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Performance Assessment and Optimisation

Race Engineering and Simulation (ACHA7026)

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Date 03/05/2026

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1. Introduction

This study presents a structured Driver-in-the-Loop (DIL) simulation methodology to evaluate and optimise driver and vehicle performance within a motorsport context. Simulation sessions were designed to replicate a full race weekend (FP1, FP2, FP3, Qualifying, and Race), enabling controlled performance analysis and iterative setup refinement. Such approaches are widely used in vehicle development and behavioural research to reduce cost and risk while maintaining high fidelity in driver–vehicle interaction (Rajamani, 2012; Jamson, 2010; Nitsch, Färber and Moussavi, 2008).

The simulator model represents the 2020–2022 MCR #40 vehicle and was tested at Donington Park and Pembrey, selected due to the availability of historical performance data. Setup configurations were refined iteratively using driver feedback, reflecting the importance of human-in-the-loop systems in capturing realistic driver behaviour (Donges, 1978; MacAdam, 1981). The validity of simulation-based studies depends on their ability to accurately reproduce real-world driving conditions and driver responses (Kaptein, Theeuwes and van der Horst, 1996).

Due to simulator limitations—particularly reduced aerodynamic modelling (Hughes, 2022)—the objective was to identify a setup that balances driver confidence, controllability, and lap time performance. Results were compared with real-world data to assess validity.

2. Driver-In-Loop Simulator



Figure 1: Simulator at UWTSD

The simulator consists of a Base Performance Driver-in-the-Loop (DIL) system with a 180° wrap-around display and VR capability, providing an immersive environment for vehicle dynamics analysis. High-fidelity simulation enhances driver immersion and improves behavioural validity (MacAdam, 1981; Jamson, 2010).

The system uses an F4-style chassis with paddle shift controls, differing from the MCR vehicle's manual gearbox and cockpit layout. These differences were considered, as driver interface influences control inputs and perceived vehicle response (Donges, 1978; Nitsch, Färber and Moussavi, 2008).

The simulation environment operates under fixed conditions (dry, 18–20°C) and does not model tyre degradation. While this reduces realism, it ensures repeatability—critical for controlled testing, although it may limit real-world validity (Rajamani, 2012; Kaptein, Theeuwes and van der Horst, 1996).

Testing was conducted with a Sport 2000 Duratec driver, who demonstrated consistent performance, supporting the reliability of the simulation approach.

3. Test Plan Development:

Testing followed a Sport 2000 Duratec race weekend structure, comprising three practice sessions, qualifying, and a single 25-minute race. The objective was to evaluate key performance metrics, including lap time, consistency, vehicle handling, and driver feedback, using a structured simulation approach to replicate real-world conditions (Rajamani, 2012; Jamson, 2010).

Simulations were conducted at Donington Park and Pembrey Circuit, selected for their extensive historical MCR data, enabling comparison with real-world performance. Pembrey served as the primary development circuit, while Donington Park was used to assess setup transferability.

Driver KPIs included reaction time, steering consistency, braking points, and throttle application, benchmarked against AI-generated inputs representing optimal control behaviour (MacAdam, 1981; Nitsch, Färber and Moussavi, 2008). Vehicle KPIs focused on tyre behaviour, suspension response, and powertrain performance (Gillespie, 1992).

Aerodynamic analysis was excluded due to simulator limitations, as only basic wing adjustments are available and key factors such as underbody flow are not modelled. Additionally, the MCR 40 relies on a front splitter and rake angle for downforce, further limiting meaningful aerodynamic correlation (Hughes, 2022).

All data was collected and analysed using MoTeC i2 Pro to ensure consistent KPI evaluation.

UWTSD MOTORSPORT			UWTSD Windtunnel Testing (MCR Bodywork)										Date	24/02/2022						
													Revision	3.1						
			All runs at 35 m/s Frontal Area 1.0m2																	
			DRAG	DOWNFORCE	EFFICIENCY	BALANCE (% Front)	FRONT DOWNFORCE	REAR DOWNFORCE	Cd	Cl	Cf	Cfr	NOTES							
			MIRA OLD	519	571	1.100	19.07	108.87	462.13	0.658	0.729	0.139	0.589	At F45 R68 static with Springs						
			MIRA OLD WORKS MCR	541	893	1.651	34.24	305.76	587.34	0.689	1.145	0.392	0.754	Ride heights unknown						
			CFD S2n BASELINE	545	2005	3.679	49.42	990.89	1014.11	0.726	2.672	1.321	1.352	At F45 R68						
RUNS	123	S2N MIRA 1	485.4	1078.7	2.22	42.43	457.69	623.99	0.648	1.44	0.611	0.833	BASELINE							
	4	S2N MIRA 2	482.4	973.8	2.02	36.15	352.07	625.49	0.644	1.3	0.47	0.835	CFD BASELINE							
5	S2N MIRA 3	486.9	1048.0	2.15	40.24	421.74	626.24	0.65	1.399	0.563	0.836									
6	S2N MIRA 4	486.9	1113.1	2.29	43.88	488.41	623.99	0.65	1.486	0.652	0.833									
7	S2N MIRA 5	493.6	1183.6	2.40	47.28	559.57	623.99	0.659	1.58	0.747	0.833									
8	S2N MIRA 6	514.6	824.0	1.60	20.36	167.80	656.20	0.687	1.1	0.224	0.876									
9	S2N MIRA 7	502.6	649.5	1.29	-0.81	-5.24	654.70	0.671	0.867	-0.007	0.874									
10	S2N MIRA 8	501.9	729.6	1.45	10.99	80.15	650.21	0.67	0.974	0.107	0.868									
11	S2N MIRA 9	508.6	862.2	1.70	24.67	212.74	649.46	0.679	1.151	0.284	0.867									
12	S2N MIRA 10	497.4	1010.5	2.03	37.14	375.29	635.23	0.664	1.349	0.501	0.848									
13	S2N MIRA 11	491.4	866.7	1.76	26.45	229.22	637.47	0.656	1.157	0.306	0.851									
14	S2N MIRA 12	501.9	848.0	1.69	23.85	202.25	645.71	0.67	1.132	0.27	0.862									
15	S2N MIRA 1	487.7	1077.2	2.21	42.00	452.45	625.49	0.651	1.438	0.604	0.835	BASELINE								
16-23 inc	16	S2N MIRA 1	483.0	1077.9	2.23	42.39	456.94	616.50	0.646	1.439	0.61	0.823	BASELINE YAW @ 0 Deg WITH TAPE							
	24	S2N MIRA 13	541.6	1331.1	2.46	34.67	461.44	869.69	0.723	1.777	0.616	1.161	Low deck gurneys							
25	S2N MIRA 14	587.3	1473.5	2.51	31.32	461.44	1012.02	0.784	1.967	0.616	1.351	High Deck gurneys								
26	S2N MIRA 15	546.1	1260.0	2.31	37.99	478.67	781.30	0.729	1.682	0.639	1.043	low deck gurney								
27	S2N MIRA 16	526.6	1318.4	2.50	35.51	468.18	850.21	0.703	1.76	0.625	1.135	low deck gurney								
28	S2N MIRA 17	553.6	1313.2	2.37	38.33	503.39	809.76	0.739	1.753	0.672	1.081	low deck gurney - back to mid wing - splitter endplates								
29	S2N MIRA 18	518.4	1409.8	2.72	41.18	580.54	831.94	0.692	1.882	0.775	1.1106	Low deck gurney - mid wing - 3 turns DOWN FRONT								
30	S2N MIRA 19	534.8	1374.6	2.57	36.35	499.64	874.19	0.714	1.835	0.667	1.167	Low deck gurney - mid wing - Ride heights back to baseline								
31	S2N MIRA 18											# SMOKE RUN ##								
													Remove Radiators							
													Smoke							

Figure 2: UWTSD Windtunnel testing plan and results

3.1 FP1 and FP2

Initial car settings:

Starting fuel	22 L (race refuelling not allowed)	Final Gear	40/105
Engine Rev Limit	7,250	1 st Gear	12/33 (7.219)
Weight Distribution (Front : Rear)	41.0 : 59.0	2 nd Gear	15/33 (5.775)
Lateral (Left : Right)	50.0 : 50.0	3 rd Gear	15/27 (4.725)
Steering Lock	14.0 deg	4 th Gear	17/26 (4.015)
Steering rotation	450.0 deg	5 th Gear	18/23 (3.354)
Aerodynamics front wing	1	6 th Gear	N/A
Aerodynamic rear wing	4	7 th Gear	N/A

Initial suspension settings:

	Front left	Front third spring	Front right
Tyre pressure	95 kPa	Detached	95 kPa
Camber	-3.0 deg	1	-3.0 deg
Caster	5.0 deg	1	5.0 deg
Spring rate	70 N/mm	1	70 N/mm
Slow bump	14	1	14
Slow rebound	14	0.0 cm	14
Fast bump	14	N/A	14
Fast Rebound	14	N/A	14
Packers	0.0 cm	N/A	0.0 cm
Ride height	4.1 cm	N/A	4.1 cm
Anti-roll bar	N/A	35 N/mm	N/A
Toe in	N/A	-0.60 deg	N/A

	Rear left	Rear third spring	Rear right
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Tyre pressure	95 kPa	Detached	95 kPa
Camber	-2.5 deg	1	-2.5 deg
Spring rate	80 N/mm	1	80 N/mm
Slow bump	14	1	14
Slow rebound	14	0.0 cm	14
Fast bump	14	N/A	14
Fast Rebound	14	N/A	14
Packers	0.0 cm	N/A	0.0 cm
Ride height	6.5 cm	N/A	6.5 cm
Anti-roll bar	N/A	15 N/mm	N/A
Toe in	N/A	0.30 deg	N/A

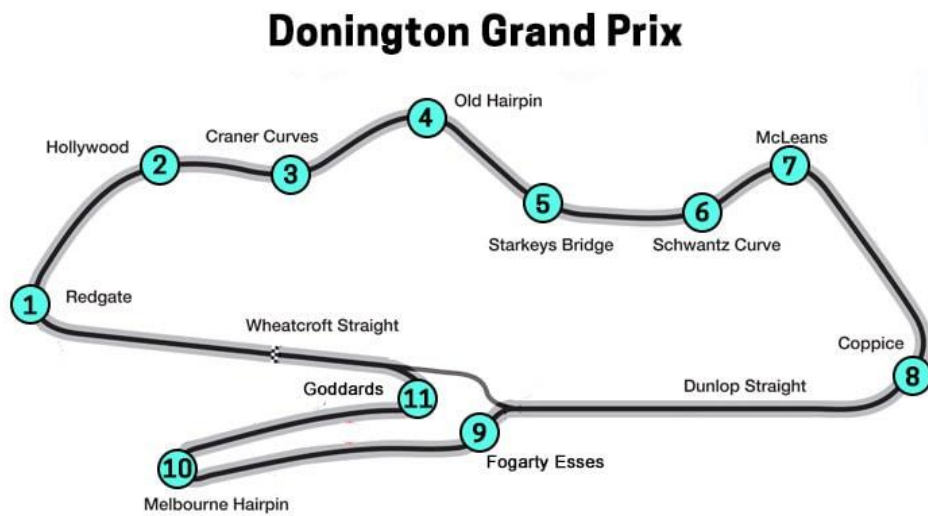


Figure 3: Donington Grand Prix circuit

Gear ratio, ride height, and suspension settings were selected based on historical Donington race data and driver feedback to ensure both performance relevance and drivability (Rajamani, 2012).

