*Predicting the number of laps in a*

# *Formula E race*

# Solving challenges for real-world impact

## Formula E – Moving at the speed of instinct

Formula E is the world's first fully electric, international single-seater, street racing series. In addition to disrupting motor racing and growing a diverse and global following, Formula E also fighting climate change. It's creating a technological and sustainable development test bed that helps address mobility and environmental issues.

In Formula E there are ten teams – each with two drivers – that compete in identically set-up, electric battery-powered race cars. Every team is focused on securing the best competitive advantage.

What happens when a race team has the data and insights to make fast, accurate decisions, working as a fully connected unit with fans boosting the car's speed?

**Podium-winning performances and an instinctive racing team!**

And that's what we need you to help us solve today...

# Problem Defination

## Situation and race conditions

- All participants have the same car and battery/power to consume during the race
- Battery consumption depends on how smoothly the driver races the car
- The race runs for 45 mins (fixed) plus one additional lap
- The driver who crosses the finish line first wins the race
- If there are crashes or problems on race day, the safety car enters the track until everything is safe. All drivers must stay behind the safety car, stay below 50kph, and cannot overtake
- If the safety car comes on there will be fewer laps as the race time is fixed

## Assessment criteria

- Candidates must show how they would predict the number of laps a driver has to complete in a race
- Available data includes previous lap times and weather

## Problem definition

**WHAT:** Help the racing team determine in real-time (while the race is on) how many more laps the race will run for. which is decided by number of laps by the driver leading the race. *This is crucial for the team's energy management strategy*

**WHY:** Once the team has predicted the number of laps left in the race it can define its strategy, eg, deciding to drive aggressively and expend more battery, or drive conservatively and save energy. The team always knows the car battery's status

**HOW:** Can you predict the number of laps a driver will need to complete in a race? Available data includes historical race timing data by lap for every driver and weather data (wind speed, rain, etc).

# Race structure, data, and criteria

## Race basic structure

- Twenty-two drivers (two per team) compete in each Formula E race
- Each driver ranks separately, but their total scores give the overall team ranking
- There are 12 races in a season held over 8 months
- There are 2 free practice sessions before a race for approximately 45 minutes each
- After the practice sessions, qualifying races run for three laps to decide the pole position (who starts in the first row and then the positions that follow). There can be multiple qualifying sessions followed by super pole to decide the driver standings at the race start
- The final race runs for 45 minutes plus 1 lap

## Race data you have to work with

- Data from the practice and qualifying races, and actual races
- Data tables:
  - **Timing Data for last five seasons**: the standings for each driver in a race
  - lap-by-lap data for each driver
  - **Weather**: how weather conditions changed during a race

# Suggested Approach

- Qualifying Race
- Practice Race
- Data Simulation

**Fastest Lap Time Historical Data**

**Historical Time of "Rank 1" Driver**

- Timing Data
- Rank 1 Driver from last seasons

- To make data independent of car technology changes and tracks

**Normalize the Data**

**Predictions**

- Predict time for each lap
- Add all lap times to 45mins

# Data Snapshot..Race Timing

| NUMBER | DRIVER_NUMBER | LAP_NUMBER | LAP_TIME | LAP_IMPROVEMENT | CROSSING_FINISH_LINE_IN_PIT | S1 | S1_IMPROVEMENT | S2 | S2_IMPROVEMENT | S3 | S3_IMPROVEMENT | KPH |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 10 | 0 | 1 | 03:17.4 | 0 | | 01:49.8 | 0 | 42.184 | 0 | 45.392 | 0 | 63 |
| 10 | 0 | 2 | 02:01.9 | 0 | | 42.246 | 0 | 40.511 | 0 | 39.179 | 0 | 101.9 |
| 10 | 0 | 3 | 02:00.2 | 0 | | 41.745 | 0 | 39.791 | 0 | 38.639 | 0 | 103.4 |
| 10 | 0 | 4 | 02:00.8 | 0 | | 43.439 | 0 | 39.186 | 0 | 38.205 | 0 | 102.9 |
| 10 | 0 | 5 | 01:57.0 | 0 | | 41.645 | 0 | 37.618 | 0 | 37.71 | 0 | 106.3 |
| 10 | 0 | 6 | 01:53.0 | 0 | | 39.526 | 0 | 36.665 | 0 | 36.842 | 0 | 110 |
| 10 | 0 | 7 | 01:52.0 | 0 | | 39.232 | 0 | 36.418 | 0 | 36.316 | 0 | 111 |
| 10 | 0 | 8 | 07:11.1 | 0 | B | 39.037 | 0 | 36.126 | 0 | 05:56.0 | 0 | 28.8 |
| 10 | 0 | 9 | 02:12.9 | 0 | | 58.901 | 0 | 36.99 | 0 | 37.009 | 0 | 93.5 |
| 10 | 0 | 10 | 01:50.9 | 0 | | 38.726 | 0 | 36.145 | 0 | 36.044 | 0 | 112.1 |

