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***Track-Based Vehicle Dynamics Analysis and
Performance Evaluation of the Aprilia
RS660/Bucci***

Motorcycle Dynamics and Data Acquisition (ACHA7020)

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1. Introduction

This report analyses data collected during a track test involving two motorcycles: a Bucci and an Aprilia RS660. Data from the Bucci was recorded using a MoTeC data logging system. The Bucci platform allowed setup changes to be made and recorded during the test. These changes were evaluated by comparing velocity traces and suspension position data to identify how setup adjustments affected performance and vehicle behaviour. Data from the Aprilia RS660 was recorded using a 2D data acquisition system and was used mainly for comparison of rider behaviour. In addition to rider behaviour analysis, data from the Aprilia RS660 was also used to investigate the relationship between steering input and motorcycle roll behaviour using handlebar-mounted strain gauges. Rider behaviour was measured using gyroscopes fitted in the rider's suit, which recorded the rider's body angle. By comparing rider body angle with motorcycle lean angle, changes in rider position and their relationship to motorcycle behaviour could be assessed (Sequenzia et al., 2014).

The aim of this report is to evaluate the effect of setup changes on the Bucci motorcycle and to compare rider behaviour across both motorcycles, demonstrating how track-acquired data can be used to understand handling and performance.

2. Vehicles, Geometry & Test Context

This section provides contextual information on the test environments, motorcycles, and baseline configurations used during the study.

2.1 Track Characteristics and Test Environment



Figure 1: Kinsham track with route outlined

Testing of the Bucci motorcycle was carried out at Kinsham, a compact kart-style circuit characterised by a short lap length (roughly 720 metres), and a high frequency of direction changes (Figure 1).

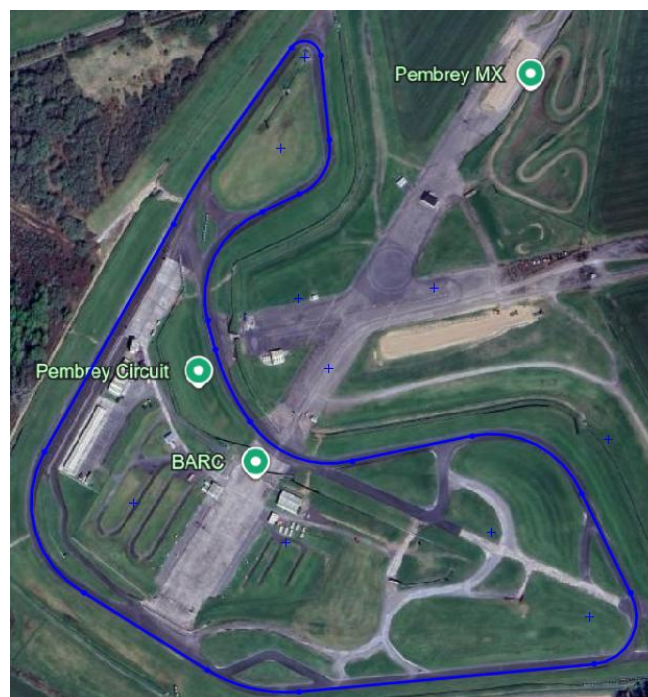


Figure 2: Pembrey track with route outlined

The Aprilia RS660 was tested at Pembrey Circuit, a significantly larger and faster circuit with longer straights and more open corner geometry (Figure 2). The layout includes a combination of medium- and high-speed corners, which place greater emphasis on stability, rider confidence, and control under sustained lean.

2.2 Track Conditions and Tyres



Figure 3: Aprilia RS660 at pembrey (water on track visible)

Track conditions differed notably between the two test days. At Pembrey, the circuit was wet throughout the test day due to heavy rainfall, resulting in consistently low grip conditions (Figure 3). The Aprilia RS660 was fitted with wet tyres for all running in order to maintain safety and consistency. These conditions influenced rider inputs and motorcycle behaviour and are considered when interpreting results later in the report.

At Kinsham, the track surface was slightly wet at the beginning of the test day but dried early as running continued. This resulted in gradually improving grip conditions over time. The Bucci was fitted with wet tarmac tyres, which remained appropriate throughout the session given the initial conditions and the nature of the circuit.

2.3 Motorcycles and Baseline Setup



Figure 4: Aprilia RS660 in between sessions

Two different motorcycles were used in this study. The Aprilia RS660 is a production-based middleweight motorcycle and is treated in this report as a reference platform rather than a development vehicle (Figure 4). No geometry or setup changes to the Aprilia are considered within the scope of this study.

