Formula 1 2022 Regulation Changes*

How did the 2022 F1 Regulations change the sport for better and for worse

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As Formula 1's new era of hybrid cars develops, a fresh range of rules and regulations have been put in place for the teams to follow attempting to create a closer, more competitive championship. This paper will investigate the impact of the 2022 Formula 1 regulations, designed to intensify the competitive landscape and elevate the racing experience through technical and fiscal adjustments. It examines lap times and overtaking dynamics, while the analysis zeroes in on the performance trajectories of the sport's leading contenders: Max Verstappen, Lewis Hamilton, and Charles Leclerc across varied circuit types from 2021 to 2022. It focuses on whether these regulatory modifications have indeed leveled the playing field, creating tighter competition and mitigating the performance differences between teams or have increased the gap even more. This research not only examines the immediate effects of the 2022 changes but also considers the balance between innovation and competition in Formula 1, thereby contributing to the ongoing dialogue on how to shape the future of this high-stakes sport.

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*Code and data are available at: https://github.com/fanger2791/F1_Regulations.

1 Introduction

Formula 1 (F1) is the pinnacle of motorsport, recognized worldwide for its high-speed and high-tech racing that pushes the limits of automotive engineering and driver skill to the limit. Established in 1950, it has evolved into a global phenomenon, comprising of a series of races, known as Grands Prix, held on different tracks and street circuits across various continents. The sport features single-seat, open-wheel cars powered by cutting-edge hybrid technology, emphasizing aerodynamic performance, energy recovery systems, and fuel efficiency. Teams, both factory-backed and independent, compete in a Constructors' Championship, while drivers compete for the Drivers' Championship, making F1 not just a test of technical innovation but also human endurance and strategy.

In 2022, Formula 1 underwent one of its most significant regulatory overhauls in the history of the sport, a change motivated by the desire to enhance competitive balance and improve racing quality. This transformation came at a critical juncture, as the world of Formula 1 sought to address growing concerns over the technological disparities among teams, and the often predictable nature of race outcomes. The regulations introduced for the 2022 season aimed to tackle these challenges by mandating a new car design philosophy, overhauling the aerodynamics to facilitate closer racing, and implementing cost caps to level the playing field among the competing teams.

The core of the 2022 regulations centered around a shift to ground-effect aerodynamics, a move designed to reduce the reliance on turbulent airflows generated by traditional wing-based designs and thereby minimize the performance degradation experienced by cars when

following closely behind competitors. Additionally, the introduction of a budget cap aimed to reduce the escalating arms race in spending that had seen the wealthiest teams dominate the sport. These changes were complemented by adjustments to race weekend formats, marking a comprehensive approach to reforming the sport.

However, the transition was not without its challenges and controversies. Critics and experts argued that while the intention was to even the competition, the rapid and radical nature of these changes risked worsening existing disparities, at least in the short term, as teams adapted at different rates to the new regulations. Furthermore, concerns were raised about the potential for unintended consequences, such as increased racing incidents due to closer pack racing, and the possibility that the budget cap could stifle technological innovation.

Despite these debates, preliminary findings suggest that the 2022 regulations have had a profound impact on Formula 1. Races have generally become more competitive, with a wider array of teams and drivers finding themselves in contention for podium finishes. The budget cap has also initiated a more strategic allocation of resources among teams, potentially leveling the competitive field over the longer term. The paper's estimand is whether the 2022 Formula 1 regulations led to a significant increase in lap time in comparison to the previous time among the top drivers across different types of circuits but also increased the number of successful overtakes during races. We aim to quantify the impact of the 2022 Formula 1 regulatory changes, providing a clear basis for evaluating their success in enhancing the sport's competitive balance and the quality of racing.

The remainder of the paper is organized as follows: Section 2 details the methodology and source data, including the use of the f1dataR package. Section 3 provides an analysis of the data with an emphasis on changes in the laptime, speed and number of overtakes completed between 2021 and 2022 F1 cars. Section 4 discusses the specific challenges that came with the new regulations and on the balance between the intended objectives and the actual outcomes, offering recommendations for future regulatory adjustments.

2 Data

2.1 Source Data

The f1dataR (Casanova 2023) package in R is designed specifically for Formula 1 enthusiasts and data analysts who wish to examine the statistical and historical aspects of Formula 1 racing. This package provides a comprehensive setf functions that facilitate the extraction and manipulation of Formula 1 data directly from the Ergast API, which is a widely recognized source for F1 statistics. With f1dataR, users can easily access detailed race results, driver standings, constructor details, and much more, across the history of F1 competitions.

