Statistical Analysis of Tire Performance & Pit Stop Strategy in Formula 1 Racing

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Introduction – Why Tire Strategy Matters

Understanding Performance Beyond the Engine

- Tire selection plays a critical role in determining race outcomes.
- Soft tires offer speed but degrade quickly; Hard tires last longer but are slower.
- Weather conditions and track dynamics heavily influence tire behavior and pit strategy.
- This study uses data analysis to understand how these factors shape performance in Formula 1 racing.

Goals of the Project

1. Analyze how tire compounds affect lap time stability and degradation.

2. Study how weather conditions impact pit stop timing

3. Use statistical models to offer data-driven insights that support real-world race strategies

Data and Methods

How the Analysis Was Conducted

Data Preparation:

Merging by RaceID, DriverID, Lap; cleaning and filtering anomalies

Statistical Tools:

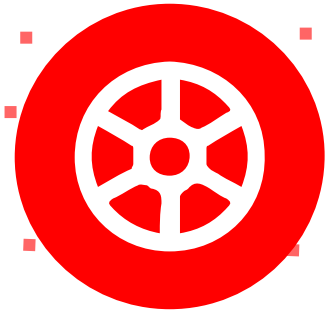
ANOVA & Tukey HSD – Compare lap times across tire types

Statistical Tools:

Kaplan-Meier – Analyze pit stop timing under different weather

Data Source II:

Kaggle Weather Dataset – temperature, rainfall, humidity (2018–2023)



Statistical Tools:

STL Decomposition – Identify degradation trends

Data Source I:

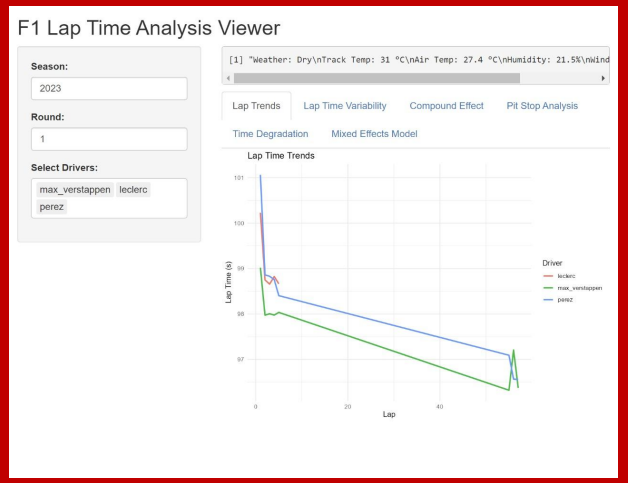
Ergast Developer API – lap times, tire types, pit stop info

Statistical Tools:

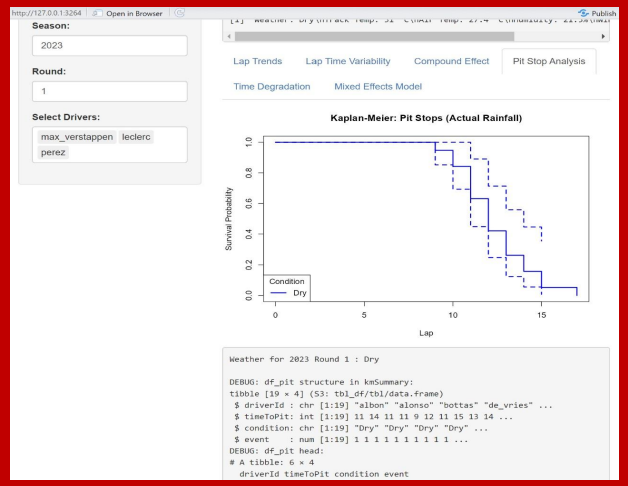
Mixed-Effects Model – Adjust for individual driver differences