Six simulation sessions were conducted, each consisting of three laps, following a structured test plan:

- **Baseline:** Two runs using default setup parameters (Table X)
- **Fuel and tyre model enabled:** Two runs with fuel consumption and tyre wear activated
- **Ride height variation:** Two runs with fuel consumption enabled and modified ride height (front = 4.8 cm, rear = 6.2 cm)

For each configuration, the first run was completed by the human driver and the second by an AI driver model, enabling direct comparison with optimised control inputs (MacAdam, 1981; Nitsch, Färber and Moussavi, 2008).

The best lap time from each condition was used as the primary performance metric, a standard approach in performance evaluation studies (Gillespie, 1992).

Run sets	Driver	AI
1	1:35.231 (lap 4)	1:33.351 (lap 2)
2	1:34.464 (lap 3)	1:33.322 (lap 2)
3	1:34.307 (lap 3)	N/A

Across all comparable conditions, the AI driver consistently outperformed the human driver by approximately 1.8–2.0 seconds per lap, reflecting its ability to apply near-optimal and highly repeatable control inputs (MacAdam, 1981; Nitsch, Färber and Moussavi, 2008).

However, as an upper-bound benchmark, AI does not fully represent realistic driving behaviour due to its lack of variability and risk sensitivity. Its performance should therefore be interpreted cautiously when evaluating real-world driver capability and setup effectiveness (Jamson, 2010).

Driver feedback indicated improved rear-end stability with increased mid-speed understeer. Despite similar lap times between Run Sets 2 and 3, performance was achieved through different driving styles, suggesting that setup changes influenced vehicle balance and driver input strategy rather than absolute pace.

This highlights that lap time alone is insufficient for evaluating setup effectiveness; driver confidence, consistency, and adaptability are equally critical (Donges, 1978; Kaptein, Theeuwes and van der Horst, 1996). Telemetry comparison supports this, with the AI exhibiting highly consistent inputs, while the human driver shows greater variation, reflecting adaptive control behaviour.

AI: black line, run 2 lap 2

Driver: coloured line, run 3 lap 3

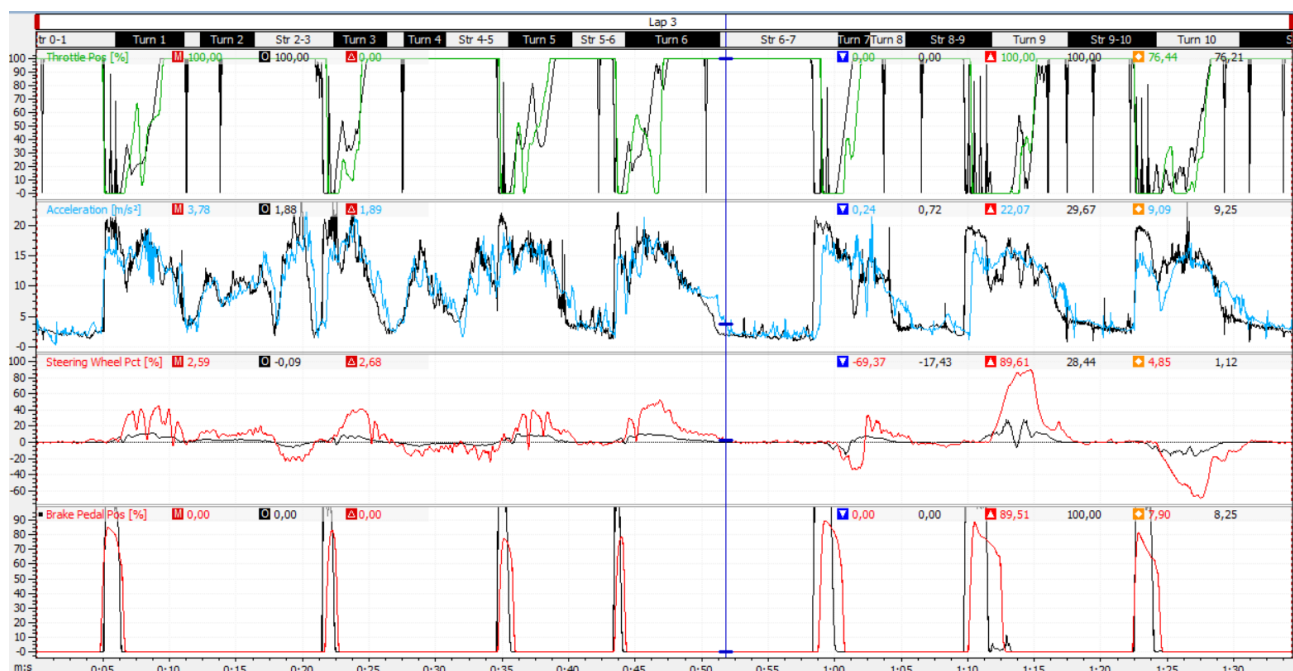


Figure 4: Throttle position, acceleration, steering wheel percentage and brake pedal position comparison

The AI driver achieved optimal tyre warm-up by the second timed lap, reflecting precise control of tyre loading, whereas human drivers required additional laps due to input variability (Nitsch, Färber and Moussavi, 2008).

Tyre degradation and track evolution had no effect in FP1 and FP2, as conditions reset between runs. While this improves repeatability, it reduces realism in modelling thermal behaviour and grip evolution (Gillespie, 1992; Kaptein, Theeuwes and van der Horst, 1996).

The selected gear ratios provided an effective balance between corner performance and straight-line efficiency, requiring no further optimisation (Rajamani, 2012).

AI: black line, run 2, lap 2

Driver: coloured line, run 2, lap 3

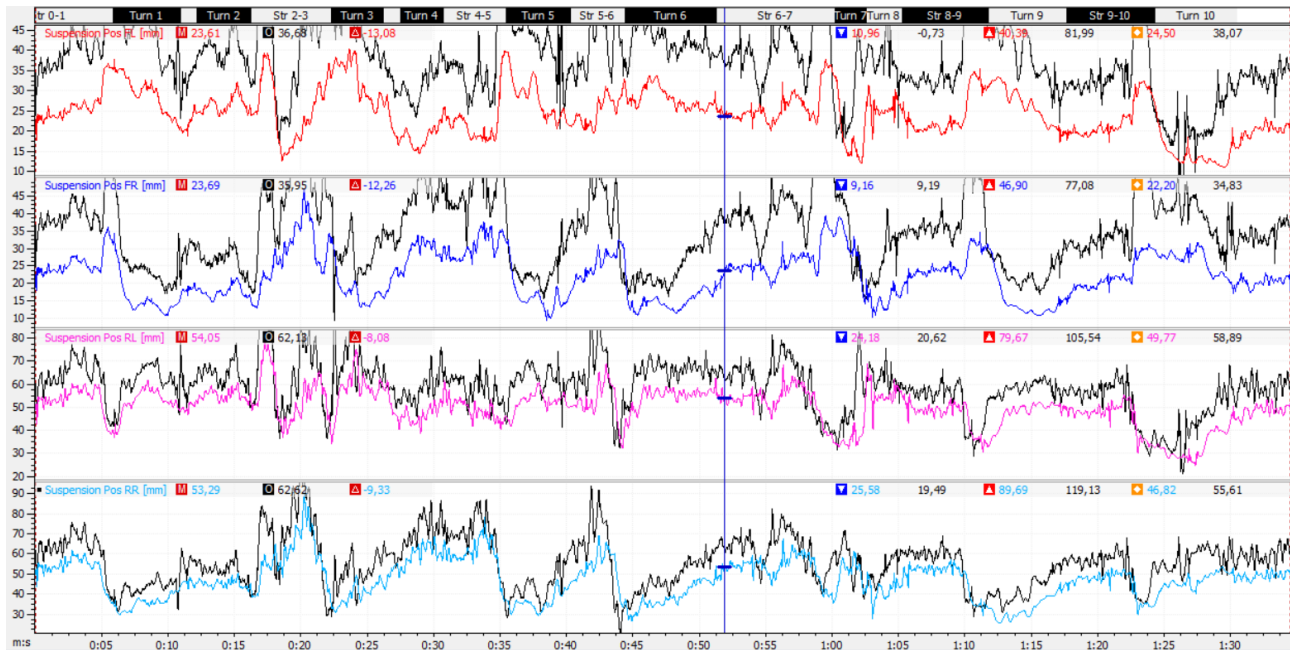


Figure 5: suspension position comparison

Suspension data indicates that the AI driver maintains a higher average ride position (reduced compression), suggesting a smoother line that avoids kerbs and minimises vertical load variation, contributing to more consistent performance (Gillespie, 1992).

In contrast, the human driver shows progressive improvement across sessions (Moghaddar, 2023), reflecting track familiarisation and adaptation to the setup. Increased confidence and more driver-oriented settings reduced lap time variation, particularly in critical sections such as the Melbourne Hairpin (Nitsch, Färber and Moussavi, 2008).

Tyre temperature increases during braking and stabilises through cornering, consistent with expected load and energy transfer (Gillespie, 1992). No clear evidence of severe lock-up was

observed, although minor transient slip cannot be excluded, as simulation models may not capture all short-duration tyre dynamics (Kaptein, Theeuwes and van der Horst, 1996).