| KPH | ELAPSED | HOUR | S1_LARGE | S2_LARGE | S3_LARGE | TOP_SPEED | DRIVER_NAME | PIT_TIME | |
|---|---|---|---|---|---|---|---|---|---|
| 63 | 03:17.4 | 8:18 | 01:49.8 | 00:42.2 | 00:45.4 | | Jarno Trulli | 01:11.9 | |
| 101.9 | 05:19.3 | 8:20 | 00:42.2 | 00:40.5 | 00:39.2 | | Jarno Trulli | | |
| 103.4 | 07:19.5 | 8:22 | 00:41.7 | 00:39.8 | 00:38.6 | | Jarno Trulli | | |
| 102.9 | 09:20.3 | 8:24 | 00:43.4 | 00:39.2 | 00:38.2 | | Jarno Trulli | | |
| 106.3 | 11:17.3 | 8:26 | 00:41.6 | 00:37.6 | 00:37.7 | | Jarno Trulli | | |
| 110 | 13:10.3 | 8:28 | 00:39.5 | 00:36.7 | 00:36.8 | | Jarno Trulli | | |
| 111 | 15:02.3 | 8:30 | 00:39.2 | 00:36.4 | 00:36.3 | | Jarno Trulli | | |
| 28.8 | 22:13.4 | 8:37 | 00:39.0 | 00:36.1 | 05:56.0 | | Jarno Trulli | | |
| 93.5 | 24:26.3 | 8:39 | 00:58.9 | 00:37.0 | 00:37.0 | | Jarno Trulli | 05:45.1 | |

# Data Snapshot..Weather

| TIME_UTC_SECONDS;TIME_UTC_STR;AIR_TEMP;TRACK_TEMP;HUMIDITY;PRESSURE;WIND_SPEED;WIND_DIRECTION; | | | | | |
|---|---|---|---|---|---|
| 1526713209;19/05/2018 7:00:09;14 | 8333;13 | 8889;68;1015 | 34;2 | 12187;79; | |
| 1526713269;19/05/2018 7:01:09;14 | 8333;14 | 4444;68;1015 | 37;2 | 12187;88; | |
| 1526713329;19/05/2018 7:02:09;14 | 8333;14 | 4444;68;1015 | 34;1 | 06093;88; | |
| 1526713389;19/05/2018 7:03:09;14 | 8889;14 | 4444;68;1015 | 44;0;88; | | |
| 1526713454;19/05/2018 7:04:14;14 | 8889;14 | 4444;68;1015 | 34;1 | 06093;88; | |
| 1526713514;19/05/2018 7:05:14;14 | 9444;14 | 4444;68;1015 | 41;2 | 12187;82; | |
| 1526713579;19/05/2018 7:06:19;15 | 0556;14 | 4444;67;1015 | 31;1 | 06093;44; | |
| 1526713644;19/05/2018 7:07:24;15 | 1111;14 | 4444;67;1015 | 34;1 | 06093;44; | |
| 1526713709;19/05/2018 7:08:29;15 | 1667;14 | 4444;66;1015 | 27;2 | 12187;42; | |
| 1526713769;19/05/2018 7:09:29;15 | 2222;14 | 4444;66;1015 | 31;2 | 12187;77; | |
| 1526713834;19/05/2018 7:10:34;15 | 2778;14 | 4444;66;1015 | 27;2 | 12187;44; | |
| 1526713894;19/05/2018 7:11:34;15 | 2778;14 | 4444;66;1015 | 21;3 | 1828;24; | |
| 1526713954;19/05/2018 7:12:34;15 | 2778;14 | 4444;66;1015 | 17;1 | 06093;25; | |
| 1526714014;19/05/2018 7:13:34;15 | 2778;14 | 4444;66;1015 | 21;0;32; | | |
| 1526714074;19/05/2018 7:14:34;15 | 3333;14 | 4444;66;1015 | 24;0;38; | | |
| 1526714134;19/05/2018 7:15:34;15 | 3889;14 | 4444;66;1015 | 27;0;38; | | |

Tip: Some of the text files need to be pre-processed programmatically to convert to data frame

