

Automating Work Orders for Winter Weather Operations Using GPS Tracks

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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 12-hour shifts, 7 days per week, if needed
- Significant record keeping burden on operators/managers
 - Need automated work order verification and generation



Figure 1. An INDOT snowplow in operation.

Management Unit	WO#	Activity	Subactivity	Work Di	Resource Type	Resource Name
223559	4204	WINAMAC UNIT (PS065480)	20847709 2630 - SNOW & ICE REMOVAL	42: PLOWING 1/31/2021	Accomplishment	Accomplishment
223662	4204	WINAMAC UNIT (PS065480)	20847709 2630 - SNOW & ICE REMOVAL	42: PLOWING 1/31/2021	Accomplishment	Accomplishment
223663	4204	WINAMAC UNIT (PS065480)	20847709 2630 - SNOW & ICE REMOVAL	42: PLOWING 1/31/2021	Equipment	064932 - TANDEM TRUCK MULTIPURPOSE BED
223664	4204	WINAMAC UNIT (PS065480)	20847709 2630 - SNOW & ICE REMOVAL	42: PLOWING 1/31/2021	Equipment	064932 - TANDEM TRUCK MULTIPURPOSE BED
223665	4204	WINAMAC UNIT (PS065480)	20847709 2630 - SNOW & ICE REMOVAL	42: PLOWING 1/31/2021	Labor	137542 - SNOW FLOW
223666	4204	WINAMAC UNIT (PS065480)	20847709 2630 - SNOW & ICE REMOVAL	42: PLOWING 1/31/2021	Labor	137542 - SNOW FLOW
223667	4204	WINAMAC UNIT (PS065480)	20847709 2630 - SNOW & ICE REMOVAL	42: PLOWING 1/31/2021	Material	450M00010 - ROAD SALT, UNTREATED
223668	4204	WINAMAC UNIT (PS065480)	20847709 2630 - SNOW & ICE REMOVAL	42: PLOWING 1/31/2021	Material	450M00010 - ROAD SALT, UNTREATED

M	A	U	M	R	I	M	S	O	P	C	R
Total Hrs	Amount	Units	Measurement	Invento	Route	Start	Start Offset	End	End Offset	Asset Type	
5.38	MHR - WORK HR	42:04:07	SR 10	44	0.206	52	0.239	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			
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			
6.62	MHR - WORK HR	42:04:08	SR 8	24	0.114	30	0.178	Snow Routes			
6.17	STN - SHORT TON	42:04:07	SR 10	44	0.206	52	0.239	Snow Routes			
7.58	STN - SHORT TON	42:04:08	SR 8	24	0.114	30	0.178	Snow Routes			

Table 1. Example work order records.