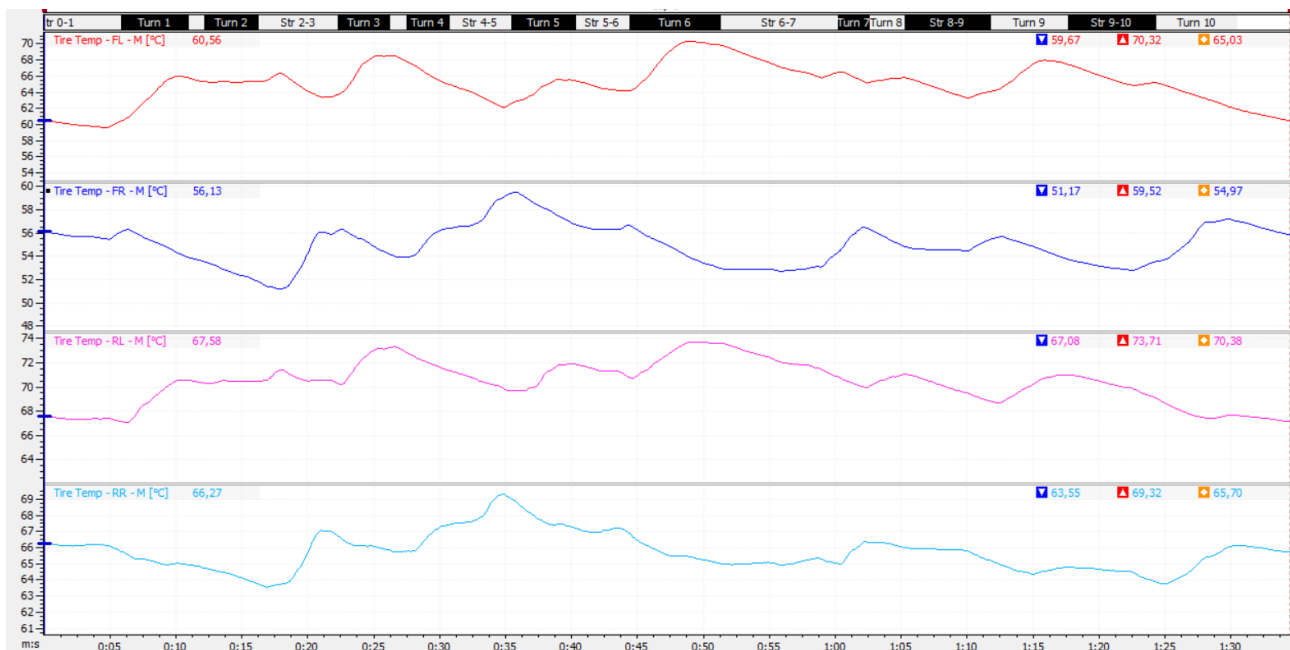


Figure 6: tyre temp comparison

Coloured line: driver, run 1, lap 3

Black line: driver, run 3, lap 3

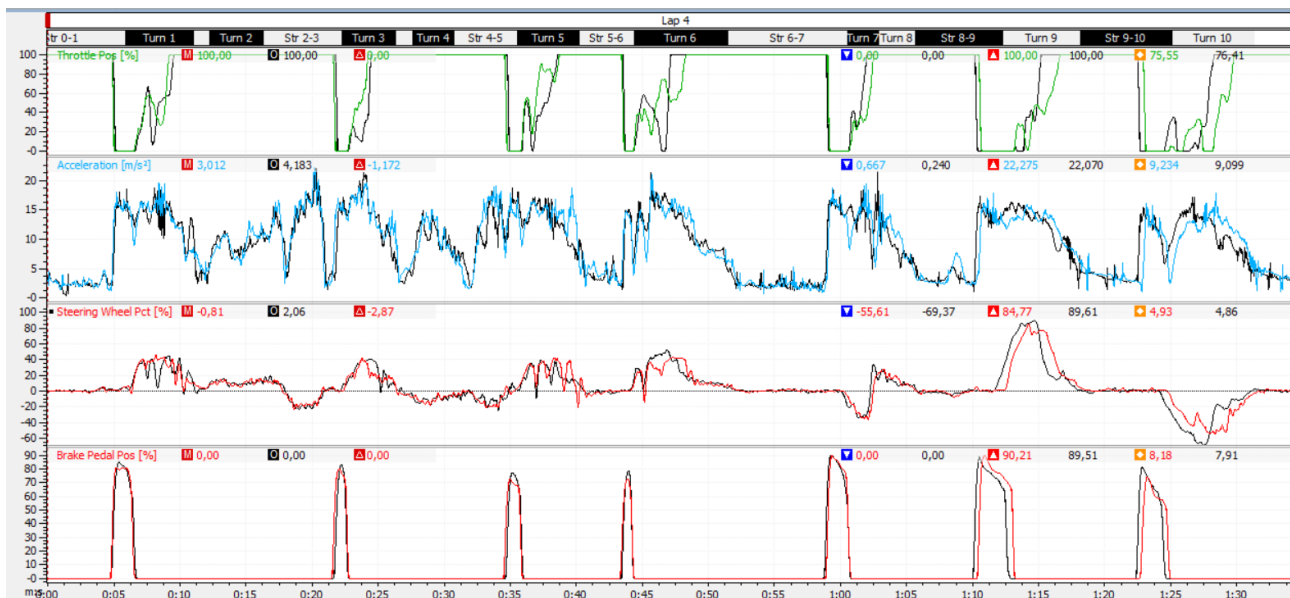


Figure 7: throttle, acceleration, steering wheel and break pedal comparison

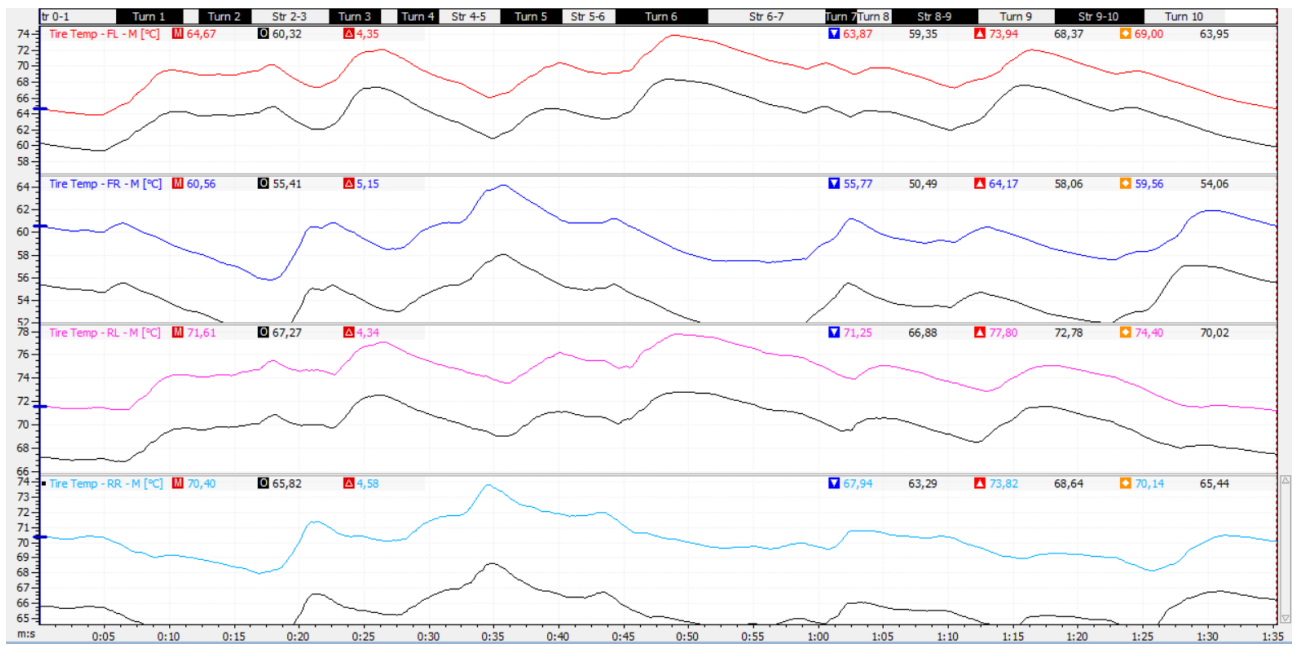


Figure 8: tyre temp comparison

3.2 FP3 and Qualifying

FP3 and Qualifying sessions were conducted on a separate day, reflecting typical race weekend conditions where later sessions occur after an interval. Following the identification of an optimal ride height during earlier phases, the focus shifted to refining the suspension setup.

This staged approach—isolating ride height before adjusting suspension parameters—enabled more controlled analysis by reducing interaction effects and improving the reliability of performance comparisons (Rajamani, 2012; Kaptein, Theeuwes and van der Horst, 1996).

Initial car settings:

Starting fuel	22 L (race refuelling not allowed)	Final Gear	40/105
Engine Rev Limit	7,250	1 st Gear	12/33 (7.219)
Weight Distribution (Front : Rear)	41.0 : 59.0	2 nd Gear	15/33 (5.775)
Lateral (Left : Right)	50.0 : 50.0	3 rd Gear	15/27 (4.725)
Steering Lock	14.0 deg	4 th Gear	17/26 (4.015)
Steering rotation	450.0 deg	5 th Gear	18/23 (3.354)
Aerodynamics front wing	1	6 th Gear	N/A
Aerodynamic rear wing	4	7 th Gear	N/A

Initial suspension settings:

	Font left	Front third spring	Front right
Tyre pressure	95 kPa	Detached	95 kPa
Camber	-3.0 deg	1	-3.0 deg
Caster	5.0 deg	1	5.0 deg
Spring rate	90 N/mm	1	90 N/mm
Slow bump	14	1	14

Slow rebound	14	0.0 cm	14
Fast bump	14	N/A	14
Fast Rebound	14	N/A	14
Packers	0.0 cm	N/A	0.0 cm
Ride height	4.8 cm	N/A	4.8 cm
Anti-roll bar	N/A	35 N/mm	N/A
Toe in	N/A	-0.60 deg	N/A

	Rea left	Rear third spring	Rear right
Tyre pressure	95 kPa	Detached	95 kPa
Camber	-2.5 deg	1	-2.5 deg
Spring rate	100 N/mm	1	100 N/mm
Slow bump	14	1	14
Slow rebound	14	0.0 cm	14
Fast bump	14	N/A	14
Fast Rebound	14	N/A	14
Packers	0.0 cm	N/A	0.0 cm
Ride height	6.2 cm	N/A	6.2 cm
Anti-roll bar	N/A	15 N/mm	N/A
Toe in	N/A	0.30 deg	N/A

Fuel consumption and tyre wear were enabled in all FP3 simulations to better represent race conditions and introduce realistic performance variability (Rajamani, 2012; Jamson, 2010).

Four test configurations were evaluated, each consisting of three laps:

- **Baseline setup:** Default vehicle configuration
- **Spring rate 1:** Front = 80 N/mm, Rear = 90 N/mm

- **Spring rate 2:** Front = 85 N/mm, Rear = 90 N/mm
- **Tyre pressure:** 100 kPa

These tests focused solely on human driver performance, with no AI benchmark runs. This approach assessed the driver's ability to adapt to setup changes under more realistic conditions, where tyre wear and fuel load introduce additional variability (Nitsch, Färber and Moussavi, 2008).

Run 1	1:34:439 (lap 1)
Run 2	1:34.048 (lap 3)
Run 3	1:33:613 (lap 3)
Run 3	1:33:617 (lap 3)

Driver's feedback

Run 1	Overall stable, with variations between understeer and oversteer depending on the section. Compared to earlier sessions, the vehicle felt quicker and more predictable.
Run 2	Improved rear-end stability at medium and high speeds, with reduced turn-in response and increased mid-corner understeer. Straight-line stability improved, but cornering responsiveness decreased.
Run 3	Neutral balance with no dominant understeer or oversteer. The vehicle was easy to control, allowing the driver to adjust rotation as required.
Run 4	No significant handling differences observed; minor variations were attributed to driver input rather than setup changes.

Red line: run 1, lap 1

Black line: run 3, lap 3

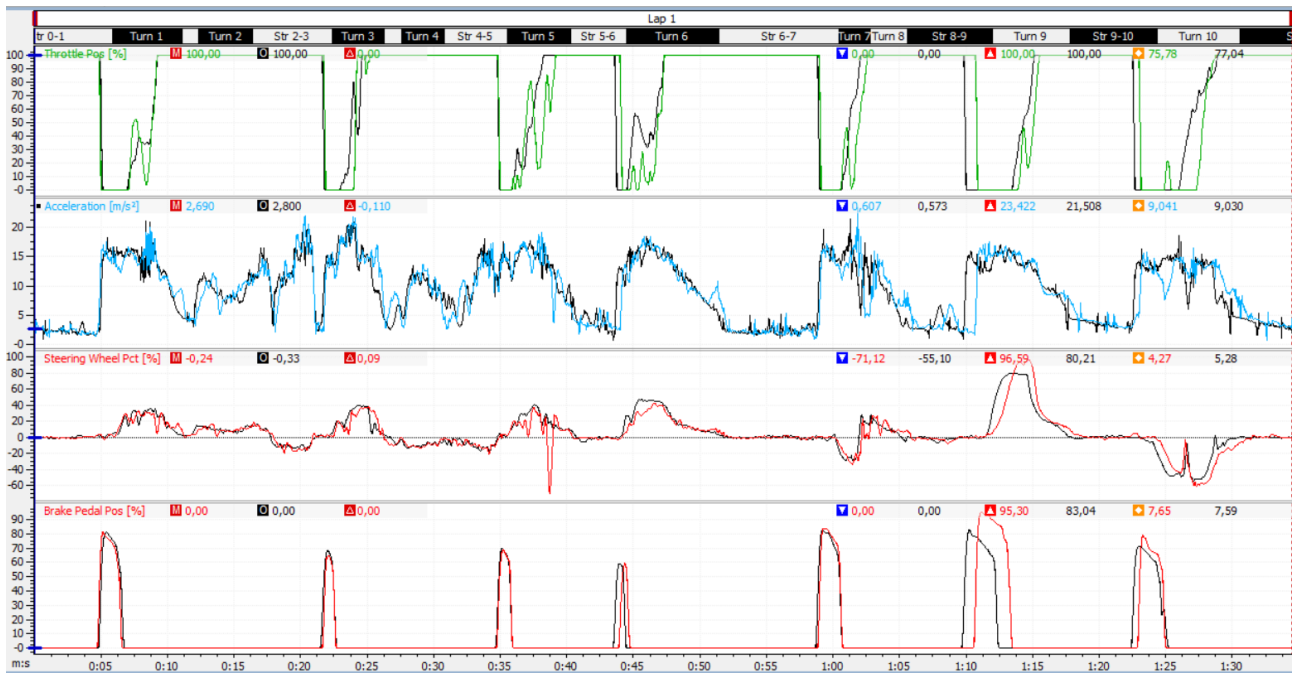


Figure 9: throttle, acceleration, steering wheel, brake pedal comparison

The primary performance improvements in Run 3 occurred at Turns 5, 9, and 10, where measurable lap time gains aligned with driver feedback indicating increased confidence during cornering. This suggests that a more neutral vehicle balance improved corner entry, mid-corner stability, and exit control.

