Benchmarking Formula 1 results using a normal model

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Abstract

There is enduring interest in disentangling the effects of skill and luck in sport. A key issue in Formula 1 is distinguishing between car-level and driver-level effects. Four elite teams currently dominate Formula 1 and have won every major race for the last four years. In this paper we use univariate and bivariate normal models to quantify reasonable performance expectations at both driver and team levels, distinguishing between elite and non-elite teams. We illustrate our approach with an application to the last fully completed 2025 season.

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1 Introduction

Key questions in sports analysis concern what constitutes reasonable performance expectations (Fry et al., 2021) and how to distinguish the effects of luck and skill (Scarf et al., 2022). Though often under-explored, Formula 1 and motorsport provide a rich source of economic problems (Wesselbaum and Owen, 2021), particularly in light of the sport's rapid recent expansion. This growth has been supported by increased media and digital engagement. This includes the reality-style Netflix series *Drive to Survive*, regulatory reforms designed to enhance competition, and strategic expansion into key markets like the United States with additional races in Miami and Las Vegas. This has significantly increased the sport's economic scale and global reach.

Analysing performance in Formula 1 is complicated by the need to disentangle car-level and driver-level effects (Fry et al., 2024). Teams may also pursue objectives beyond simply winning

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like improving on the previous season, outperforming close rivals, securing higher prize-money, and strengthening longer-term competitive standing (Mourão et al., 2025).

At the time of writing, Formula 1 consists of ten teams, each fielding two drivers. Four elite teams – Red Bull, Mercedes, Ferrari, and McLaren – dominate the sport and, at the time of writing, had won every major race over the past four seasons. Despite this dominance, competition within these confines remains intense. In this paper, we investigate reasonable performance expectations under these conditions, explicitly accounting for the distinction between elite and non-elite teams. Furthermore, within a team, driver finishing positions are negatively correlated, violating the independence assumption common to most sports' models (Scarf et al., 2019). Building on Fry et al. (2024), we develop a novel framework based on univariate and bivariate normal distributions that simultaneously addresses both the elite/non-elite distinction and within-team correlations. This provides a more realistic evaluation of performance, and captures strategic and competitive aspects of the sport. We obtain analytical expressions for winning probabilities and supplement these with Monte Carlo simulation analyses. These simulations establish benchmark expectations for elite and non-elite drivers and teams. This enables us to identify which drivers and teams exceed, meet, or fall short of reasonable performance expectations.

Our analysis reveals that elite drivers Norris, Piastri and Verstappen performed well above expectations. However, several other elite-team drivers seem to under-perform. Many non-elite drivers also exceeded expectations, highlighting the depth of talent the sport. At the team level, McLaren exceeded expectations, whilst other elite teams Red Bull, Ferrari and Mercedes under-performed. Results obtained thus cast the sport in a new light and offer a more nuanced understanding of performance across teams and drivers.

The layout of this paper is as follows. Section 2 outlines a univariate model to assess individual driver performance. Section 3 outlines a bivariate model to assess the performance of a team of two drivers. Empirical applications, including performance benchmarking of drivers and teams in the last fully completed 2025 Formula 1 season, are presented in Section 4. Section 5 concludes and discusses opportunities for further research.

2 Univariate modelling of individual driver performance

In this section we outline a univariate model to describe the performance of individual drivers. Teams are classified into elite and non-elite categories, with 8 drivers in elite-team cars (two drivers per team across 4 teams) and 12 drivers in non-elite cars (across 6 teams). We assume that successive races are independent. Let the final finishing position in a race be approximated by a normal distribution. Whilst this may seem a strong assumption, this is consistent with the use of regression-based models in applications (Fry et al., 2024). For elite-team drivers, we set

$$\mathrm{E}\left[\text{Elite driver Finishing Position}\right] = \mathrm{E}\left[\mathrm{U}\{1,8\}\right] = 4.5, \tag{1}$$

