Predicting NYC Auto Collision Volume

Team Information

Team Number: 45

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Project Background

While motor vehicle collisions have emotional, financial and health costs associated with them, they also present an opportunity to add/restore value in the form of auto repairs.

This project aims to help a fictitious local auto repair center in New York state, estimate the volume of incoming vehicles they can expect each year, assuming their market share[1] is known.

Problem Statement - Nick

Primary

- Use historic auto collision data from NYC to estimate the future collision volume.
- Then, take these collision estimates and combine them with known market share of the fictitious auto repair business to forecast their expected auto repair volume.

Secondary

- Recommend a targeted marketing campaign for market share growth, and then forecast gains
- Evaluate the effect of COVID-19 on this industry sector.

Literature review

Regev et. al. (2022)

- Evaluated the crash risk of drivers of different ages and genders adjusting for travel exposure
- Found that drivers between the ages of 21 and 29 carry the highest level of risk for being in a car crash contrary to popular belief
- Impactful for our project since it grounded us and allowed us to let the data speak

Literature review (cont.)

He et. al. (2021)

- Developed a technique using GPS data to predict where accidents happen.
- Allow policymakers to create targeted solutions e.g., install traffic calming devices in areas that are predetermined to be risky.
- We were inspired by the advanced models that they built.

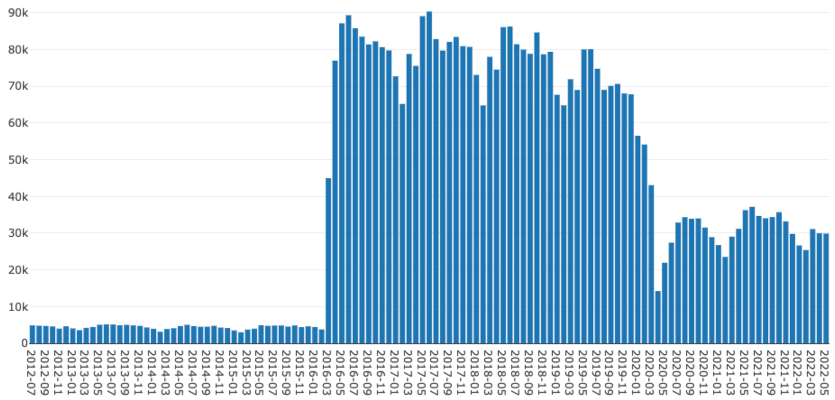
Data Sources

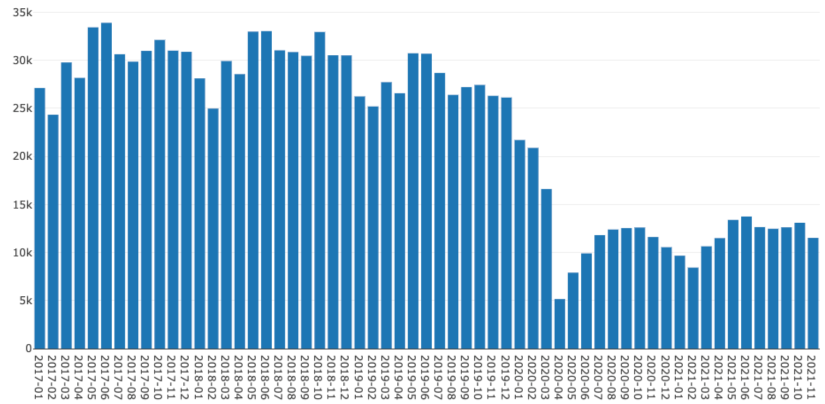
DATA.GOV

- The main data sources for this project are sourced from data.gov. These data represent New York state vehicle collisions. We will be using data from 3 sources, which share common factors: COLLISION ID, UNIQUE ID, and VEHICLE ID.
    - The Crashes dataset contains data on the actual crash events in NYC from 2013-01-01 to 2021-12-31.
    - The vehicle dataset contains data on the actual crash vehicles in NYC from 2013-01-01 to 2021-12-31.
    - The person dataset contains data on the actual crash persons in NYC from 2013-01-01 to 2021-12-31.

