Rowan University
HENRY M. ROWAN
COLLEGE OF ENGINEERING

A NOVEL APPROACH TO IDENTIFY DISTRACTED DRIVING EVENTS IN NEW JERSEY

Mohammad Jalayer, Ph.D.
Associate Professor,
Department of Civil and Environmental Engineering,
Rowan University

Acknowledgement

❖ Rowan University

- **Mr. Ahmed Sajid Hasan**
- **Mr. Deep Patel**
- **Ms. Ruqaya Alfaris**
- **Mr. Omar Alshiekhyoussef**
- **Mr. Imam Hasan Araf**

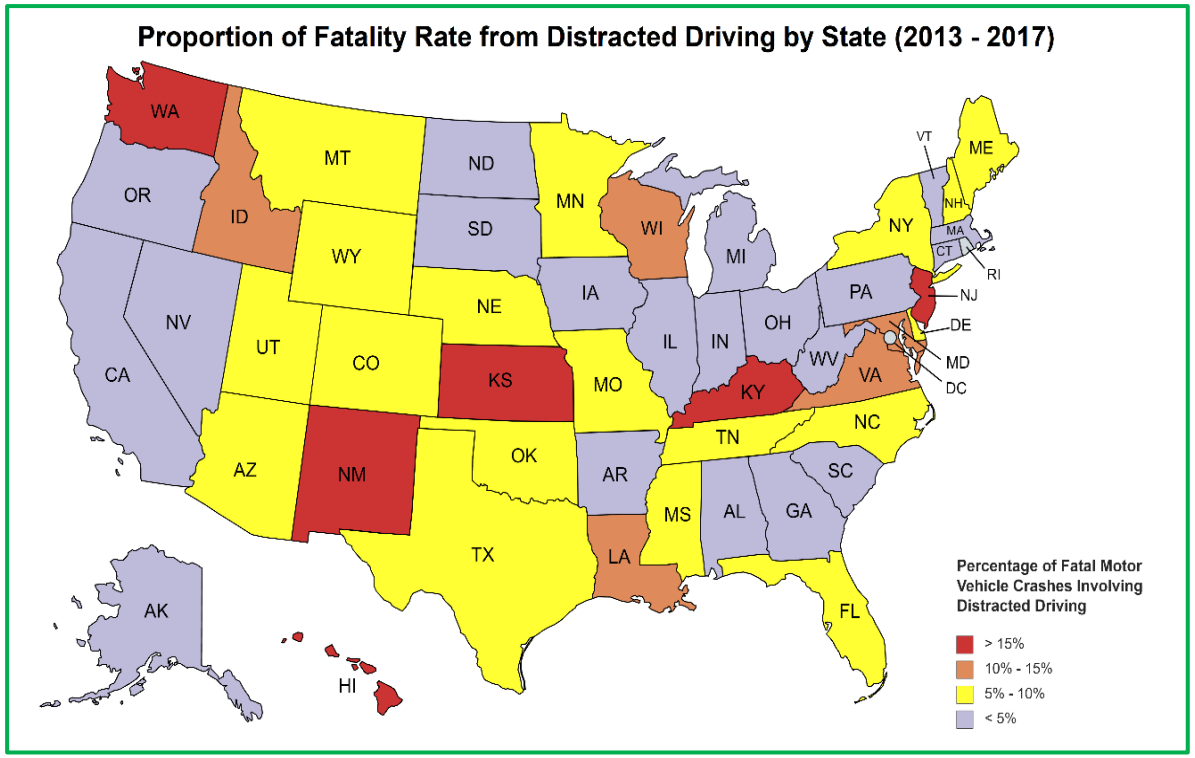
❖ New Jersey Division of Highway Traffic Safety (NJDHTS)

- **Mr. Eric Heitmann**,
- **Mr. Joseph Weiss**
- **Mr. Robert Gaydosh**

Background

"Anything that takes the drivers attention away from the task of safe driving is distracted driving" (NHTSA, 2012)

- One of the top 5 causes of death in motor vehicle crash in USA (NHTSA, 2020)
- 3,142 fatalities and 424,000 injuries happened due to motor vehicle crashes involving distracted drivers in 2019 (NHTSA, 2020)
- New Jersey has the 2nd highest traffic fatality rate (25%) among the states (FARS, 2020)

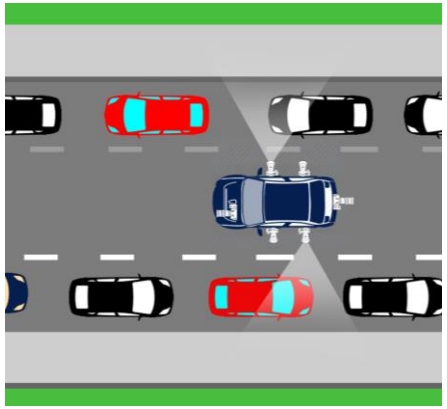


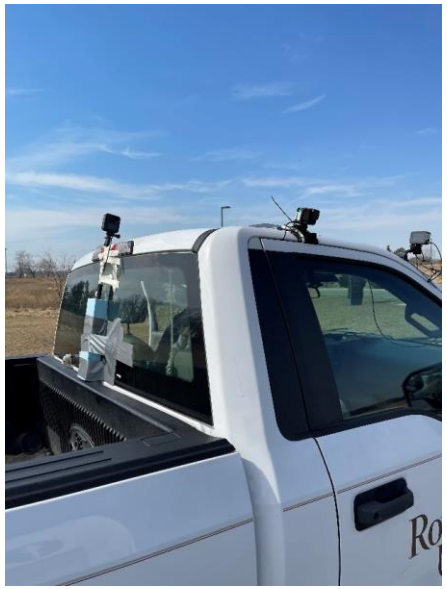
Research Objective

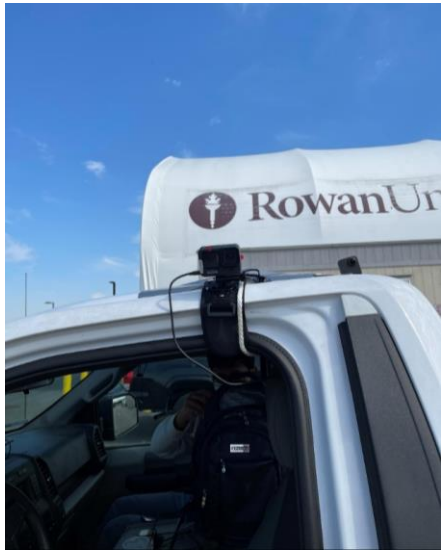
- Research Gaps in Present Practice
  - Unreported events
  - Detection of drivers' behavior from cameras inside car
  - Mostly cross-sectional event data collection
- Objective of the Research
  - Longitudinal event data analysis (Analysis of distraction events from manual data collection)
  - Video data analysis (Detection of distraction events from video data taken from cameras outside the car)

Data Collection Technique (Floating Car Method)

- Driver behavior is captured from **camera outside the vehicle**
- **Go Pro Hero 9** Cameras mounted on a moving vehicle
- Capturing driver's behavior at **60 frames per second** with a **resolution of 2704x1520**
- Collecting data continuously