The Bucci is a pit bike platform configured for testing and development work. Prior to testing, the motorcycle was set up with a defined baseline suspension and preload configuration. All baseline settings and subsequent changes were documented using a setup sheet and are referenced later in the report where relevant.

2.4 Geometry Information

Table 1: bike geometry info (where available)

	BUCCI	APRILLIA
WHEELBASE	1200 mm	1390 mm
MASS		166 kg
RAKE		23.55 deg
TRAIL		104.6 mm
SEAT HEIGHT	830 mm	815 mm
TRIPLE CLAMP OFFSET		30 mm
SWINGARM LENGTH		540 mm
REAR WHEEL RADIUS		314 mm
FRONT WHEEL RADIUS		300 mm

The baseline geometric parameters for both motorcycles are summarised in Table 1. These values describe the configuration of each motorcycle during the test sessions and provide necessary reference information for later sections of the report. Geometry-related analysis is presented separately and is not discussed further in this section.

3. Data Acquisition & Methodology

This section describes the data acquisition systems used during the test days, the signals recorded from both motorcycles and the rider, and the methodology used to align and select data for analysis. The methodological choices reflect the different objectives of each test platform and provide the basis for the analyses presented in subsequent sections.

3.1 Data Acquisition Systems

Data from the Bucci motorcycle were recorded using a MoTeC C125 data logging system. The system recorded speed, suspension movement, braking, and motorcycle attitude.

Data from the Aprilia RS660 were recorded using a 2D data acquisition system. The system recorded both vehicle dynamics data and inertial measurements from the motorcycle. The Aprilia was fitted with two six-axis inertial measurement units (IMUs), providing information on motorcycle orientation and angular rates.

Rider motion was measured independently using gyroscopes integrated into the rider's suit. These sensors recorded rider roll rate, rider body angle, and rider movement. Rider data were logged separately from the motorcycle data on both test days.

3.2 Signals Recorded

For both motorcycles, velocity data were recorded and used as the primary reference for comparing laps. Suspension position was measured independently at the front and rear of the motorcycle, allowing changes in suspension behaviour to be assessed separately for each axle. Brake pressure data were recorded to identify braking events and braking intensity.

Motorcycle attitude was captured through measurements of lean angle and roll rate. Roll rate was used as the primary dynamic response variable for comparison with steering input measured via handlebar strain gauges on the Aprilia RS660. These signals were obtained from onboard inertial sensors fitted to the motorcycles. For the Aprilia RS660, inertial data were provided by the two six-axis IMUs. Rider behaviour was characterised using roll rate and body angle measured from the suit-mounted gyroscopes, allowing rider motion to be compared with motorcycle motion. Handlebar strain measurements were treated as an indirect representation of steering load rather than direct steering torque.

3.3 Data Synchronisation and Alignment



Figure 5: Bucci data trace, session 2 vs session 3 comparison

Because rider data and motorcycle data were logged separately, post-processing was required to align the datasets. Velocity traces and GPS data were used as the primary references for synchronisation as seen in the Figure 5 comparison. Velocity and GPS features were aligned to bring rider and motorcycle signals into a common time base.

This approach allowed direct comparison between rider motion and motorcycle response during the same sections of track.