Table 1: F1 Driver Standings 2022

Driver	Position	Points	Wins	Constructors
Max Verstappen	1	454	15	Red Bull
Leclerc	2	308	3	Ferrari
Perez	3	305	2	Red Bull
Russell	4	275	1	Mercedes
Sainz	5	246	1	Ferrari
Hamilton	6	240	0	Mercedes
Norris	7	122	0	Mclaren
Ocon	8	92	0	Alpine
Alonso	9	81	0	Alpine
Bottas	10	49	0	Alfa

Table 2: F1 Driver Standings 2021

Driver	Position	Points	Wins	Constructors
Max Verstappen	1	395.5	10	Red Bull
Hamilton	2	387.5	8	Mercedes
Bottas	3	226.0	1	Mercedes
Perez	4	190.0	1	Red Bull
Sainz	5	164.5	0	Ferrari
Norris	6	160.0	0	Mclaren
Leclerc	7	159.0	0	Ferrari
Ricciardo	8	115.0	1	Mclaren
Gasly	9	110.0	0	Alphatauri
Alonso	10	81.0	0	Alpine

2.2 2021 Standings vs 2022 Standings

The Formula 1 driver standings from 2021 to 2022 as seen in Table 1 and Table 2 show a notable progression and shift in team and driver performance. In 2021, Max Verstappen secured the championship with a 7.5-point lead over Lewis Hamilton, with 10 wins to Hamilton's 8. Mercedes appeared strong, with both Hamilton and Bottas in the top three. Come 2022, Verstappen further solidified his dominance by extending his lead to a substantial 146 points and achieving a record 15 wins in a single season. Notably, Ferrari improved their standing with Leclerc finishing second, and Red Bull maintained their position as the team to beat with Perez also featuring in the top three. The 2022 season's F1 regulations, which introduced major changes to the car design with an emphasis on ground-effect aerodynamics, appear to have shaken up the order slightly. This aimed to allow cars to follow each other more closely and to increase overtaking opportunities. The impact of these changes can be inferred from

the reshuffling seen in team performance. Mercedes, for example, slipped from the top spot as Ferrari emerged as a stronger challenger to Red Bull. The midfield battle also saw shifts, with drivers like Ocon and Alonso gaining points, indicating that the new regulations might have provided an opportunity for teams to reset and challenge the established order.

2.3 Method of Analysis

To analyze the impact of track characteristics on Formula 1 car performance, specifically comparing the lap times and speeds at the Saudi Arabia Jeddah Corniche Circuit (a top-speed track) and the Netherlands' Circuit Zandvoort (a high-downforce track) as seen in Table 3 for the 2021 and 2022 seasons, a structured approach will be employed. Initially, data will be gathered using the f1dataR package, which extracts detailed information about lap times and speeds from the Ergast API. This dataset will include drivers' performances during both qualifying and race sessions.

The analysis will begin with descriptive statistics to outline the basic trends in the ranges of lap times and top speeds for each session across both tracks and years. This provides a preliminary view of the data and helps identify any outliers or anomalies. For deeper insights, a comparative analysis will be conducted between the two tracks and between the two years. This involves comparing average speeds and lap times to determine how the distinct characteristics of each track influence performance and how performance metrics have evolved from one year to the next.

To enhance the method of analysis for comparing lap times and speeds at the Jeddah Corniche Circuit and Circuit Zandvoort over the 2021 and 2022 Formula 1 seasons, we will focus on three top drivers: Max Verstappen, Lewis Hamilton, and Charles Leclerc. Including these specific drivers in the study adds a layer of depth by enabling comparisons not just between tracks and years, but also among leading competitors known for their distinctive driving styles and performance under varying circuit conditions.

The analysis will proceed by segmenting the data to include only the laps completed by Verstappen, Hamilton, and Leclerc. This will allow us to conduct a detailed examination of how each driver's performance varies across the two contrasting track types and over the two seasons.

Finally, the results will be visually represented through various graphs and plots to illustrate variability and distribution. This focused approach on Verstappen, Hamilton, and Leclerc will provide richer insights into driver-specific strategies and skills, adding substantial value to the overall analysis of Formula 1 performances across varied circuit designs. This comparative layer will help in understanding how individual capabilities and team strategies play out in high-speed vs. high-downforce conditions, thereby enriching the conclusions drawn from the data.

Table 3: F1 Circuits Analysis

Circuit_Name	Track_Type	Tyre_Wear
Saudi Arabia	Top Speed	High
Netherlands	High Downforce	Low

2.4 Data Limitations

While the f1dataR (Casanova 2023) package offers valuable resources for analyzing Formula 1 data, it does come with certain limitations that users need to consider. First, the quality and completeness of the data are dependent on the Ergast API, which means any missing or inaccurately recorded data in the API will be reflected in the outputs obtained through f1dataR. Additionally, the API's update frequency might not align with real-time event conclusions, potentially leading to delays in accessing the most current race data. The historical data provided may also have gaps, particularly from the earlier years of Formula 1 racing, which could limit analyses of long-term trends or comparisons over extended periods. Moreover, the package may not include certain types of data, such as detailed telemetry or in-depth weather conditions, which could be crucial for more nuanced analyses or predictive modeling. Therefore, while f1dataR facilitates access to a wealth of F1 data, users must be mindful of these constraints when conducting comprehensive or real-time analyses.

2.5 Data Cleaning

R (R Core Team 2023) was the language and environment used for this paper as well as throughout the data cleaning process, with different packages such as tidyverse (Wickham et al. 2019), ggplot2 (Wickham 2016), dplyr (Wickham et al. 2023), tidyr (Wickham et al. 2024), knitr (Xie 2023), janitor (Firke 2023), lubridate (Spinu, Grolemund, and Wickham 2023) packages.