GPS Records from INDOT Data Warehouse

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

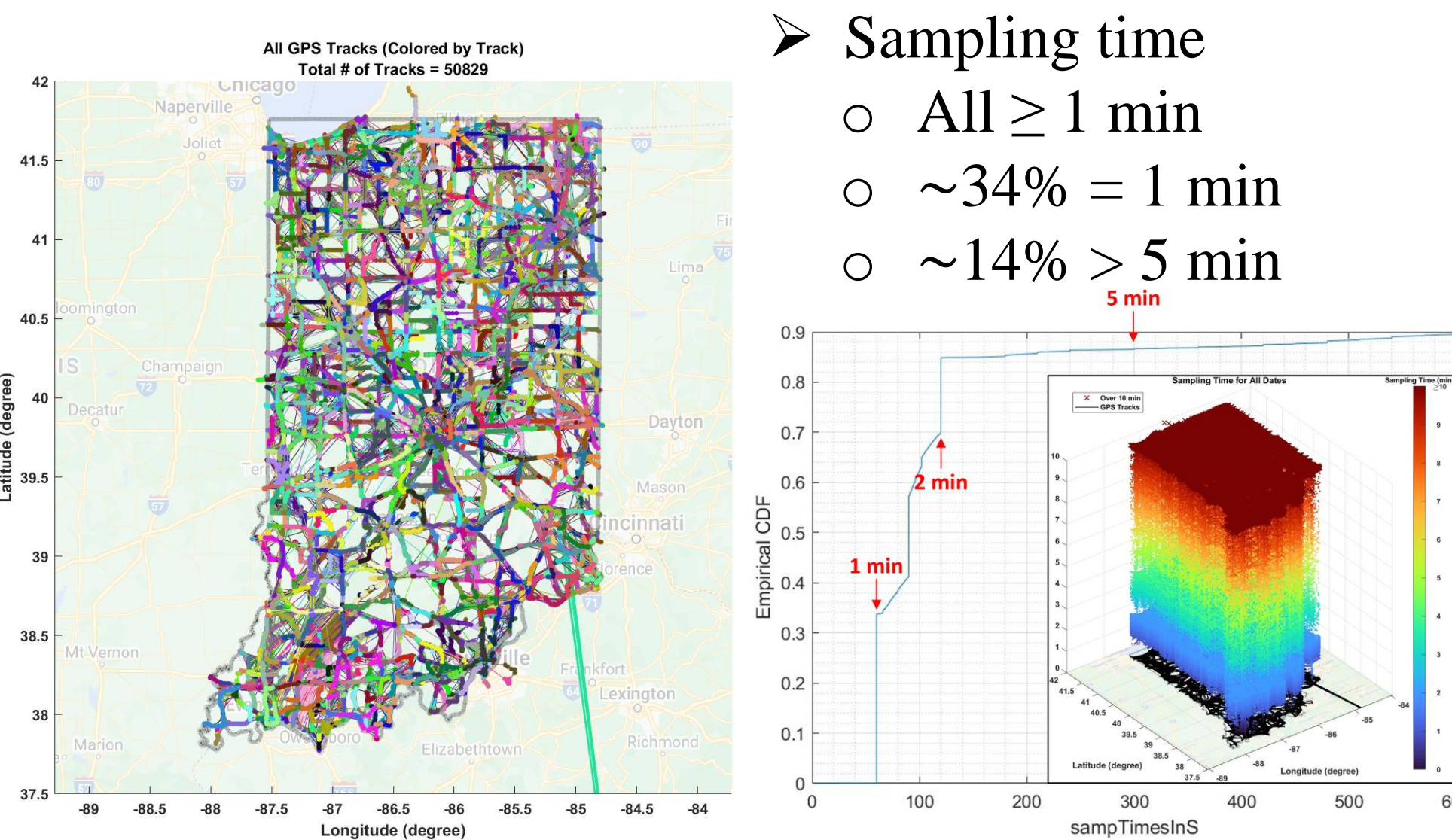


Figure 2. Overview of GPS tracks for one winter season.

- Sampling time
 - All ≥ 1 min
 - $\sim 34\% = 1$ min
 - $\sim 14\% > 5$ min

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.

