centerlines [2022/09/18 15:43:14] Done!</pre>	colorOrder 7x3 double ch curFileName 'matchWorkOrdersW ch curHostname 1x6 char curPyEnv 1x1 PythonEnvironm ch dataTimeStr '18-Sep-2022 15:41:3			
		<pre>[2022/09/18 15:43:14] Loading work orders and GPS tracks [2022/09/18 15:43:14] Raw data processed before. Loading cached results [2022/09/18 15:43:15] Done!</pre>	3) DATE_RAN 1x2 datetime DATETIME 'yyyy-MM-dd HH DATETIME 'yyyyMMdd' datetimeFor 'yyyy/mm/dd HH datetimeRa 1x2 datetime			
No details available		<pre>[2022/09/18 15:43:15] Filtering records by time range of interest: 31-Jan-2021 [2022/09/18 15:43:15] Updating GPS tracks in the cache .mat file [2022/09/18 15:43:18] Done!</pre>	<ul> <li>defaultLine</li> <li>ch fileNameHi</li> <li>✓ FLAG_GEN</li> <li>✓ FLAG_PREP</li> </ul>	, ', 1		
		<pre>[2022/09/18 15:43:18] Extracting and formatting needed GPS information [2022/09/18 15:43:18] Parsing vehicle IDs and names 77%[======&gt; ] fx</pre>	✓ FLAG_SILEN 1 ✓ FLAG_SILEN 1 ✓ flagSaveRes 1 gpsLocTable 204774x47 table HOURS_AF 0 HOURS BEE 0			

**Figure 1. An INDOT snowplow in operation.** 

	А	В		С	D	E	F			G	
1	Management Unit	- WO#	Activity		- Subactivity	- Work Da	Resource T	ype 👻 Resource I	Name		•
223659	(4204) - WINAMAC UNIT (PS065480	) 20847709 2	2630 - SNOW 8	& ICE REMOVA	L 42: PLOWIN	G 1/31/202	1 Accomplish	ment Accomplish	nment		
223660	(4204) - WINAMAC UNIT (PS065480	) 20847709 2	2630 - SNOW 8	& ICE REMOVA	L 42: PLOWIN	G 1/31/202	1 Accomplish	ment Accomplish	nment		
223661	(4204) - WINAMAC UNIT (PS065480	) 20847709 2	2630 - SNOW 8	& ICE REMOVA	L 42: PLOWIN	G 1/31/202	1 Equipment	064932 - T	ANDEM 1	TRUCK MULTIF	PURPOSE BED
223662	(4204) - WINAMAC UNIT (PS065480	) 20847709 2	2630 - SNOW 8	& ICE REMOVA	L 42: PLOWIN	G 1/31/202	1 Equipment	064932 - T	ANDEM 1	TRUCK MULTIF	PURPOSE BED
223663	(4204) - WINAMAC UNIT (PS065480	) 20847709 2	2630 - SNOW 8	& ICE REMOVA	L 42: PLOWIN	G 1/31/202	1 Equipment	137542 - S	NOW PLC	WC	
223664	(4204) - WINAMAC UNIT (PS065480	) 20847709 2	2630 - SNOW 8	& ICE REMOVA	L 42: PLOWIN	G 1/31/202	1 Equipment	137542 - S	NOW PLC	WC	
223665	(4204) - WINAMAC UNIT (PS065480	) 20847709 2	2630 - SNOW 8	& ICE REMOVA	L 42: PLOWIN	G 1/31/202	1 Labor				
223666	(4204) - WINAMAC UNIT (PS065480	) 20847709 2	2630 - SNOW 8	& ICE REMOVA	L 42: PLOWIN	G 1/31/202	1 Labor				
223667	(4204) - WINAMAC UNIT (PS065480	) 20847709 2	2630 - SNOW 8	& ICE REMOVA	L 42: PLOWIN	G 1/31/202	1 Material	450M0001	.0 - ROAD	SALT, UNTRE	ATED
223668	(4204) - WINAMAC UNIT (PS065480	) 20847709 2	2630 - SNOW 8	& ICE REMOVA	L 42: PLOWIN	G 1/31/202	1 Material	450M0001	.0 - ROAD	SALT, UNTRE	ATED
		Н	I	J	К	L	M N	Ο	Р	Q	R
		Total Hrs 🔻	Amount 👻	Units 🔻 Meas	urement 🔻 Ir	nvento - R	oute 👻 Start	- Start Offset -	End 👻	End Offset 👻	Asset Type 🔻
				100 MIL -	MILES 4	2-04-07 SI	R 10	44 0.206	5 52	0.239	Snow Routes
				123 MIL -	MILES 4	2-04-08 SI	R 8	24 0.114	1 30	0.178	Snow Routes
		5.38	3	MHR	- WORK HR 4	2-04-07 SI	R 10	44 0.206	5 52	0.239	Snow Routes