where $U\{1,8\}$ denotes a discrete uniform distribution over the integers 1–8. Similarly, for non-elite drivers we set

$$\mathrm{E}\left[\text{Non-elite driver Finishing Position}\right] = \mathrm{E}\left[\mathrm{U}\{9,20\}\right] = 14.5, \tag{2}$$

where $\mathrm{U}\{9,29\}$ denotes a discrete uniform distribution over the integers 9–20. Elite drivers thus typically occupy top positions, with non-elite drivers finishing lower. The finishing rank of an elite-team driver is modeled as $N(4.5, \sigma_E^2)$. Similarly, the rank of a non-elite team driver is modeled as $N(14.5, \sigma_N^2)$. Thus, the probability that an elite-team driver wins a race can be calculated as

$$\Pr(\text{Win}) = \Pr(\text{Rank} \leq 1.5) = \Phi\left(\frac{1.5 - 4.5}{\sigma_E}\right) = \Phi\left(-\frac{3}{\sigma_E}\right) \tag{3}$$

where $\Phi(\cdot)$ denotes the $N(0,1)$ Cumulative Distribution Function (CDF). If one of the eight elite-team driver is guaranteed to win a race, consistent with trends from the past four completed seasons, it follows that

$$8\Phi\left(-\frac{3}{\sigma_E}\right) = 1; \;\; \sigma_E = -\frac{3}{\Phi^{-1}\left(\frac{1}{8}\right)} = 2.607903. \tag{4}$$

Similarly, the probability that a non-elite team driver finishes in the top 9 positions is given by

$$\Pr(\text{Rank} \leq 9.5) = \Phi\left(\frac{9.5 - 14.5}{\sigma_N}\right) = \Phi\left(-\frac{5}{\sigma_N}\right). \tag{5}$$

Since there are only 8 elite-team drivers, at least one of the 12 non-elite drivers is guaranteed to finish in the top 9. It follows that

$$12\Phi\left(-\frac{5}{\sigma_N}\right) = 1;\ \sigma_N = -\frac{5}{\Phi^{-1}\left(\frac{1}{12}\right)} = 3.615344. \tag{6}$$

Equation (6) highlights that caution is needed when comparing drivers from different teams as the performance of non-elite drivers is inherently more variable with $\sigma_N > \sigma_E$[1].

Continuing in this way Table 1 presents analytical expressions for the probabilities of finishing in points scoring positions – quantities that may be of particular interest to teams beyond winning (Mourão et al., 2025). The current Formula 1 scoring rules for the 2025 season are given in Table 2. Whilst some analytical results can be obtained from Tables 1–2, the analysis can be simplified using Monte Carlo simulation. As an illustration, a full Formula 1 season for elite-team drivers can be simulated using

(i) Simulate a finishing position from $N(4.5, \sigma_E^2)$.

(ii) Round to the nearest integer between 1 and 20.

(iii) Allocate points according to Table 2.

(iv) Repeat Steps (i)–(iii) for the rest of the races in a season.

3 Bivariate modelling of team performance

In this section, we extend the previous univariate model to a bivariate model for the performance of two drivers within the same team. This explicitly accounts for negative correlations in teammates' finishing positions. Following Section 2 we model the finishing rank of an elite-team driver as $N(4.5, \sigma_E^2)$, where σ_E^2 is given by Equation (4). The joint performance of the two drivers is then represented by a bivariate normal distribution:

$$\begin{pmatrix} r_1 \\ r_2 \end{pmatrix} \sim N\left(\begin{pmatrix} 4.5 \\ 4.5 \end{pmatrix}, \begin{pmatrix} \sigma_E^2 & \sigma_{EE} \\ \sigma_{EE} & \sigma_E^2 \end{pmatrix}\right), \tag{7}$$

[1]Note that equation (6) can equivalently be derived by making the simplifying assumption that at least one of the 12 non-elite drivers is guaranteed to finish last.