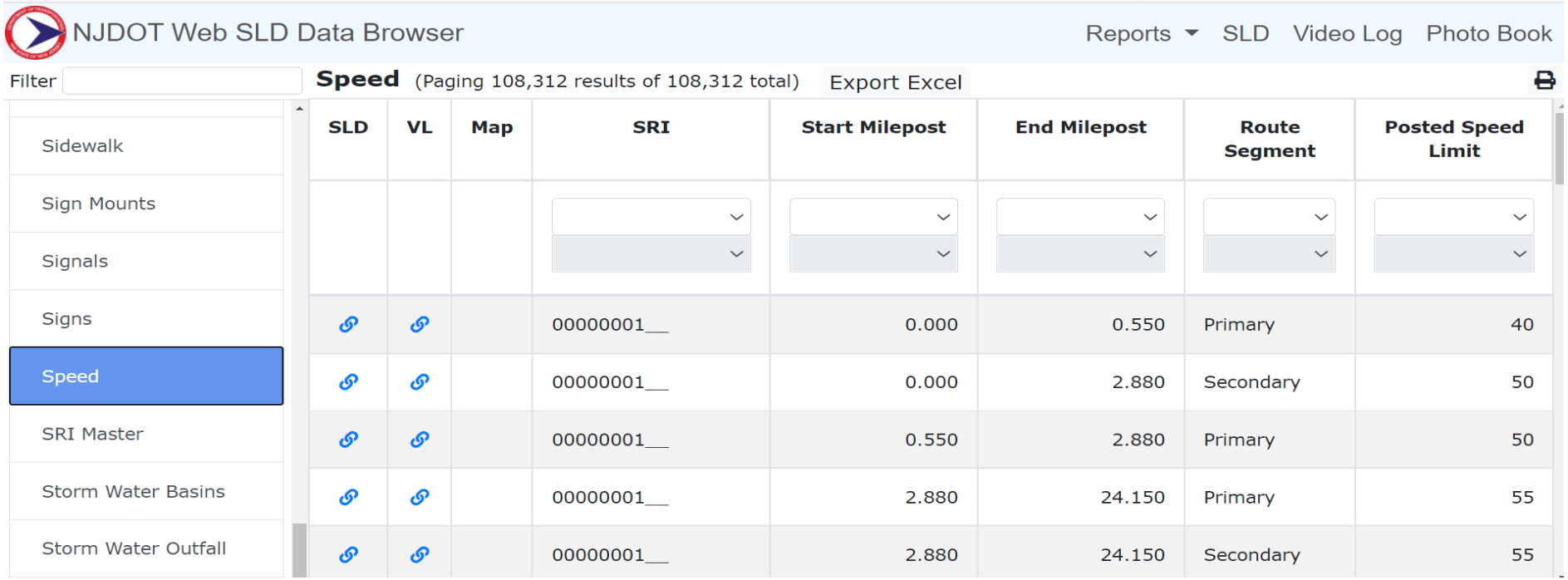






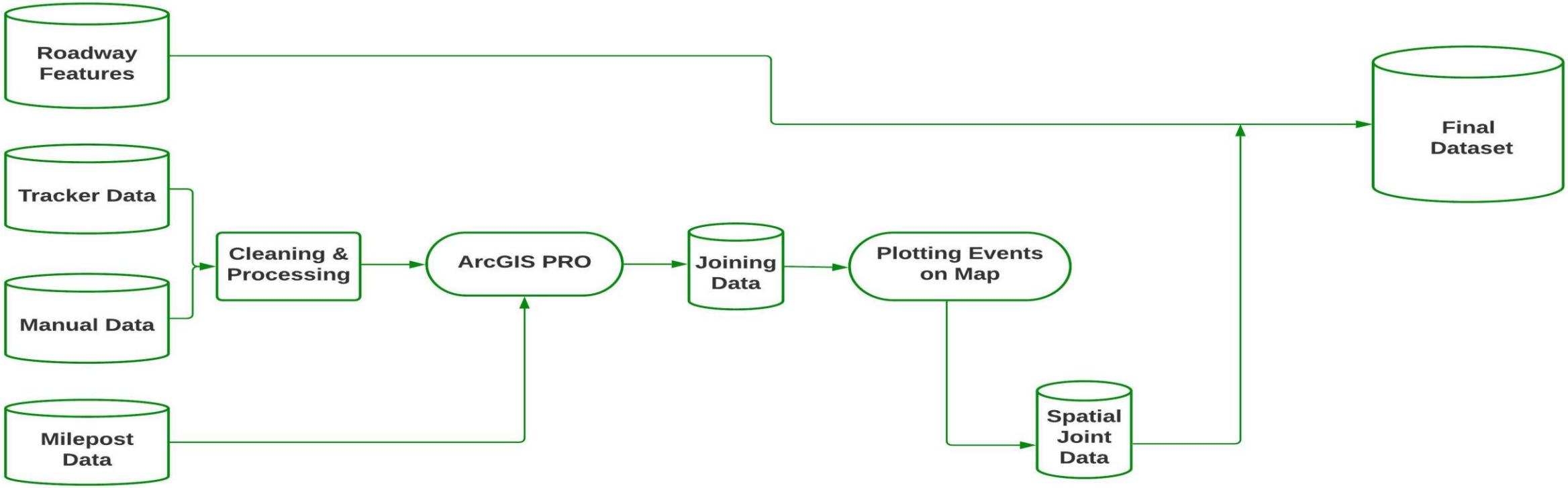
Data Collection Technique (Manual Counting Method)

- **Counter mobile app** was used to count and classify drivers' distraction events
- **Exact time and location of the events** was archived using a GPS logger device
- **NJDOT website** is used to get **features of roadway** (posted speed limit, number of lanes, median type) of route segments by milepost

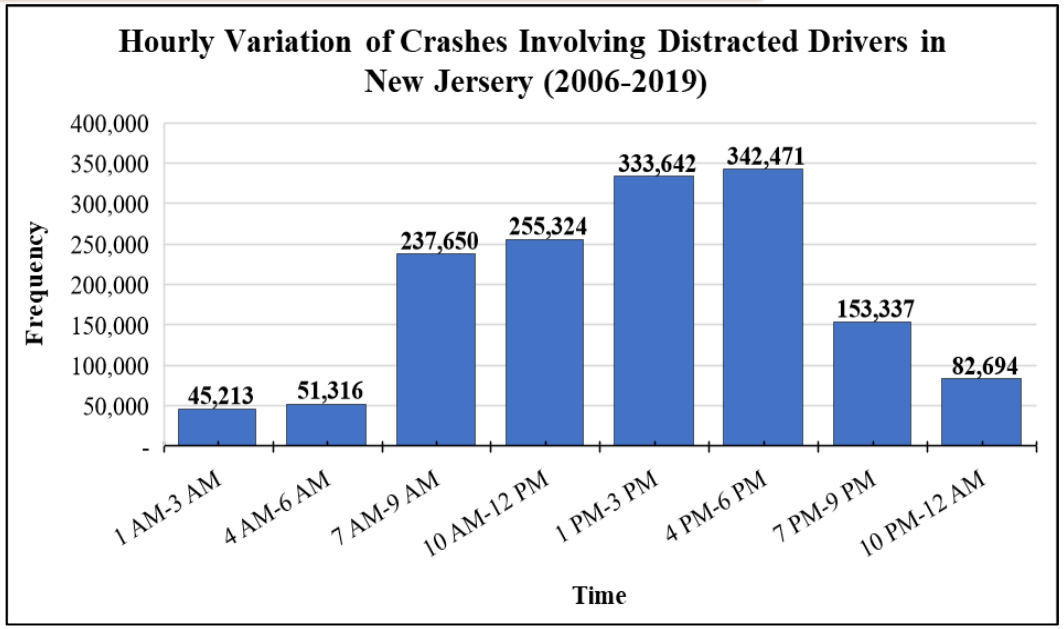


Data Collection Technique (Manual Counting Method) (cont.)