	6.62		MHR - WORK HR	42-04-08	SR 8	24	0.114	30	0.178 Snow Routes
	6.62		MHR - WORK HR	42-04-08	SR 8	24	0.114	30	0.178 Snow Routes
	5.38		MHR - WORK HR	42-04-07	SR 10	44	0.206	52	0.239 Snow Routes
Table 1. Example	6.62		MHR - WORK HR	42-04-08	SR 8	24	0.114	30	0.178 Snow Routes
Table 1. Example	5.38		MHR - WORK HR	42-04-07	SR 10	44	0.206	52	0.239 Snow Routes
	da	6.17	STN - SHORT TON	42-04-07	SR 10	44	0.206	52	0.239 Snow Routes
work order recor	us.	7.58	STN - SHORT TON	42-04-08	SR 8	24	0.114	30	0.178 Snow Routes



Roanok

Chesterton<sup>4</sup>

**GPS Records from INDOT Data Warehouse** 

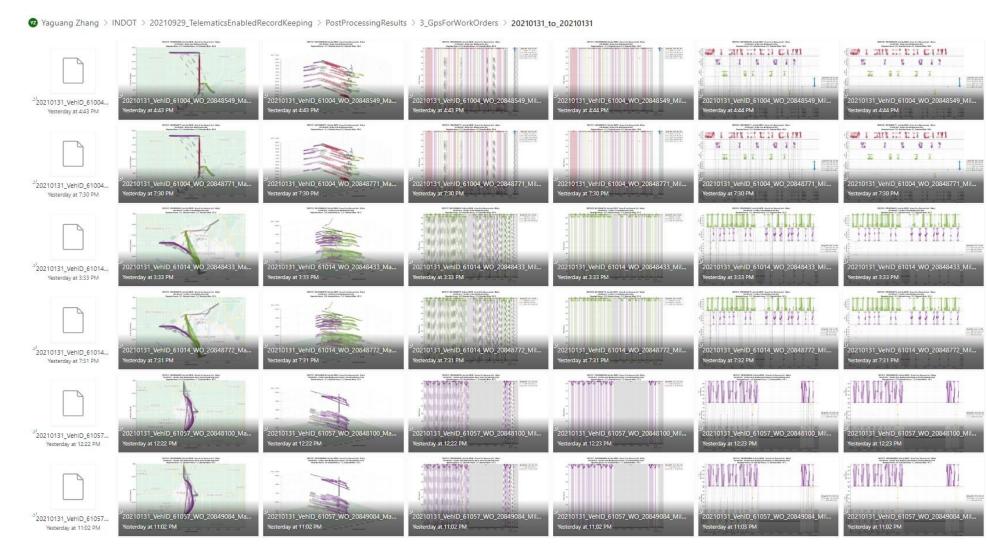
- ➤ Winter: 12/2/2020-4/30/2021
- ➤ In total: 1,051 vehicles; 5,115,844 location points



Figure 4. Block diagram for automated work order verification<sup>[a]</sup>.