Probability	Elite-Team Driver	Non-Elite Team Driver
Pr(Win)	$\Phi\left(-\frac{3}{\sigma_E}\right)$	$\Phi\left(-\frac{13}{\sigma_N}\right)$
Pr(Second)	$\Phi\left(-\frac{2}{\sigma_E}\right) - \Phi\left(-\frac{3}{\sigma_E}\right)$	$\Phi\left(-\frac{12}{\sigma_N}\right) - \Phi\left(-\frac{13}{\sigma_N}\right)$
Pr(Third)	$\Phi\left(-\frac{1}{\sigma_E}\right) - \Phi\left(-\frac{2}{\sigma_E}\right)$	$\Phi\left(-\frac{11}{\sigma_N}\right) - \Phi\left(-\frac{12}{\sigma_N}\right)$
Pr(Fourth)	$\frac{1}{2} - \Phi\left(-\frac{1}{\sigma_E}\right)$	$\Phi\left(-\frac{10}{\sigma_N}\right) - \Phi\left(-\frac{11}{\sigma_N}\right)$
Pr(Fifth)	$\Phi\left(\frac{1}{\sigma_E}\right) - \frac{1}{2}$	$\Phi\left(-\frac{9}{\sigma_N}\right) - \Phi\left(-\frac{10}{\sigma_N}\right)$
Pr(Sixth)	$\Phi\left(\frac{2}{\sigma_E}\right) - \Phi\left(\frac{1}{\sigma_E}\right)$	$\Phi\left(-\frac{8}{\sigma_N}\right) - \Phi\left(-\frac{9}{\sigma_N}\right)$
Pr(Seventh)	$\Phi\left(\frac{3}{\sigma_E}\right) - \Phi\left(\frac{2}{\sigma_E}\right)$	$\Phi\left(-\frac{7}{\sigma_N}\right) - \Phi\left(-\frac{8}{\sigma_N}\right)$
Pr(Eighth)	$\Phi\left(\frac{4}{\sigma_E}\right) - \Phi\left(\frac{3}{\sigma_E}\right)$	$\Phi\left(-\frac{6}{\sigma_N}\right) - \Phi\left(-\frac{7}{\sigma_N}\right)$
Pr(Ninth)	$\Phi\left(\frac{5}{\sigma_E}\right) - \Phi\left(\frac{4}{\sigma_E}\right)$	$\Phi\left(-\frac{5}{\sigma_N}\right) - \Phi\left(-\frac{6}{\sigma_N}\right)$
Pr(Tenth)	$\Phi\left(\frac{6}{\sigma_E}\right) - \Phi\left(\frac{5}{\sigma_E}\right)$	$\Phi\left(-\frac{4}{\sigma_N}\right) - \Phi\left(-\frac{5}{\sigma_N}\right)$
Pr(Podium finish)	$\Phi\left(-\frac{1}{\sigma_E}\right)$	$\Phi\left(-\frac{11}{\sigma_N}\right)$
Pr(Top 8 finish)	$\Phi\left(\frac{4}{\sigma_E}\right)$	$\Phi\left(-\frac{6}{\sigma_N}\right)$
Pr(Top 10 finish)	$\Phi\left(\frac{6}{\sigma_E}\right)$	$\Phi\left(-\frac{4}{\sigma_N}\right)$

Table 1: Analytical expressions for race outcome probabilities derived from the univariate normal model (Section 2), where Φ is the CDF of a standard normal and σ_E, σ_N denote the standard deviation of elite and non-elite team finishing positions (Equations (4) and (6)).

