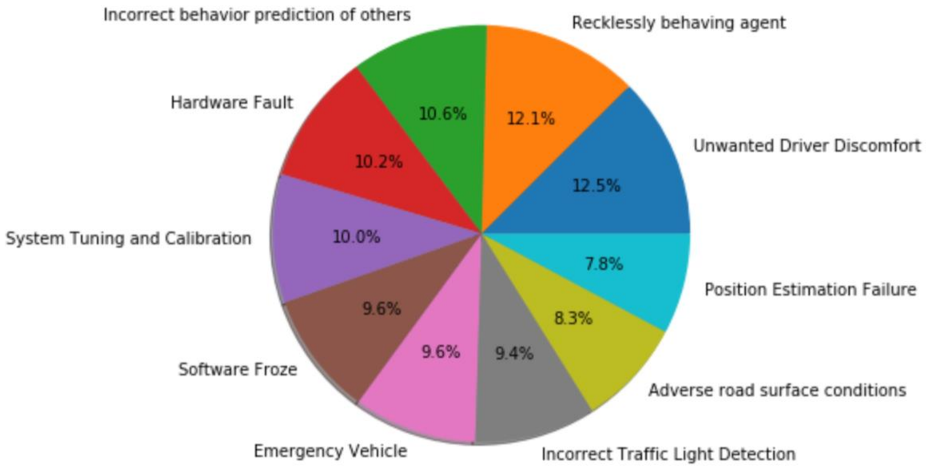
Autonomous Vehicle Safety Analysis

Badrinarayanan Rajasekaran (br17)
Aniruddha Sharma (ashar29)
Anunay Sharma (anunays2)

Task 0

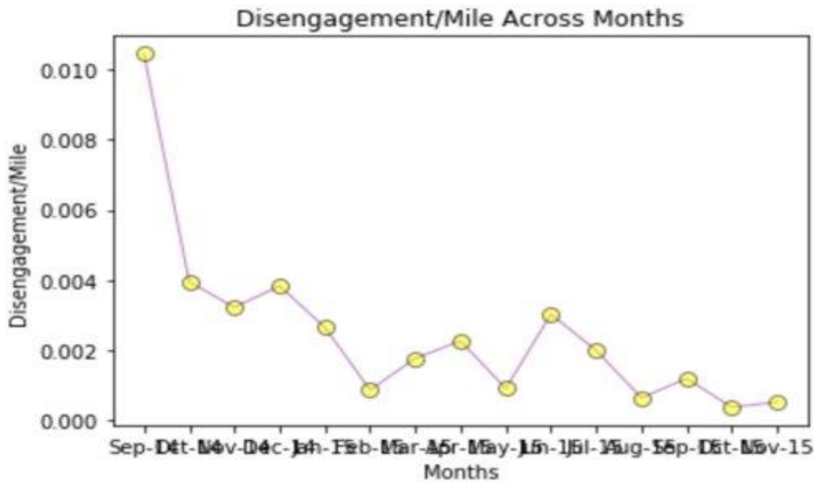
	Summary – Question 2	KPI
a.)	Total Disengagements	1024
b.)	Unique Months	12
c.)	Unique Locations	2 (Urban-street & Highway)
d.)	Unique Causes	10
e.)	Rows with missing values	532

Question 3 : Pie chart : causes of AV disengagement



The top 2 causes of disengagement are : **Unwanted Driver discomfort** and **Recklessly behaving agent**

Question 4 : Total disengagement/mile



The trend of disengagement/mile decreases over the course of time. It has the highest disengagement per mile in the month of September 2014 and lowest being November 2015

Task 1

Question 1 : What does the different distributions signify about samples drawn from it?

Normal – For any sample drawn there is a **95%** chance that an observation will be within 2 standard deviation from the mean and almost **99.7%** of the observations will lie within 3 standard deviations of the mean.