Known Issue

- In our research, we discovered that as a result of a traffic safety initiative to eliminate traffic fatalities, the NYPD replaced its record management system with an electronic one, (FORMS), in 2016.*** We see this change reflected in the chart to the right. The amount of data collected from March 2016 on greatly surpasses the amount previously collected.
- Resolution:
    - Because of this, and the fact that we want to help our local repair center forecast their yearly volume, we will use data collected after 2017-01-01 for full year modeling





Approach

STEP 1 — Data Wrangling

Join datasets, engineer synthetic features

STEP 2 — Feature Selection

Use identified key predictors, experiment w/ LASSO elastic net for auto feature selection

STEP 3 — Training/Validation

Cross-Validate/Train using different models, select based on R^2 or MAE

STEP 4 — Testing

Compute expected car crash count on test data using best model

FINAL — Prediction

Use model to estimate demand for local shop * market share

Hypotheses

1. Be able to estimate the monthly demand for a fictitious auto shop in New York state by extrapolating the monthly car crash volume with reasonable accuracy.

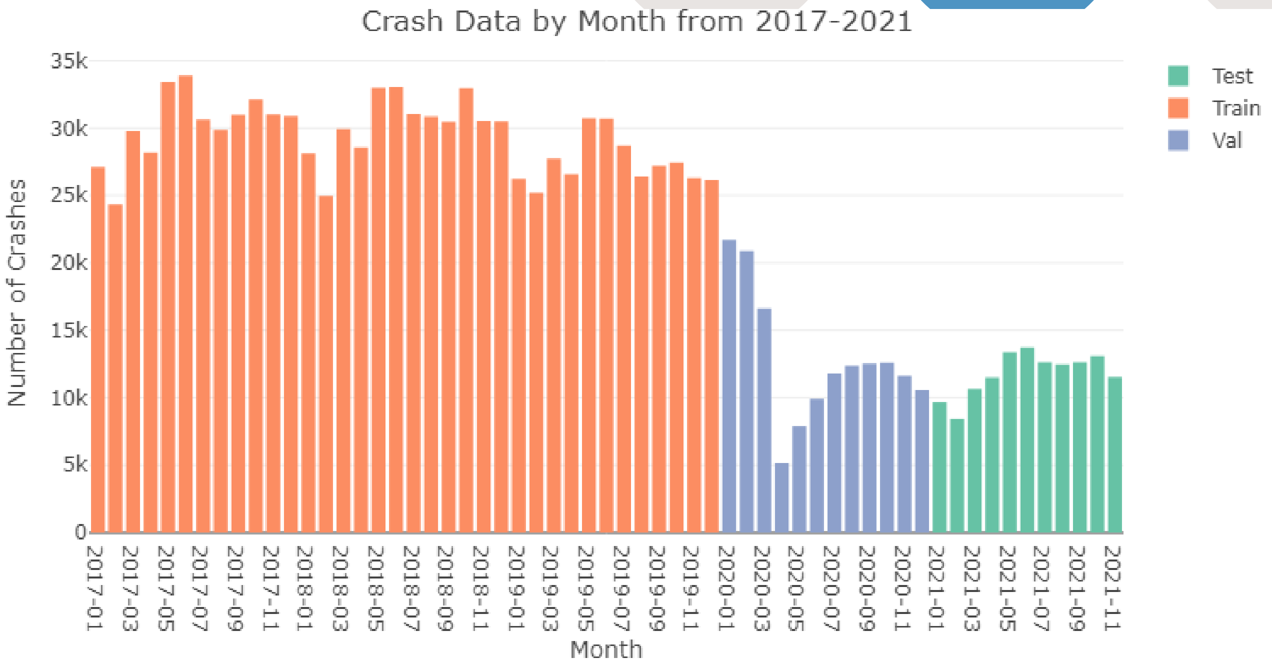
2. Identify a demographic that comprises the largest market segment for motor vehicle repairs after an accident; from our preliminary investigation, we suspect that young men comprise this demographic.