Full Race		Sprint Race	
Position	**Points**	**Position**	**Points**
1	25	1	8
2	18	2	7
3	15	3	6
4	12	4	5
5	10	5	4
6	8	6	3
7	6	7	2
8	4	8	1
9	2		
10	1		

Table 2: Points awarded to drivers in Formula 1 for Full Races (top 10) and Sprint Races (top 8) under the rules of the 2025 season; all other positions receive 0 points.

where r_i denotes the rank of Driver i, and σ_{EE} is the covariance. The value of σ_{EE} in equation (7) can be derived as follows. Using the linear transformation property of the normal distribution, (Bingham and Fry, 2010), the sum of the ranks satisfies $r_1 + r_2 \sim N(9, 2\sigma_E^2 + 2\sigma_{EE})$. The sum of the ranks must satisfy $\Pr(r_1 + r_2 \leq 3) = 0$, giving

$$\Pr(r_1 + r_2 \leq 3) = \Phi\left(\frac{3 - 9}{\sqrt{2\sigma_E^2 + 2\sigma_{EE}}}\right) = 0.$$

Tabulated values of the standard normal from Neave (1978) give $\Phi(-4.9) = 0$. Thus,

$$\frac{3-9}{\sqrt{2\sigma_E^2 + 2\sigma_{EE}}} = -4.9; \; \sigma_{EE} = \frac{36}{48.02} - \sigma_E^2 = -6.051472. \tag{8}$$

For a non-elite team equation (7) is replaced by

$$\begin{pmatrix} r_1 \\ r_2 \end{pmatrix} \sim N\left(\begin{pmatrix} 14.5 \\ 14.5 \end{pmatrix}, \begin{pmatrix} \sigma_N^2 & \sigma_{NN} \\ \sigma_{NN} & \sigma_N^2 \end{pmatrix}\right). \tag{9}$$

The value of the covariance σ_{NN} in equation (9) can be derived as follows. From the linear transformation property of the normal distribution $r_1 + r_2 \sim N(29, 2\sigma_N^2 + 2\sigma_{NN})$. The sum of the ranks must satisfy $\Pr(r_1 + r_2 \leq 39) = 1$. Tabulated values in Neave (1978) give $\Phi(4.9) = 1$, so

$$\frac{39-29}{\sqrt{2\sigma_N^2 + 2\sigma_{NN}}} = 4.9; \; \sigma_{NN} = \frac{100}{48.02} - \sigma_N^2 = -10.98825. \tag{10}$$

As in Section 2, the analysis of finishing ranks can be performed via Monte Carlo simulation. As an illustration, results for negatively correlated drivers within the same elite-team can be simulated using

1. Simulate finishing positions from $N\left(\begin{pmatrix} 4.5 \\ 4.5 \end{pmatrix}, \begin{pmatrix} \sigma_E^2 & \sigma_{EE} \\ \sigma_{EE} & \sigma_E^2 \end{pmatrix}\right)$.
2. Round to the nearest integers between 1 and 20.
3. Allocate points according to Table 2.
4. Repeat Steps 1–3 for the rest of the races in a season.

4 Empirical applications

In this section, we compare results models in Section 2–3 with the last fully completed 2025 season, which featured 24 Full Races and 6 Sprint Races. Table 3 presents Monte Carlo simulation results for the expected value and 95% confidence intervals (CIs) for season-long points totals across elite and non-elite drivers and teams. These CIs provide a benchmark for reasonable performance expectations, across all sectors, and can then be compared with actual performances from the 2025 season.

Category	Mean points	95% CI
Elite driver	315.456	(253-381)
Elite team	630.91	(594–669)
Non-elite driver	10.636	(1–29)
Non-elite team	21.305	(5–44)

Table 3: Monte Carlo simulation of total season points under the 2025 Formula 1 scoring system (Table 2), based on 1,000,000 simulations. Drivers are simulated with the univariate model (Section 2) and teams with the bivariate model (Section 3). Reported values are mean total points and 95% CIs for elite and non-elite drivers and teams.