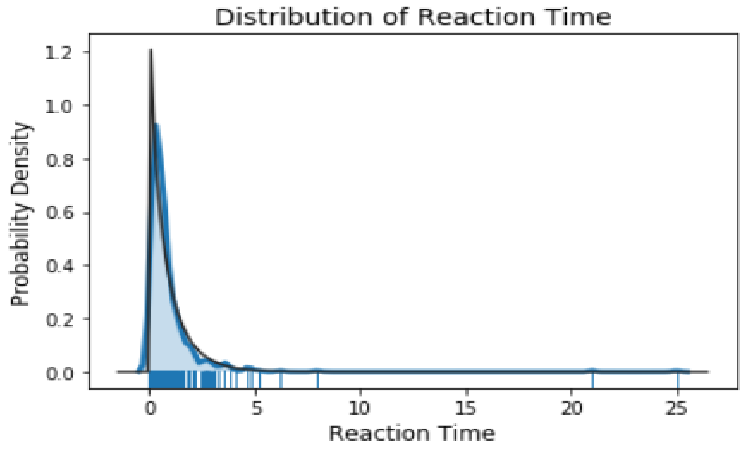
Exponential - When we plot the samples taken from an exponential distribution, the series of will follow a decreasing trend regardless of the sample and the distribution appears skewed. The probability of each point in the sample is independent of previous values.

The samples drawn from **Weibull distribution** will behave very versatile and can behave like a normal/exponential distribution. It depends on the shape parameter beta and scaling parameter alpha.

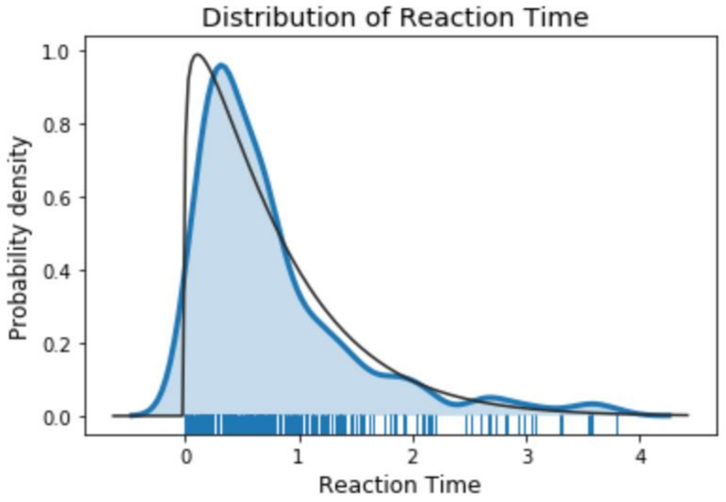
However, as the sample size increases, the distributions of samples resemble close to their parent distribution and mean of the sample converges towards the mean of the entire population (**Central Limit Theorem**)

Task 1

Question 2: Probability distribution of reaction times



After removing outliers



The reaction time follows a Weibull distribution. The distribution signifies that most of the drivers have a reaction time of 0-2s

Question 3 : Average Reaction times

(a) Over entire dataset: **0.93 seconds**

(b.) Over entire dataset per location

Location	Reaction Time (in seconds)
Highway	**1.48**
Urban Street	**0.93**

Task 1

Q4 : Hypothesis Testing

Q 5 : Probability distribution of disengagements/mile

Assumption: We consider both the independent population to have the same variance

Null Hypothesis :

Mean reaction time for humans in AV cars is same as non-AV cars ($\mu_1 = \mu_2$)