3.4 Lap Selection Criteria

Laps	Time				Time Offset	Distance Off...
Kinsham, kinshan						
05/12/2025, outing 1						
12:11:31, .20251205-114920000.Jd						
Out Lap	26:57.518				+26:00.599	0:00.000 0:00
Lap 1	1:00.189				+0:03.270	0:00.000 0:00
Lap 2	0:57.992				+0:01.073	0:00.000 0:00
Lap 3	0:57.554				+0:00.635	0:00.000 0:00
Lap 4	0:56.919				+0:00.000	0:00.000 0:00
In Lap	1:04.825				+0:07.906	0:00.000 0:00
05/12/2025, outing 2						
12:32:07, .20251205-114920001.Jd						
Out Lap	0:22.173				+0:16.900	0:00.000 0:00
Lap 1	0:58.407				+0:53.135	0:00.000 0:00
Lap 2	0:05.272				+0:00.000	0:00.000 0:00
Lap 3	0:55.803				+0:50.531	0:00.000 0:00
Lap 4	0:07.876				+0:02.603	0:00.000 0:00
Lap 5	0:56.398				+0:51.126	0:00.000 0:00
Lap 6	0:07.281				+0:02.008	0:00.000 0:00
Lap 7	0:55.702				+0:50.429	-0:31.382 -357.00
Lap 8	0:08.539				+0:03.267	0:00.000 0:00
In Lap	0:24.107				+0:18.834	0:00.000 0:00
05/12/2025, outing 3(rear preload, front comp)						
13:01:08, .20251205-114920002.Jd						
Out Lap	1:00.173				+0:53.808	0:00.000 0:00
Lap 1	0:57.315				+0:50.951	0:00.000 0:00
Lap 2	0:06.364				+0:00.000	0:00.000 0:00
Lap 3	0:54.645				+0:48.281	0:13.942 215.00
Lap 4	0:09.098				+0:02.733	0:00.000 0:00
Lap 5	0:55.665				+0:49.301	0:04.699 45.00
Lap 6	0:08.086				+0:01.722	0:00.000 0:00
In Lap	0:58.787				+0:52.422	0:00.000 0:00
05/12/2025, outing 4						
13:29:27, .20251205-114920003.Jd						
Out Lap	0:54.173				+0:46.002	0:00.000 0:00
Lap 1	0:55.035				+0:46.864	0:00.000 0:00
Lap 2	0:08.644				+0:00.473	0:00.000 0:00
Lap 3	0:55.509				+0:47.338	0:00.000 0:00
Lap 4	0:08.170				+0:00.000	0:00.000 0:00
Lap 5	0:54.652				+0:46.481	-0:00.943 -10.00
Lap 6	0:09.191				+0:01.020	0:00.000 0:00
In Lap	0:50.787				+0:42.616	0:00.000 0:00
05/12/2025, outing 5						
13:39:42, .20251205-114920004.Jd						
Out Lap	0:36.173				+0:29.066	0:00.000 0:00
Lap 1	0:56.573				+0:49.466	0:00.000 0:00
Lap 2	0:07.106				+0:00.000	0:00.000 0:00
Lap 3	0:54.332				+0:47.225	0:00.000 0:00
Lap 4	0:09.347				+0:02.240	0:00.000 0:00
Lap 5	0:53.997				+0:46.890	-0:41.166 -522.00
Lap 6	0:10.457				+0:03.351	0:00.000 0:00
In Lap	0:07.787				+0:00.680	0:00.000 0:00
05/12/2025, outing 6						
13:53:12, .20251205-114920005.Jd						
Out Lap	1:01.173				+0:53.830	0:00.000 0:00
Lap 1	0:56.337				+0:48.995	0:00.000 0:00
Lap 2	0:07.342				+0:00.000	0:00.000 0:00
Lap 3	0:55.026				+0:47.684	0:00.000 0:00
Lap 4	0:08.653				+0:01.311	0:00.000 0:00
Lap 5	0:54.460				+0:47.118	0:14.507 220.00
Lap 6	0:09.157				+0:01.815	0:00.000 0:00
Lap 7	0:55.225				+0:47.883	0:00.000 0:00
Lap 8	0:08.454				+0:01.112	0:00.000 0:00
In Lap	0:58.107				+0:50.764	0:00.000 0:00

Figure 6: Bucci laps separated manually by distance (720 m) (values below 52 seconds have been identified as errors)

Different lap selection approaches were used for each motorcycle, reflecting their different roles within the study. For the Bucci, the fastest lap from each session was selected for analysis, with laps separated manually by distance (Figure 6). This approach ensured that comparisons between setup conditions were based on representative laps with consistent rider intent. For the Aprilia RS660, laps were selected randomly from the available data. This reflects the use of the Aprilia as a reference platform for rider behaviour rather than for setup or performance optimisation. Laps affected by known ECU map issues were excluded prior to selection.

4. Geometry Influence on Handling – Bucci

Table 2: Bucci setups

	sessions					
Setup features	1	2	3	4	5	6
front rebound	7/22	7/22	7/22	10/22	10/22	10/22
Front compression	11/22	11/22	20/22	22/22	22/22	22/22
Rear rebound	26/46	26/46	26/46	46/46	46/46	46/46
Rear compression	19/42	19/42	19/42	25/42	42/42	42/42
Rear preload	baseline	baseline	Reduced 1.5 mm	Reduced 1.5 mm	Reduced 1.5 mm	Reduced 1.5 mm

This section examines how geometry- and setup-related changes influenced the dynamic behaviour of the Bucci motorcycle during the Kinsham test day. Only sessions where setup changes were applied are considered (setups seen in Table 2), in order to focus on cause–effect relationships rather than baseline repeatability.



Figure 7: Bucci data trace, session 3 vs session 4 comparison

A reduction in rear suspension preload produced the most pronounced change in vehicle behaviour. Following this adjustment, rear suspension position showed increased travel under acceleration, with the rear operating lower in the stroke and exhibiting higher suspension velocity. During braking phases, front suspension

response is strongly influenced by longitudinal load transfer effects, which act in addition to static loading and setup-related characteristics (Hesapchieva and Yanachkov, 2025, Section: Experimental results). Front suspension data showed delayed compression at several braking points, consistent with reduced rear ride height. Despite the increased rear compliance, fastest lap performance did not improve, indicating that the altered balance did not provide a net advantage on the Kinsham circuit.