The data cleaning process for these datasets involves several steps to ensure the data is accurate and suitable for analysis. Initially, the dataset's structure is reviewed to verify data types and identify any inconsistencies. This is crucial for understanding the data's composition and guiding subsequent transformations. Key transformations include converting relevant columns to appropriate data types, such as changing lap times to numeric values for analytical operations and categorizing seasons as factors for grouped analyses. Such transformations are essential for maintaining data integrity and ensuring computational accuracy. A critical cleaning step involves filtering out anomalies, specifically laps exceeding 100 seconds, based on the assumption that these represent non-standard race conditions like pit stops or errors. This step helps focus the dataset on typical racing performance. Further, the dataset undergoes a purging of incomplete records, removing any rows with missing data to enhance the robustness of the statistical analysis. Finally, renaming columns to more descriptive terms

facilitates easier understanding and manipulation of the data, aligning with best practices in data documentation and usability.

3 Results

3.1 Lap Time Comparison Between 2021 and 2022 in Jeddah - Max Verstappen

Figure 1 presents Max Verstappen's lap times in Jeddah for two consecutive Formula 1 seasons, 2021 and 2022. The laps are numbered from 1 to over 50 on the horizontal axis, while the vertical axis shows the lap time in seconds. In 2021, denoted by the blue line, there's a sharp decrease in lap times from the first lap, stabilizing around the 93-second mark, suggesting a rapid adjustment to the track or conditions before finding consistency. Notably, there's less variation in lap times for this season, with most laps being clustered closely around the 93 to 95-second range, indicating a relatively steady performance.

In contrast, the 2022 season, shown in red, exhibits more variability, with lap times generally higher and more erratic. Starting around the 97-second mark, these lap times show greater fluctuations, including some particularly slow laps that spike above 95 seconds, which could indicate instances of traffic, mistakes, or other delays. Overall, the performance in 2022 seems to be less consistent and slower compared to 2021. The distinct difference in patterns between the two seasons could be attributed to changes in car performance, track conditions, strategic decisions, or regulations affecting the car's capabilities.

3.2 Lap Time Comparison Between 2021 and 2022 in Jeddah - Lewis Hamilton

Figure 2 tracks Lewis Hamilton's lap times at the Jeddah circuit over two different seasons, 2021 and 2022. In 2021, represented by the purple line, we observe a swift decrease in lap times at the start, steadying to just below 93 seconds and maintaining a relatively consistent pace with minor fluctuations throughout the race. The 2021 data suggests a quick adaptation to track conditions, with Hamilton managing to keep a tight window of performance throughout his laps.

Comparatively, the 2022 season, indicated by the yellow line, shows a different performance profile. The lap times start higher than in 2021, showing Hamilton's laps initially hover around 97 seconds. There is a notable increase in variability, with spikes suggesting laps significantly slower than the general trend. These spikes could imply various events, such as dealing with traffic, pitting, or possible errors. Towards the latter part of the graph, the lap times improve, hinting at a potential adaptation or strategic changes during the race.

The broader range of lap times in 2022 and the overall slower laps compared to 2021 might be influenced by the aforementioned regulation changes. These changes could have affected car handling and performance characteristics, necessitating a period of adaptation. Additionally,

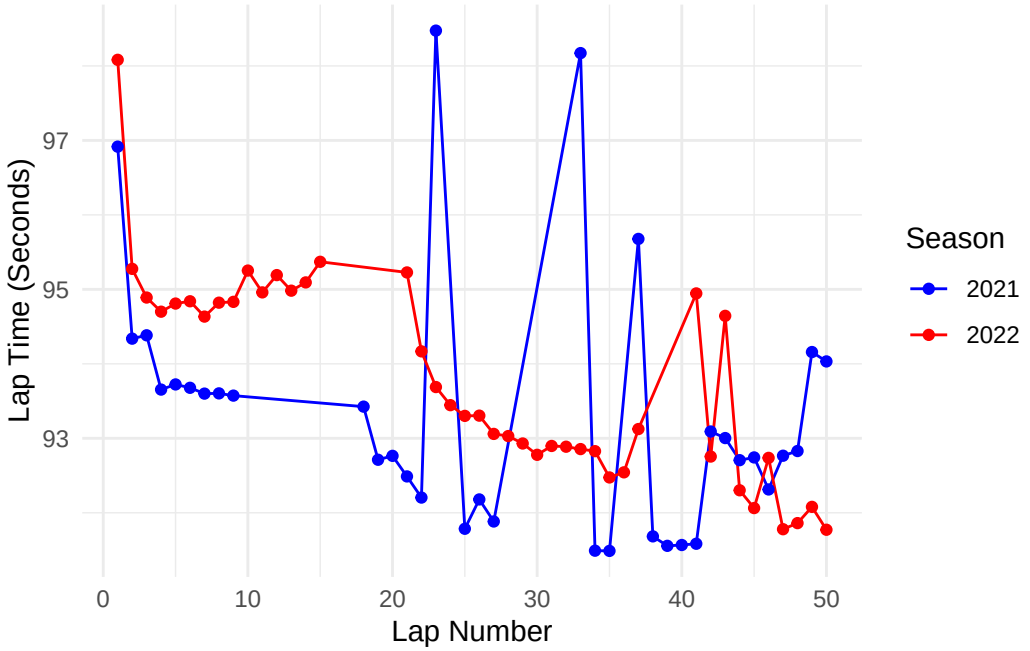

Figure 1: Max Verstappen Lap Times in Jeddah - 2021 vs. 2022

it's possible that the 2022 Mercedes car may not have been as well-suited to the demands of the Jeddah circuit as the previous year's model, or that team strategies were different in response to the new regulations and competition.

