# Examining the Correlation Between Circuit Demands and Performance Gaps between F1 Constructors

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## Abstract

This project investigates the relationship between the characteristics of various Formula 1 tracks and constructor performance, examining how varying circuit demands influence team competitiveness. The tracks are categorized by attributes such as high speed or more technical layouts. The study will analyze whether constructors with car design traits such as enhanced engine power or high downforce perform better on specific track types. Performance differences are analyzed across the various tracks, highlighting how certain car designs align with the demands of the track. Essentially, this project is designed to determine whether certain teams display a favorable advantage on particular track types, clarifying the strategic interactions between track characteristics and car performance in Formula 1. The findings revealed that teams with specific aerodynamic and powertrain strengths consistently performed better on tracks suited to their car design, confirming the hypothesis and highlighting the importance of track-specific strategies in Formula 1.

## Introduction

Formula 1 is a sport driven by both the skill of its drivers and the engineering of each team’s car. Every season, teams design their cars to handle a variety of circuits, each with unique features. Some circuits require pure speed, while others require tight handling and high downforce. This presents different challenges to the teams when balancing their car's strengths across all track types. These variations in track characteristics influence team performance and require constructors to adopt different engineering strategies.

For example, some teams focus on engine power and aerodynamic drag to excel on high-speed circuits like Monza, with its long straights and high-speed corners. Others, however, might wish to maintain high levels of downforce and agility, beneficial for technical tracks like Silverstone, where sharp corners and precision are critical. These differences in track design beg a question: How do the characteristics of each circuit type influence team performance in Formula 1?

This paper classifies circuits by track type: high-speed, technical, or balanced. Then, it explores constructors' performance across those categories. Lap times, finishing positions, and points earned will be analyzed to identify patterns in the performance of different car designs on different track types. This approach makes it possible to compare top-tier and mid-tier teams in terms of track characteristics’ impact on performance gaps.

The analysis will explain how car design and circuit demands are related and how strategic engineering decisions shape a constructor's performance throughout a season. If some constructors prefer certain track types, this could indicate the car traits that function well

with those circuits. These findings could provide insight into how teams might adjust car setups to improve performance on less favorable track types.

Overall, this research will provide a detailed view of how Formula 1's engineering and strategy interact with racing environments, contributing to a deeper understanding of how car design and circuit characteristics combine to impact competitiveness in the sport.

**Methodology**

The following project will analyze data from Formula 1 races in a recent season based on race performance and its link to track characteristics. Information on lap times, constructor finishing positions, and basic track information, including the number of corners, average speeds, and elevation changes, will be gathered. From these track specifics, we can classify circuits as high-speed, technical, or balanced, which will become the basis of the comparison of teams' performance across different types of tracks.

Data on lap times and race results will be sourced from publicly available databases such as the F1 official website and ESPN. These websites offer historical data for every race, including individual lap times, constructor standings, and final race positions. To classify the tracks further based on their nature, information about track layouts, average speeds, and elevation changes is extracted from official sources such as the Formula 1 website, track profiles, or other motorsport analysis platforms. Such data would highlight the nature of each track, such as whether it is a high-speed circuit with long straights or a technical track with many bends and elevation shifts.

Once all the data is prepared, each constructor's average performance in each track category will be determined. The performance metrics considered include the fastest lap times during each qualifying session, where a minimal number of variables could affect the lap time. The final race positions and number of points earned will be assessed for each track. All tracks are different, so they will be separated into 3 categories: High-Speed Power Circuits, Technical Circuits, and Balanced Circuits.

- High-Speed Circuits: Tracks with long straights and minimal sharp corners, favoring powerful engines and efficient aerodynamics.
- Technical Circuits: Tracks with sharp corners and frequent braking zones that require high downforce and agility.
- Balanced Circuits: Tracks that feature both high-speed sections and technical sectors, requiring a mix of power and handling.

Statistical correlation tests will be used to determine how certain track characteristics correlate with constructor performance. Performance patterns are to be displayed through

various visual tools, such as line graphs, bar charts, and box plots, to make it clear how the different constructors perform depending on track conditions.

**Results**

Based on measurements of average speed and elevation changes, the circuit in the 2023 F1 calendar can be categorized into three distinct groups: high-speed circuits, technical circuits, and balanced circuits.