Subsequent changes focused on rear damping, with increases in compression and rebound damping applied. These adjustments reduced rear suspension velocity and kept the rear suspension closer to its static position through braking and acceleration phases, indicating improved control and stability, as seen in Figure 7 (Garziad and Saka, 2018, Section: introduction). Increased rebound damping was particularly effective in limiting suspension recovery between successive braking zones, resulting in a more settled rear. However, this improved control was accompanied by reduced responsiveness, which is undesirable on a tight circuit with frequent direction changes (Carratù et al., 2018, Section: V. Experimental Results) (Podosek et al., 2023, Section: Introduction). Lap time data reflect this trade-off, showing no improvement and, in some cases, a slight reduction in performance (BalaMurugan and Jancirani, 2012, Section: Overview).

Overall, the results show that rear preload and damping changes have a clear influence on suspension behaviour and front–rear balance (Podosek et al., 2023, Section: Introduction). However, on a low-speed, technical circuit such as Kinsham, improvements in mechanical stability do not necessarily translate to faster lap times, highlighting the importance of matching geometry and damping choices to circuit characteristics.

5. Steering Load vs Roll Rate – Aprilia RS660

Steering force input during motorcycle roll is expected to show an approximately linear relationship with roll rate when looking at magnitudes (Cossalter, Lot and Massaro, 2010, section: Time domain analysis), with variation arising due to vehicle speed as a result of the gyroscopic behaviour of the front wheel (Barbagallo et al., 2015, Section: *Description of the instrument and of the control*). This relationship is well established in motorcycle dynamics literature, (Cossalter, 2006, Section: Motorcycle manoeuvrability and handling), where steering force is shown to scale predictably with roll response.

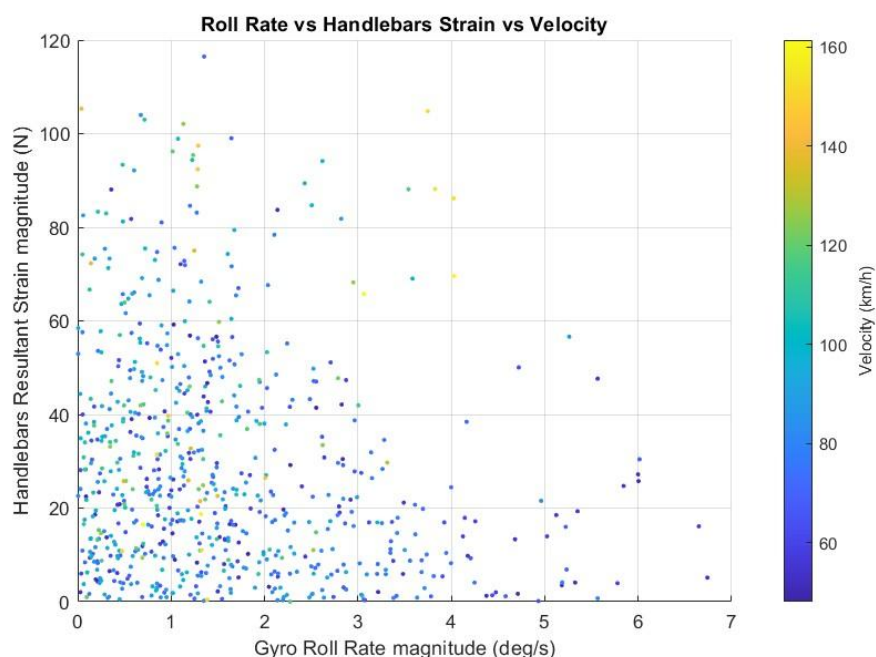


Figure 8: Aprillia handlebar resultant strain (magnitude) against bike roll rate (magnitude), with colour coded velocity

Strain gauge data recorded from the Aprilia RS660 handlebars was examined to investigate this relationship. However, when handlebar strain was plotted against roll rate and velocity (Figure 8), no clear linear trend or velocity-dependent scaling could be identified. The data shows a highly scattered distribution, with elevated strain values occurring across a wide range of roll rates, including conditions where minimal steering input would be expected. In addition to rider input, structural compliance within the front-end assembly may influence the measured steering load, as torsional compliance of the front forks alters steering response during both straight running and turning (Hatakeyama et al., 2024, Abstract).