Such improvements are consistent with the benefits of a balanced suspension setup, enabling higher cornering speeds and more consistent throttle application (Gillespie, 1992; Rajamani, 2012).

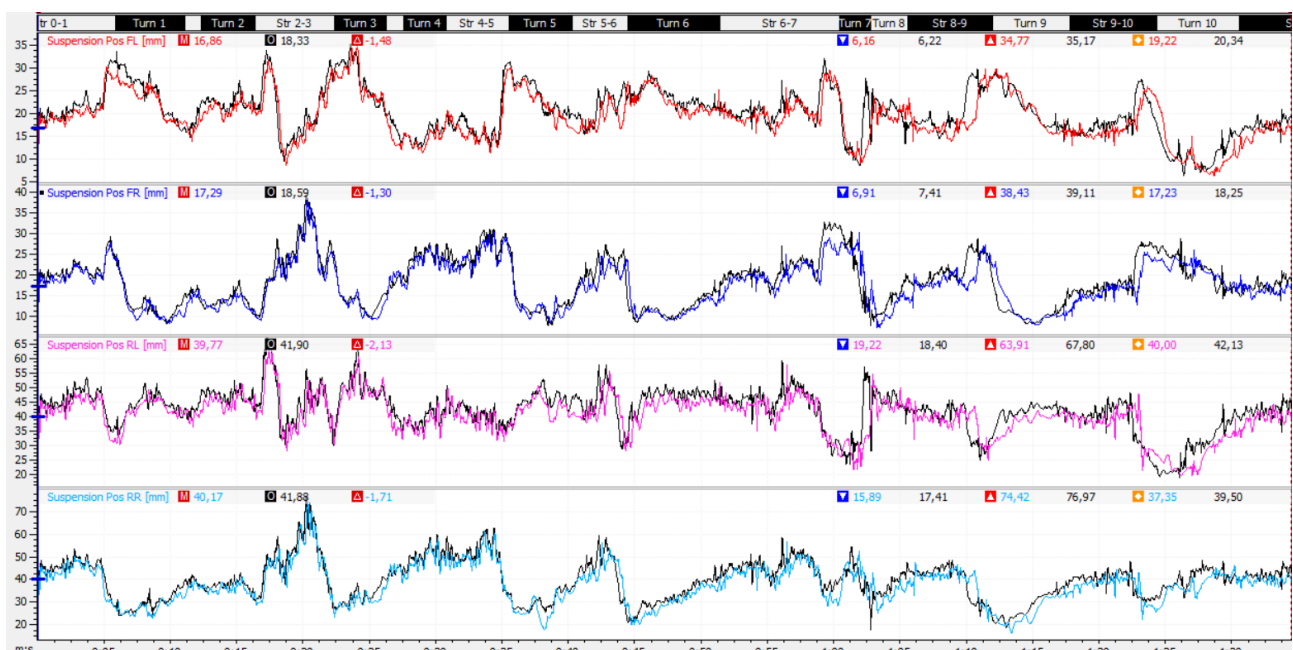


Figure 10: suspension position comparison

Overall, increased suspension stiffness improved vehicle stability and driver confidence during cornering and over track surface irregularities. This resulted in more predictable handling characteristics and reduced unwanted body motion, particularly in medium- and high-speed sections.

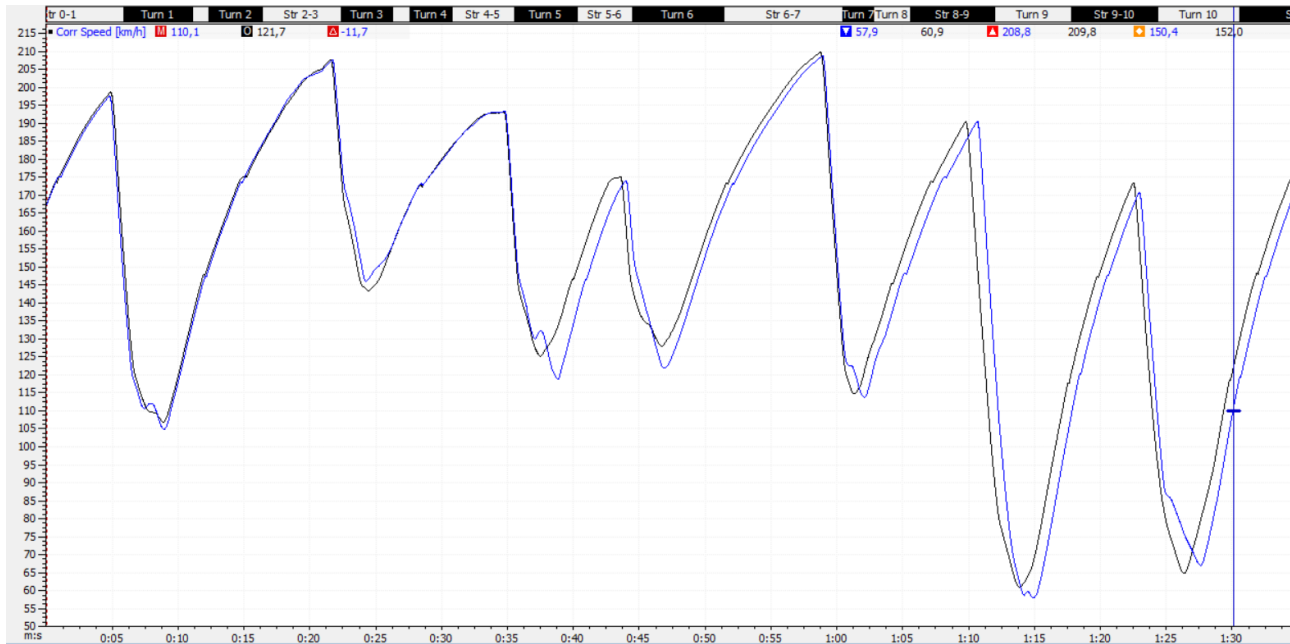


Figure 11: speed comparison

The top speed and overall speed profile remain largely consistent between runs up to Turn 5, indicating that straight-line performance and acceleration characteristics were not

significantly affected by the setup changes.

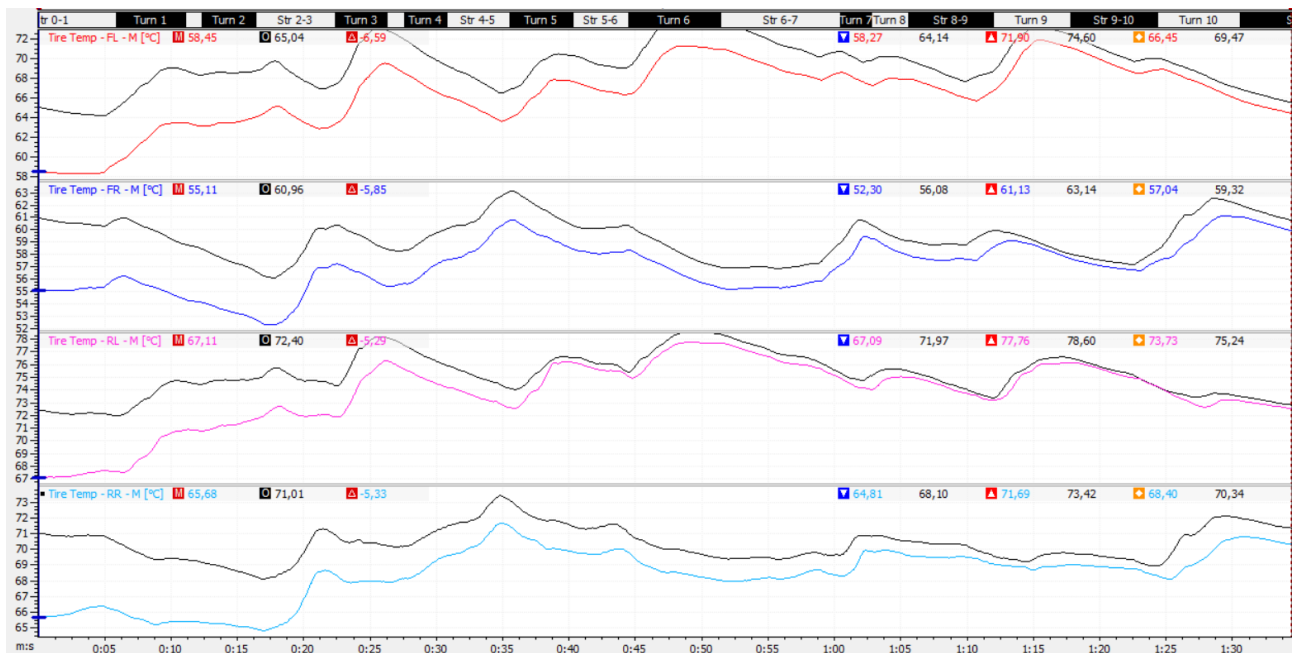


Figure 12: Tyre temp comparison

Tyre temperature increases during braking into Turn 5, reaching approximately 71°C, before stabilising through the corner and remaining consistent until the next braking zone at Turn 6.

For qualifying, the only change was a reduction in fuel load from 22 L to 13 L, resulting in improved lap time performance due to reduced vehicle mass.