*High-speed circuits*

These circuits emphasize top-end speed, with anaverage speed of over220 kilometers per hour, long straights, and minimal technical sections. Tracks that fall under this category include:

- Bahrain International Circuit (Bahrain GP)
- Jeddah Corniche Circuit (Saudi Arabia GP)
- Baku City Circuit (Azerbaijan GP)
- Red Bull Ring (Austrian GP)
- Silverstone Circuit (British GP)
- Circuit de Spa-Francorchamps (Belgian GP)
- Monza (Italian GP)
- Lusail International Circuit (Qatar GP)

*Technical Circuits*

These tracks focus on sharp turns, with an average speed of less than 200 kilometers per hour, slower corner speeds, and technical precision:

- Monaco (Monaco GP)
- Marina Bay Circuit (Singapore GP)
- Zandvoort (Dutch GP)
- Hungaroring (Hungarian GP)
- Suzuka International Racing Course (Japanese GP)

*Balanced Circuits*

These tracks strike a balance between straight-line speed, with an average speed ranging from 200 to 220 kilometers per hour, and challenging technical sections:

- Albert Park (Australian GP)
- Miami International Autodrome (Miami GP)
- Circuit de Barcelona-Catalunya (Spanish GP)
- Circuit Gilles-Villeneuve (Canadian GP)

- Circuit of the Americas (US GP)
- Interlagos (Brazilian GP)
- Hermanos Rodríguez (Mexico GP)
- Las Vegas Street Circuit (Las Vegas GP)
- Yas Marina Circuit (Abu Dhabi GP)

For the complete data set, refer to Supplementary Material 1.

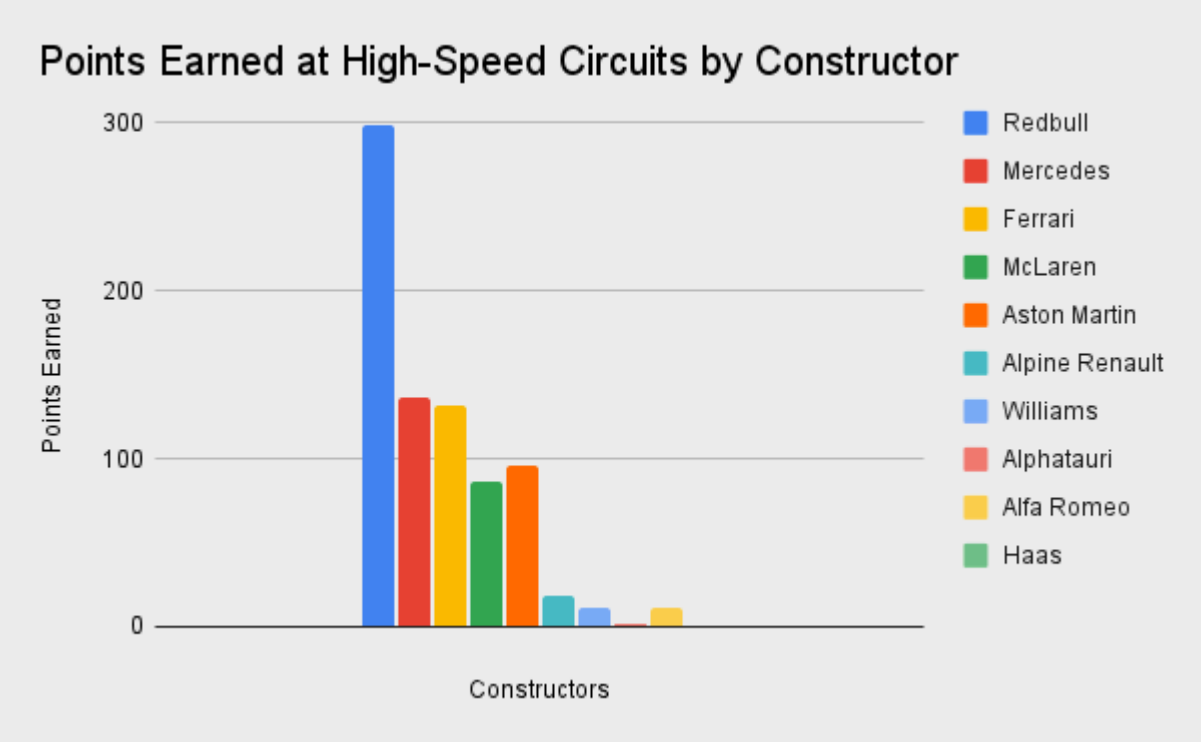


Figure 1: Bar graph representing the number of points each constructor earned on high-speed circuits

