Formula 1 Tire Degradation: Mathematical Modeling

This document outlines the mathematical framework underlying the Formula 1 Tire Degradation Simulator. The model is designed to illustrate how age, stress, temperature, and fuel dynamically influence tire degradation throughout a stint.

Model Overview

The model estimates tire degradation through four factors: age, stress, temperature, and fuel. Tire age captures how long the tire has been exposed to racing conditions. Stress uses speed variation as a proxy for braking, acceleration, and cornering intensity. Temperature approximates the thermal environment, since public data does not provide true internal tire temperature. Fuel adjusts the degradation environment by accounting for car weight: heavier loads increase tire stress earlier in the race, while lighter loads reduce that burden later.

The first output, Expected Pace Loss per Lap, estimates the tire-related performance penalty on a given lap. In simple terms, it asks: how much is this tire condition slowing the car right now?

The second output, Cumulative Pace Loss, sums those lap-by-lap penalties across the stint. It should not be read as a perfect measure of physical tire wear. Instead, it acts as a proxy for accumulated degradation exposure: the longer a tire runs under the effects of age, stress, temperature, and fuel, the greater the performance burden it carries into the next lap.

Tire Degradation Factor Inputs

Prior Track-Tire Deg Rate = average degradation rate for selected Track & Tire

Age Multiplier = 1 + Tire Age Factor · (Tire Age / Expected Stint Length)^2

Temperature Multiplier = 1 + Temp Weight · ((Track Temp - Baseline Temp) / 10)

Stress Multiplier = 1 + Stress Weight · ((Speed Variation - Baseline Speed Variation) / 10)

Avg FuelBurn PerLap = (Max Race Fuel - Min Race Fuel) / Race Length

Fuel Load Lap = max(Min Race Fuel, Starting Fuel Load - Avg Fuel Burn Per Lap · (Tire Age - 1))

Fuel Adjustment = Fuel Weight · ((Fuel Load Lap - Baseline Fuel) / 10)

Tire Degradation Statistical Outputs

Expected Pace Loss per Lap =
Prior Track-Tire Deg Rate
· Age Multiplier
· Temperature Multiplier
· Stress Multiplier
+ Fuel Adjustment

Cumulative Pace Loss = Σ Expected Pace Loss(lap)
- where Tire Age is evaluated from 1 -> selected TireAge

Model Assumptions & Data Collection

Data Collection

Race, lap, weather, tire, and telemetry data were collected from the FastF1 API across every completed Formula 1 race from 2021 to 2025. The extraction pipeline filtered pit laps and extreme outliers before calculating stint-level degradation metrics, fuel-adjusted pace, weather classifications, and telemetry-based tire stress proxies. The final datasets combined lap timing, tire information, fuel estimates, weather conditions, and telemetry summaries into a unified tire degradation modeling environment.

Model Assumptions

Tire degradation is estimated through observable racing conditions rather than direct tire measurements.
Tire age contributes nonlinearly to degradation, accelerating pace loss deeper into a stint.
Expected stint length acts as a compound-specific baseline for tire age.
Expected Pace Loss per Lap estimates tire-related performance burden, not physical tire wear.
Cumulative Pace Loss represents accumulated degradation exposure rather than exact time lost.
Historical track-tire degradation rates are treated as structural baselines.
The model estimates degradation dynamics and strategy, not tire physics.