Driver	Team	Points	Performance
Lando Norris	McLaren	423	↑
Oscar Piastri	McLaren	410	↑
George Russell	Mercedes	319	→
Kimi Antonelli	Mercedes	150	↓
Max Verstappen	Red Bull	421	↑
Yuki Tsunoda	Red Bull	33	↓
Charles Leclerc	Ferrari	242	↓
Lewis Hamilton	Ferrari	156	↓
Alexander Albon	Williams	73	↑
Carlos Sainz Jr	Williams	64	↑
Isack Hadjar	Racing Bulls	51	↑
Liam Lawson	Racing Bulls	38	↑
Fernando Alonso	Aston Martin	56	↑
Lance Stroll	Aston Martin	33	→
Oliver Bearman	Haas	41	↑
Esteban Ocon	Haas	38	↑
Nico Hülkenberg	Sauber	51	↑
Gabriel Bortoleto	Sauber	19	→
Pierre Gasly	Alpine	22	→
Franco Colapinto	Alpine	0	↓

Table 4: Total points scored by drivers in the 2025 season (elite-team drivers are highlighted). The *Performance* column compares points with Monte Carlo CIs (Table 3), which provide benchmark expectations based on the univariate model (Section 2); Symbols indicate performance relative to expectations: ↑ = above, → = meeting, ↓ = below.

Results for individual drivers are reported in Table 4. Several elite drivers exceed expectations (Norris, Piastri, and Verstappen). Some elite drivers may be under-performing (Antonelli, Hamilton, Leclerc and Tsunoda). Remarkably, most non-elite drivers exceed expectations, highlighting the talent and depth of competition in Formula 1. Colapinto is the only non-elite driver potentially under-performing. Results in Table 5 provide further insights into team performance. McLaren, exceed expectations after an outstanding season. In contrast, the remaining elite teams seem to under-perform. Most non-elite teams, exceed expectations. In contrast, Alpine perform in line with reasonable performance expectations.

Team	Points	Performance
McLaren	833	↑
Mercedes	469	↓
Red Bull	454	↓
Ferrari	398	↓
Williams	137	↑
Racing Bulls	92	↑
Aston Martin	89	↑
Haas	79	↑
Sauber	70	↑
Alpine	22	→

Table 5: Total points scored by teams in the 2025 season (elite teams are highlighted). The *Performance* column compares points with Monte Carlo CIs (Table 3), which provide benchmark expectations based on the bivariate model (Section 3); Symbols indicate performance relative to expectations: ↑ = above, → = meeting, ↓ = below.

5 Conclusions and further work

Formula 1 consists of teams of two drivers, with four elite teams – Red Bull, Mercedes, Ferrari, and McLaren – dominating the sport in recent seasons. Despite this, competition remains intense. In this paper, we develop univariate and bivariate normal models to assess reasonable performance expectations for drivers and teams. By explicitly incorporating the elite/non-elite distinction and within-team correlations, the models provide a more realistic evaluation of performance. We derive analytical results for winning probabilities, and conduct Monte Carlo simulations. These simulations provide benchmarks for drivers and teams, enabling a rigorous evaluation of performance in the last fully completed 2025 season. We can thus clearly identify who exceeded, met, or fell short of expectations.

The empirical analysis casts Formula 1 results in a new light. At the driver level, Norris, Piastri, and Verstappen exceeded expectations. Several elite drivers under-perform relative to model predictions. At the team level, McLaren exceeded expectations, whilst other elite teams Mercedes, Red Bull and Ferrari under-perform. Remarkably, most non-elite drivers exceed expectations, with Colapinto the only exception. This emphasizes the increasingly competitive landscape beyond the elite top teams.

Overall results demonstrate the value of incorporating both the elite/non-elite distinction and within-team correlations when benchmarking performance. This offers a more nuanced and quantitative understanding of outcomes in Formula 1. Future work will focus on quantitative modeling of reasonable performance expectations in sport (Fry et al., 2021) and on disentangling the effects of luck and skill (Scarf et al., 2022). Analytical modeling of sport continues to attract enduring interest (Singh et al., 2023).

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