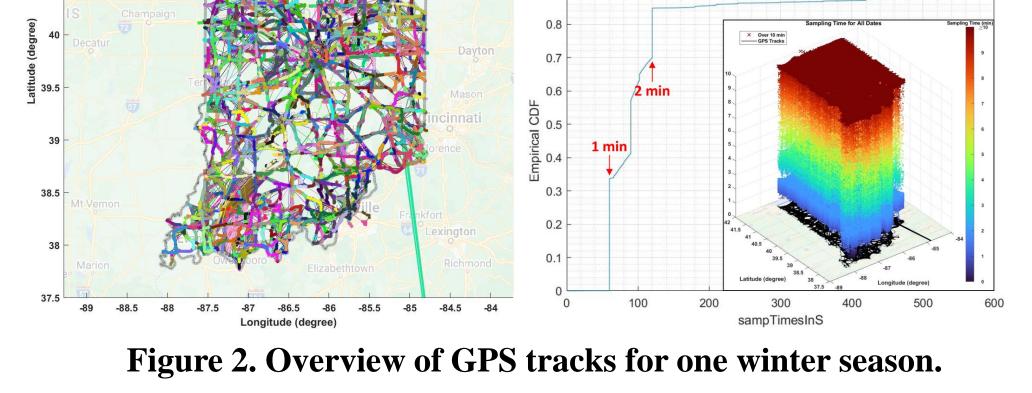
(Gray) N/A: 1.2 h, 2.2 mil Figure 5. Example mile markers on map <sup>[b]</sup> and proposed activity visualizations. U35: 8.0 h, 206.5 mil 20210131 WO #20850229, Activity #2630 - Snow & Ice Removal (mil - Miles) 10131, WO #20850229, Activity #2630 - Snow & Ice Removal (mil - Miles Veh #62894 - Tandem Truck Multipurpose Bed Veh #62894 - Tandem Truck Multipurpose Bed Hours: 8.0. Detected Hours: 7.9. Detected Miles: Reported Hours: 8.0, Detected Hours: 7.9, Detected Miles: 125. Fort Wayne 0131, WO #20850229, Activity #2630 - Snow & Ice Removal (mil - Mil Veh #62894 - Tandem Truck Multipurpose Bed ted Hours: 8.0. Detected Hours: 7.9. Detected Miles: 125

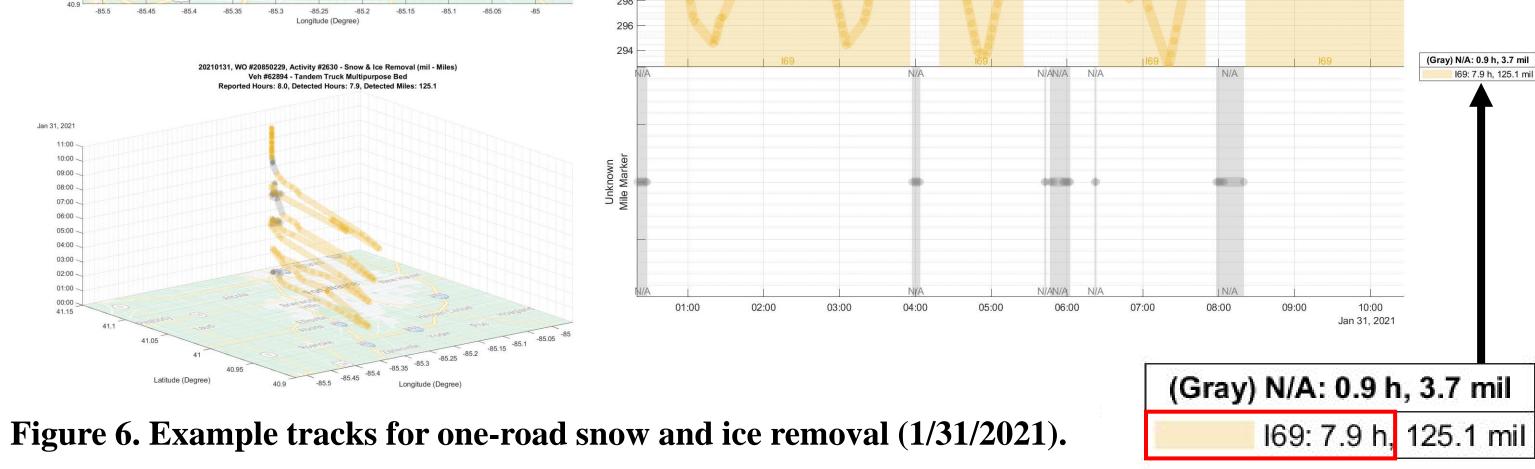
#### **Figure 8. Screenshot of the program.**