The fastest qualifying laps recorded were:

Lap 1	1:33.251
Lap 2	1:33.587
Lap 3	1:33.265

Black line: lap 1

Coloured line: lap 2

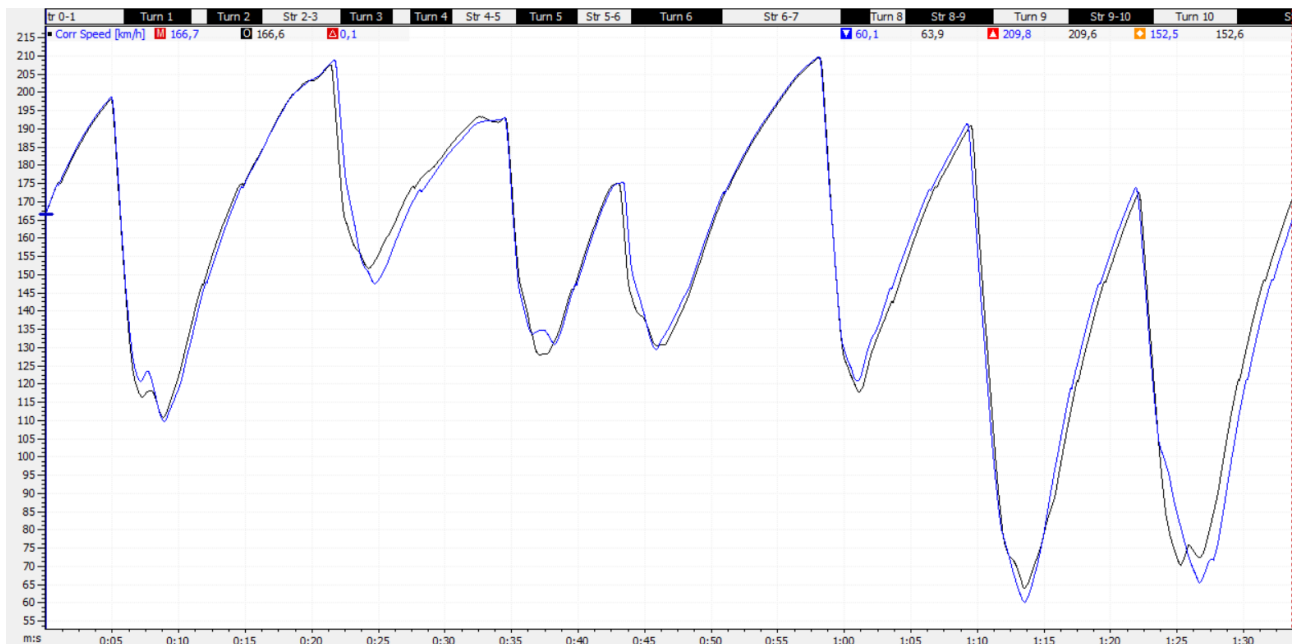


Figure 13: speed comparison

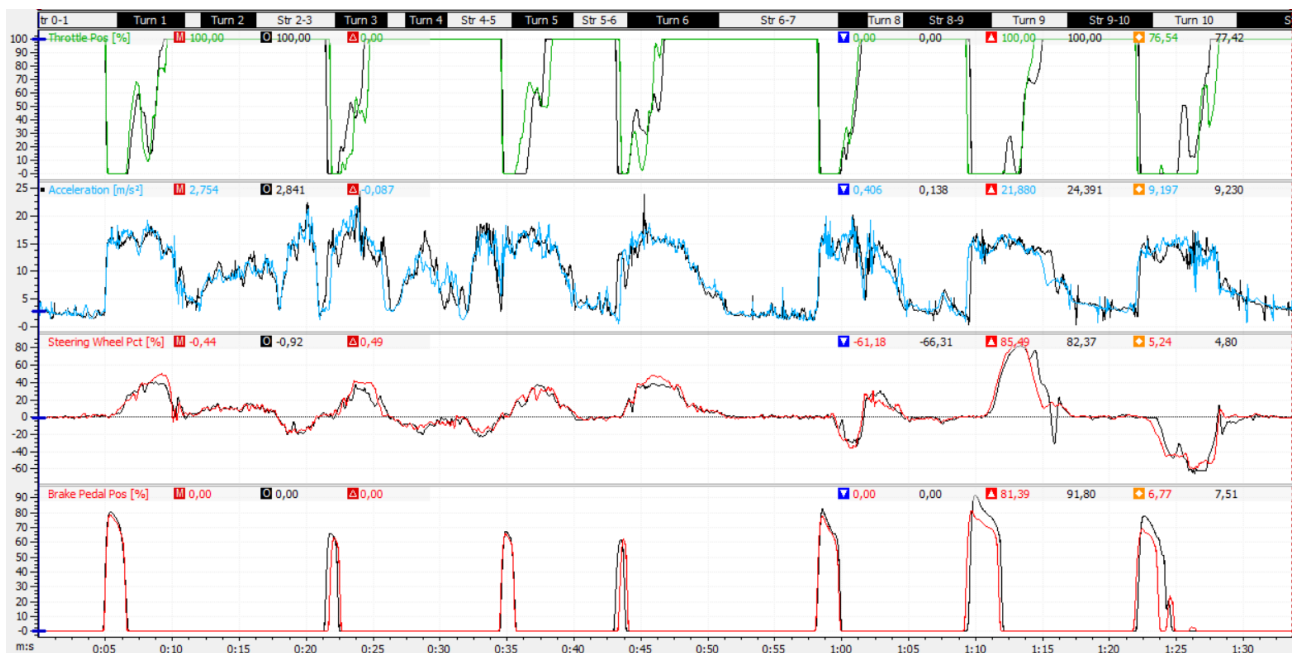


Figure 14: throttle, acceleration, steering wheel, brake pedal comparison

The main performance differences occur at Turns 3, 9, and 10, where more efficient braking in Lap 1 enables higher exit speeds onto the following straights. This behaviour is also reflected in the suspension position data, indicating more controlled load transfer during braking phases.

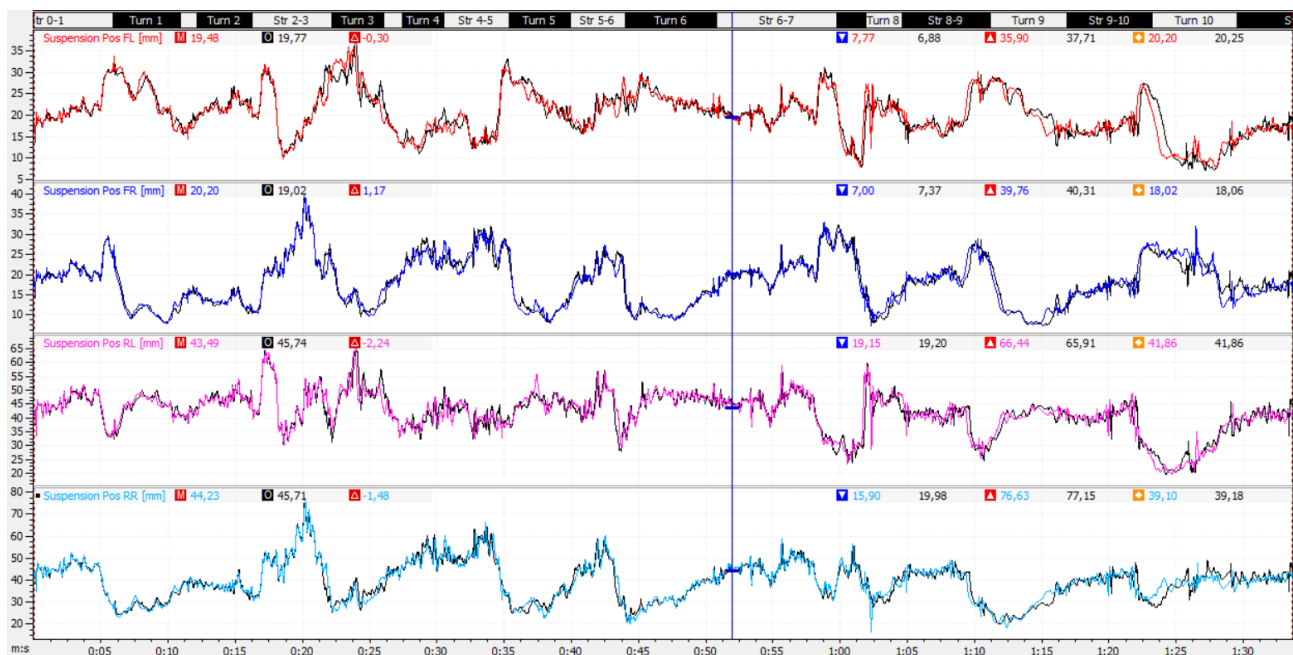


Figure 15

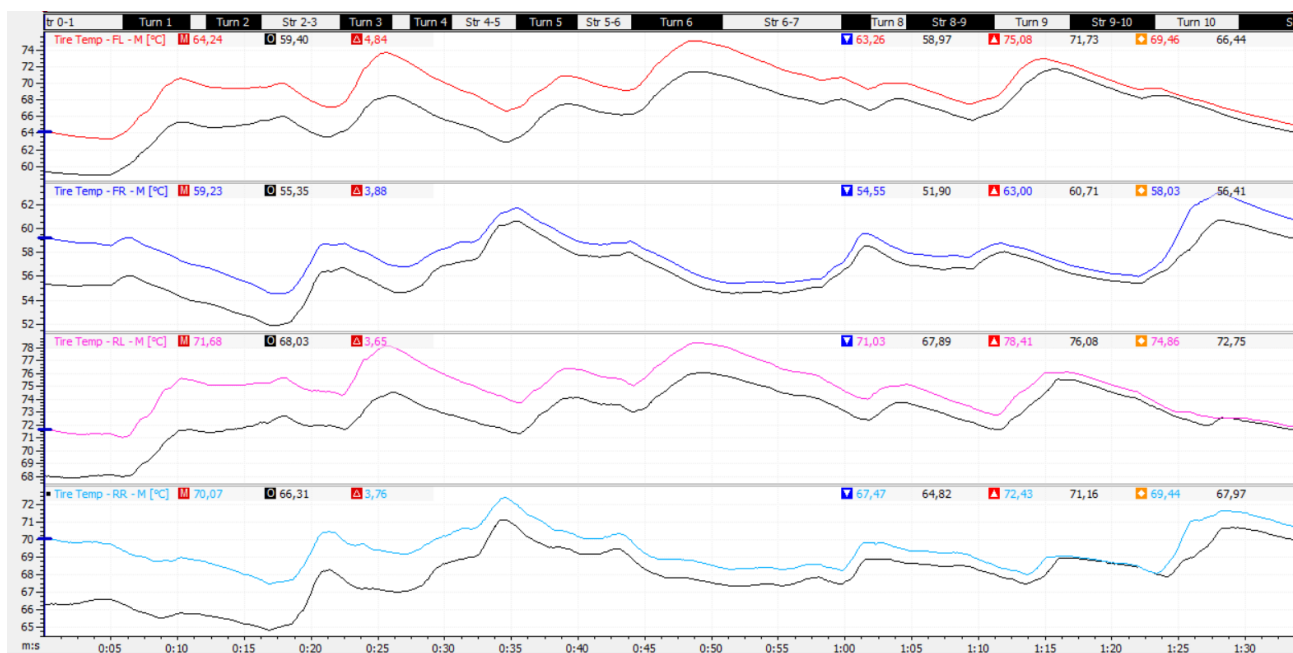


Figure 16

Tyre temperature trends directly correlate with braking intensity.



Figure 17: fuel consumption

Fuel consumption shows a near-linear trend with short plateaus before corners, suggesting consistent use of lift-and-coast to reduce fuel usage before braking.

3.3 Race

Race was run at Pembrey circuit for two main reasons: first to see if the same settings result in same performances and same driver's feedback, and second to have a larger number of laps on a thinner circuit thus putting more stress on the driver.

The race event has a time cap of 25 minutes, which means that at Pembrey there would be 21 laps approximately.