3. Be able to assert that $x expenditure on advertising targeted towards the most valuable demographic will result in $x+y revenue.

4. Be able to quantify the impact of COVID-19 on demand in this sector. Our preliminary investigation has already highlighted this.

Data Partitioning and Modeling Steps

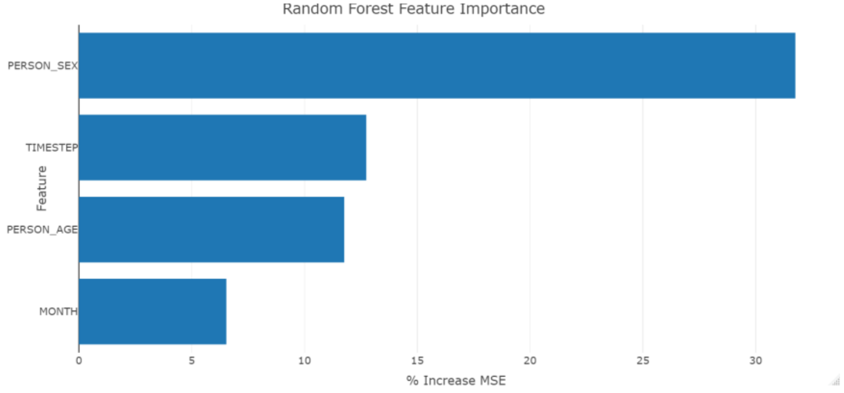
- Time-aware Modeling required chronological partitioning
- Initial Models / Hyperparameter Tuning
  - Training – 2017-01 to 2019-12
  - Validation – 2020-01 to 2020-12
- Models Rebuilt on Train + Validation
  - Training + Validation - 2017-01 to 2020-12
- Test set left aside for Final evaluation



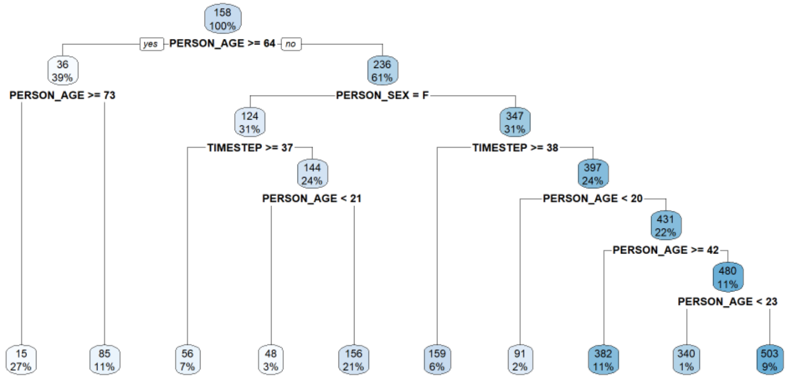
Model Evaluation Overview

- Models Explored:
  - Multiple Linear Regression
  - Random Forest
  - Classification and Regression Trees
  - Extreme Gradient Boosted Trees
  - Ensemble of models above