Lap vs Driver vs Tyre vs Weather Analysis

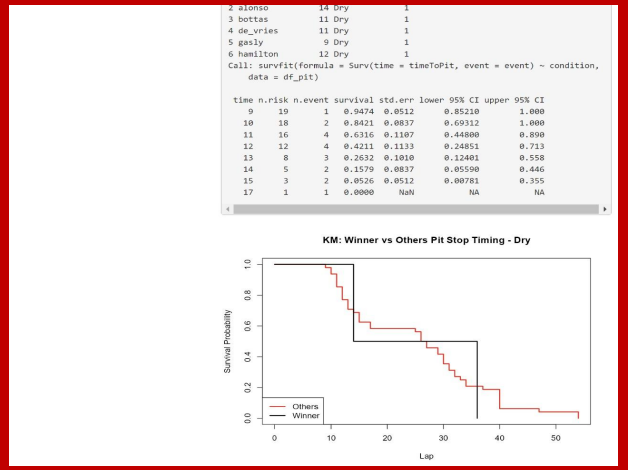
Lap Trends



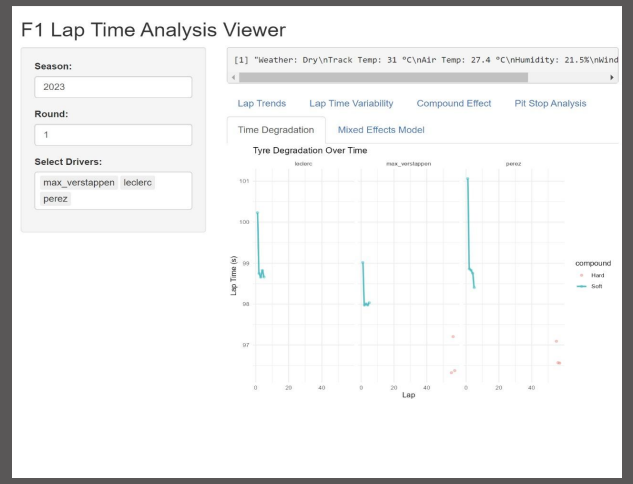
Kaplan Meier - Pit Stops



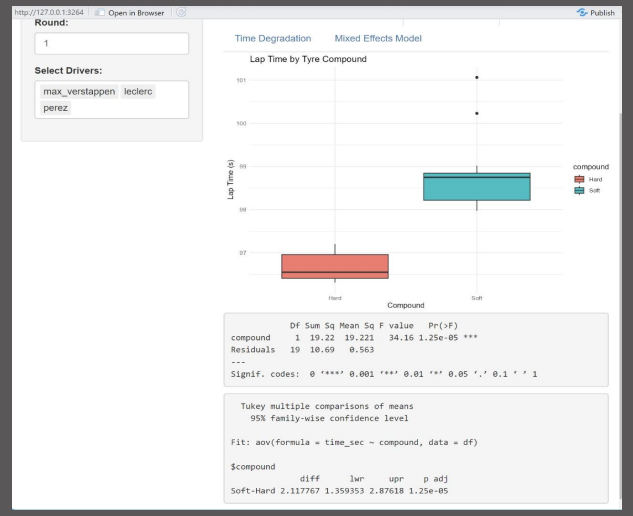
Kaplan Meier - Winner vs Others



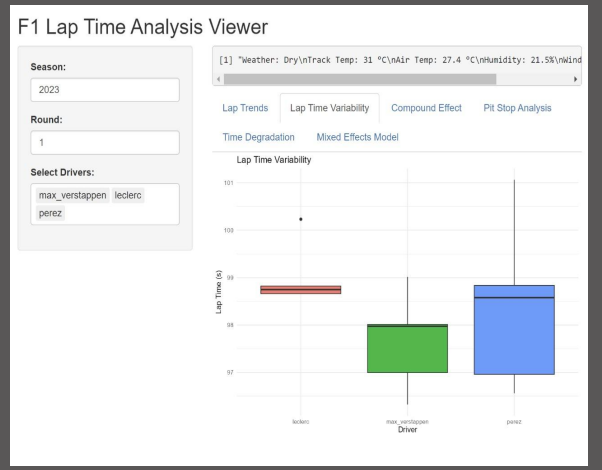
Tyre Degradation over Time



Lap Time by Tyre Compound



Lap Time Variability



Key Findings

Insights from the Data: Answering the Research Questions

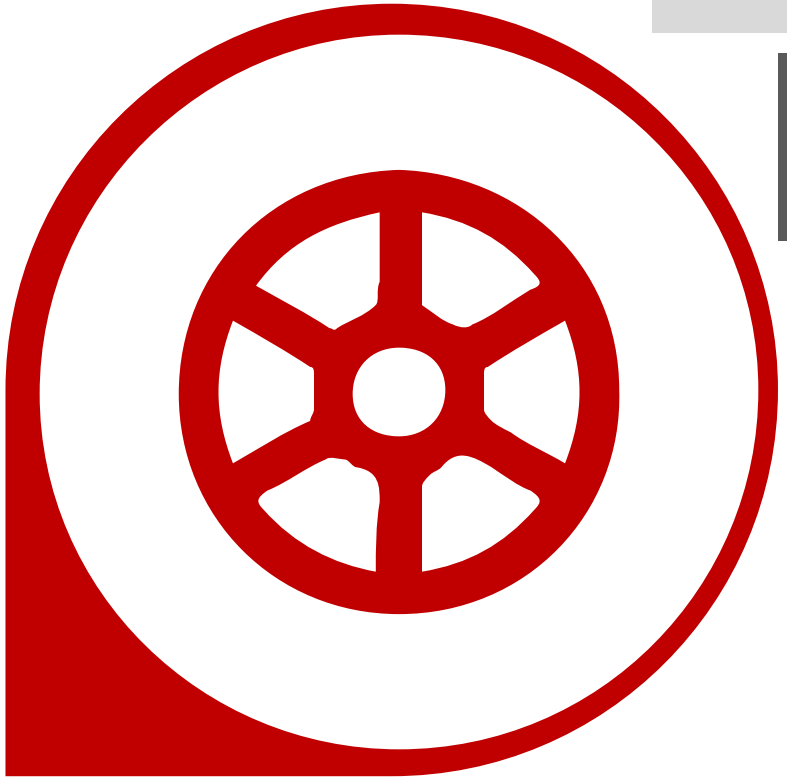
How do tire compounds (Soft, Medium, Hard) impact lap time consistency and performance?

- **ANOVA** showed tire compounds significantly affect lap times ($p < 0.001$).
- **Soft tires** were fastest but inconsistent due to rapid degradation. **Hard tires** offered stable, slower laps—better for endurance.
- **STL decomposition** confirmed these degradation patterns over race stints.
- **Mixed-Effects Model**: Even after accounting for driver, **Soft tires added ~2.07s/lap** over Medium.

How do weather conditions influence pit stop timing and strategy?

- **Kaplan-Meier Survival Analysis** showed clear differences in pit stop behavior based on weather:
  - In **dry conditions**, pit stops occurred later (longer stints).
  - In **wet conditions**, **median pit stop laps were lower**, indicating earlier and more frequent pitting.
- The **hazard rate** increased during rain, confirming that unpredictable weather pressures teams into **reactive pit strategies**.
- This analysis allows us to **model pit stop likelihood** across conditions, improving pre-race strategy and in-race adaptability.

Conclusion



Tire compounds play a decisive role in determining lap time performance and race stability. Soft tires deliver higher speed but degrade quickly, while Hard tires offer consistency over longer stints with lower lap time volatility.

Weather conditions significantly shape pit stop strategy. Under wet conditions, drivers are forced to pit earlier and more frequently due to reduced grip and faster tire wear, highlighting the importance of real-time adaptability.

The use of robust statistical tools—**ANOVA, survival analysis, time-series decomposition, and mixed-effects modeling**—allowed for accurate, driver-adjusted comparisons, strengthening the validity of results.

These insights are not just theoretical; they can support **data-informed decision-making** for teams, enabling smarter tire selection and pit planning before and during races.

THANK YOU