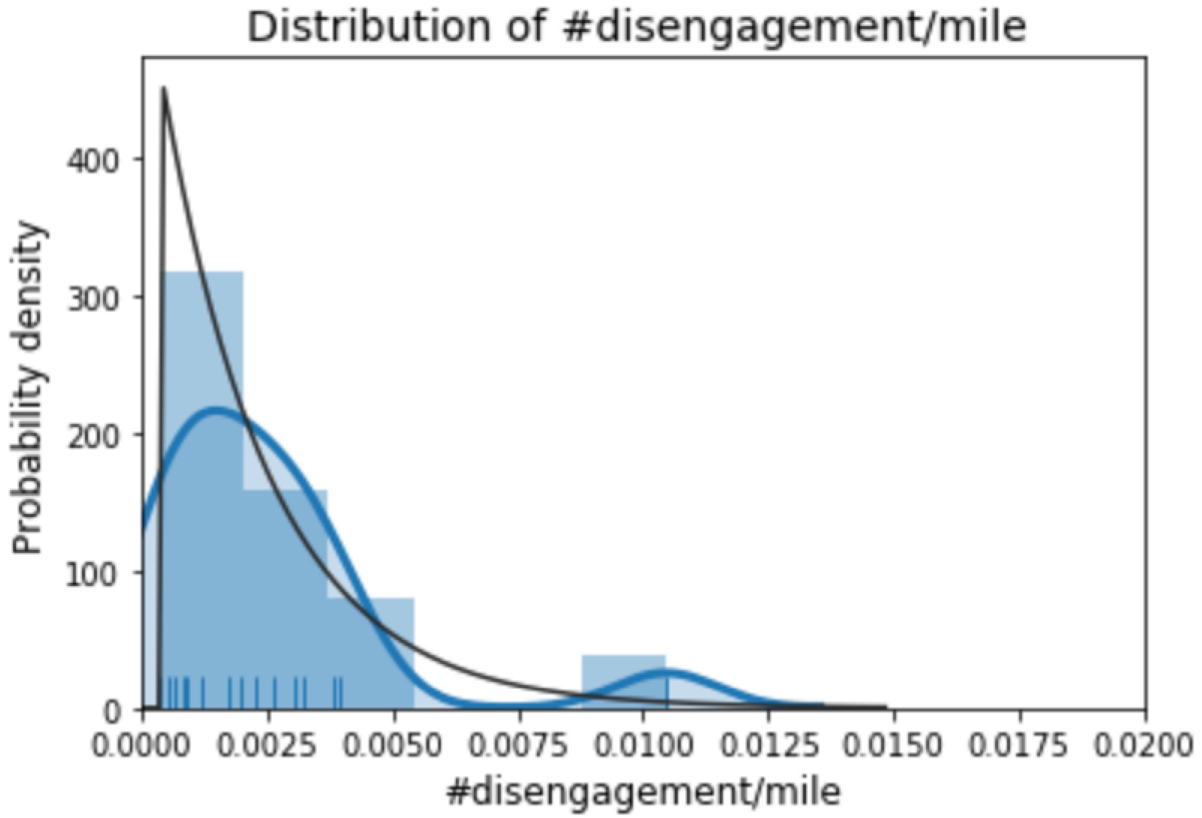
Alternative Hypothesis :

Mean reaction time for humans in AV cars is different from non-AV cars ($\mu_1 \neq \mu_2$)

Statistic Value : t-statistic = $\frac{\mu 1 - \mu 2}{s/\sqrt{n}}$ = **3.028**

Outcome of the hypothesis test (for α=0.05):

We reject the null hypothesis and conclude that the mean reaction time for humans in AV cars is different from non-AV cars



The above figure follows more or less an exponential distribution (Except that it has a local peak due to data).

Task 2

Qn 1

(a) Bernoulli distribution

(b) Probability of disengagement/mile on a cloudy day: 0.0059

(c) Probability of disengagement/mile on a clear day: 0.00052

(d) Probability of automatic disengagement/mile

(i) on a cloudy day: 0.0028

(ii) on a clear day: 0.00026

(e)

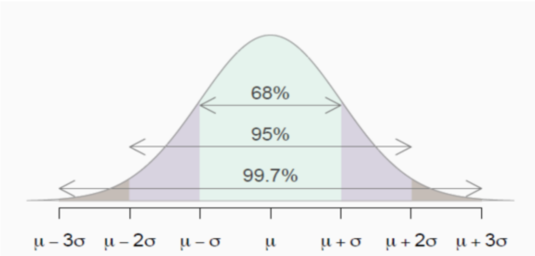
The given distribution can be represented as a binomial distribution which can then be approximated to a normal distribution using Central Limit Theorem

P-value =1.98 * e^{-21}

Qn 2 – Hypothesis Testing Concepts

(a)

Normal distribution represents an approximate representation of the data in the hypotheses test when one needs to compare two samples or a sample and population given its parameters



Normal Distribution with mean μ and standard deviation σ

b)

It is not necessary that rejecting the NULL hypothesis means accepting the alternate hypothesis. It depends on the formulation of the experiment and a relationship may exist between 2 phenomena that is not identified by the experiment

For example, there can be a set of hypothesis such as:

H_0: $\mu_1 = \mu_2$ **(Null Hypothesis)**

H_A: $\mu_1 > \mu_2$ **(Alternate Hypothesis)**

There is a solution of $\mu_1 < \mu_2$ outside the scope of this hypothesis which might be left out as a part of this experiment

Task 2

Qn 3 : Z-test

Null Hypothesis : The AV on cloudy days has same disengagement on clear days

Alternative Hypothesis : The AV has more disengagement on cloudy days than clear days

Statistic Value (Z) = **7.64**

P-value= **4.84 e-14**

Outcome of the hypothesis test:

P-value is extremely less than the significance level (0.05)

Conclusion:

We reject the Null Hypothesis - The AV on cloudy days has same disengagement on clear days