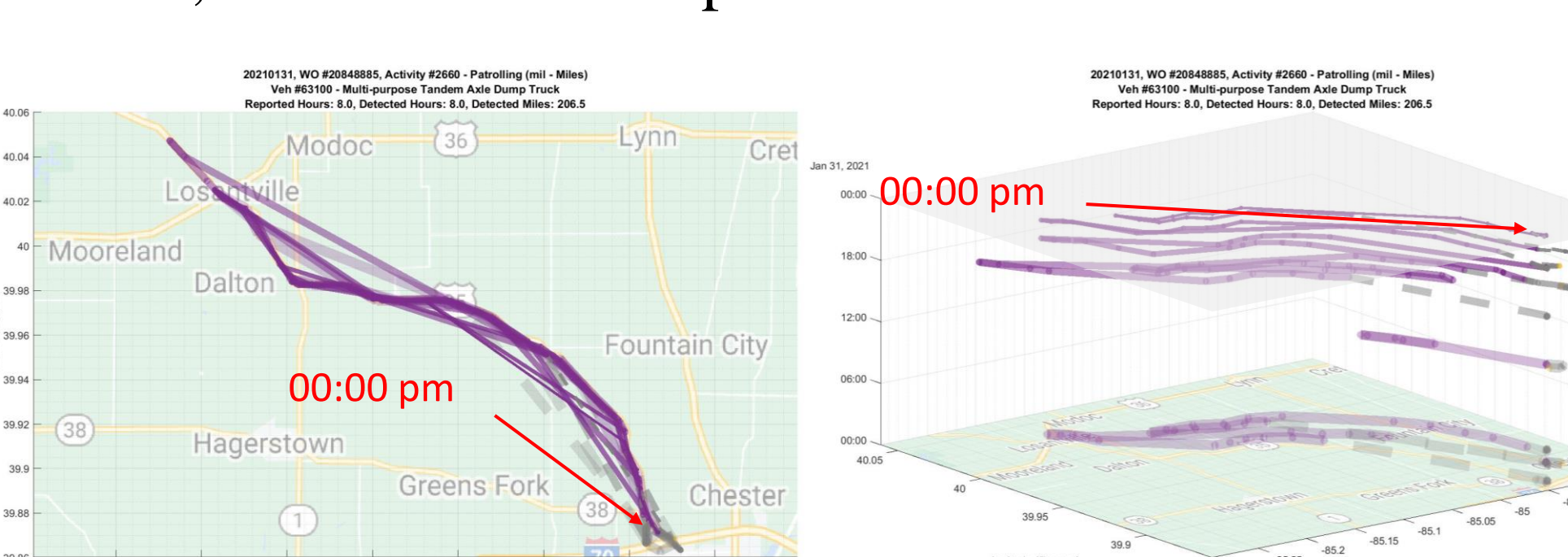


Figure 3. Example tracks for one-road patrolling (1/31/2021).

Work order record verification is fully automated based on GPS data. Furthermore, extra details revealed can enhance existing/future records.

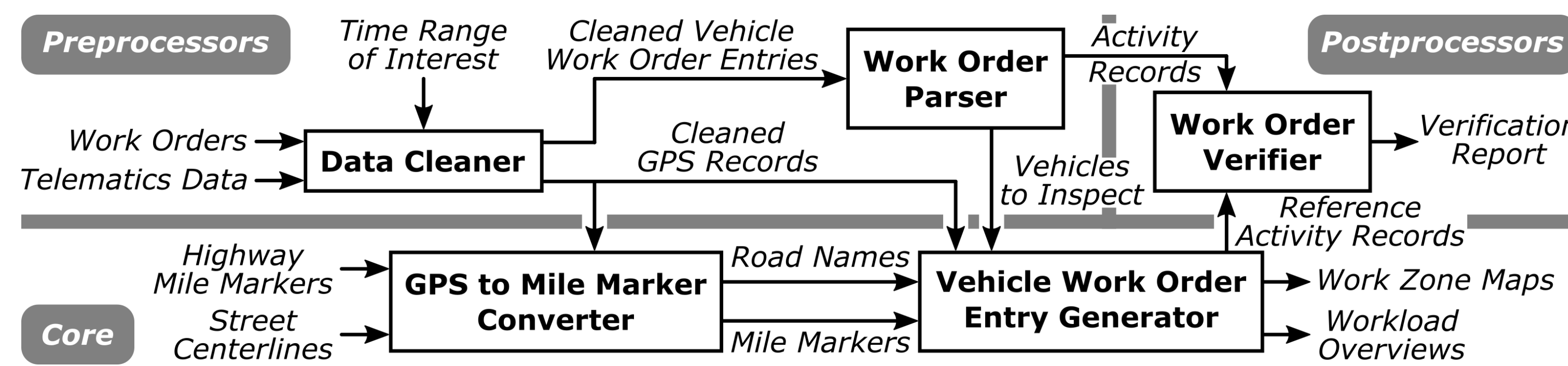


Figure 4. Block diagram for automated work order verification^(a).