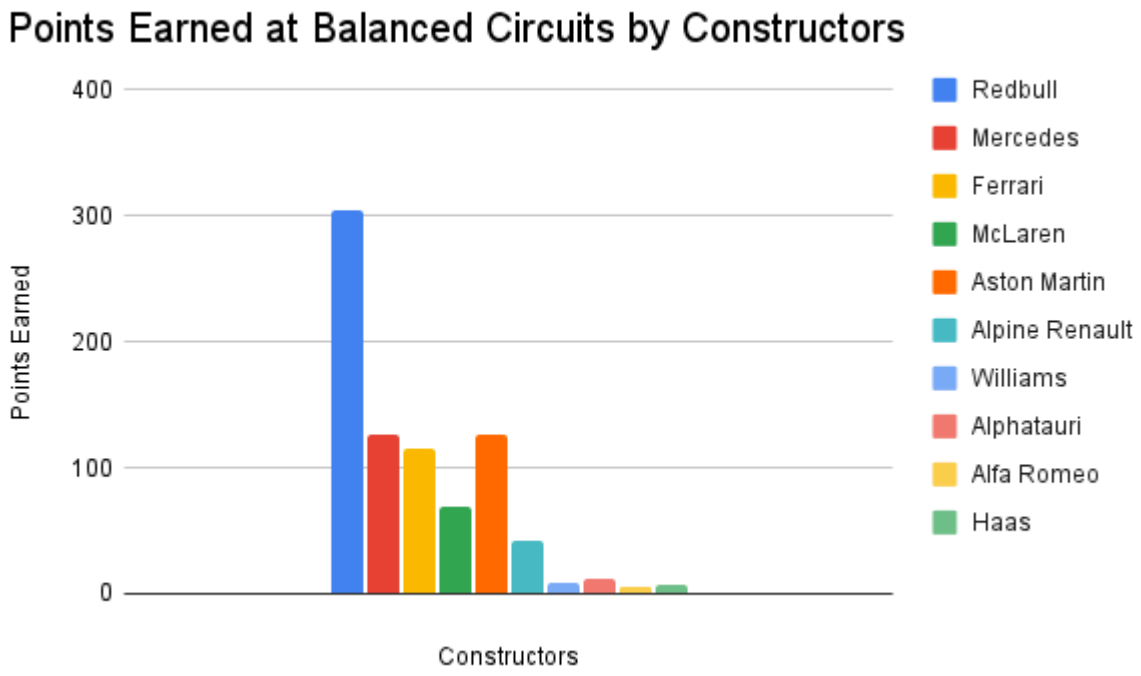


Figure 2: Bar graph representing the number of points each constructor earned at balanced circuits

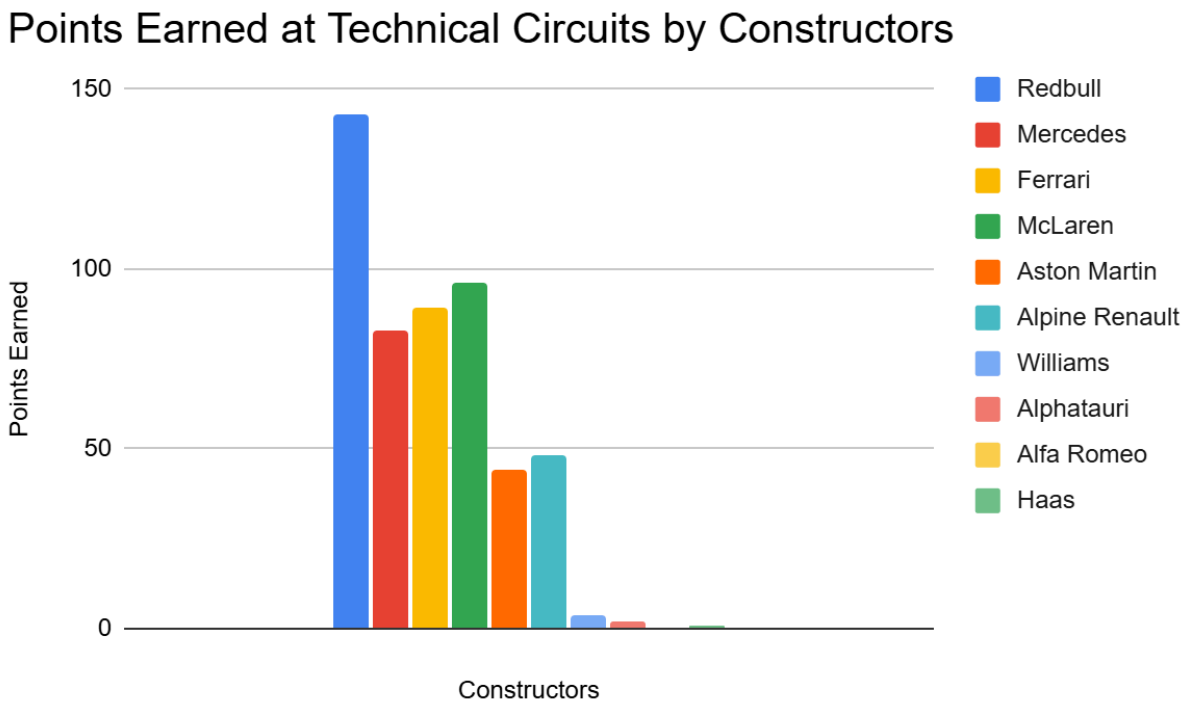


Figure 3: Bar graph representing the number of points each constructor earned at technical circuits

## Data Analysis

*High-Speed Circuits*

By taking high-speed circuits such as those at Monza, Bahrain, Spa-Francorchamps, and Saudi Arabia into consideration, Redbull Racing emerged from those races as the clear leader. This is expected because the aerodynamics and engine power of Redbulls means that they outclass the others on tracks with more straight-line speed and high-speed corners. The scores shown in the figures confirm this evidence of their domination on the high-speed track.