3.3 Lap Time Comparison Between 2021 and 2022 in Jeddah - Charles Leclerc

Figure 3 illustrates Charles Leclerc's lap times at the Jeddah circuit, contrasting his performance across the 2021 and 2022 Formula 1 seasons. In the 2021 season, shown in red, we observe an initial spike in lap times, which quickly reduces and then follows a trend with some fluctuation around the 95-second mark, with several outliers suggesting instances of slower laps. The spread of lap times in 2021 is relatively broad, which may reflect varying conditions or incidents during the race that affected performance.

For the 2022 season, represented by the green line, the initial lap times are also high but quickly improve. After the initial laps, the times are mostly clustered around the 95-second mark, similar to the 2021 season, but with less variability. Notably, towards the end of the session, there is a sharp drop in lap times followed by a significant spike. The less volatile lap times throughout most of the race compared to 2021 might suggest better consistency or adaptation to the 2022 car's handling.

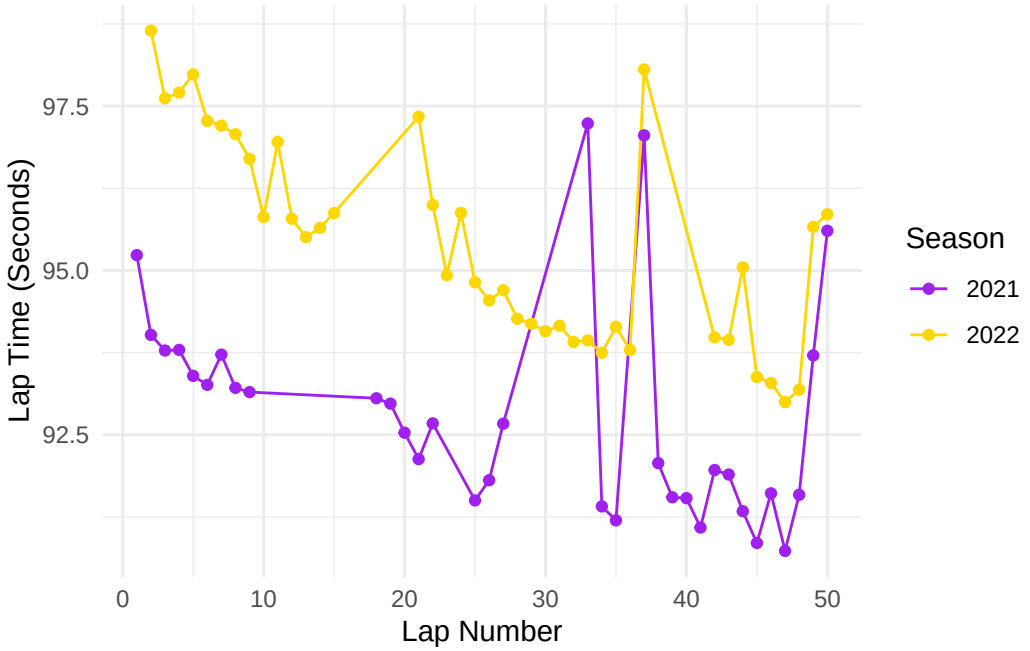

Figure 2: Lewis Hamilton Lap Times in Jeddah - 2021 vs. 2022

It's evident that in both seasons, there are moments of performance drops, which are likely due to non-competitive laps such as pit stops or laps following safety car periods. The general improvement in consistency in 2022, despite the new regulations, could indicate that Leclerc and his team were able to adapt effectively to the changes, possibly benefiting from the new aerodynamics rules designed to aid in car stability and handling. The sharp variations, especially in the 2022 data, could be indicative of specific incidents affecting those laps or strategic choices that temporarily influenced lap time performance.