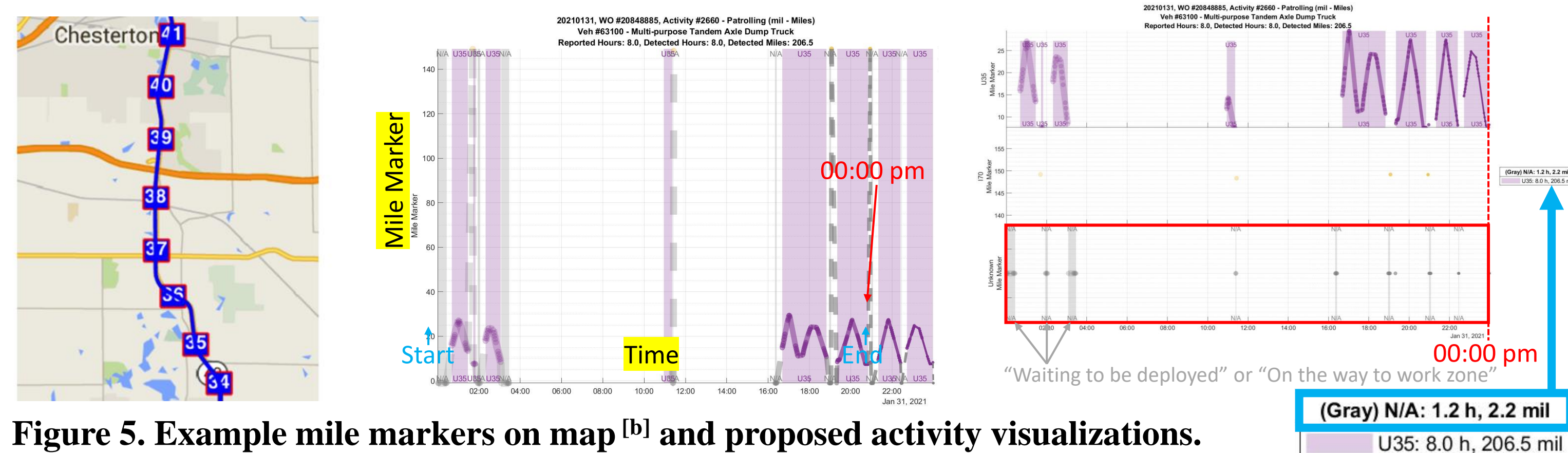


Figure 5. Example mile markers on map^(b) and proposed activity visualizations.