Random Forest model



CART Model



Linear Model

```
Call:
lm(formula = n ~ TIMESTEP + MONTH + PERSON_AGE + PERSON_SEX,
    data = train_val_df)

Residuals:
    Min      1Q  Median      3Q     Max
-441.83  -64.83    4.23   58.78  299.83

Coefficients:
             Estimate Std. Error t value Pr(>|t|)
(Intercept) 352.82536    5.76803  61.169  < 2e-16 ***
TIMESTEP     -2.92533    0.09545 -30.646  < 2e-16 ***
MONTH02     -10.16349    6.23071  -1.631 0.102891
MONTH03       5.85028    6.23281   0.939 0.347952
MONTH04     -17.30053    6.27381  -2.758 0.005837 **
MONTH05      13.68098    6.25907   2.186 0.028862 *
MONTH06      19.14640    6.25344   3.062 0.002208 **
MONTH07      13.20477    6.25124   2.112 0.034689 *
MONTH08      12.80773    6.26345   2.045 0.040905 *
MONTH09      18.11904    6.27356   2.888 0.003886 **
MONTH10      27.72251    6.28432   4.411 1.04e-05 ***
MONTH11      22.61087    6.30316   3.587 0.000336 ***
MONTH12      23.03289    6.32485   3.642 0.000273 ***
PERSON_AGE   -3.92659    0.05504 -71.344  < 2e-16 ***
PERSON_SEXM 150.90275    2.55012  59.175  < 2e-16 ***
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Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Residual standard error: 111.3 on 7619 degrees of freedom
Multiple R-squared:  0.5457,    Adjusted R-squared:  0.5449
F-statistic: 653.8 on 14 and 7619 DF,  p-value: < 2.2e-16
```
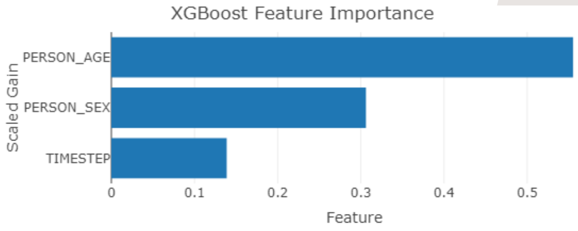
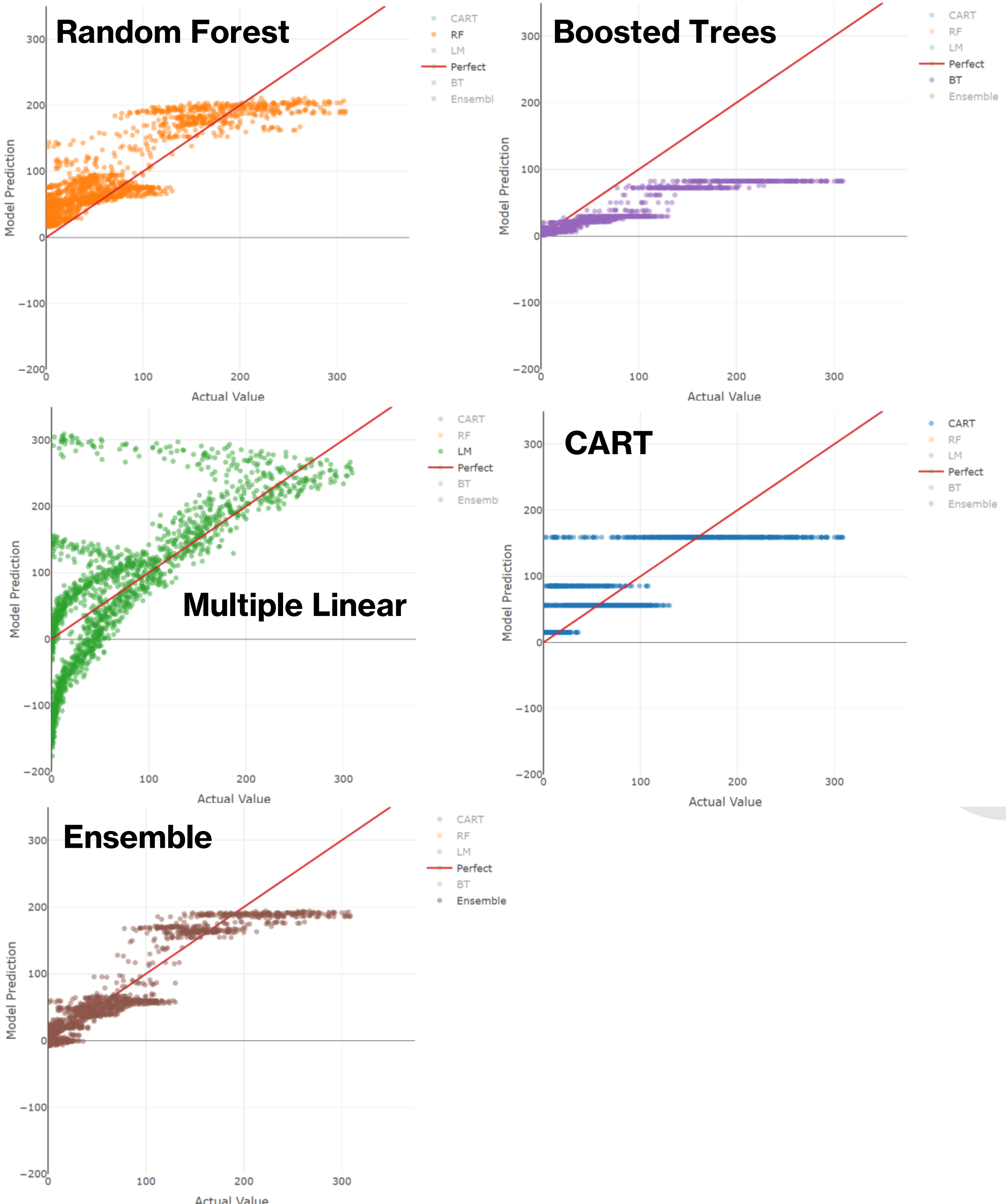