- **Time** event from manual counter is matched with **time** of tracker data
- **Event map** is created by joining **geolocation** with event data in ArcGIS
- **Spatial data** from event maps are integrated with **roadway features** from NJDOT using excel



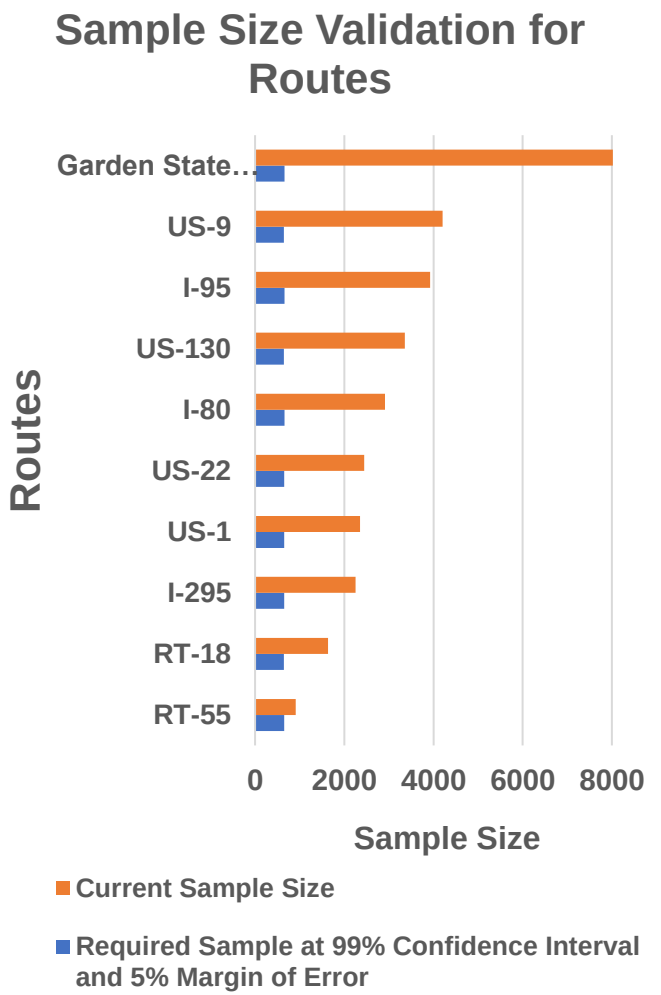
Data Collection (Corridor Selection)



Location	% of Total Crash
US 1	2.85
Garden State Parkway	1.80
US 9	1.89
I-80	1.23
US 22	1.17
US 130	1.12
Source: NJDHTS; Years: 2006-2019	

Sample Size Validation for Selected Corridors

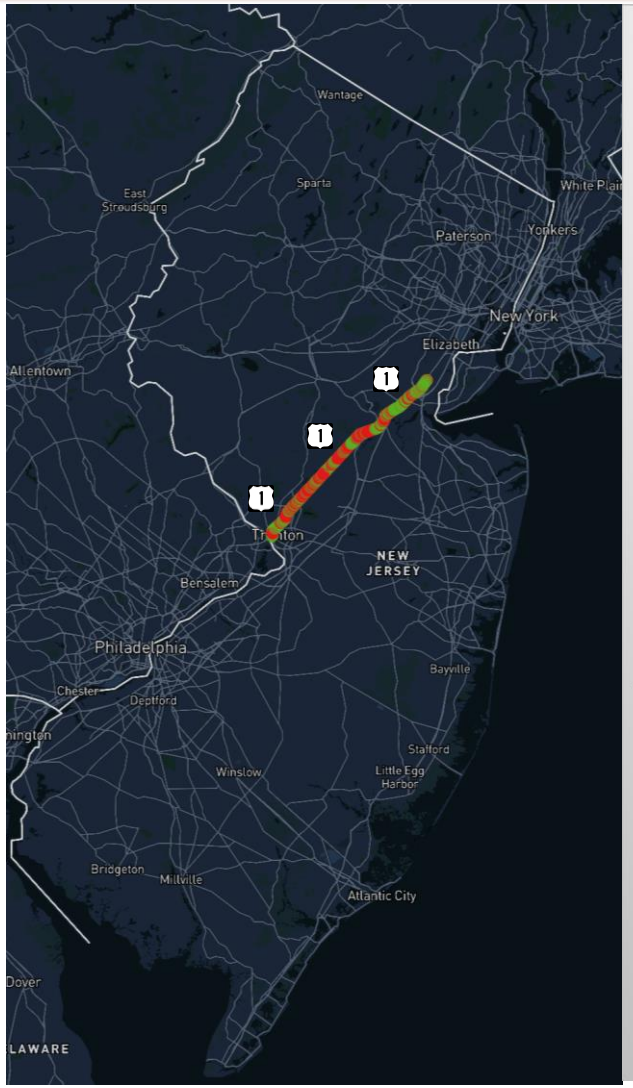
Route	Signalized/ Unsignalized	Toll/ Non-Toll	Route Length in Miles (Round)	Total Miles of obs.	Total hours of obs.	AADT (2018)
RT-18	Signalized	Non-Toll	85.5	684	20	27,424
US-1	Signalized	Non-Toll	76	608	20	31,395
US-130	Signalized	Non-Toll	156	1,248	32	22,653
US-9	Signalized	Non-Toll	106	848	40	25,836
US-22	Signalized	Non-Toll	80	640	15	29,933
RT-55	Unsignalized	Non-Toll	127	1,016	20	27,819
I-295	Unsignalized	Non-Toll	142	1,136	20	50,378
I-80	Unsignalized	Non-Toll	135	1,080	20	61,355
I-95	Unsignalized	Toll	234	1,872	32	60,213
Parkway	Unsignalized	Toll	342	2,736	48	102,941
Total			**1,484**	**11,868**	**267**	