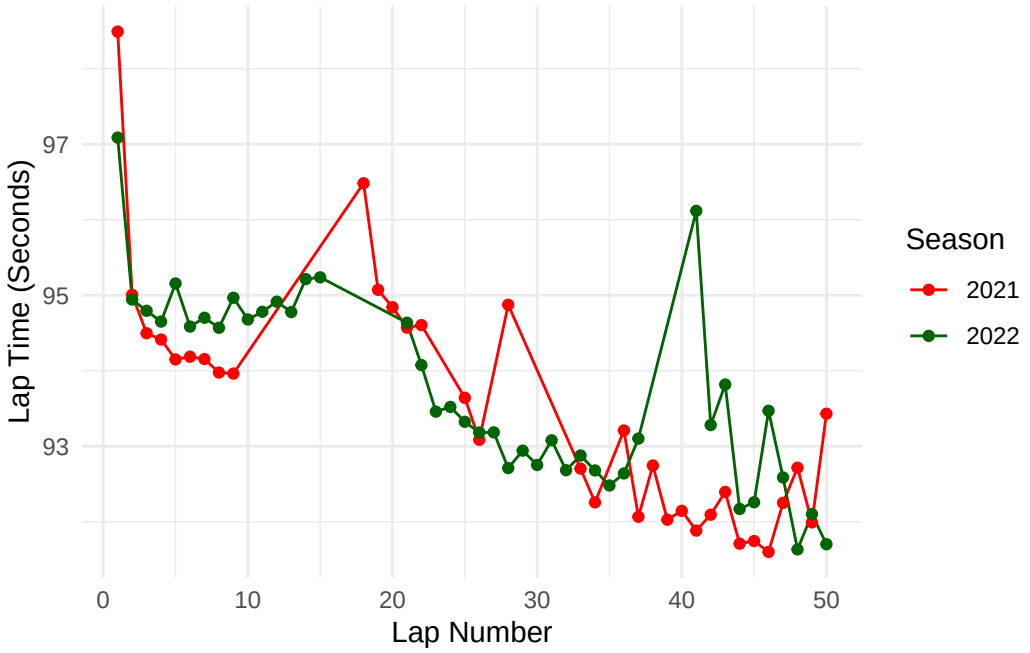

Figure 3: Charles Leclerc Lap Times in Jeddah - 2021 vs. 2022

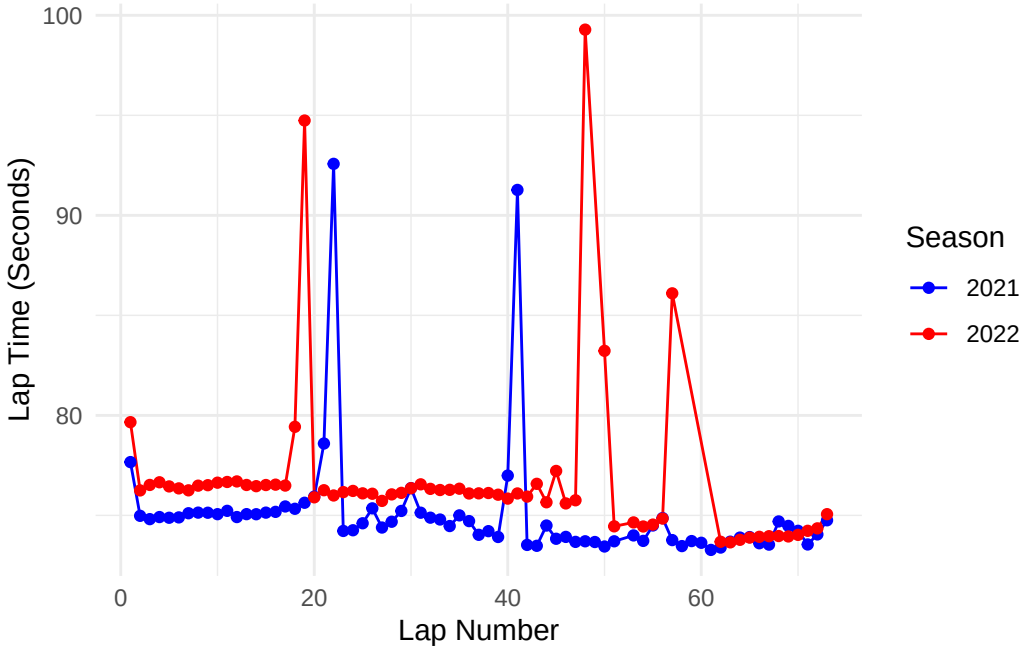

Figure 4: Max Verstappen Lap Times in the Netherlands - 2021 vs. 2022

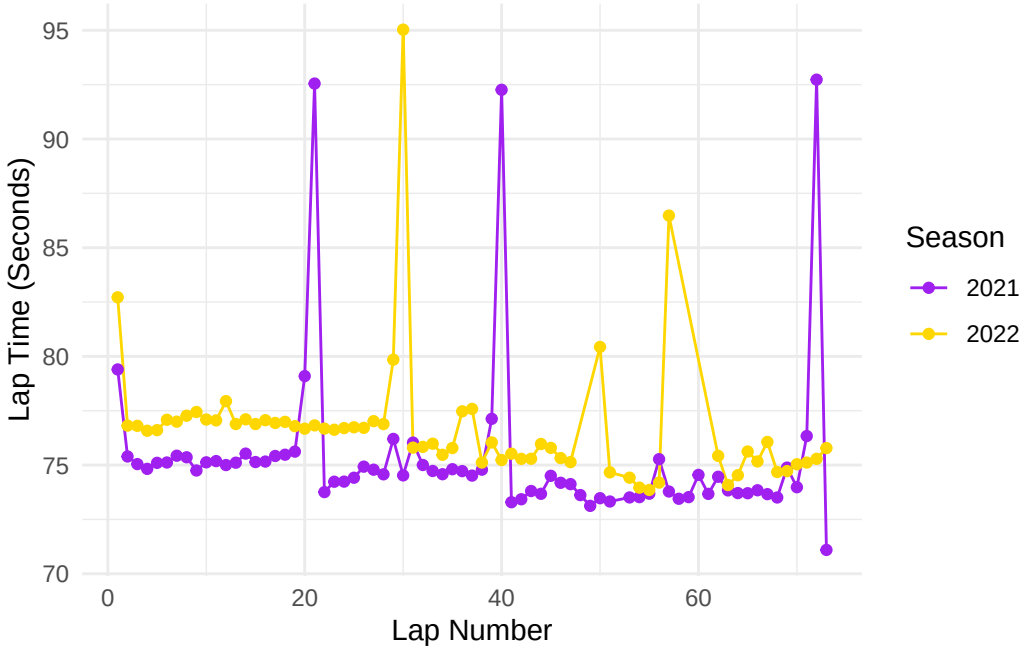

Figure 5: Lewis Hamilton Lap Times in the Netherlands - 2021 vs. 2022

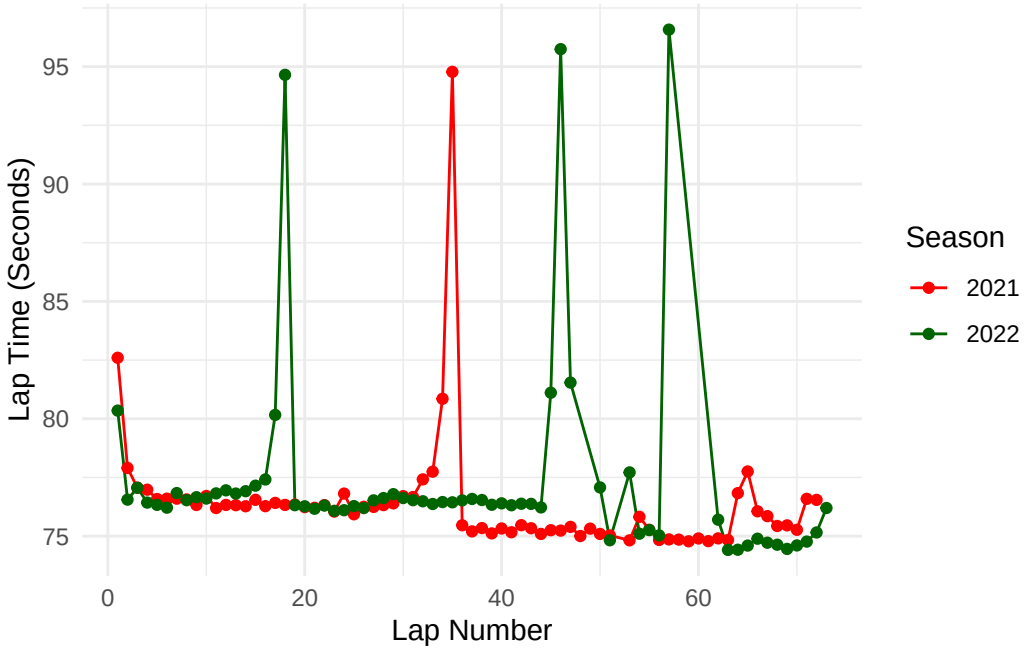

Figure 6: Charles Leclerc Lap Times in the Netherlands - 2021 vs. 2022

3.4 Lap Time Comparison Between 2021 and 2022 in the Netherlands - Max Verstappen

3.5 Lap Time Comparison Between 2021 and 2022 in the Netherlands - Lewis Hamilton

3.6 Lap Time Comparison Between 2021 and 2022 in the Netherlands - Charles Leclerc

3.7 Comparison of Number of Overtakes throughout each Season 2021 vs 2022