Qn 4 – Conditional Probability

(Write both the probability expression and the computed probability value)

(a)

$$P(Dm \mid Cloudy) = P(Dm, Cloudy \mid P(C)\ ) = 0.47$$

(b)

$$P(Dm \mid Clear) = \frac{P(Dm, Clear)}{P(Clear)} = 0.28$$

Qn 5 – Conditional Probability and Total Probability

Theorem of total probability would be:

$$P(accident\ per\ mile) = P(Dm \mid Cloudy)\ * P\ (Cloudy) + P(Dm \mid Clear)\ * P(Clear)$$

= 0.34

Task 2

Qn 6 – **Comparing AVs to human drivers**

The probability of human driver causing a car accident is **0.0002** while the probability of AV for the same comes to be **0.34**.

There is a bigger risk associated with AV's as they can't be trained with all the possible scenarios of accident that happens in the real life.
On the other hand, the humans react to any known/unknown signs of danger and their sudden response would to avoid accidents and mitigate the impact

The system needs to be trained with different conditions like the weather, road and cities

Qn 7 – **KS Test**
Hypothesis:

H0: Both the samples (clear and cloudy) are from the same distribution
Hα: Both the samples (clear and cloudy) are not from the same distribution

Outcome of the hypothesis test:

Statistic Value = **0.056,** P value = **0.95**

Decision Rule:
If:
p-value < α → Reject Null Hypothesis
p-value > α → Fail to reject Null Hypothesis

Here, 0.95 > 0.1; fail to reject Null Hypothesis

Conclusion:
Weather (cloudy or clear) doesn't have any impact on the disengagement reaction time.

Task 3

Qn 3 – Conditional Probability Tables for NB classifier

Location	Class	#	P(Location/Class)
Highway	Computer System	16	0.93
Urban-street	Computer System	226	0.07
Urban-street	Controller	294	1
Urban-street	Perception system	283	1

Location

Weather

Weather	Class	#	P(Weather/Class)
Clear	Computer System	149	0.62
Cloudy	Computer System	93	0.38
Cloudy	Controller	294	1
Cloudy	Perception system	283	1

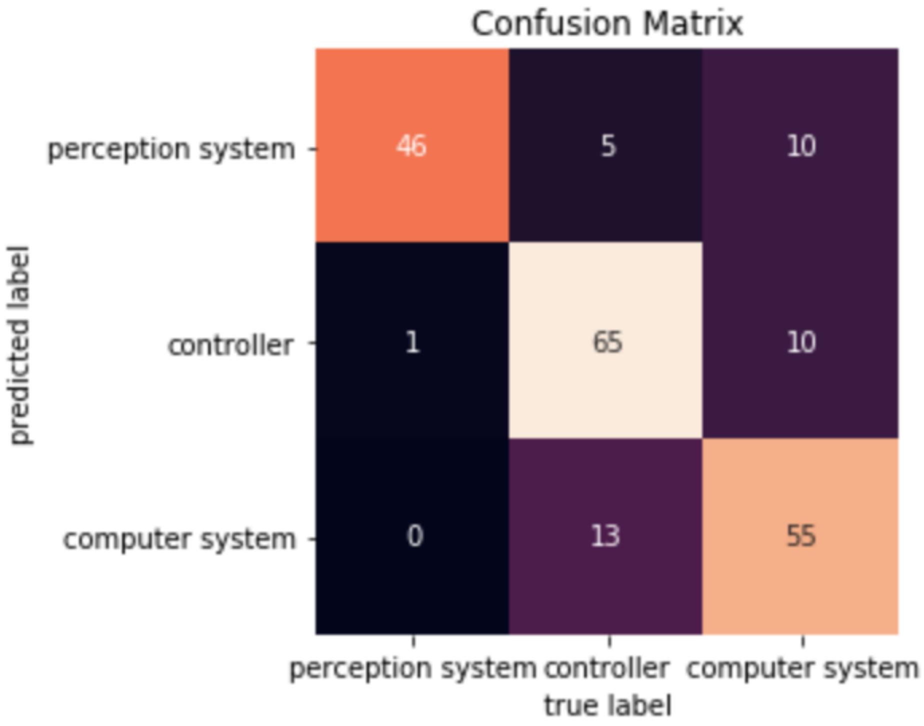
Type of Trigger	Class	#	P(Trigger/Class)
Automatic	Computer System	112	0.47
Manual	Computer System	130	0.53
Automatic	Controller	35	0.12
Manual	Controller	259	0.88
Automatic	Perception System	239	0.85
Manual	Perception System	44	0.15