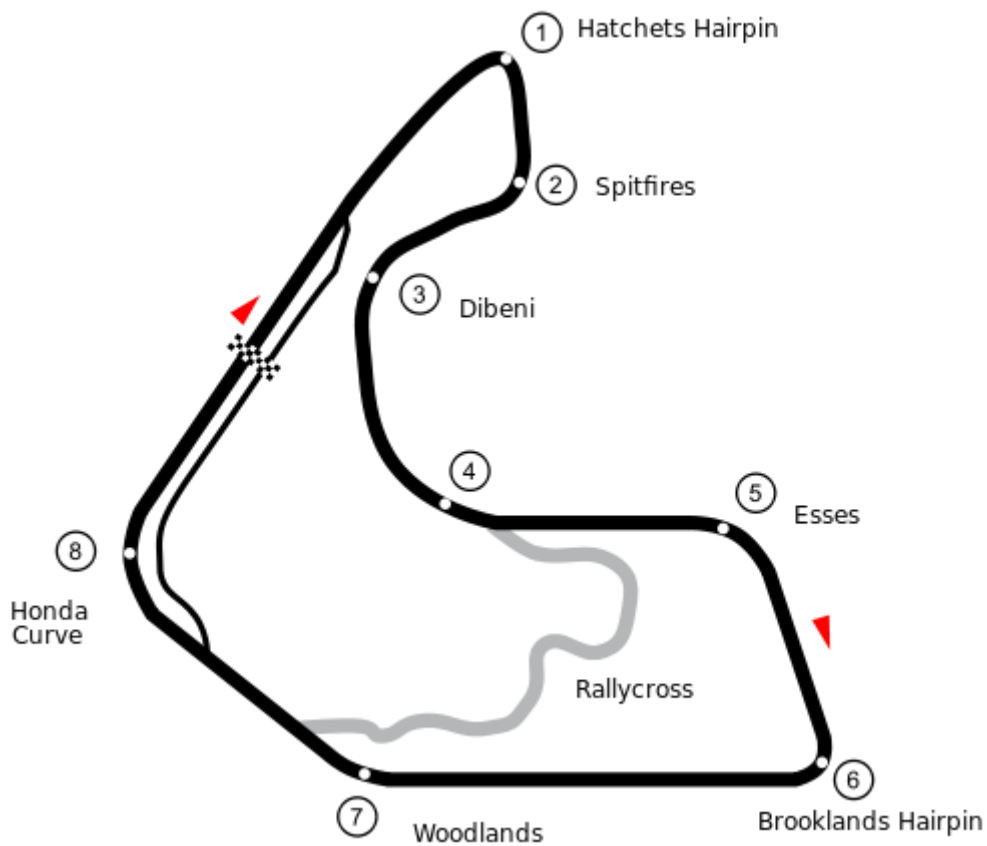


Figure 18: Pembrey Circuit

For the race the driver had to run against other 15 AI generated medium skilled drivers to test traffic conditions in the first part and racing with fresh air in the second part.

Lap 1 – 2

Lap 1	1:00.204
Lap 2	0:59.798

Coloured line: Lap 1

Black line: Lap 2

Starting 12th out of 16, the driver recovered from an initial incident and began gaining positions after Turn 7 as pace improved.

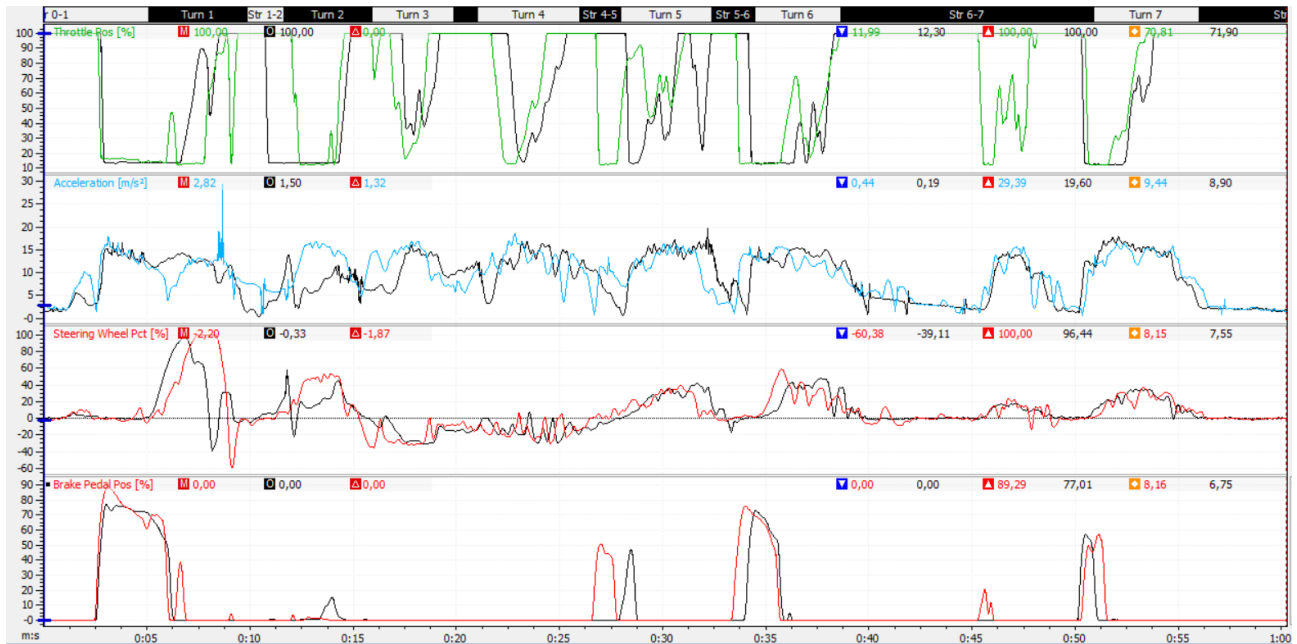


Figure 19: throttle, acceleration, steering wheel, brake pedal position comparison

Suspension position data is consistent with hard braking events, indicating significant load transfer.

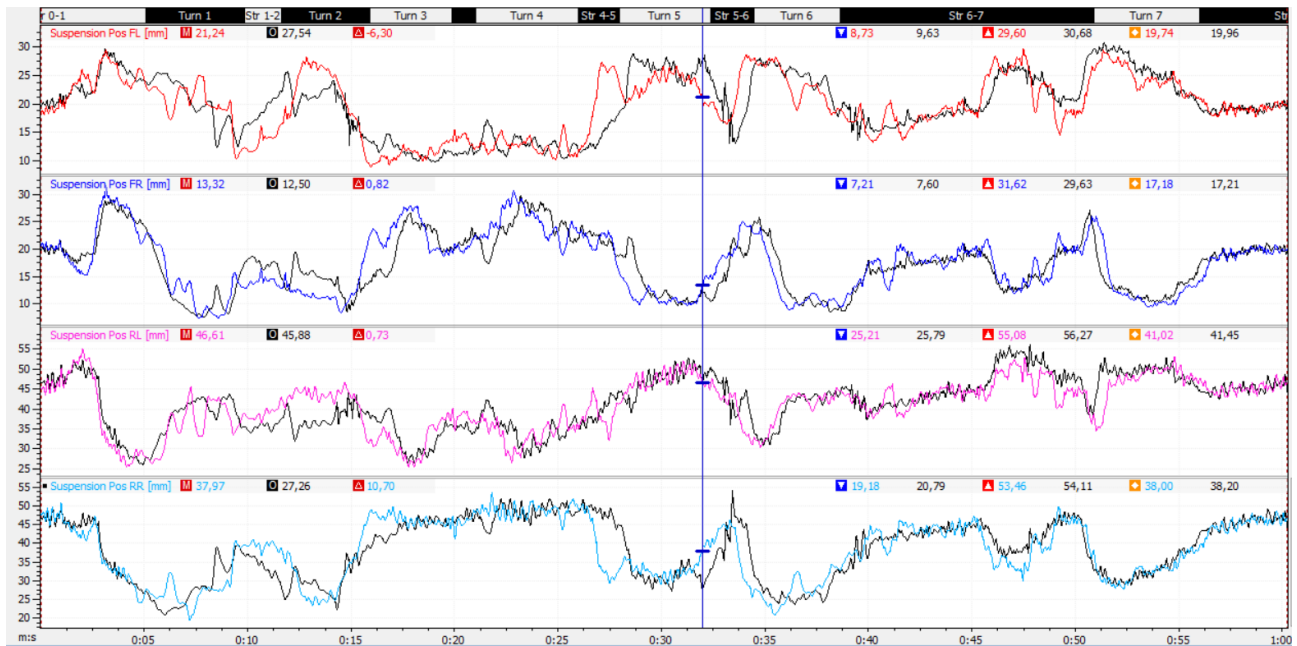


Figure 20: Suspension position comparison

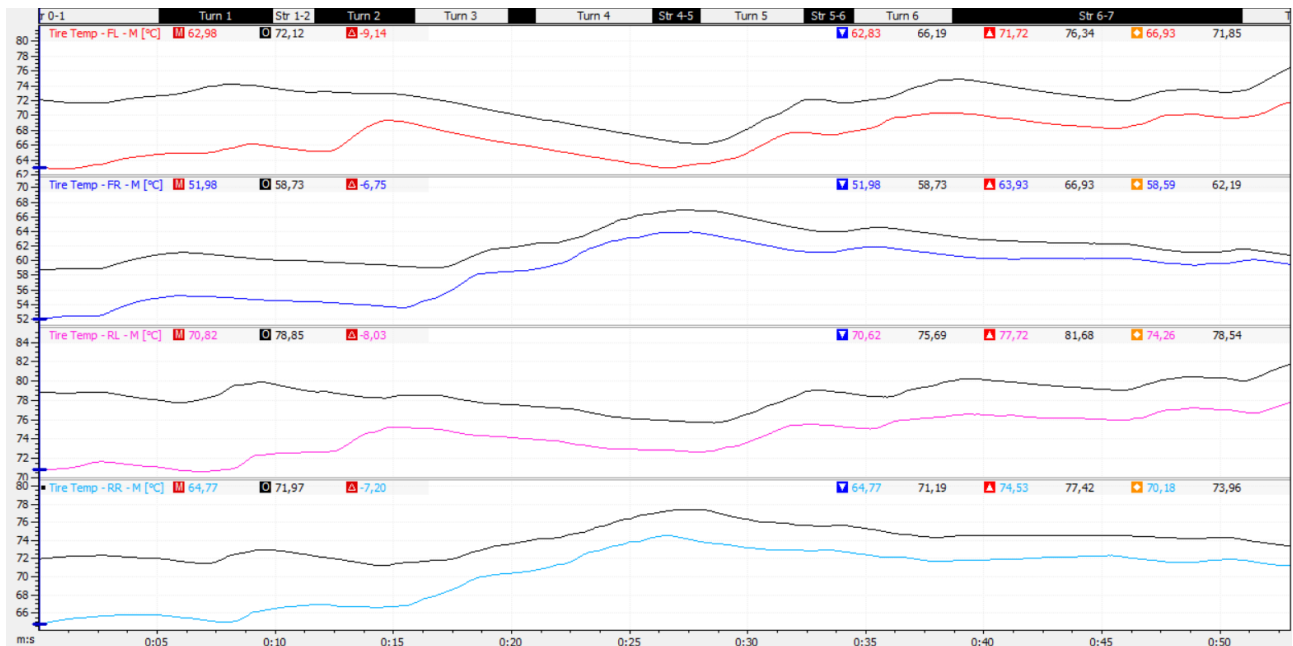


Figure 21: tyre temperature comparison

Tyre temperature trends indicate higher thermal load on the left-side tyres.



Figure 22: fuel comparison

Fuel consumption follows a linear trend with no significant fluctuations.