Figure 7 compares the number of overtakes during the Formula 1 racing seasons of 2021 and 2022, with Chart A focusing on total overtakes and Chart B on overtakes shown on TV. In both charts, there is a noticeable increase in the number of overtakes in the 2022 season compared to 2021.

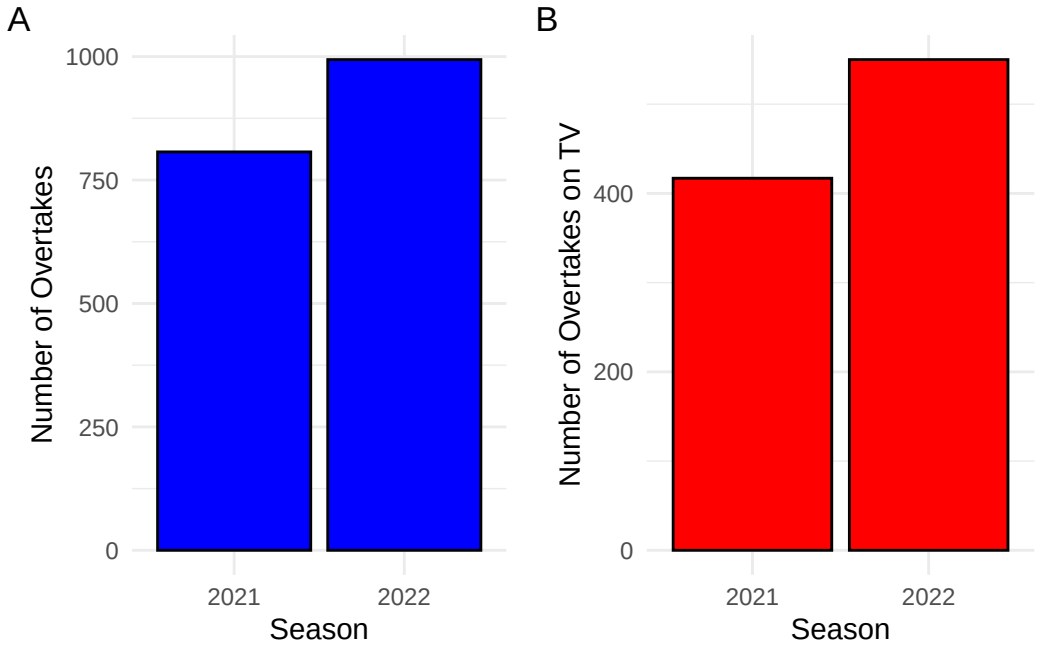

Figure 7: Number of Overtakes Throughout Each Season 2021 v 2022

3.8 Comparison of Average Number of Overtakes throughout each Season 2021 vs 2022

Figure 8 represent the average number of overtakes per race in the Formula 1 seasons of 2021 and 2022. Chart A shows a slight increase in the average number of overtakes from the 2021 to the 2022 season, while Chart B illustrates a more noticeable increase in the average number of overtakes broadcast on TV during the same period.