XGB Model



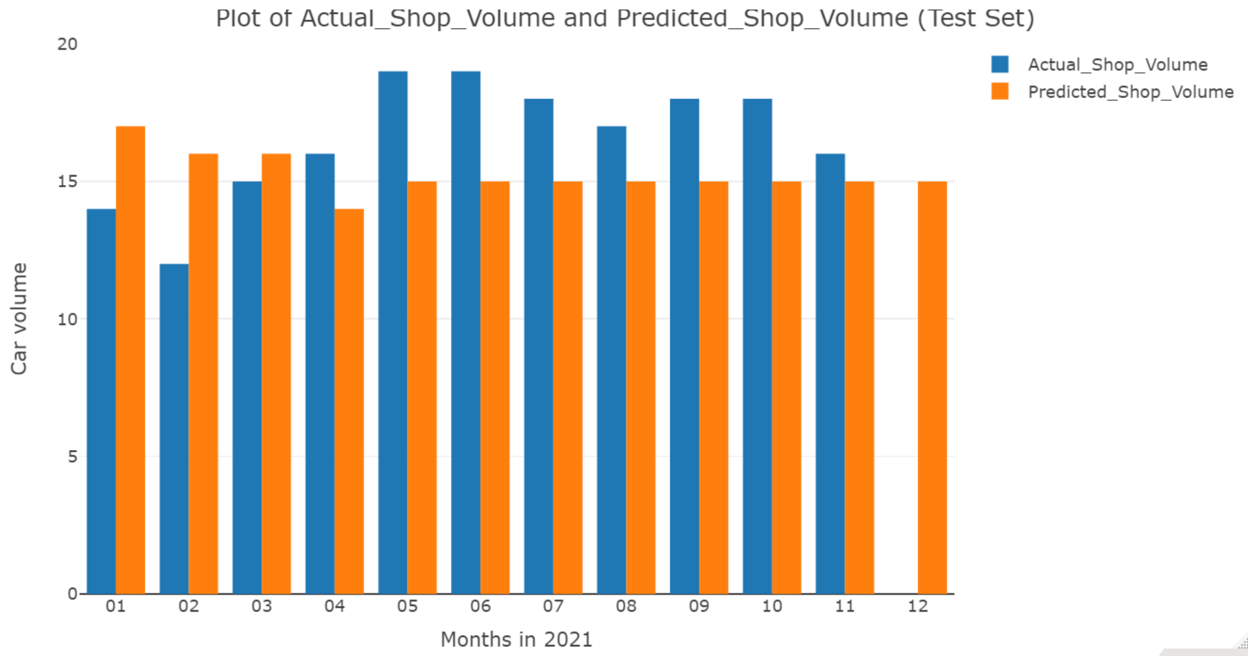
Modeling Results

Model_Type	R_sq_train	R_sq_val	R_sq_train_val	R_sq_test
Linear	0.58	-1.15	0.55	0.08
Random Forest	0.87	-0.49	0.85	0.73
CART	0.95	-1.75	0.90	0.65
Boosted Trees	0.37	0.77	0.41	0.23
Ensemble	NA	0.91	0.96	0.86



Ensemble Model Output

- Model performs very well
- We hypothesize that the model would be even better with out the impact of COVID-19.
- Next, we'll discuss secondary research objectives for our project.



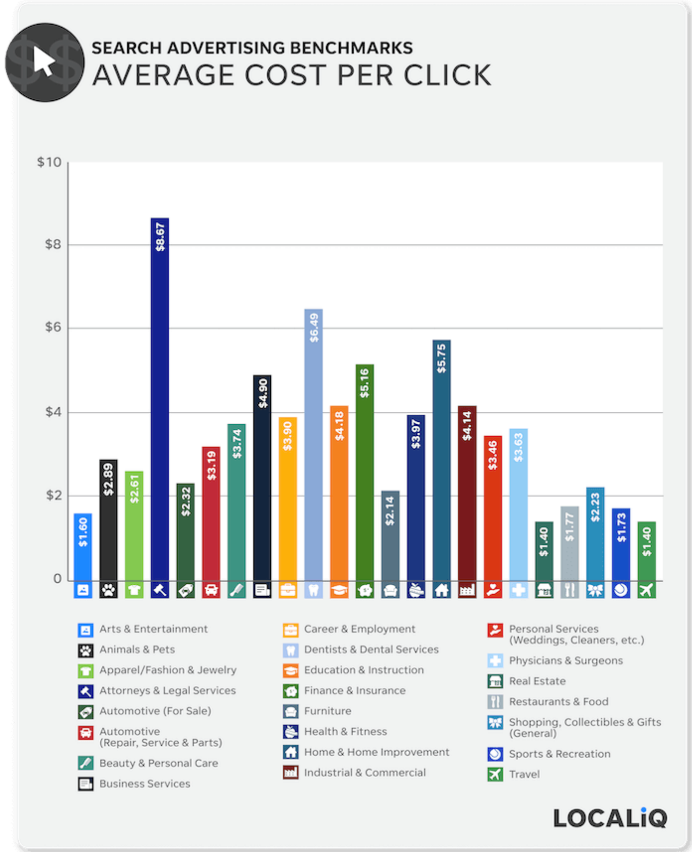
Secondary Problem Statement: Marketing Campaign

- Recommend a targeted marketing campaign for market share growth, and then forecast gains

2021 Paid Search Industry Benchmarks

Automotive — Repair, Service & Parts

CTR	5.39%
CPC	$3.19
Conversion Rate	15.23%
Cost-per-Lead	$17.81



Marketing Campaign – Financials

- In-order-to build out a costing model of shop performance, we sourced average financial metrics from an industry publication. We adjusted the ARO to $2400 to account for collisions being a higher cost service.

Average Repair Shop Financial Metrics

Average Repair Order (Units)	$2,400
Gross Profit	40%
Net Profit Margin	10%

The Typical Shop

Just over 200 industry professionals completed the Shop Performance Survey, and, while they were evenly dispersed across all U.S. markets, the majority of respondents followed a distinct demographic pattern that also closely aligns with our overall readership.

