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Does Mechanical Reliability Increase by the End of an F1 Regulatory Period?

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Abstract

In modern Formula 1 there are large changes to the regulations governing car design every 4 to 5 years [1]. Since the introduction of this updated regulatory format, it has been suggested that mechanical issues will be more common in the early years of the new regulations. This is due to cars still being under development, and by the end of this period upgrades to components are expected to have reached a natural peak of performance and reliability that possible within those rules. In this paper I determine through statistical analysis that there is no statistically significant difference in mechanical reliability between the first and last year of a regulatory period.

Keywords: *Sports; Probability/Statistics; Statistical analysis; Mechanical reliability; Formula 1 (F1).*

Introduction

Formula 1 (F1) is often referred to as the peak of motorsport. Innovations made in F1 have often led to improvements in road vehicles as well [2]. These include traction control, active suspension, and semi-automatic paddle shift gearboxes to name a few [3, 4].

To keep the sport fresh and exciting, but also to keep the playing field level, regulations governing F1 change regularly [1]. Each regulation sets out new rules that the cars must conform to, and each team will compete to extract the most performance within these regulations. These changes commonly include maximum sizes and weights for the cars, but also new engines, gearboxes, suspension systems, and aerodynamics [1]. Due to this, in the first season of a regulatory period mechanical failures are assumed to be more common. As a regulatory period approaches its end, the teams are presumed to have found the maximum of performance and reliability possible and therefore be less likely to suffer mechanical failure.

To determine whether this assumption about mechanical reliability is true, I will be performing statistical analysis on data obtained from the first and last season of each regulatory set. The null hypothesis of the statistical tests I will use is that there is no

statistically significant difference in reliability between the first and final years of a regulatory period. The alternative hypothesis if this is rejected is that there is a statistically significant difference.

Method

Era Title/General Outline	First Year	Final Year
Regulatory Overhaul	1994	1997
Narrow-track & Grooved-tyres	1998	2004
2.4L V8	2005	2008
Aerodynamic reset & KERS	2009	2013
Turbo-hybrid era	2014	2016
Higher-downforce Turbo-hybrid	2017	2021
Ground-effect era	2022	2025

Table 1 – F1 seasons that are focused on in this study. The starting point for this study is the 1994 season, as the large overhaul in regulations for 1994 is the first big regulation change before the trend of 4-5 seasons before regulatory overhauls began.

Race result data from the seasons in Table 1 were obtained from Jolpica, which is a Formula 1 results API (application programming interface) accessible via Python [5]. This API lists the final classifications for each car from every race. Any classifications related to mechanical failure (e.g.: brake failure, engine

failure, gearbox) were defined as mechanical Did Not Finishes (DNFs). I then extracted mechanical DNF values for the first year of a regulation set and the final year, categorised by each team.

Era first year	Era last year	Teams
1994	1997	8
1998	2004	6
2005	2008	6
2009	2013	6
2014	2016	8
2017	2021	6
2022	2025	9

Table 2 – Displays each era is listed and the number of teams considered. This is less than the total number of teams competing in each of these time periods, since only teams that competed under the same name in the first and last year of the era were considered for consistency [5].

Mean difference	t	p
-0.0019	-0.0283	0.9782
-0.1194	-1.7714	0.1367
-0.0290	-0.5592	0.6001
0.0815	1.1428	0.3049
0.0472	1.0187	0.3422
0.2000	2.3355	0.0668
0.0222	0.4264	0.6810

Table 3 – Displays calculations produced through Jupyter by accessing Jolpica F1 API using Python [5]. These are the results of the two-tailed t-tests run for each regulatory era. Mean difference is an average of all teams' difference in mechanical DNF rate (a negative value indicates that more DNFs took place in the last year than the first).

The t-value is the paired t-test statistic which shows how large the average difference is relative to the variation between teams. The p-value shows the probability of seeing a difference this large or more if there was no difference between each of the years, so the lower it is the stronger the evidence against the null hypothesis. If it is lower than the $p < 0.05$ threshold we can reject the null hypothesis [6].

It is important to note here that a two-tailed t-test has been used to analyse this data [6,7]. This is because for each team the number of mechanical DNFs in the final year will be dependent on the first year. Even in situations where a team has completely changed design concepts within the regulations instead of developing a single car design, the data that a team has collected and improved their

mechanical components on will influence the data. For this reason, the data must be separated by team and considered parametric.

Limitations

For this study, use of Jolpica's race classification database reduced the need for manual data collection. However, the exact information on how this database has defined each classification is not completely certain. In situations where cars have retired due to mechanical issues, yet have returned to the pitlane to do so, or the mechanical issue has led to a crash, could be classified as either Retirement or Crash instead of as mechanical. This may particularly impact the 2022-25 results, as the 2022 data was collected from Jolpica, but the 2025 data it was compared with was collected manually [8-31]. The difference in these results might be exaggerated by varying classification criteria between myself and Jolpica.

Also, since this database only has data on race classification, it does not include any data from practice, qualifying, or testing sessions. As a result, any mechanical DNFs from these sessions would not be recorded, but our statistical test accounts for this by using the number of race-starts and not the number of track sessions for calculations.

Finally, some data has been missed. This is due to the complications of F1 team names changing during the regulatory periods. Finding and defining all the different team names for every team, then getting them to register as the same for comparison within the code became convoluted. For simplicity only teams that had the same name at the beginning and end of the regulatory period were used, and the number of teams used for each is included in the results table. A more conclusive study can be done by accounting for all the name changes undergone by a team to have more reference points for the data.

Conclusion

Comparing the p-values above to the $p < 0.05$ threshold for rejecting the null hypothesis and suggesting a statistically significant difference, we see that there is not a statistically significant difference in mechanical failures between the beginning and end of a regulatory period. Since the null hypothesis is accepted, I can conclude that statistically there is no change in reliability between the first season of a regulatory period and the last.

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