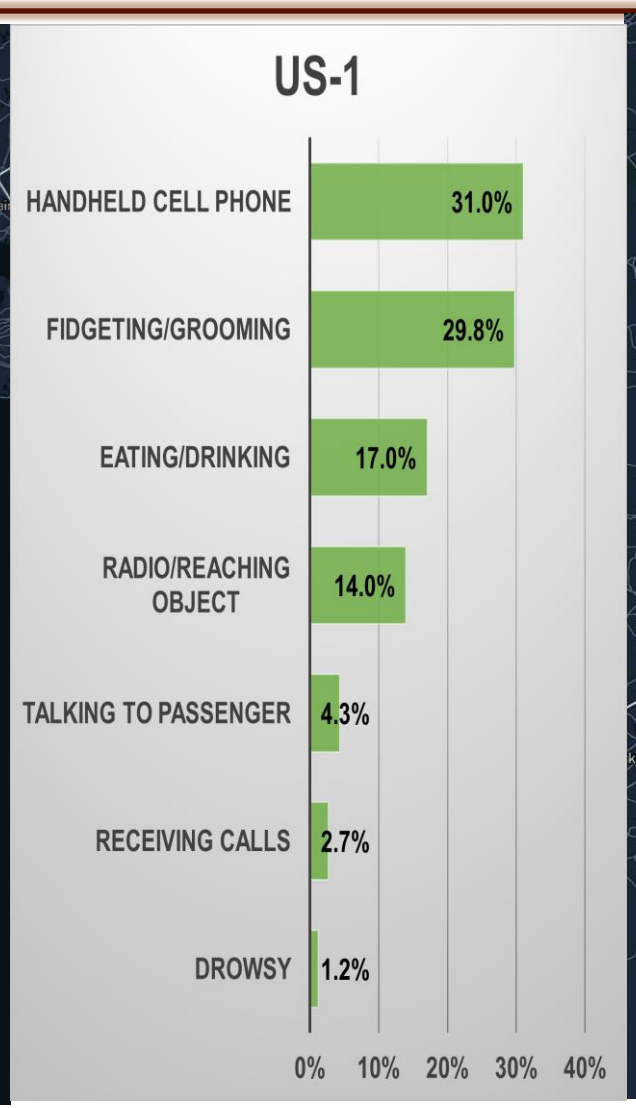


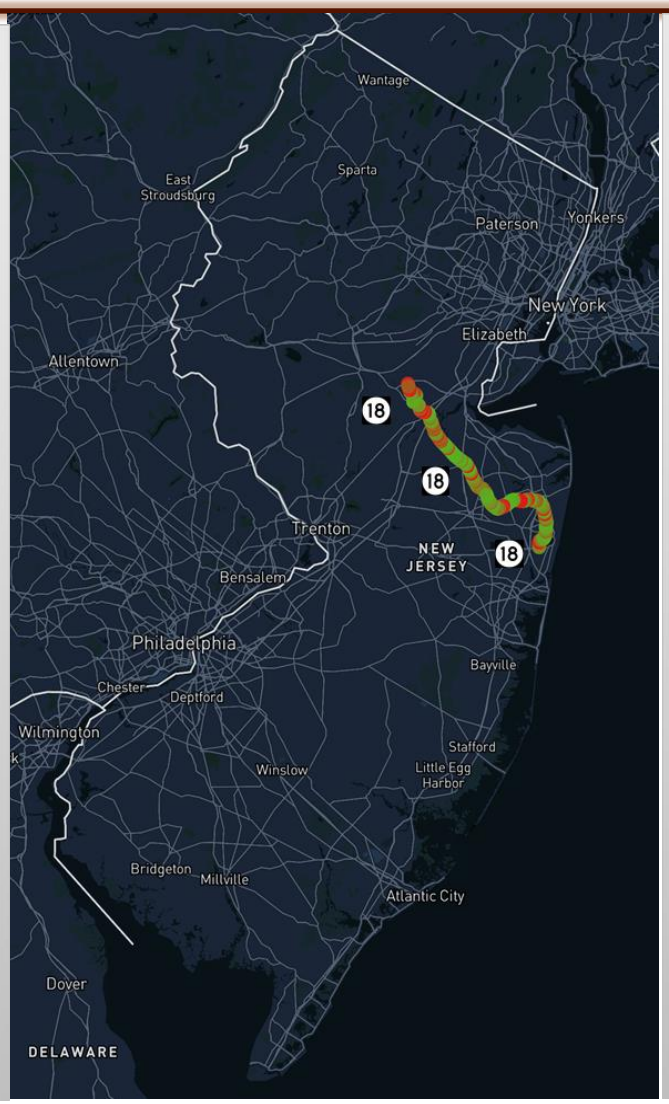
Summary of Distraction Events in Selected Corridors

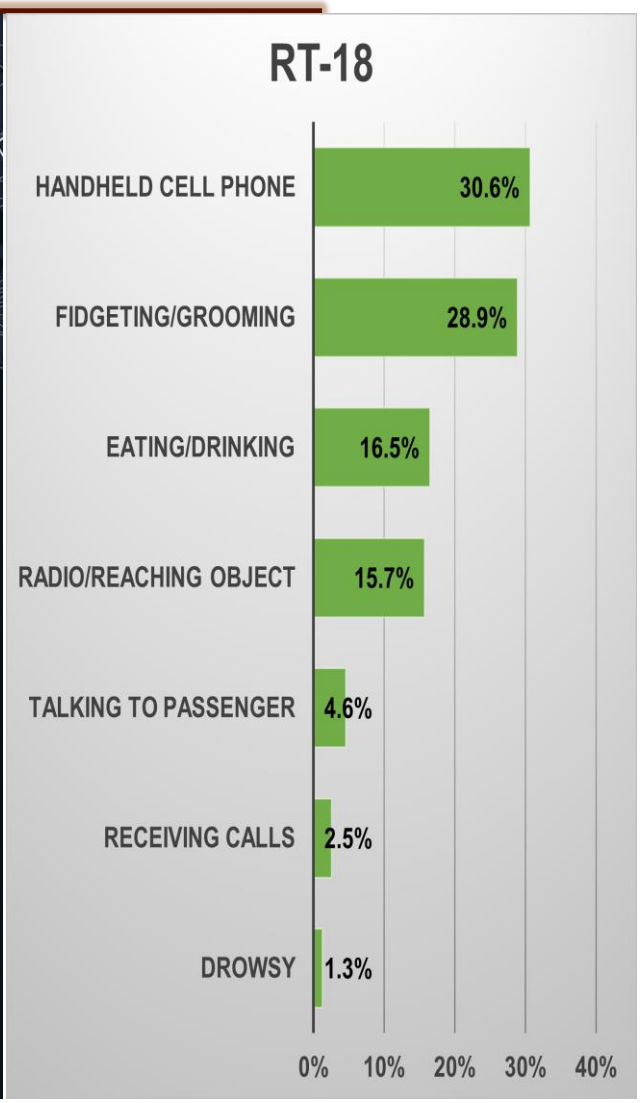
Route	Handheld cell phone	Fidgeting/ Grooming	Eating/ Drinking	Radio/ Reaching Object	Talking To Passenger	Receiving Calls	Drowsy	Non-Distraction	Distraction Rate (%)
US-1	151	145	83	68	21	13	6	1330	26.8
RT-18	121	114	65	62	18	10	5	1163	25.4
US-22	77	93	46	49	16	16	7	942	24.4
I-80	194	143	127	128	39	48	6	2,230	23.5
US-130	258	165	163	108	37	34	8	2,585	23.0
I-95	238	151	132	120	40	49	9	2,545	22.5
Garden State Parkway	576	397	238	286	104	125	32	6,261	21.9
I-295	145	140	87	92	57	28	8	1,997	21.8
RT-55	65	44	25	29	16	8	2	723	20.7
US-9	233	116	83	81	29	44	10	2,802	17.5
Total	2,058	1,508	1,049	1,023	377	375	93	22,578	**22.8**