The Average Shop

Shop Type: Independent repair business (87%)

Work Type: General repair (68%)

Shop Size: 2,000–4,999 square feet (41%)

Number of Lifts: 3–4 (32%)

Number of Bays: 3–4 (28%)

Annual Revenue: $1M–$2.49M (30%)

Average Monthly Car Count: 100–149 (19%)

Average Repair Order: $200–$399 (45%)

Gross Profit Margin: 40–49% (28%)

Net Profit Margin: 10–14% (22%)

Marketing Campaign - Performance

- Using the Industry Search Benchmarks and Financial metrics we were able to cost out performance of three different Search Ad Spends.
- If we have a Market Share Goal of reaching 25 basis points, we can see that a $300 monthly ad campaign gets closest to achieving this.

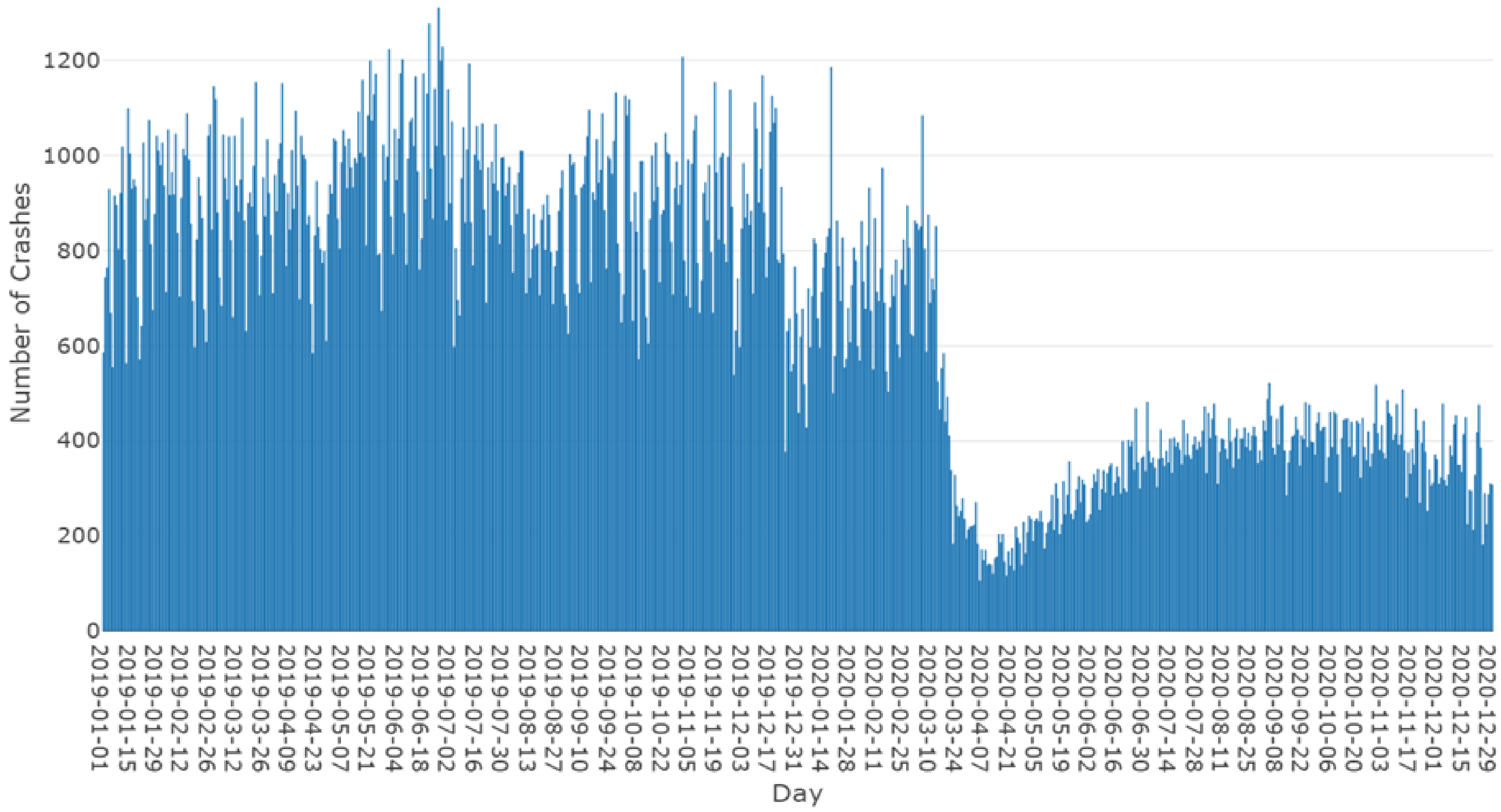
	Search Ad Spend		
Campaign KPIs	$200	$300	$400
Clicks	63	94	125
Conversion	10	14	19
Revenue	$22,916.61	$34,374.92	$45,833.23
ROAS	114.58	114.58	114.58
Market Share Lift	0.0006	0.0009	0.0012
Gross Profit	$9,166.65	$13,749.97	$18,333.29
Net Profit	$2,291.66	$3,437.49	$4,583.32
ROI	1146%	1146%	1146%