Lap 3 – 11:

Lap 3	0:58.561
Lap 4	0:59.093
Lap 5	0:59.805
Lap 6	0:58.772

Lap 7	0:58.396
Lap 8	0:58.313
Lap 9	0:58.609
Lap 10	0:58.051
Lap 11	1:00.051

Coloured line: lap 8

Black line: lap 11

Performance in traffic remained consistent overall, though irregular steering inputs in Lap 11 (Turns 2–4) suggest increased driving corrections. Turn 6 was identified as the most time-consuming section.



Figure 23

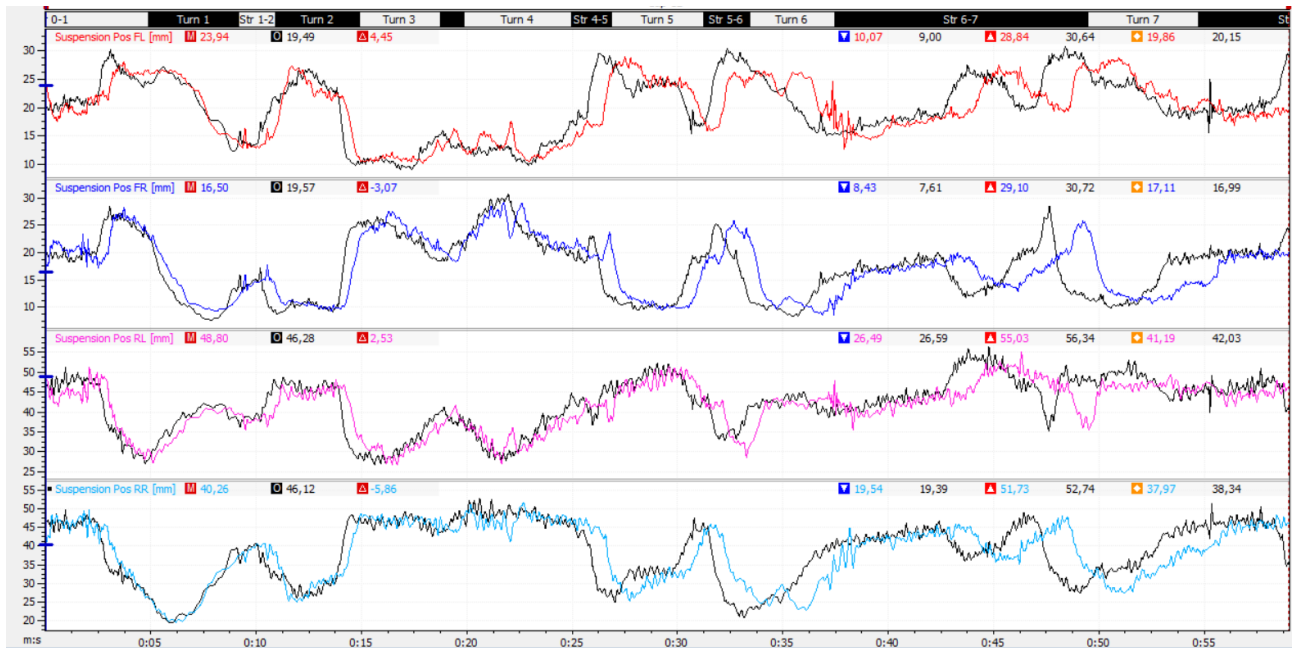


Figure 24

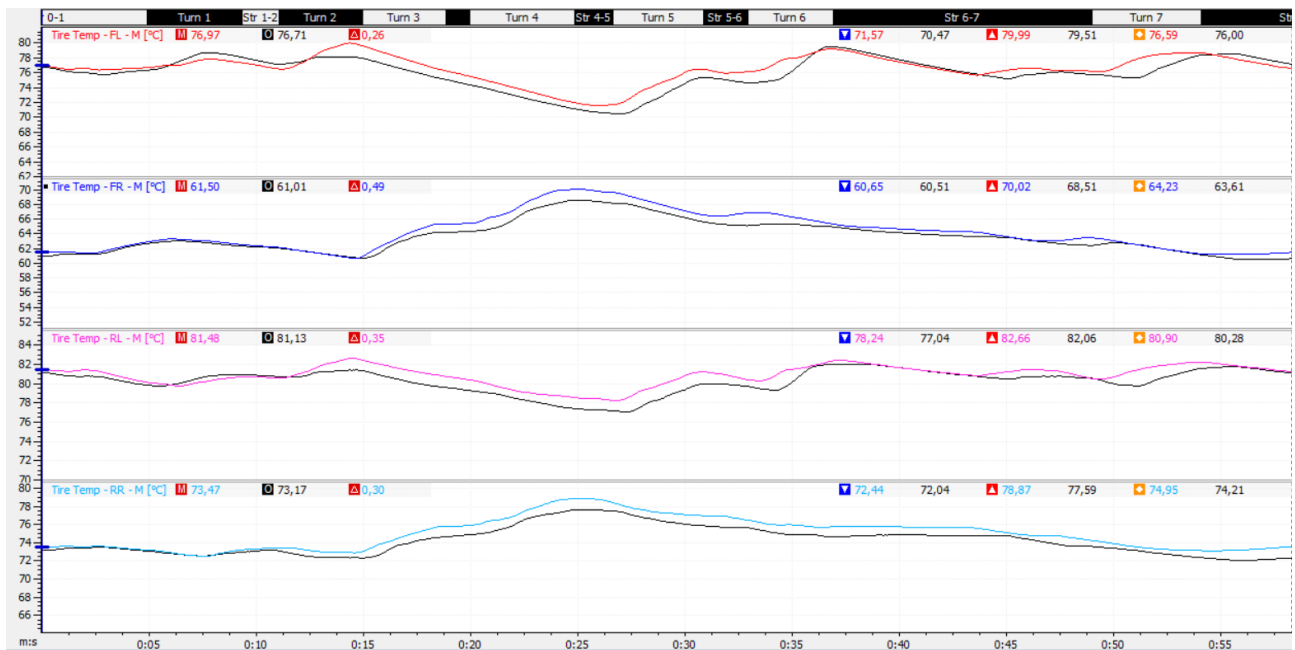


Figure 25

Tyre temperatures drop in Lap 11 as traffic influence decreases.



Figure 26

Lap 12 – 21

Lap 12	0:58.982
Lap 13	0:58.571
Lap 14	0:58.030
Lap 15	0:57.884
Lap 16	0:57.670
Lap 17	0:58.052
Lap 18	0:57.873
Lap 19	0:57.674
Lap 20	0:57.482
Lap 21	0:56.784