Event Maps


Wantage
East Stroudsburg
Sparta
White Plains
Paterson
Yonkers
New York
Elizabeth
Allentown
1
1
1
Trenton
NEW JERSEY
Bensalem
Philadelphia
Chester
Deptford
Bayville
Stafford
Winslow
Little Egg Harbor
Bridgeton
Millville
Atlantic City
Dover
LAWARE


US-1
HANDHELD CELL PHONE
31.0%
FIDGETING/GROOMING
29.8%
EATING/DRINKING
17.0%
RADIO/REACHING OBJECT
14.0%
TALKING TO PASSENGER
4.3%
RECEIVING CALLS
2.7%
DROWSY
1.2%
0%
10%
20%
30%
40%


Wantage
East Stroudsburg
Sparta
Paterson
Yonkers
New York
Elizabeth
Allentown
18
18
18
Trenton
NEW JERSEY
Bensalem
Philadelphia
Chester
Deptford
Bayville
Wilmington
Stafford
Winslow
Little Egg Harbor
Bridgeton
Millville
Atlantic City
Dover
DELAWARE


RT-18
HANDHELD CELL PHONE
30.6%
FIDGETING/GROOMING
28.9%
EATING/DRINKING
16.5%
RADIO/REACHING OBJECT
15.7%
TALKING TO PASSENGER
4.6%
RECEIVING CALLS
2.5%
DROWSY
1.3%
0%
10%
20%
30%
40%

Manual Data Analysis (Statistical Tests)

Mann Whitney U Test	Kruskal Wallis Test
Non-parametric	Non-parametric
Not necessarily Normal distribution	Not necessarily Normal distribution
For comparison of 2 variables	For comparison of 3 or more variables
Statistically Significant at $P < 0.05$	Statistically Significant at $P < 0.05$ and H> Chi-squared value
There is no difference in mean rank between the samples drawn from two groups	*There is no difference in mean rank between the samples drawn from different groups*

Variation of Distraction Events Data

Parameter Considered	Variations	Significance Test
Day of the Week	Weekday, Weekend	Mann Whitney U Test
Traffic Signal	Signalized, Unsignalized	Mann Whitney U Test
Season	Spring, Summer	Mann Whitney U Test
Toll Roads	Toll Road, Non-Toll road	Mann Whitney U Test
Time of Day	Peak Hour, Off-Peak Hour	Mann Whitney U Test
Posted Speed Limit (mph)	25- 35, 36- 45 mph, 46- 55 mph, 56- 65 mph	Kruskal Wallis Test
Number of Lanes	2 Lanes, 3 Lanes, 4 or more Lanes	Kruskal Wallis Test
Median Type	Undivided, Positive, Curbed	Kruskal Wallis Test

Event Data Analysis (Weekday/Weekend)

Type of Distraction	Mean Rank Weekdays	Mean Rank Weekends	Delta Mean Rank	Mann-Whitney U	Z-score	P-Value
Handheld Cell Phone	29.5	32.5	3	360	-0.62	0.54
Fidgeting/Grooming	31.18	29.15	-2.03	373	0.42	0.67
Radio/Reaching Objects	31.55	28.4	-3.15	358	0.65	0.52
Eating/Drinking	31.08	29.35	-1.73	377	0.35	0.73
Talking to Passenger	30.39	30.72	0.33	396	-0.06	0.95
Receiving Calls	33.67	24.15	-9.52	273	1.98	**0.05***
Drowsy	32.45	26.6	-5.85	322	1.22	0.22
Non-Distracted	29.02	33.45	4.43	341	-0.92	0.36

* means statistically significant

Event Data Analysis (Signalized/Unsignalized Corridors)

Driver Behavior	Mean Rank Signalized Road	Mean Rank Unsignalized Road	Delta mean Rank	Mann-Whitney U	Z-score	P-Value
Handheld Cell Phone	32.73	28.27	-4.46	383	0.98	0.33
Fidgeting/Grooming	34.5	26.5	-8	330	1.77	0.08
Radio/Reaching Objects	29	32	3	405	-0.66	0.51
Eating/Drinking	33.97	27.03	-6.94	346	1.53	0.13
Talking to Passenger	25.5	35.5	10	300	-2.21	**0.03***
Receiving Calls	26	35	9	315	-1.99	**0.05***
Drowsy	32.78	28.22	-4.56	382	1.01	0.31
Non-Distracted	28.2	32.8	4.6	381	-1.01	0.31

* means statistically significant

Event Data Analysis (Peak Hour/Off-Peak Hour)

Driver Behavior	Mean Rank Peak Hour	Mean Rank Off-Peak Hour	Delta mean Rank	Mann-Whitney U	Z-score	P-Value
Handheld Cell Phone	54.43	47.90	-6.53	1107.50	-1.12	0.26
Fidgeting/Grooming	54.34	47.97	-6.37	1111.50	-1.09	0.28
Radio/Reaching Objects	49.86	52.03	2.17	1217.50	0.37	0.71
Eating/Drinking	52.68	49.48	-3.20	1191.50	-0.54	0.59
Talking to Passenger	54.44	47.89	-6.55	1107.00	-1.12	0.26
Receiving Calls	55.73	46.72	-9.01	1045.00	-1.54	0.12
Drowsy	49.35	52.49	3.14	1193.00	0.53	0.60
Non-Distracted	44.86	56.56	11.70	977.50	2.00	**0.05***

* means statistically significant

Event Data Analysis (Toll Road/Non-Toll Road)

Driver Behavior	Mean Rank Toll Road	Mean Rank Non-toll Road	Delta mean Rank	Mann-Whitney U	Z-score	P-Value
Handheld Cell Phone	32.5	30	-2.5	264	-0.43	0.67
Fidgeting/Grooming	23.5	32.25	8.75	204	1.54	0.12
Radio/Reaching Objects	32.67	29.96	-2.71	262	-0.47	0.64
Eating/Drinking	28.5	31	2.5	264	0.43	0.67
Talking to Passenger	30.83	30.42	-0.41	284	-0.06	0.95
Receiving Calls	42	27.62	-14.38	150	-2.54	**0.01***
Drowsy	36.33	29.04	-7.29	218	-1.28	0.20
Non-Distracted	31	30.38	-0.62	282	-0.10	0.92
* means statistically significant						

Event Data Analysis (Spring/Summer)

Driver Behavior	Mean Rank Spring	Mean Rank Summer	Delta mean Rank	Mann-Whitney U	Z-score	P-Value
Handheld Cell Phone	29.34	31.58	2.24	416	0.49	0.62
Fidgeting/Grooming	23.31	37.23	13.92	241	3.02	**0.00***
Radio/Reaching Objects	29.48	31.45	1.97	420	0.43	0.67
Eating/Drinking	22.41	38.06	15.65	215	3.46	**0.00***
Talking to Passenger	31.03	30	-1.03	434	-0.22	0.83
Receiving Calls	28.52	32.35	3.83	392	0.84	0.40
Drowsy	29.57	31.37	1.8	423	0.39	0.70
Non-Distracted	38.72	22.81	-15.91	211	-3.52	**0.00***