# Data Snapshot..Race Timing

| NUMBER | DRIVER_NUMBER | LAP_NUMBER | LAP_TIME | LAP_IMPROVEMENT | CROSSING_FINISH_LINE_IN_PIT | S1 | S1_IMPROVEMENT | S2 | S2_IMPROVEMENT | S3 | S3_IMPROVEMENT | KPH |
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| 10 | 0 | 3 | 02:00.2 | 0 | | 41.745 | 0 | 39.791 | 0 | 38.639 | 0 | 103.4 |
| 10 | 0 | 4 | 02:00.8 | 0 | | 43.439 | 0 | 39.186 | 0 | 38.205 | 0 | 102.9 |
| 10 | 0 | 5 | 01:57.0 | 0 | | 41.645 | 0 | 37.618 | 0 | 37.71 | 0 | 106.3 |
| 10 | 0 | 6 | 01:53.0 | 0 | | 39.526 | 0 | 36.665 | 0 | 36.842 | 0 | 110 |
| 10 | 0 | 7 | 01:52.0 | 0 | | 39.232 | 0 | 36.418 | 0 | 36.316 | 0 | 111 |
| 10 | 0 | 8 | 07:11.1 | 0 | B | 39.037 | 0 | 36.126 | 0 | 05:56.0 | 0 | 28.8 |
| 10 | 0 | 9 | 02:12.9 | 0 | | 58.901 | 0 | 36.99 | 0 | 37.009 | 0 | 93.5 |
| 10 | 0 | 10 | 01:50.9 | 0 | | 38.726 | 0 | 36.145 | 0 | 36.044 | 0 | 112.1 |