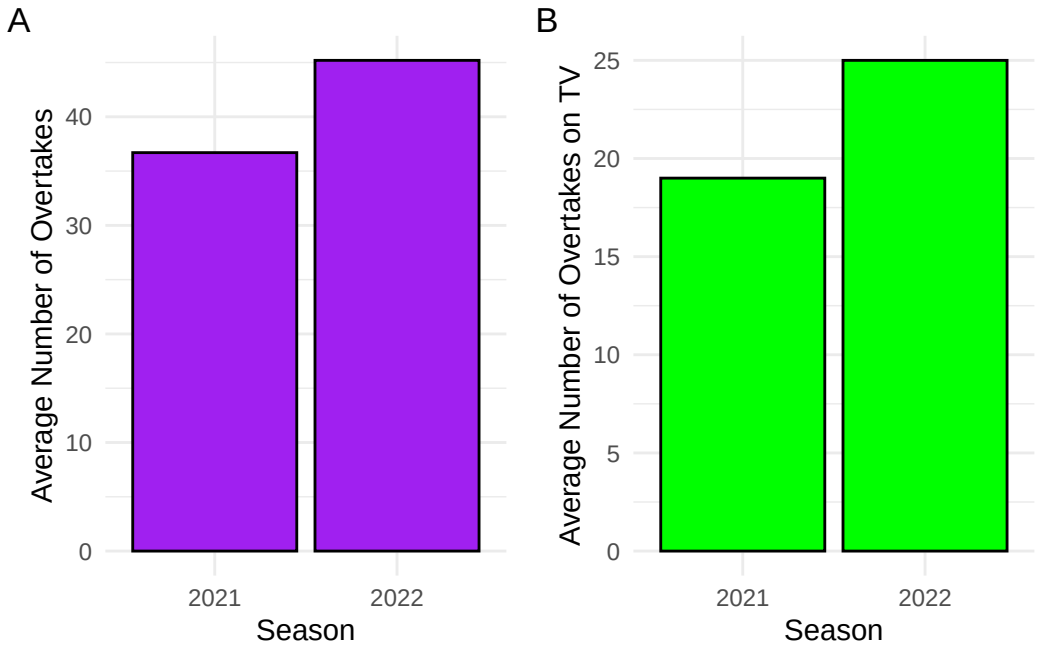

Figure 8: Average Number of Overtakes Per Race 2021 v 2022

3.9 How the regulations had an effect on total and average number of overtakes

This increase can be attributed to the major regulatory changes introduced in 2022, which aimed at promoting closer racing and more overtaking opportunities. The 2022 regulations involved a shift to ground-effect aerodynamics, allowing cars to follow each other more closely without losing significant downforce, which is crucial for maintaining speed in corners. Additionally, changes were made to the car's wings and wheel design to reduce the aerodynamic wake that can disturb the airflow for following cars, further facilitating overtaking maneuvers.

As a result, the data suggests that these regulations had their intended effect, leading to more competitive races with increased overtaking, which is reflected in both the total number of overtakes and those broadcast on television. The changes not only improved the chances of

overtaking but also likely enhanced the viewing experience for fans, as reflected in the consistency of overtakes shown on TV, which closely aligns with the actual increase in overtakes. This might indicate that more of the action was deemed broadcast-worthy, potentially due to the more dynamic and visually engaging nature of the overtakes under the new regulations.