* means statistically significant

Pairwise Comparison for Speed Limit

Type of Distraction	56-65 mph Rank Value	46-55 mph Rank Value	36-45 mph Rank Value	25-35 mph Rank Value	25-35 mph vs. 36-45 mph	25-35 mph vs. 46-55 mph	25-35 mph vs. 56-65 mph	36-45 mph vs. 46-55 mph	36-45 mph vs. 56-65 mph	46-55 mph vs. 56-65 mph
Handheld Cell Phone	133.7	159.9	113.7	74.8	↑	↑	↑	↑	-	-
Fidgeting/Grooming	127.4	156.3	111.3	87.1	-	↑	↑	↑	↑	-
Radio/Reaching Objects	140.0	148.7	108.9	84.3	-	↑	↑	↑	-	-
Eating/Drinking	138.6	153.9	109.7	79.9	↑	↑	↑	↑	-	-
Talking to Passenger	137.5	148.2	110.2	86.1	-	↑	↑	↑	-	-
Receiving Calls	137.9	157.0	107.9	79.2	-	↑	↑	↑	-	↓
Drowsy	131.8	137.5	115.3	97.4	↑	-	-	-	↑	-
Non-Distracted	126.3	168.2	99.2	88.3	↑	↑	↑	↑	-	-

Decrease in distraction event ↓ Increase in distraction event ↑ Insignificant -

Pairwise Comparison for Median Type

Type of Distraction	Unprotected Rank Value	Positive Rank Value	Curbed Rank Value	Unprotected vs Positive	Unprotected vs Curbed	Positive vs Curbed
Handheld Cell Phone	97.7	113.2	60.6	-	↓	↓
Fidgeting/Grooming	95.4	115.3	60.8	-	↓	↓
Radio/Reaching Objects	89.0	115.9	66.6	↑	↓	↓
Eating/Drinking	84.7	120.3	66.5	↑	-	↓
Talking to Passenger	91.9	113.2	66.4	-	↓	↓
Receiving Calls	84.5	122.2	64.8	↑	↓	↓
Drowsy	82.1	115.1	74.3	↑	-	↓
Non-Distracted	97.1	105.6	68.9	-	↓	↓

Decrease in distraction event ↓ Increase in distraction event ↑ Insignificant -

Pairwise Comparison for No. of Lanes

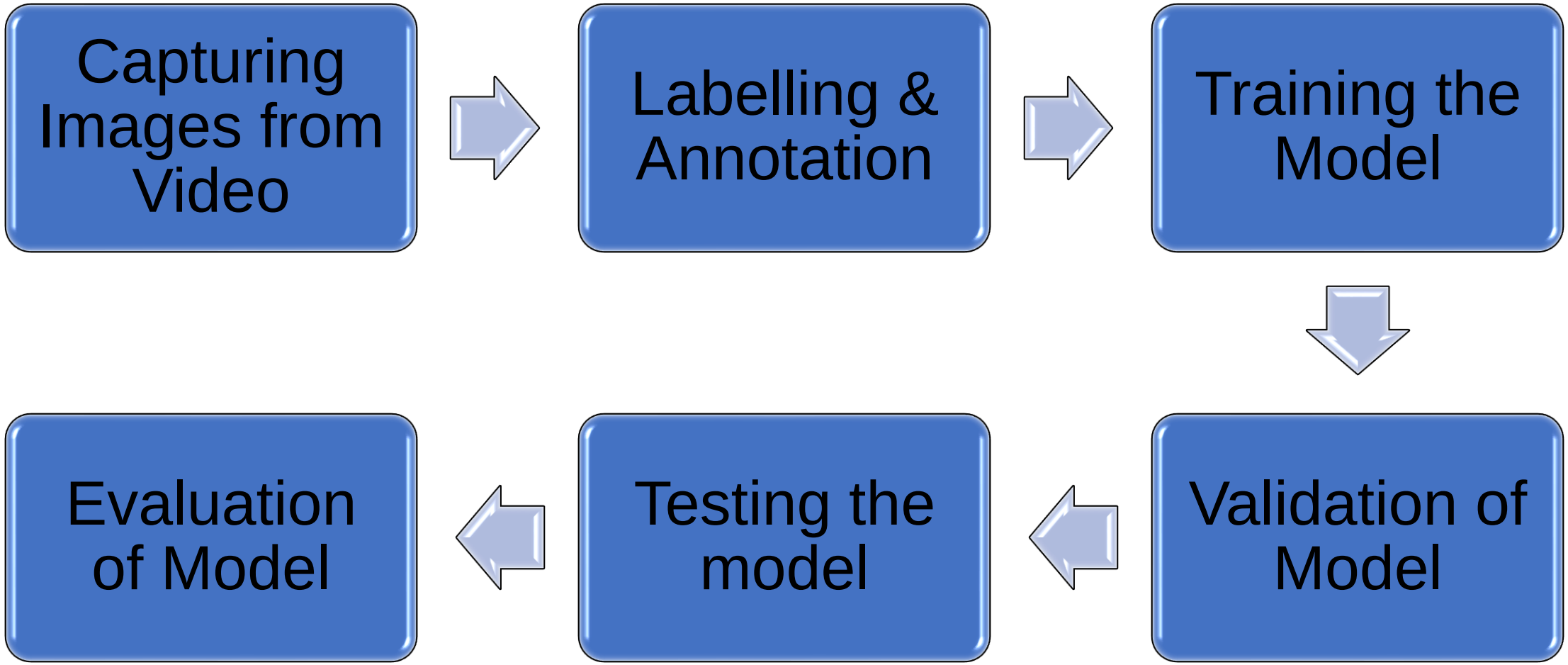
Type of Distraction	2 Lanes Rank Value	3 Lanes Rank Value	4 or more Lanes Rank Value	2 Lanes vs. 3 Lanes	2 Lanes vs. 4 or more Lanes	3 Lanes vs. 4 or more Lanes
Handheld Cell Phone	109.9	96.1	65.6	-	↓	↓
Fidgeting/Grooming	100.5	99.0	71.9	-	↓	↓
Radio/Reaching Objects	99.6	108.7	63.2	-	↓	↓
Eating/Drinking	98.9	107.3	65.3	↑	↓	↓
Talking to Passenger	95.5	105.8	70.2	-	↓	↓
Receiving Calls	95.5	103.3	72.7	-	↓	↓
Drowsy	86.8	108.7	76.1	↑	↓	-
Non-Distracted	104.1	85.6	81.8	-	-	-

Decrease in distraction event ↓ Increase in distraction event ↑ Insignificant -

Summary of Manual Data Analysis

- Receiving call events significantly increased during the weekdays
- A higher speed limit is associated with more distraction events
- The presence of curbed median significantly decreased the number of distraction events
- An increase in the total number of roadway lane is associated with lower distraction events

Methodology for Detection of Distracted Driving



Detection Steps (Labelling and Annotation)

Definition of the labels

1.Handheld Cell Phone = **Hands** intersecting with **cellphone**

2.Receiving Calls = **Hands** intersecting with **cellphone** and **ear**

3.Food/Drink = **Hands** intersecting with **cup/food/cigarette**

4.Radio/Reaching Object = **Hands** intersecting with **radio**/any place on **dash**