Mercedes and Ferrari also showed strong performances on these circuits, but not as consistently as Redbull. Teams like Aston Martin and McLaren faced more significant performance gaps in comparison. While Ferrari's strong aerodynamics give them an edge on circuits with long straights, their overall pace on tracks like Monza was not enough to challenge Redbull's dominance. Similarly, McLaren, despite some strong qualifying performances on high-speed tracks, failed to deliver on race pace, either because of limitations in car setup or reliability issues.

This would then suggest that Redbull's dominance on high-speed circuits is because its car design is more suited to aerodynamics and engine power. The teams that rely more on downforce and precision in handling find it tougher to keep up with the pace of Redbull.

*Technical Circuits*

On Technical Circuits such as Monaco, Singapore, Hungary, and Japan, the teams that did well were those in which low-speed cornering and high downforce were a strong suit. Red Bull and McLaren are two teams that showed increased performance on technical tracks, with McLaren able to leverage its car's high downforce for better handling in tight corners, with excellent braking stability and cornering agility.

Aston Martin had impressive improvements in the technical tracks in 2023, and this probably relates to the development of chassis design, as one could observe the team's results in Singapore and Hungaroring. However, data shows that they lacked competitiveness in technical tracks compared to teams like Redbull, McLaren, Mercedes, and Ferrari. Occasionally, Alpine had shown impressive performances on the technical track but generally needed to be more consistent with race results to get it into competition with top teams.

At the technical circuits, by contrast, Mercedes had rather poor results. The car design was focused more on high-speed performance, whereas the nature of these circuits highlighted some limitations of their design in lower-speed corners.

*Balanced Circuits*

The Balanced Circuits include tracks like Brazil, Las Vegas, and Abu Dhabi, where teams have to find a balance between straight-line speed and cornering stability. These tracks are

characterized by a mix of long straights and technical sections, making them a true test of versatility in car setup.

Here, Mercedes was great, especially on circuits like Circuit of the Americas and Brazil, where a mix of high-speed and technical sections let their balanced car design shine. Mercedes' ability to set up its car for a variety of circuit types without giving up too much performance either in straight-line speed or handling gave it an edge on Balanced Circuits. It was always in the mix for podiums, outpacing rivals like Ferrari.

Ferrari and Aston Martin tended to, more often than not, be less competitive on these balanced tracks. In particular, Ferrari showed inconsistency on circuits like Brazil and the United States, where their car's handling was sometimes less stable compared to Mercedes, especially in mixed-speed corners.

McLaren also had success on Balanced Circuits, but it struggled to keep up the pace of competitiveness during the season. Its performance in circuits like Las Vegas and Abu Dhabi showed glimpses of brilliance but poor mechanical reliability, and tire management often hindered their results.

**Conclusion**

This study examined the influence of track characteristics on the performance of Formula 1 constructors over the 2023 season, focusing on how high-speed, technical, and balanced circuits impact team competitiveness. By classifying the circuits based on their special features, like average speed, track layout, and elevation changes, this paper discerned how teams with particular car design traits — aerodynamics, engine power, and downforce, among others — perform on different track types.

The results confirm that Red Bull Racing was the dominating force in all aspects due to superior aerodynamics and engine power. Ferrari, Aston Martin, and McLaren fared better on technical circuits, where downforce and handling matter, while Mercedes, with a versatile car design, managed to be competitive in every balanced circuit, which demands a compromise between speed and handling.

On the other hand, the study also showed performance gaps for teams like Aston Martin and McLaren, especially on tracks that did not play to their car's strengths. These findings indicate the need to adapt car settings to the particular demands of each type of track and show how car design directly influences constructor performance. The rest of the grid, including teams like Williams, Alpine, Haas, Alfa Romeo, and AlphaTauri, all showed poor performance throughout the season.

In general, this research gives exceptional insight into how Formula 1 teams can adapt their strategies and car designs to optimize performance across different track types. Teams can use these findings to make strategic adjustments, improving their competitiveness on tracks where they face challenges. Further studies could explore these trends over multiple seasons, providing a broader understanding of how evolving car designs and track characteristics shape the outcome of future seasons.

## Supplementary Materials

1. Complete data set

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