Assumes cost/unit static w/ increase (labor + parts)

Secondary Problem Statement: Effect of COVID-19

- First reported case of COVID-19 in New York state on March 1, 2020, but as many as 10,700 New Yorkers had already contracted the virus
- March 9: 16 cases in NYC alone
- March 16: public schools close, beginning COVID-19 lockdown
- Stay-at-home orders in place until June 8, when phase 1 of reopening began under safety protocols
- Estimated 44% of all metro NY residents infected by end of 2020
- Total of 25,000 confirmed deaths of NY citizens with 5,000 probable

NYC Vehicle Collision Data by Day



Regression Analysis

$$Crashes = \beta_0 + \beta_1 * Covid$$

- Using COVID as an indicator variable and the number of daily crashes in NYC as the response variable, we built a linear regression model to analyze the effect of COVID-19 on vehicle collisions in NYC.
- Our findings suggest that before Covid, there was an average of 602 crashes a day in NYC. This number dropped to 233 crashes a day after Covid.
- NYC safer-at-home policies led to a 61.3% reduction in vehicular collisions

```
Call:
lm(formula = n ~ covid, data = covid_df)

Residuals:
   Min      1Q Median      3Q     Max
-600.8 -230.8  102.7  245.5  708.2

Coefficients:
            Estimate Std. Error t value Pr(>|t|)
(Intercept)   601.80      13.77   43.71   <2e-16 ***
covid        -369.04      21.73  -16.98   <2e-16 ***
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Residual standard error: 347.5 on 1062 degrees of freedom
Multiple R-squared:  0.2135,    Adjusted R-squared:  0.2128
F-statistic: 288.3 on 1 and 1062 DF,  p-value: < 2.2e-16
```

Decrease in Costs Due to Accidents

13.6 million car accidents annually in United States	The average cost of vehicle repair per collision: $21,036
22% of collision claims involve vehicles that are totaled	Accidents not totaled will be potential business for our auto body repair center
470 average accidents/day before COVID-19	182 average accidents/day after COVID-19

Effect on Fictitious Auto Body Repair Shop

$6,054,581 in lost revenue for auto body shops in NYC post COVID

Assuming .14% market share for our auto body shop, approximate lost revenue totals $8,476 a day

Total of $712,019 lost revenue during the COVID-19 lockdown in NYC from March - June

Literature review (cont.)

Li and Zhao (2022)

- Quantity of vehicular collisions has plummeted, but cyclists’ fatalities have tripled since the start of the pandemic.
- Cycling kilometers increased by 150% in Philadephia.
- Collisions tend to happen in temporal and spatial hot zones.

Future work

- Understand differences between traffic collisions that involve cyclists and those that do not.
- Determine features of vehicular and cycling collision hot spots.
- Use the sophisticated formulae for traffic exposure from Regev et. al. (133) on new data sets to see if it applies in other places.
- Perform more data exploration through advanced visualizations to pull out and analyze any other trends in the data.

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Thank you for watching our presentation!

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