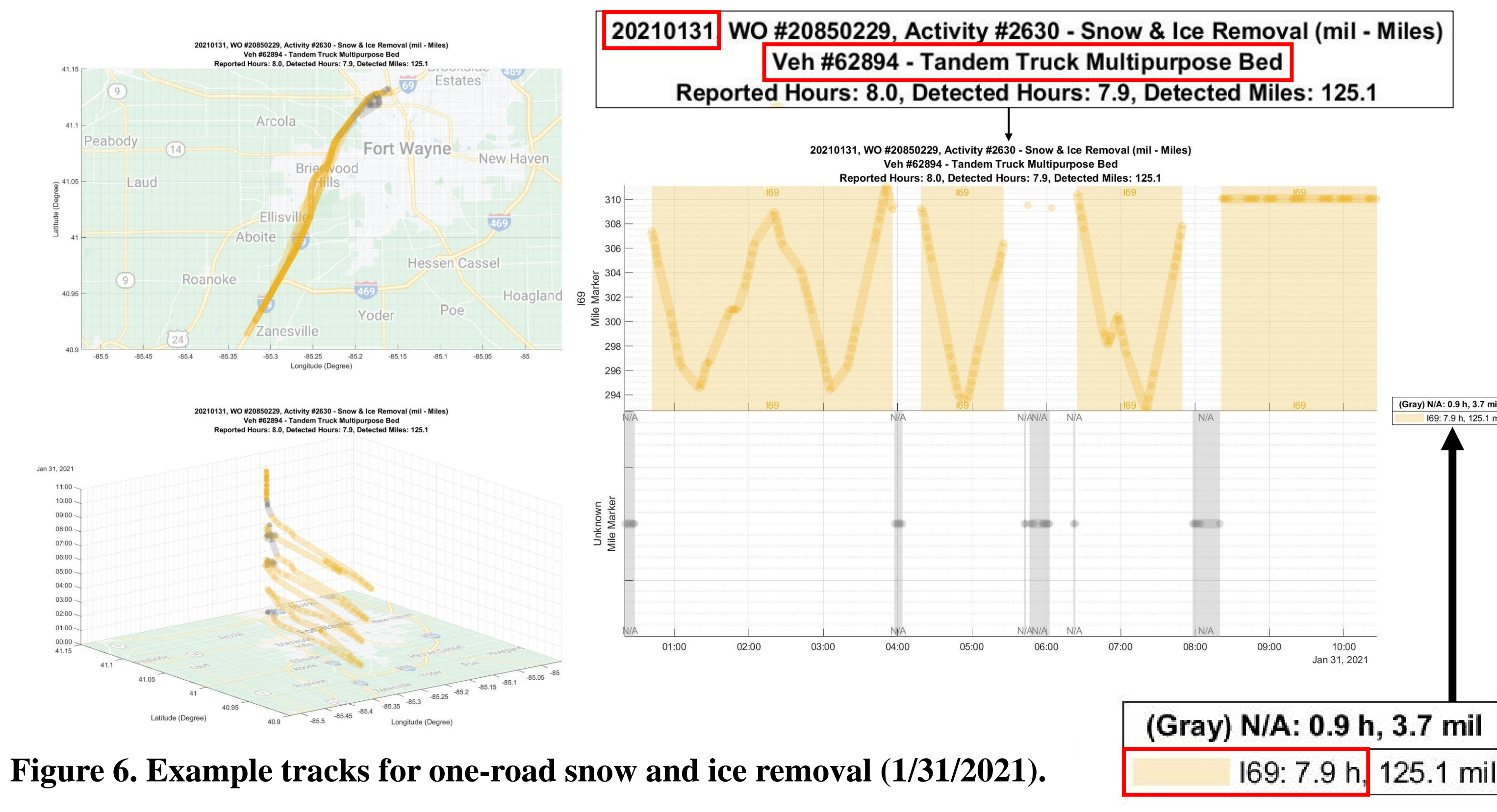


Figure 6. Example tracks for one-road snow and ice removal (1/31/2021).