#### Figure 9. Part of the algorithm outputs for 1/31/2021.

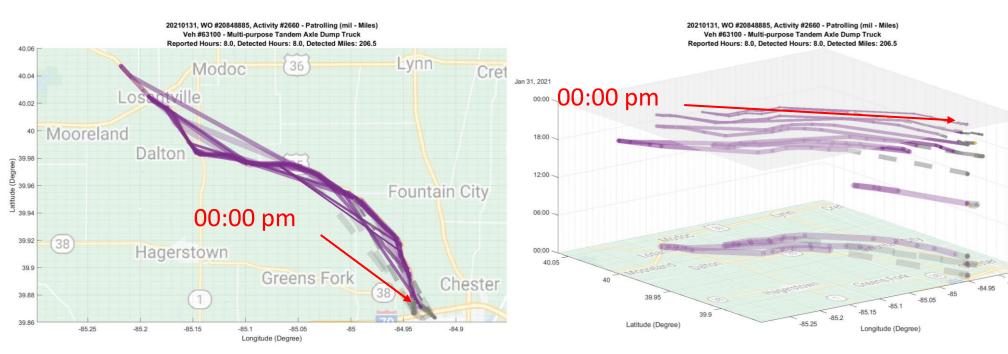
1	A	В	C	D	Е	F	G	н	1	J	ĸ
1 LocalD	DateRangeStr	Vehid	VehName	WOlds	ActId	ActName	ActTotalHs	DetectedWorkInH	DetectedWorkInMi	MatchingScore	Note
2 20	0210131	61306	M.p Tandem Axle Dump	20848268 & 20848843	2630	Snow & Ice Removal (mil - Miles)	22	22	398.46	100%	
2 20 3 20	0210131	63100	Multi-purpose Tandem Axle Dump Truck	20848885	2660	Patrolling (mil - Miles)	7.99	7.99	206.51	100%	
	0210131	64166	Tandem Truck Multipurpose Bed	20848734 & 20848851	2630	Snow & Ice Removal (mil - Miles)	24	23.96	467.47	100%	
5 20	0210131	61290	Tandem Axle Dump Truck	20850220	2630	Snow & Ice Removal (mil - Miles)	12	12.15	168.76	99%	
5 20	0210131	62894	Tandem Truck Multipurpose Bed	20850229	2630	Snow & Ice Removal (mil - Miles)	8	7.85	125.13	99%	
7 20	0210131	63364	Single Axle Dump Truck	20848296 & 20848984	2660	Patrolling (mil - Miles)	20	20.1	325.85	99%	
3 20	0210131	63493	Tandem Truck Multipurpose Bed	20849804	2630	Snow & Ice Removal (mil - Miles)	9	8.94	220.02	99%	
20	0210131	64057	Tandem Truck Multipurpose Bed	20848326 & 20848907	2630	Snow & Ice Removal (mil - Miles)	24	24.09	521.04	99%	
0 20	0210131	64637	Tandem Axle Dump Truck	20848320	2630	Snow & Ice Removal (mil - Miles)	12	12.1	214.99	99%	
1 20	0210131	65447	Single Axle Dump Truck	20848129	2660	Patrolling (mil - Miles)	7.52	7.45	141.63	99%	
2 20	0210131	62028	Tandem Truck Multi Purpose Bed	20848962	2660	Patrolling (mil - Miles)	4.01	3.83	83.15	98%	
3 20	0210131	62459	M.p Single Axle Dump W/underbody Plow	20848833	2630	Snow & Ice Removal (mil - Miles)	12.01	12.21	219.21	98%	
4 20	0210131	63620	Tandem Truck Multipurpose Bed	20848300	2630	Snow & Ice Removal (mil - Miles)	4	4.2	70.06	98%	
5 20	0210131	64610	Single Axle Dump Truck	20849840	2630	Snow & Ice Removal (mil - Miles)	2	2.15	40.5	98%	
6 20	0210131	65120	Multi-purpose Tandem Axle Dump Truck	20847638	2660	Patrolling (mil - Miles)	3.04	2.8	71.32	98%	
7 20	0210131	65217	Single Axle Dump Truck	20848281	2660	Patrolling (mil - Miles)	7.5	7.33	175.53	98%	
8 20	0210131	65342	Tandem Truck Multipurpose Bed	20848980	2660	Patrolling (mil - Miles)	4	3.79	89.95	98%	
9 20	0210131	65376	Freightliner Tandem Axle Hook Lift Truck	20848876	2630	Snow & Ice Removal (mil - Miles)	9.5	9.7	198.31	98%	
0 20	0210131	65724	Multipurpose Single Axle Dump	20848881	2630	Snow & Ice Removal (mil - Miles)	9.5	9.33	155.42	98%	