| KPH | ELAPSED | HOUR | S1_LARGE | S2_LARGE | S3_LARGE | TOP_SPEED | DRIVER_NAME | PIT_TIME | |
|---|---|---|---|---|---|---|---|---|---|
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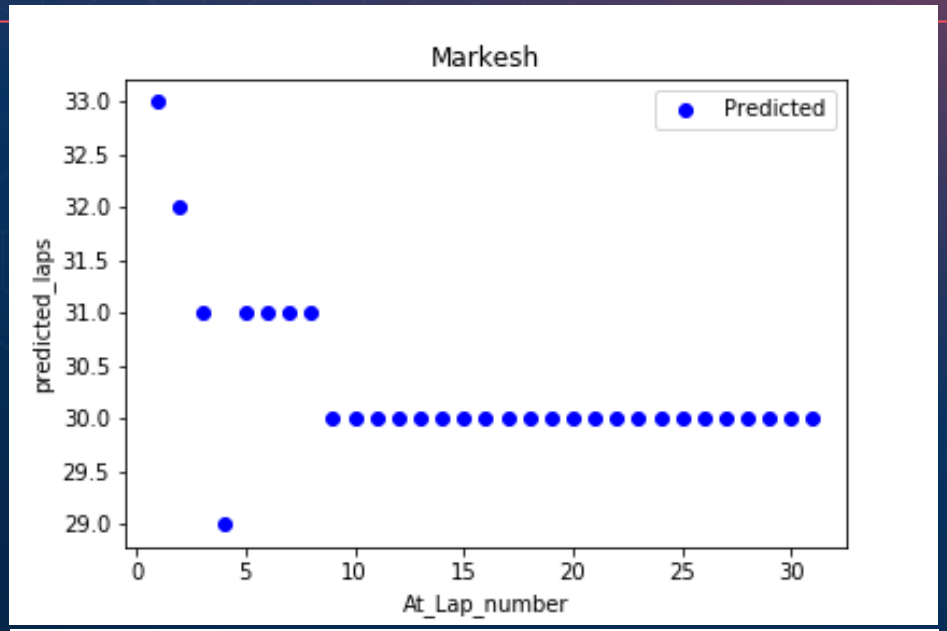
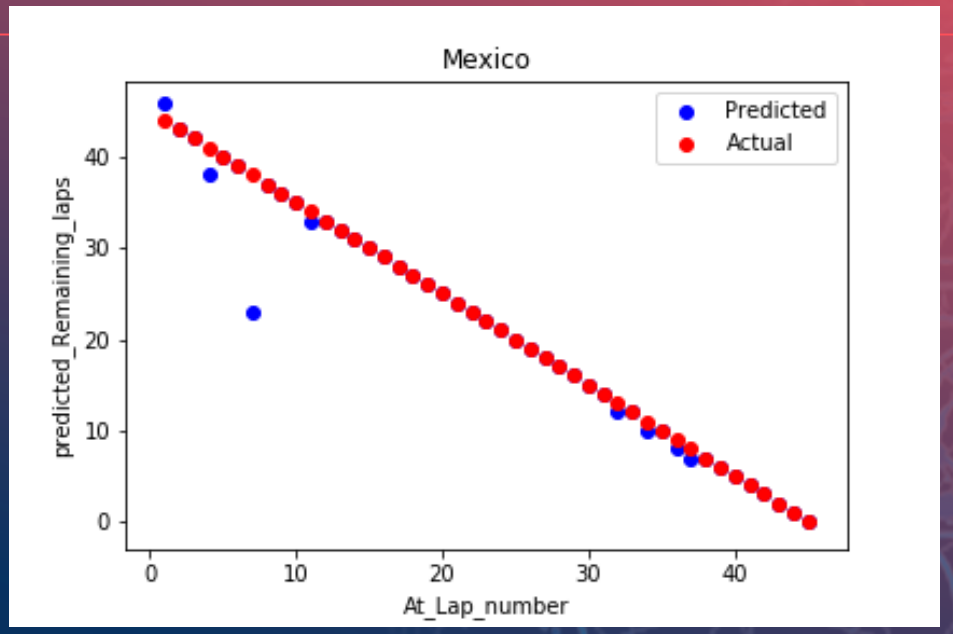
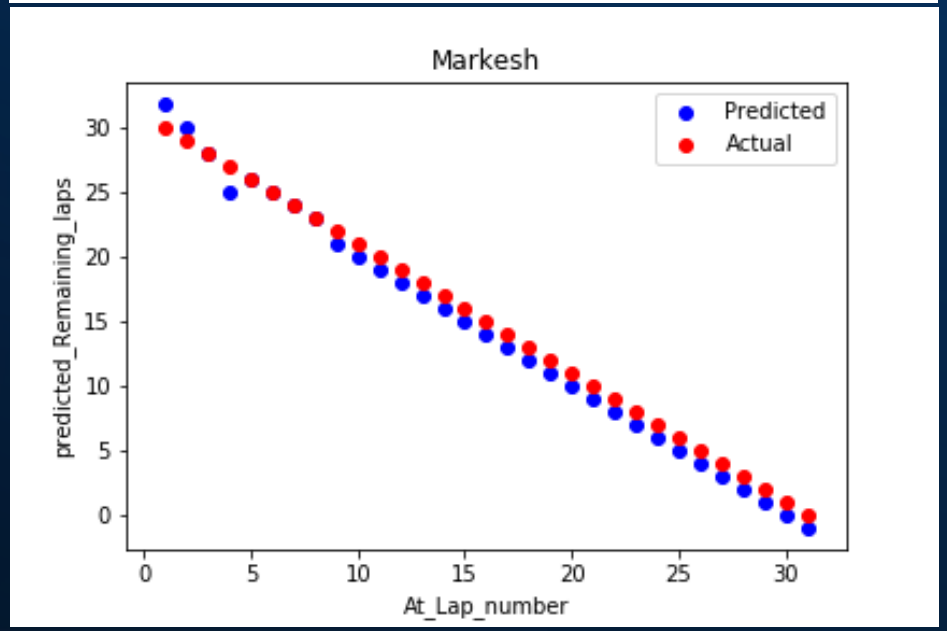
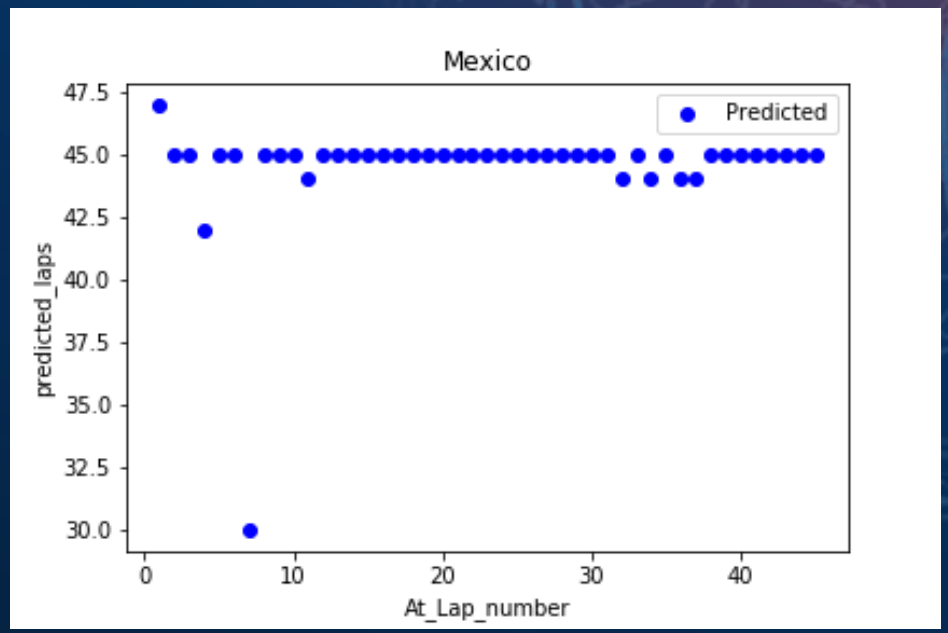
| 28.8 | 22:13.4 | 8:37 | 00:39.0 | 00:36.1 | 05:56.0 | | Jarno Trulli | | |
| 93.5 | 24:26.3 | 8:39 | 00:58.9 | 00:37.0 | 00:37.0 | | Jarno Trulli | 05:45.1 | |

# Example Prediction Results

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