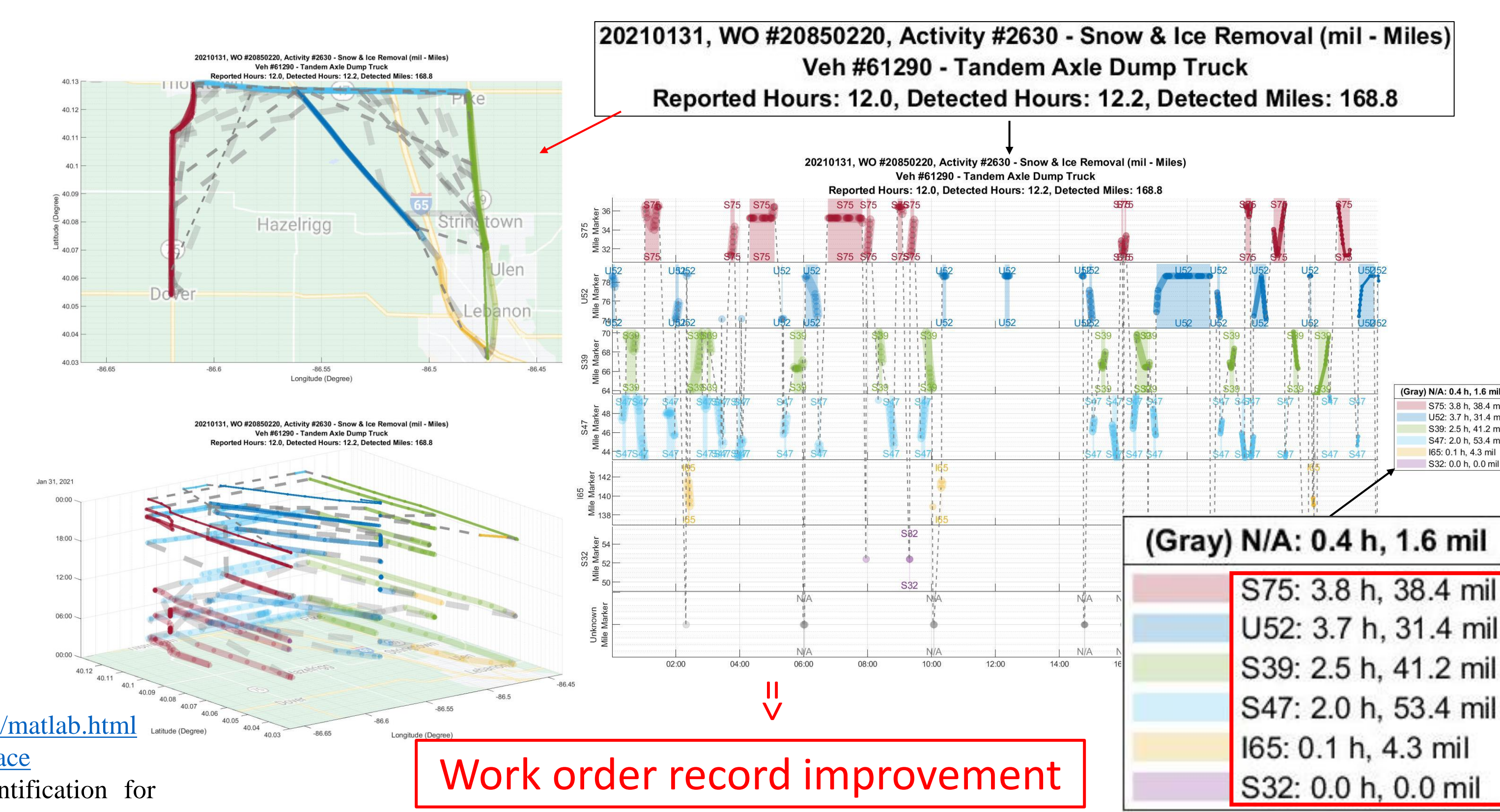


Figure 7. Example tracks for multi-road snow and ice removal (1/31/2021).

