

University of Wales Trinity Saint David

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Vehicle Performance Optimisation using Optimum Lap

Introduction to Automotive Engineering, ACHA4035

Steffan Selwood

2502394

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¹ Introduction

During this report, the author will explore the capabilities of simulation software to optimise vehicle performance through setup and gear ratio analysis. Data collected from six circuits was analysed to provide feedback and develop optimised vehicle setups within a strict budget. The testing used a fixed gearbox and final drive ratio, meaning gear ratios were evaluated to determine the most effective configuration across all circuits. These circuits represent a variety of driving conditions, including high-speed straights, technical corners, and elevation changes. Multiple runs were completed at each circuit using different aerodynamic maps, engine settings, weights, tyre compound, and driveline efficiencies to accurately identify the most effective setup.

The following sections outline the testing methodology, present the collected results, and discuss the key findings that led to the final setup recommendations. Multiple simulation runs were completed using track and vehicle models relevant to the assignment. For each circuit, several tests were carried out to determine the best aerodynamic, engine, and tyre configuration. All testing was conducted with fixed vehicle parameters to ensure consistent and reliable results.

² Methodology

Through simulations at all six circuits, the author determined the optimal gear ratios. The baseline ratios (3.1, 2.2, 1.8, 1.6, 1.4, 1.2) were revised to (2.6, 2.0, 1.6, 1.2, 1.0, 0.9). An overdrive final gear was required for Silverstone, Spa, and Le Mans to provide competitive speeds on long straights, while lower ratios improved acceleration at Monaco, Portugal, and Catalunya.

To ensure consistent comparisons, several factors were kept identical during testing, including the final drive (fixed at 2.8), frontal area, and air density. These controlled parameters ensured that any lap time improvements were due solely to setup changes. In the following sections, each circuit is examined to identify the most effective configurations and to discuss the performance impacts of aerodynamic balance, engine maps, mass, and tyre compound.

³ Results and Analysis

Silverstone

Silverstone is a circuit that places a high demand for aerodynamic efficiency, stability, and consistent mechanical grip through sections such as Maggots, Becketts and Chapel. Fast straights including the hangar straight require sufficient drag reduction, but this drag reduction must be balanced against the need for downforce for stability through the high-speed sweeping corners (Hucho, 1998). As a result of this a compromise was made between outright top-speed capability and cornering ability to complete a competitive lap time at this circuit.

During testing, the author completed a number of setup runs with varying vehicle mass, aerodynamic profiles, tyre compounds, engine maps, and various driveline efficiencies. Setups featuring low drag were ultimately ruled out, as the corresponding loss of downforce caused instability through the fast-sweeping sections of the circuit. This mirrored Catalunya where excessive drag reduction similarly compromised lap times (Joslin R, Brinklow G, 2025).

Across the tests performed the author identified that the most effective configuration was Setup 5 (as shown in the attached spreadsheet), this setup utilised a moderate weight, a mid-range aerodynamic profile, a mid-range tyre compound and, the maximum engine mapping. With this setup the author achieved a 93.44-second lap, which was 6.55 seconds quicker than the standard vehicle. This outcome clearly demonstrated that aerodynamic and stability upgrades were more beneficial at this circuit rather than pursuing aggressive drag reduction strategies.

⁴ Monaco

The Monaco street circuit is characterised almost entirely by low-speed, technical, and tightly constrained corners, with minimal opportunity for high-speed running. This combination makes it one of the most demanding circuits on the calendar, often catching both engineers and drivers out. The circuit places an emphasis on mechanical grip, traction, and low-speed stability rather than aerodynamic efficiency or outright top-end speed.

The simulation results showed that a mid-range vehicle mass, combined with a high downforce aerodynamic profile, and an appropriate tyre compound delivered the best overall performance on this narrow and traction-dependent layout. This balance provided stable handling through the tight sections and improved traction during corner entry and exit. Engine mapping also played a crucial role at Monaco as smoother torque transfer prevents wheelspin when accelerating out of slow corners.

At Monaco, the optimal configuration identified was Setup 4, which achieved a lap time of 79.56 seconds, making the vehicle approximately 3.5 seconds faster per lap than the standard car. This improvement clearly demonstrates that increased downforce, tyre grip, and controlled power delivery offered the greatest performance gains at Monaco, where agility and traction significantly outweigh the benefits of outright speed or aggressive drag reduction.

⁵ Spa-Francorchamps

Spa has long been known as one of the worlds fastest and most exciting circuits, featuring numerous long straights, high-speed corners, and dramatic elevation changes. These aspects place a high emphasis on mechanical grip, aerodynamic efficiency, and strong top-end performance. The vehicle must maintain high speed and outstanding stability through sections like Eau-Rouge and Raidillon, while still having readily available acceleration for the uphill straights that follow.

The author explored setups which minimised drag while still maintaining acceleration, downforce, and overall top-end speed. This approach ensured that the vehicle could take full advantage of Spa's extended high-speed sections while still providing adequate stability through the circuit's fast-flowing corners.