5.Fidgeting/Grooming = **Hands** intersecting with **face**

6.Drowsy= **Hands** intersecting with **Mouth**

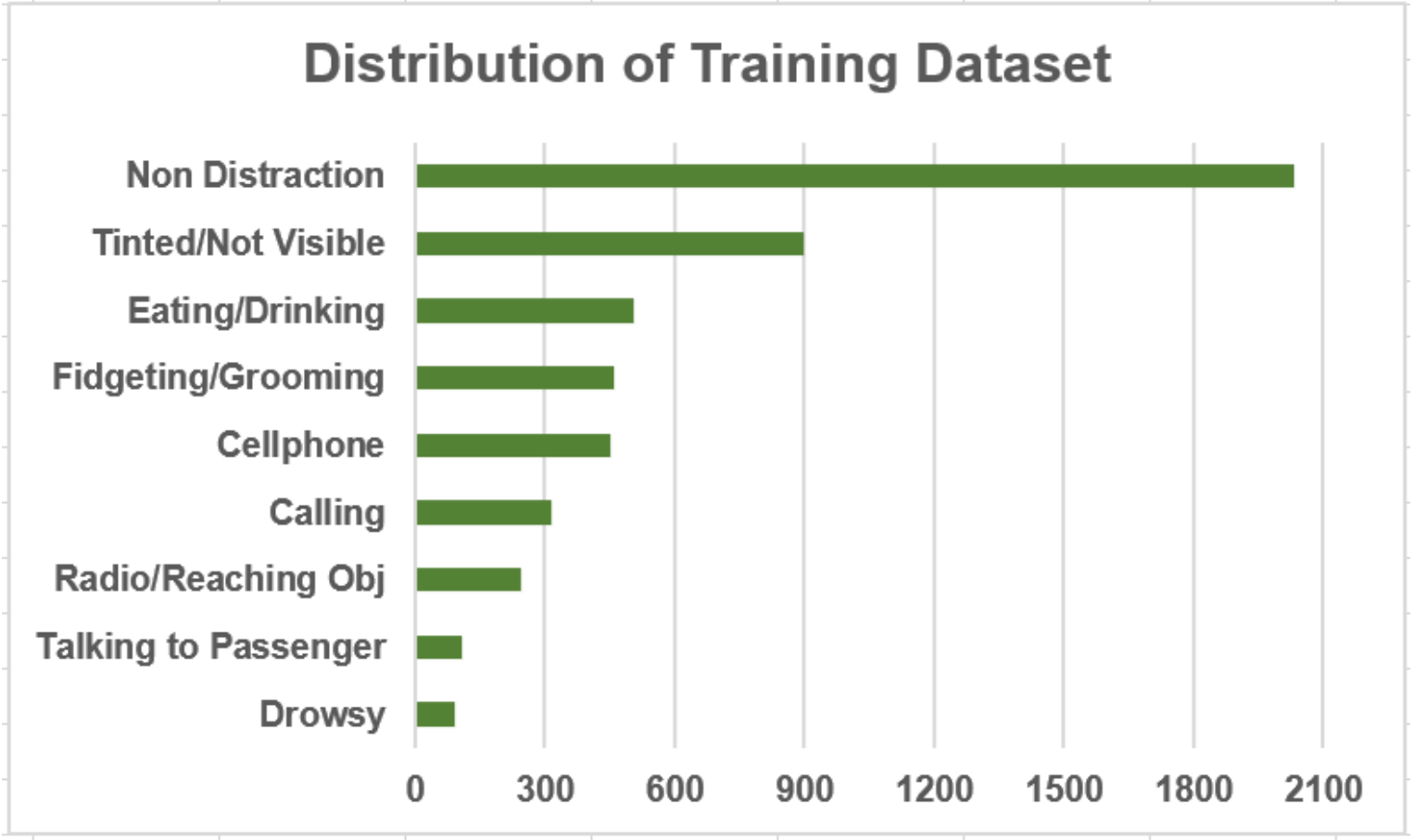
7.Talking to Passenger = **Eyes/Face** orientation is on the side of passenger

8.Non-Distracted = **Hands** intersecting with **Steering**

9.Tinted Window = Window black or glare

Detection Steps (Training Data)

- **5,382** images are considered for training purpose.
- The training of the model is done using an AI based algorithm: **YOLOv5**