Fully Automated Work Order Verification

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

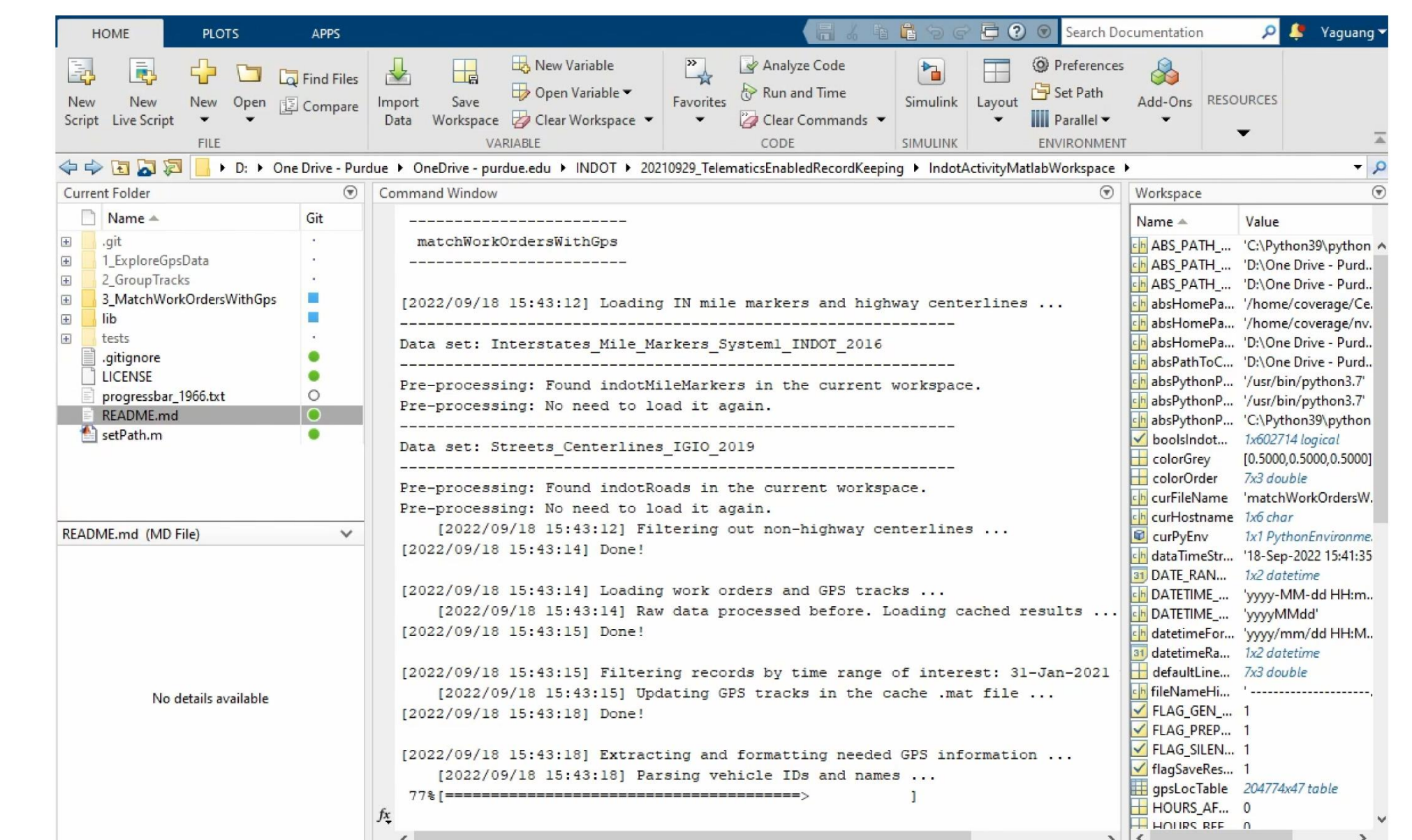


Figure 8. Screenshot of the program.