Trigger

Task 3

Qn 4 – NB Classifier Accuracy:

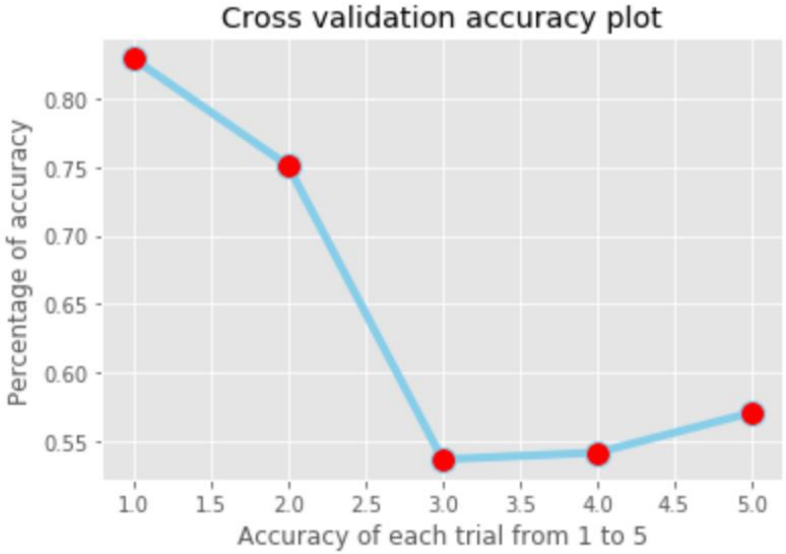
80.97 %



Qn 5 – NB Cross Validation Accuracy:

a.) Through sklearn library 5-fold CV resulted in an accuracy of **58.7 %**

b.) Performing manual CV 5 times gave an accuracy in the range of **(58 -65 %)** if we ran the cross validation function multiple times



Task 3

Qn 6 – Is your NB model doing better than chance? Explain.

- Yes, the NB model is performing better than chance. The model predictions were nearly **75 %** correct for the test data set when we used the **validation set approach** .

- We further validated this accuracy by performing k-fold cross validation approach (using Sklearn library and manually coding the k-fold CV). In both the cases the minimum average accuracy we achieved was nearly **58% (accuracy range: 58% - 65%).**

- By randomly guessing, we can have at max 50% correct predictions, which is lower than the accuracy achieved by the NB model.

Task 3

Qn 7 - Assumptions in NB in this context of AV safety analysis

a. Assumption:

- Naive Bayes assumes that the features are class conditionally independent (independent given/conditioning on the class) which may not always

  hold in a real-world problem. Here we have three features, which we assume to be independent
  - Location
  - Weather
  - Type of Trigger

- No. The assumptions are not completely realistic.
  - The location (urban-street and highway) where the AV is driven doesn't depend on the weather.
  - Also the type of trigger is not related to the weather
  - The type of trigger can depend on the location where the AV is driven. For instance, if the AV is driven in urban street, there are more chances of risk which can lead to the driver taking control of the vehicle.

Task 3

Qn 8 – Possible improvements to increase classification accuracy

- 1.) Here we have a quite small dataset, a general approach which can increase the accuracy is collecting more data as training a model on a more diverse dataset which has more variability can result in a model with better accuracy score

- 2) **Bayesian Networks** do not assume class conditional independence and hence could have been a better choice for this problem and thus might have produced a higher accuracy

- 3) Since the assumption of the naive Bayes may not be applicable in context of this problem, one way to improve the model accuracy is to use a different classification process like **Linear Discriminant Analysis, Quadratic Discriminant Analysis, Multi-class logistic regression.**

- 4) **Ensemble models** which involves combining multiple models to improve the accuracy using **bagging and boosting**. Ensemble Learning can improve the predictive performance more than any single model.