Coloured line: lap 12

Black line: lap 17

Green line: lap 21

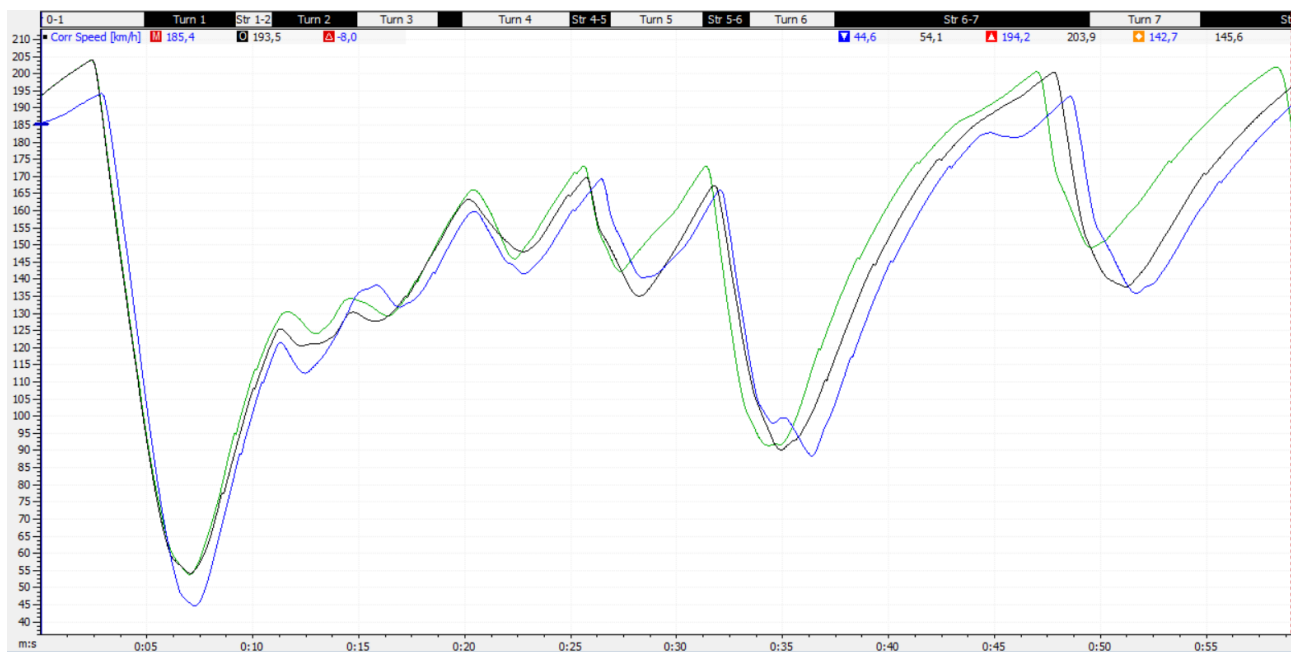


Figure 27

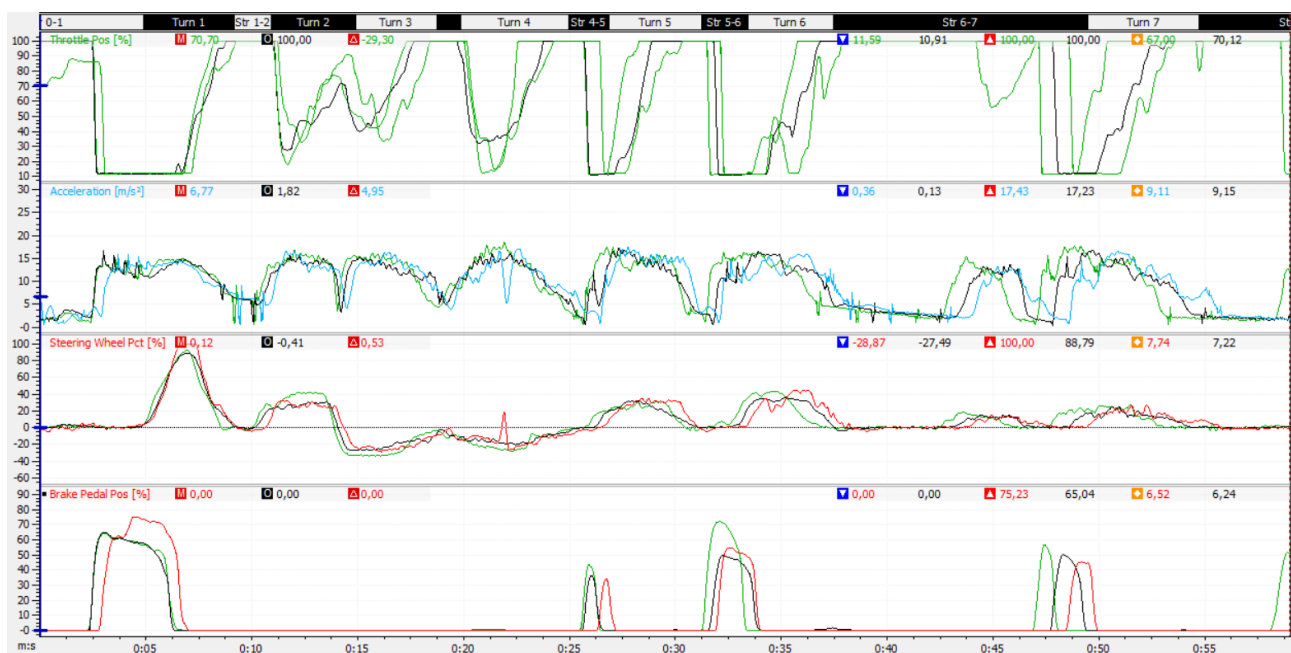


Figure 28

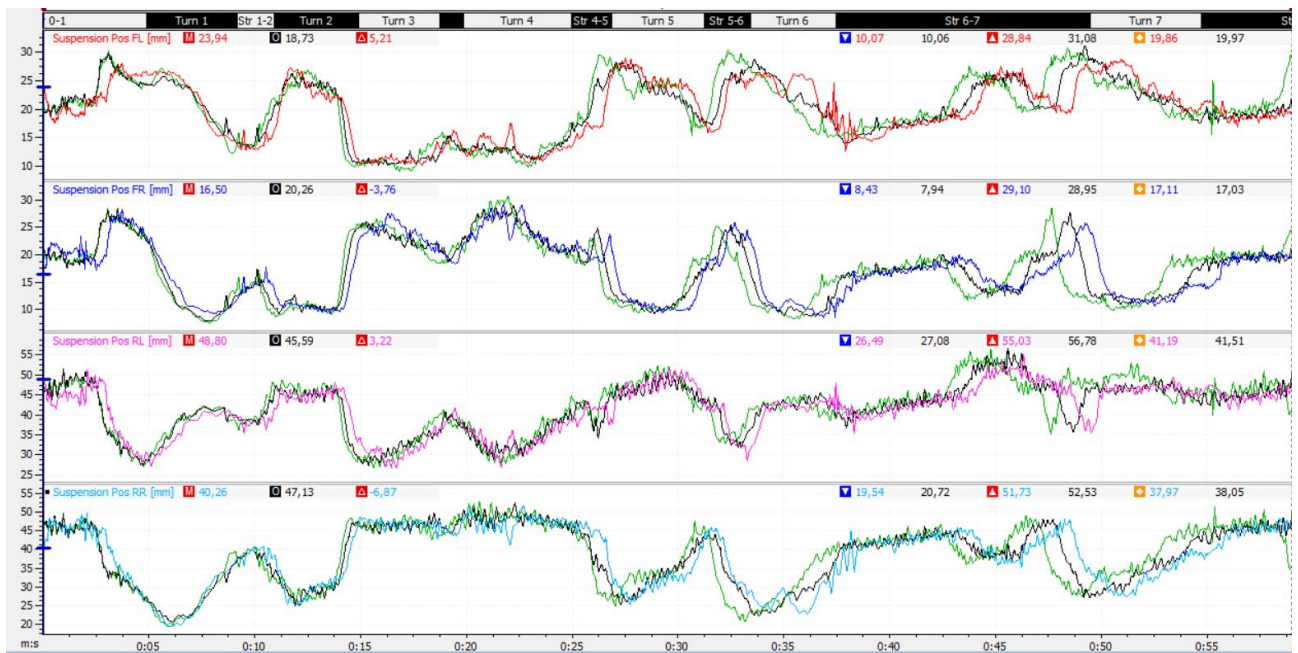


Figure 29

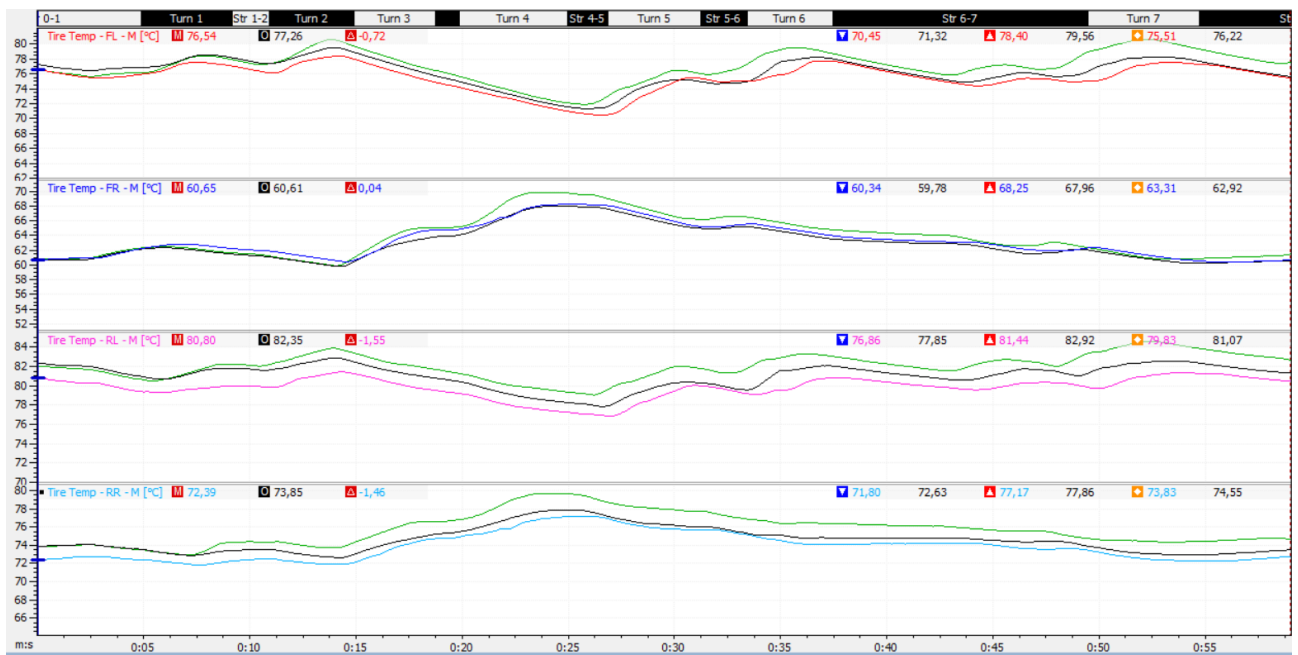


Figure 30



Figure 31

In clear air, performance improved progressively as fuel load decreased and track conditions stabilised, resulting in consecutive fastest laps until Lap 17, where time was lost after Turn 5. The driver ultimately won the race.

Driver feedback indicated mild understeer, though the vehicle remained predictable and easy to control, allowing operation at approximately 95% pace with the ability to induce rotation when required.

AI competitors exhibited unrealistic behaviour, including short gear ratios that favoured cornering at the expense of straight-line speed, leading to inconsistent and non-representative race pace. Additionally, their aggressive driving style, late reactions, and frequent line changes under braking reduced realism.

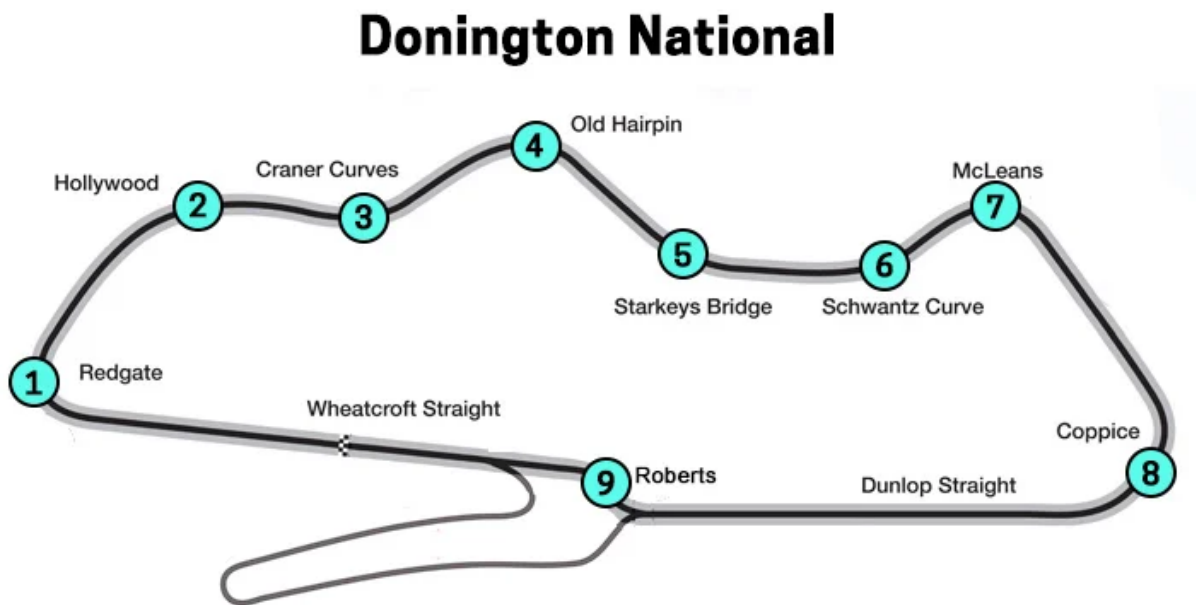
During the opening laps, cold tyres and brakes negatively affected vehicle balance, making overtaking in traffic more challenging.

4. Recommendations for improvement

Further improvements are constrained by simulator limitations, including restricted suspension parameters, simplified aerodynamic modelling, and limited ride height range. In particular, the maximum ride height does not replicate real-world MCR #40 configurations (2020–2022), reducing setup accuracy and correlation with on-track performance.

5. Critical comparison & contrast between simulation model against real-world

Real-world comparison at Donington Park is constrained by differences in circuit configuration, as the championship layout excludes Turns 9–11, limiting the validity of direct performance correlation.



Historical data indicates that the fastest recorded lap was set by Professor Tudor, with a time of 1:09.745 during Race 1 in 2022.

At Pembrey, direct comparison is further complicated by variable weather conditions and its primary use as a test circuit rather than a championship venue. As a result, setups developed at Pembrey are not always transferable to other tracks. This was observed in the simulation, where an identical setup produced understeer at Pembrey but achieved a well-balanced performance at Donington Park.

5. Conclusion

This study demonstrated the effectiveness of Driver-in-the-Loop (DIL) simulation as a tool for evaluating driver performance and optimising vehicle setup within a controlled motorsport environment. By replicating a full race weekend, the methodology enabled systematic analysis of both quantitative performance metrics and qualitative driver feedback.

The results showed that while AI driver models provide a useful upper-bound benchmark, they do not fully represent realistic driving behaviour. Consequently, human driver feedback proved essential in identifying setups that enhance confidence, consistency, and overall controllability. The optimal configuration was achieved through a balanced suspension setup, which provided a neutral handling characteristic and allowed the driver to maintain higher cornering performance while retaining adaptability.

Performance gains were primarily associated with improved cornering efficiency rather than straight-line speed, highlighting the importance of vehicle balance and driver interaction. Additionally, the study confirmed that setup effectiveness is circuit-dependent, with limited transferability observed between Pembrey and Donington Park.

However, several limitations were identified, including simplified aerodynamic modelling, lack of tyre degradation effects, and restricted setup parameters. These factors reduce the accuracy of real-world performance correlation, particularly over longer runs and varying environmental conditions.

Overall, DIL simulation represents a valuable tool for driver and vehicle development but should be used in conjunction with real-world testing to ensure comprehensive validation and reliable performance optimisation.

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