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

WO#	Vehicle	Activity	Reported Hours	Detected Hours	Detected Miles	Verification	Note		
20210131	61106	Mp Tandem Axle Dump	20847826 26404	2640	Patrolling (mil - Miles)	22	22	306.46	95%
20210131	61100	Multi-purpose Tandem Axle Dump Truck	20847805	2640	Patrolling (mil - Miles)	7.99	7.99	206.15	99%
20210131	61290	Tandem Axle Dump Truck	20847826 26404	2640	Patrolling (mil - Miles)	24	23.99	407.47	99%
20210131	61290	Tandem Axle Dump Truck	20847826 26404	2640	Patrolling (mil - Miles)	12	13.25	186.76	99%
20210131	61290	Tandem Axle Dump Truck	20847826 26404	2640	Patrolling (mil - Miles)	8	7.85	129.33	99%
20210131	61364	Single Axle Dump Truck	20847826 26404	2640	Patrolling (mil - Miles)	20	20.1	325.85	95%
20210131	61364	Single Axle Dump Truck	20847826 26404	2640	Patrolling (mil - Miles)	9	8.96	225.62	99%
20210131	64057	Tandem Truck Multi-purpose Bed	20847826 26404	2640	Patrolling (mil - Miles)	24	24.09	524.04	95%
20210131	64057	Tandem Truck Multi-purpose Bed	20847826 26404	2640	Patrolling (mil - Miles)	12	12.1	248.95	95%
20210131	64057	Tandem Truck Multi-purpose Bed	20847826 26404	2640	Patrolling (mil - Miles)	13.2	14.21	143.83	95%
20210131	64057	Tandem Truck Multi-purpose Bed	20847826 26404	2640	Patrolling (mil - Miles)	6.2	5.83	81.5	95%
20210131	64057	Tandem Truck Multi-purpose Bed	20847826 26404	2640	Patrolling (mil - Miles)	7	7.23	46.5	95%
20210131	61107	Multi-purpose Tandem Axle Dump Truck	20847826 26404	2640	Patrolling (mil - Miles)	3.86	2.8	73.32	95%
20210131	61217	Single Axle Dump Truck	20847826 26404	2640	Patrolling (mil - Miles)	5.3	7.23	175.33	95%
20210131	61362	Tandem Truck Multi-purpose Bed	20847826 26404	2640	Patrolling (mil - Miles)	4	3.79	89.95	95%
20210131	61362	Tandem Truck Multi-purpose Bed	20847826 26404	2640	Patrolling (mil - Miles)	5.3	6.2	126.33	95%
20210131	61362	Tandem Truck Multi-purpose Bed	20847826 26404	2640	Patrolling (mil - Miles)	3.5	3.93	155.42	95%
20210131	61362	Tandem Truck Multi-purpose Bed	20847826 26404	2640	Patrolling (mil - Miles)	12	11.46	186.76	95%
20210131	61724	Multi-purpose Tandem Axle Dump Truck	20847826 26404	2640	Patrolling (mil - Miles)	11	11.3	314.43	95%
20210131	61724	Multi-purpose Tandem Axle Dump Truck	20847826 26404	2640	Patrolling (mil - Miles)	12	12.1	248.95	95%
20210131	61750	Single Axle Dump Truck	20847826 26404	2640	Patrolling (mil - Miles)	11	11.3	314.43	95%
20210131	61750	Single Axle Dump Truck	20847826 26404	2640	Patrolling (mil - Miles)	12	12.1	248.95	95%
20210131	61750	Single Axle Dump Truck	20847826 26404	2640	Patrolling (mil - Miles)	11.97	12.15	248.94	95%
20210131	61750	Single Axle Dump Truck	20847826 26404	2640	Patrolling (mil - Miles)	4	3.76	123.65	95%
20210131	64060	Tandem Axle Dump Truck	20847826 26404	2640	Patrolling (mil - Miles)	24	24.27	526.13	95%
20210131	64060	Tandem Axle Dump Truck	20847826 26404	2640	Patrolling (mil - Miles)	7.78	11.86	172.65	95%
20210131	61367	Tandem Truck Multi-purpose Bed	20847826 26404	2640	Patrolling (mil - Miles)	6	6.12	97.58	95%
20210131	61367	Tandem Truck Multi-purpose Bed	20847826 26404	2640	Patrolling (mil - Miles)	5	5.29	126.29	95%
20210131	61367	Tandem Truck Multi-purpose Bed	20847826 26404	2640	Patrolling (mil - Miles)	12	13.38	232.65	95%
20210131	61367	Tandem Truck Multi-purpose Bed	20847826 26404	2640	Patrolling (mil - Miles)	3	3.38	51.28	95%
20210131	61367	Tandem Truck Multi-purpose Bed	20847826 26404	2640	Patrolling (mil - Miles)	5	5.29	126.29	95%
20210131	61367	Tandem Truck Multi-purpose Bed	20847826 26404	2640	Patrolling (mil - Miles)	12	13.38	232.65	95%
20210131	61367	Tandem Truck Multi-purpose Bed	20847826 26404	2640	Patrolling (mil - Miles)	3	3.38	51.28	95%
20210131	62229	Multi-purpose Tandem Axle Dump Truck	20847826 26404	2640	Patrolling (mil - Miles)	14	14.4	248.94	95%
20210131	61750	Single Axle Dump Truck	20847826 26404	2640	Patrolling (mil - Miles)	14	14.38	372.63	95%
20210131	64129	Multi-purpose Tandem Axle Dump Truck	20847826 26404	2640	Patrolling (mil - Miles)	7.3	7.33	193.82	95%
20210131	64129	Multi-purpose Tandem Axle Dump Truck	20847826 26404	2640	Patrolling (mil - Miles)	14	14.38	372.63	95%
20210131	64047	Single Axle Dump Truck	20847826 26404	2640	Patrolling (mil - Miles)	7	7.45	143.83	95%
20210131	61002	Single Axle Dump Truck	20847826 26404	2640	Patrolling (mil - Miles)	5	5.45	73.3	95%
20210131	61010	Multi-purpose Tandem Axle Dump Truck	20847826 26404	2640	Patrolling (mil - Miles)	23.3	23.09	404.87	95%
20210131	61076	Multi-purpose Tandem Axle Dump Truck	20847826 26404	2640	Patrolling (mil - Miles)	24	23.48	423.25	95%

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
- 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

Sponsorship for this work was provided by the Joint Transportation Research Program under project SPR-4605. Map data shown on this poster were from Google Maps.

^(a) Implemented using Matlab. More about Matlab at: <https://www.mathworks.com/products/matlab.html>
 Matlab code available at: <https://github.com/YaguangZhang/IndotActivityMatlabWorkspace>
^(b) Y. Zhang, A. Balmos, J. V. Krogmeier and D. Buckmaster, "Working Zone Identification for Specialized Micro Transportation Systems Using GPS Tracks," 2015 IEEE 18th Int. Conf. on Intell. Transp. Syst., Gran Canaria, Spain, 2015, pp. 1779-1784, doi: 10.1109/ITSC.2015.289.