Insights on AV safety

Insights

1) It takes an average of ~0.9s for the driver to take control of the car after an automatic trigger

There is a reaction time of lesser than 0.5s for 45% of the disengagements that have happened

The #disengagements per mile keeps decreasing over the course of time. It says that AV is performing well and risk of accidents are lesser than expected

Insights Continued

Cause of disengagement	Occurences
Unwanted Driver Discomfort	12.50%
Recklessly behaving agent	12.11%
Incorrect behavior prediction of others	10.64%
Hardware Fault	10.16%
System Tuning and Calibration	9.96%
Emergency Vehicle	9.57%
Software Froze	9.57%
Incorrect Traffic Light Detection	9.38%
Adverse road surface conditions	8.30%
Position Estimation Failure	7.81%

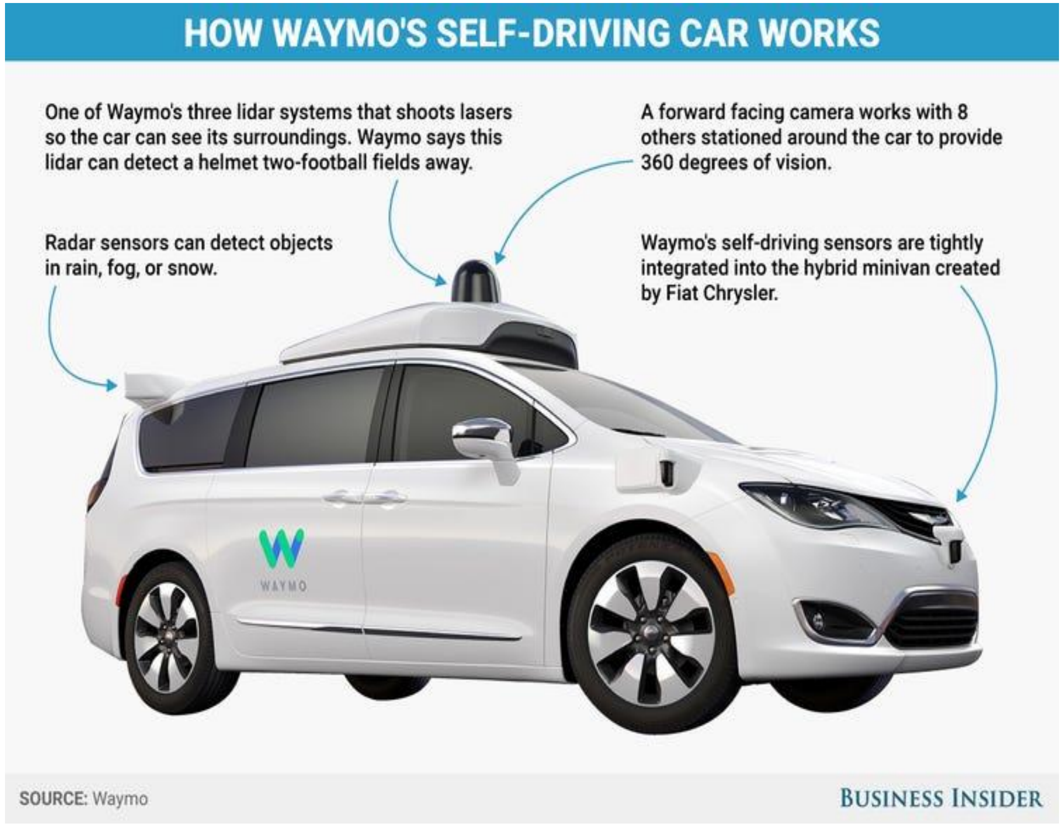
Would you ride in an AV based on the data you have analyzed?

There is no doubt that AV are maturing over time as the metric Disengagement per mile has reduced by 95% from Sep 2014 to Nov 2015. There are still sudden increase in disengagements at random time periods. It would be ideal to start using AV when we could see a continuous decline in the #disengagement per mile by observing the pattern in the next 24 months

Insights on AV safety

What do you think about the future of AVs and how soon they will be deployed?

- The future of AV's looks to be promising as it can be trained to be protective against all the odd conditions even when human beings would fail to avoid accidents
- Waymo has been successful in launching self driving cars in the streets of California and Arizona and it has driven a total of more than 5 million miles



Insights on AV safety

- What would you change about the MP? What other analysis would you have done?
  - A dataset with more observations would bring variance in the model that is always better
  - Bringing in more features like vehicle speed
  - Analysis of AV across different locations (Cities) could give us an insight on how it performs in the densely populated area

Individual Contributions

Index	Name	Contribution
1.)	Badrinarayanan Rajasekaran	• Analysis : 40 % • Modeling : 30 % • Presentation : 20 % • Quality check: 10%
2.)	Aniruddha Sharma	• Analysis : 30 % • Modeling : 40 % • Presentation : 20 % • Quality check: 10%
3.)	Anunay Sharma	• Analysis : 20 % • Modeling : 30 % • Presentation : 40 % • Quality check: 10%