At Spa, the optimal setup solution found by the author was setup 7 which can be found in the spreadsheet attached. The setup maintained a higher weight similar to Silverstone, and instead focussed on aerodynamics, tyre compound, and engine performance. The findings at Spa, combined with the insight gained from Silverstone and Monaco helped guide the optimisation strategy for the remaining circuits. Using setup 7, the vehicle achieved a 113.6 second lap, approximately 3.91 seconds a lap faster than the baseline configuration.

⁶ Portugal

This circuit presented a unique challenge as it is made up of many elevation changes and a combination of high and medium speed corners similar to Spa's many high-speed elevation changes and corners. Unlike Spa this circuit required a more balanced approach with greater focus on traction and aerodynamic efficiency while also providing enough top end speed for the main straight.

The layout at this circuit means the vehicle experiences hard downhill braking and hard uphill acceleration. As a result of this the vehicle must provide sufficient downforce to keep the vehicle stable during high-speed corners and minimised drag levels. Without these crucial components the vehicle would not achieve acceptable acceleration and the speed which is crucial to complete an optimal lap at this circuit.

At this circuit, the author determined that Setup 2 was the optimal lap solution utilising a high downforce setup with a mid-range tyre compound which helped with traction on corner exits. Using Setup 2 the author managed a result of 84.64 seconds which was approximately 3.91 seconds quicker per lap than the baseline.

⁷ Catalunya

Circuit de Barcelona-Catalunya presents a challenge when it comes to vehicle optimisation due to its mixture of sections containing high speed straights and high and low speed technical corners. Similar to Portugal previously, this circuit requires balanced setup across all areas. The circuit contains several sweeping fast corners which places a strong requirement on aerodynamic stability, while the later sections on the circuit are slow and technical corners which require consistent traction and mechanical grip.

Along with this Catalunya's long main straight also places a demand on sufficient drag reduction to maximise top-end speed. However excessive drag reduction would cause issues with stability in the sweeping corners that follow. As a result of this the optimal setup for this circuit would utilise and find an effective compromise between drag force and downforce while also providing exceptional handling through fast and slow corners.

At Catalunya, the author determined that the most effective setup was Setup 6 which delivered a lap time of 86.51 seconds which was 5.22 seconds quicker than the baseline vehicle. Setup 6 utilised a mid range weight, mid range aero package, and a low range tyre compound. This shows that extreme over the top setups were ineffective at Catalunya which requires a significant compromise between aero, grip, and speed. This was confirmed earlier at Portugal and influenced the optimisation strategy for the next circuit Le Mans.

⁸ Le Mans

Le Mans presents a unique challenge when it comes to lap-by-lap optimisation. The circuit contains a large mix of long straight sections, including the Mulsanne Straight, which demand exceptional top-end performance through efficient aerodynamics and effective engine mapping. However, the circuit also features medium- and high-speed corners such as Virage de Mulsanne and the Esses d'Indianapolis, where aerodynamic stability is essential (Joslin R, Brinklow G, 2025). Similar to circuits like Silverstone and Catalunya, Le Mans required a balanced setup in which compromises in top-end speed were traded for increased aerodynamic load and stability.

During the test runs, the author identified that setups with extreme drag reduction had to be ruled out, as the corresponding loss of downforce caused instability in the circuit's high-speed corners. The ruling factor at Le Mans was achieving sufficient cornering stability without excessively compromising drag levels on the long straight sections.

Using Setup 1, the author achieved a lap time of 186.82 seconds, approximately 13.6 seconds quicker than the baseline. This setup combined a mid-range vehicle mass, a high-downforce aerodynamic profile, mid-range tyres, a high engine map, and a 92% driveline efficiency. Ultimately, extreme low-drag configurations proved ineffective at this circuit, as their instability through faster corners outweighed any gains in straight-line performance. Balanced downforce, moderate drag, and strong engine performance were preferred.

⁹ Conclusion

From the results gathered across all six circuits, the optimisation process showed that vehicle performance is strongly influenced by achieving the correct balance between aerodynamic downforce and drag, tyre selection, engine mapping, and driveline efficiency. Circuits with long straights benefitted from controlled drag reduction combined with sufficient stability for high-speed corners, while circuits like Monaco and Catalunya required a greater emphasis on traction and handling. The simulation data showed that extreme setup choices were rarely effective, with balanced configurations consistently delivering better results. Overall, the optimisation process improved lap times significantly, validating both the methodology and configuration strategy.

¹⁰ References

1. Hucho, W. (1998). Aerodynamics of Road Vehicles. 4th ed.
2. Joslin R, Brinklow G. Open wheel competition car rear wing placement and underbody aerodynamic interactions: Aerodynamic design for a competitive advantage in motorsports. *Proceedings of the Institution of Mechanical Engineers, Part P: Journal of Sports Engineering and Technology*. 2025.