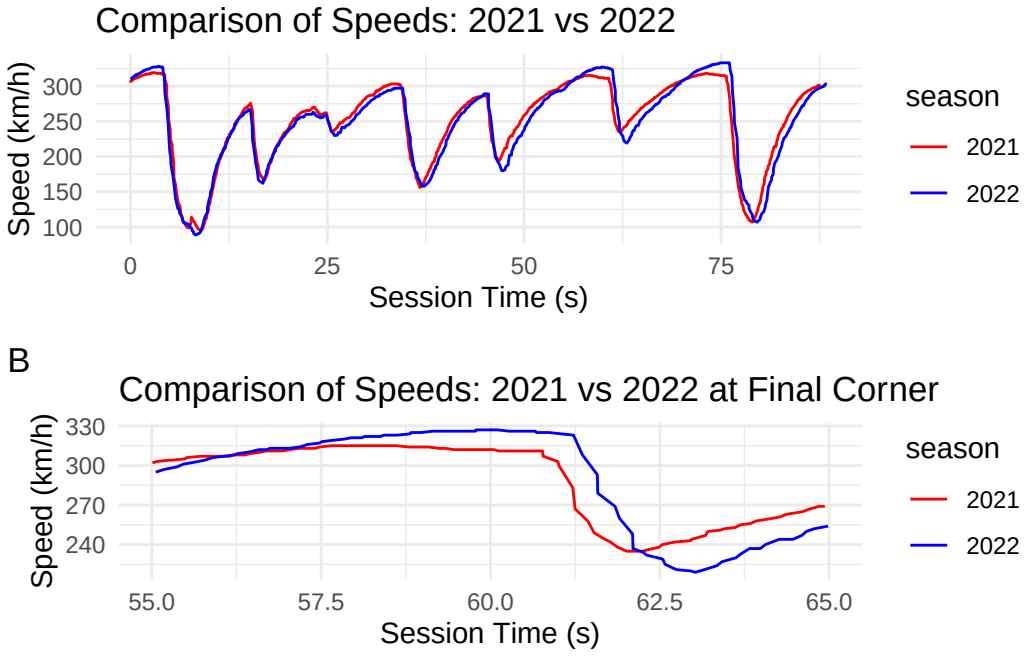

Figure 9: Verstappen Speed Comparison - Qualifying Jeddah 2022 vs 2021

4 Discussion

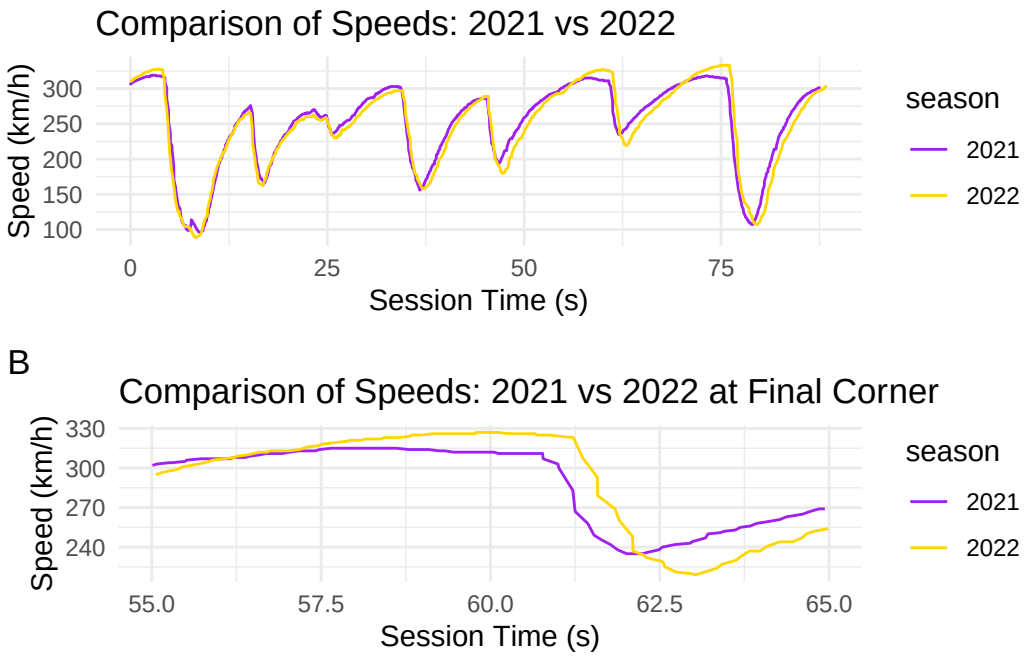

Figure 10: Hamilton Speed Comparison - Qualifying Jeddah 2022 vs 2021

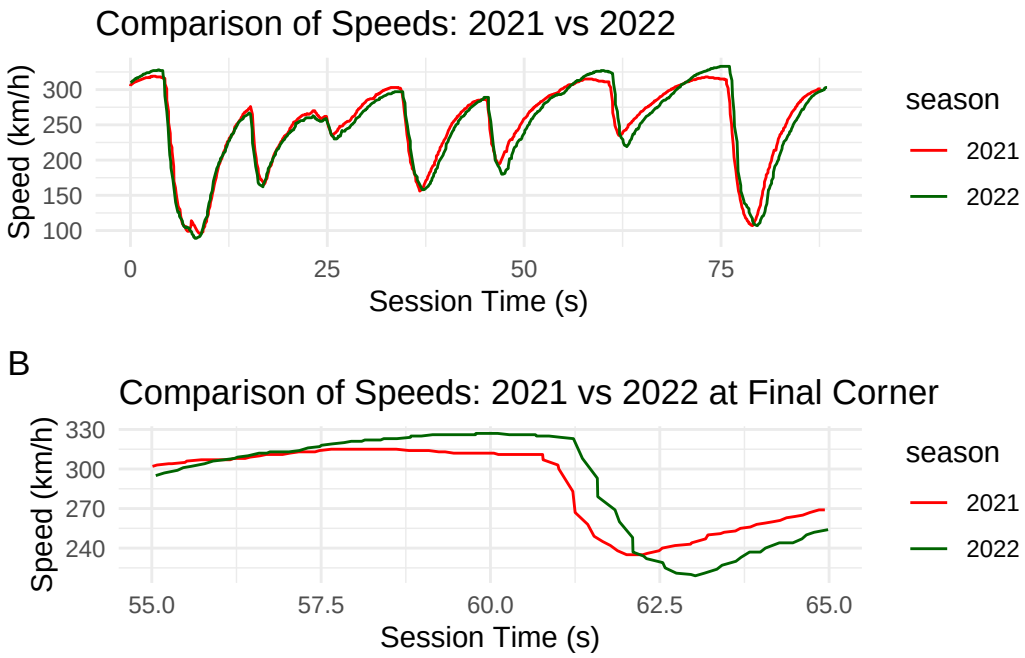

Figure 11: Leclerc Speed Comparison - Qualifying Jeddah 2022 vs 2021

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