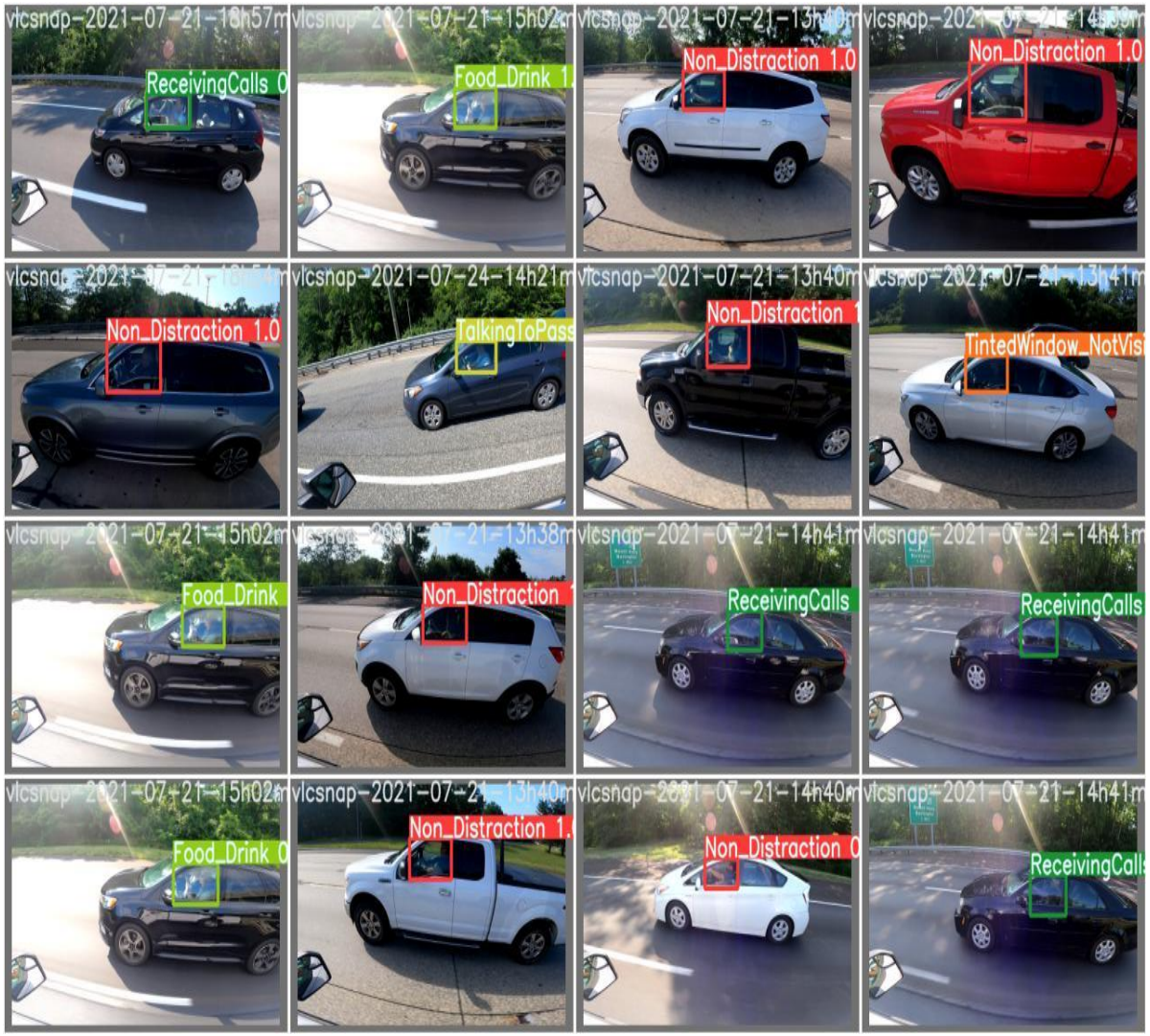


Why YOLO?

- Fast (Less duration for computation)
- Accurate in prediction
- Less requirement for GPU
- Batch/ parallel processing

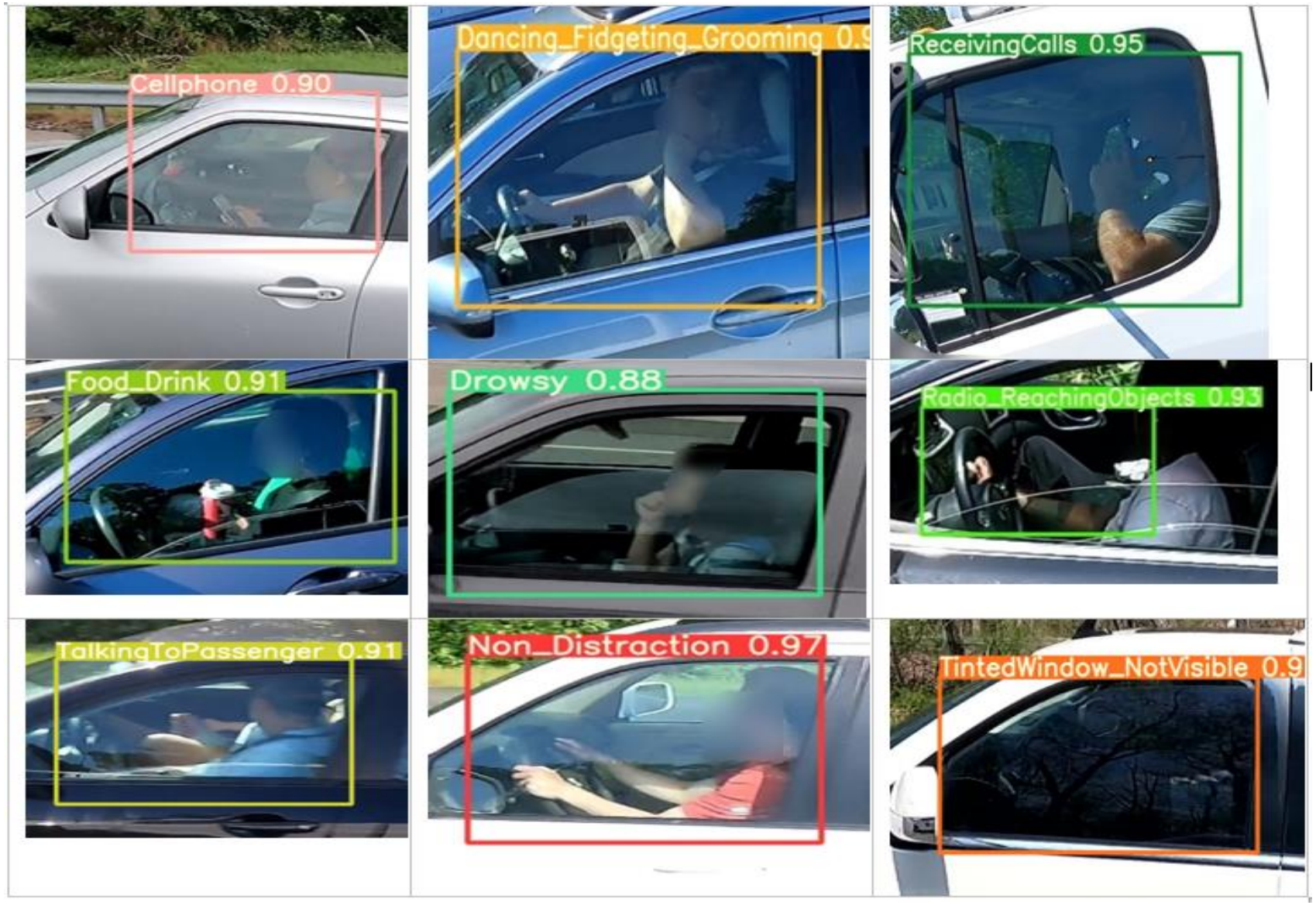
Detection Steps (Training & Validation of Data)

Training on a Batch of 16 images



Validation on a Batch of 16 images

Detection Steps (Testing)



- The name of the predicted type of distraction is shown above the bounding box
- The model also shows the confidence of the prediction (model is 90% confident that the first image is a cellphone)

Model Evaluation

- The model predicted **511 images** correctly out of **598 images**
- **Accuracy** of the model is **85.5%**
- **Non-Distraction, Tinted Windows, Cellphone & Eating/Drinking** have prediction accuracy above 80%

Class	Non Distraction	Cellphone	Tinted/ Not Visible	Fidgeting/ Grooming	Talking to Passenger	Radio/ Reaching Obj	Eating/ Drinking	Drowsy	Calling
Non Distraction	**0.92**	0.10	0.09	0.16	0.33	0.30	0.20	0.20	0.11
Cellphone	0.00	**0.86**	0.00	0.04	0.00	0.00	0.00	0.00	0.00
Tinted/ Not Visible	0.05	0.00	**0.91**	0.04	0.00	0.00	0.00	0.20	0.00
Fidgeting/ Grooming	0.04	0.04	0.00	**0.76**	0.00	0.00	0.00	0.00	0.11
Talking to Passenger	0.00	0.00	0.00	0.00	**0.67**	0.00	0.00	0.00	0.00
Radio/ Reaching Obj	0.00	0.00	0.00	0.00	0.00	**0.70**	0.00	0.00	0.00
Food/Drink	0.00	0.00	0.00	0.00	0.00	0.00	**0.80**	0.00	0.00
Drowsy	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.60**	0.00
Calling	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.77**

Predicted

Actual

Conclusion

- Variation of temporal variables and roadway features have a significant influence on the driver's behavior involving distraction
- “Handheld cellphone” was the leading type of distraction
- Receiving Calls, Talking to Passengers, Fidgeting/Grooming significantly varied due to variation of temporal and roadway features
- Overall results from video analysis confirmed that driver's behavior (from cameras outside the vehicle) could be detected with fair accuracy using deep learning models

Thank You