1 20	0210131	61305	M.p Tandem Axle Dump Truck	20850188	2630	Snow & Ice Removal (mil - Miles)	12	11.66	198.74	97%	
2 20	0210131	61750	Single Axle Dump Truck	20848534 & 20848660	2630	Snow & Ice Removal (mil - Miles)	11	11.3	311.43	97%	
3 20	0210131	61965	Multi-purpose Tandem Axle Dump Truck	20848688	2630	Snow & Ice Removal (mil - Miles)	12	12.31	243.54	97%	
4 20	0210131	61965	Multi-purpose Tandem Axle Dump Truck	20848742	2660	Patrolling (mil - Miles)	11.97	12.31	243.54	97%	
5 20	0210131	64270	Tandem Truck Multi Purpose Bed	20849117	2630	Snow & Ice Removal (mil - Miles)	4	3.74	122.65	97%	
5 20	0210131	64665	Tandem Axle Dump Truck	20848325 & 20848910	2630	Snow & Ice Removal (mil - Miles)	24	24.27	520.15	97%	
7 20	0210131	65344	Tandem Truck Multipurpose Bed	20848127	2630	Snow & Ice Removal (mil - Miles)	8	7.73	118.88	97%	
8 20	0210131	65347	Tandem Truck Multipurpose Bed	20849815	2630	Snow & Ice Removal (mil - Miles)	6	6.32	97.58	97%	
9 20	0210131	65681	Multipurpose Single Axle Dump	20848132	2630	Snow & Ice Removal (mil - Miles)	5	5.29	136.29	97%	
0 20	0210131	61014	Tandem Truck Multipurpose Bed	20848433 & 20848772	2630	Snow & Ice Removal (mil - Miles)	24	24.44	402.92	96%	
1 20	0210131	61080	Single Axle Multipurpose Bed	20848676 & 20850067	2630	Snow & Ice Removal (mil - Miles)	12	12.38	212.65	96%	
2 20	0210131	61288	Single Axle Dump Truck	20848658	2630	Snow & Ice Removal (mil - Miles)	3	3.38	55.28	96%	
3 20	0210131	62239	gle Axle Multipurpose Bed W/underbody P	20849090 & 20849348	2630	Snow & Ice Removal (mil - Miles)	14	14.4	248.82	96%	
4 20	0210131	63178	Tandem Truck Multipurpose Bed	20848380 & 20849856	2630	Snow & Ice Removal (mil - Miles)	14	14.36	372.01	96%	
5 20	0210131	64129	Multi-purpose Tandem Axle Dump Truck	20848295	2630	Snow & Ice Removal (mil - Miles)	7.5	7.13	191.82	96%	
6 20	0210131	64381	andem Axle Snow Dump Truck W/twin Aug	20848385 & 20848472	2630	Snow & Ice Removal (mil - Miles)	24	24.36	474.13	96%	
7 20	0210131	65447	Single Axle Dump Truck	20848880	2630	Snow & Ice Removal (mil - Miles)	7	7.45	141.63	96%	
8 20	0210131	65802	Single Axle Dump Truck	20849115	2630	Snow & Ice Removal (mil - Miles)	3	3.41	77.3	96%	
9 20	0210131	66180	Axle Multipurpose Dump Truck W/underbo	20849482 & 20849820	2630	Snow & Ice Removal (mil - Miles)	23.5	23.89	404.67	96%	
40 20	0210131	61078	Multipurpose Tandem Axle Dump Truck	20848753 & 20849381	2630	Snow & Ice Removal (mil - Miles)	24	23.48	423.25	95%	



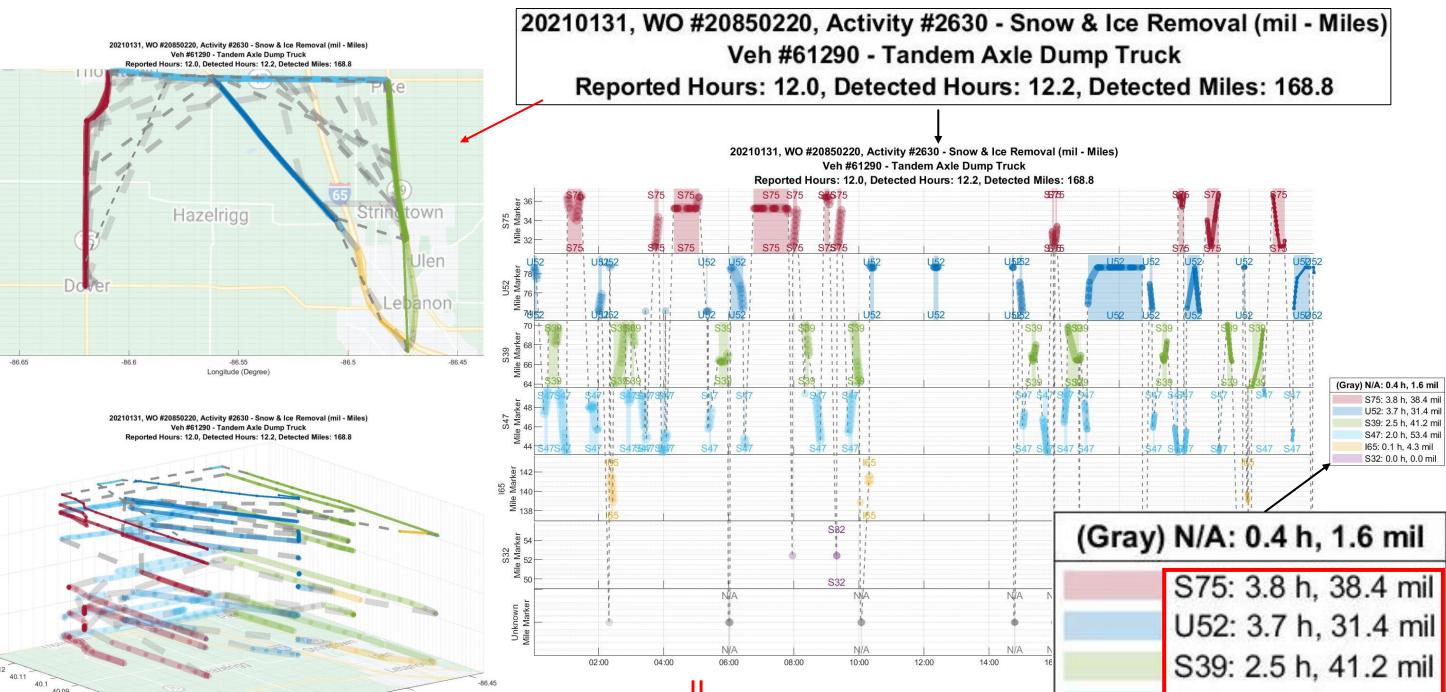


### **Case Studies and Data Visualization**

- > Traditional geospatial data visualization methods fall short even for the simple one-vehicle patrolling scenario.
- > New activity overview methods are proposed to concisely show maintenance efforts, possibly covering multiple roads, in both time and space.



**Figure 3. Example tracks for one-road patrolling (1/31/2021).** 



#### **Figure 10. Example work order verification scoring results.**

## Discussion

- ➢ GPS data usage and quality evaluation
  - Systematically inspected INDOT GPS records
  - Improvement in data will benefit this project.

➢ Full automation

- Only requires GPS + date + vehicle ID
- Removes/Lightens record keeping burden Ο

Rich details

- Activity records with minute level precision
- Various compact visualization methods
- May solve existing challenges faced by INDOT
- Future work: activity matching over multiple dates

## Acknowledgements