This indicates that the measured strain does not reliably represent steering torque, likely due to the influence of non-steering loads acting on the handlebars. As a result, no meaningful relationship between steering strain and roll behaviour can be established, and the strain gauge data is not used for further analysis in this report.

6. Rider Behaviour Analysis – Cross-Vehicle Comparison

This section examines rider behaviour using body-mounted inertial data, focusing on rider positioning and movement during cornering. Analysis is presented separately for each test location, reflecting differences in motorcycle platform, sensor availability, and test intent. Greater emphasis is placed on the Pembrey dataset due to the higher quantity and quality of rider-specific measurements available.

6.1 Rider Behaviour at Pembrey (Aprilia RS660)

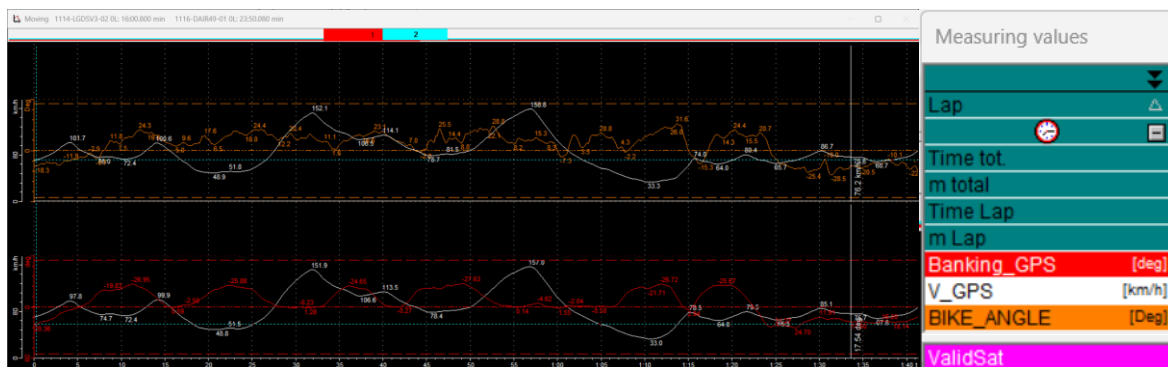


Figure 9: Pembrey rider lean angle (lower trace) compared with bike lean angle (upper trace)

Rider behaviour at Pembrey is characterised by deliberate and active body positioning throughout all phases of the corner. In right-hand corners, the rider consistently leans further into the corner than the motorcycle, with rider lean angle exceeding bike lean angle (Figure 9) (Barbagallo et al., 2015, Section: *Results*). This behaviour indicates confident body positioning aimed at moving centre of gravity to increase motorcycle lean and increasing potential cornering speed.

In left-hand corners, the rider adopts a more upright posture relative to the motorcycle. Bike lean angle frequently exceeds rider lean angle, and lean-in transitions are less consistent, with occasional delays between motorcycle roll initiation and rider body movement. This behaviour suggests reduced rider confidence or comfort when cornering to the left, rather than a limitation imposed by the motorcycle itself.



Figure 10: Pembray rider lateral roll rate (lower trace) compared with bike lateral roll rate (upper trace)

Roll rate data provides further insight into lean initiation and exit behaviour. During corner entry, rider roll rate consistently leads before the motorcycle roll rate, demonstrating that the rider actively initiates lean through body movement (Figure 10) rather than passively following the motorcycle (Barbagallo et al., 2015, Section: *Description of the instrument and of the control*). This reduces the motorcycle roll angle relative to the bike's plane, improving rider control (Sequenzia et al., 2014, Section: Rider's multibody model). During corner exit, rider roll rate often exceeds that of the motorcycle, indicating that the rider returns to a central body position more quickly than the bike uprights. This reflects an anticipatory riding style, with the rider preparing early for subsequent braking, direction changes, or acceleration.

Longitudinal movement data shows structured rider positioning across distinct riding phases. During braking, the rider adopts a more upright body position relative to the motorcycle, increasing frontal area and contributing to deceleration. In this phase, front suspension loading is dominated by braking forces and the associated longitudinal load transfer arising from motorcycle geometry, rather than rider movement. As braking concludes and corner entry begins, the rider transitions forward and down into the corner, with this change in body position further increasing front suspension loading in combination with the existing braking-induced load transfer (Hesapchieva and Yanachkov, 2025, Section: Experimental results). Through the mid-corner phase, the rider remains leaned into the corner, maintaining a forward and lowered posture that supports stability and control. Under acceleration, the rider continues to position

forward and down into the motorcycle, adopting a tucked posture that reduces aerodynamic drag. Across all phases, rider motion magnitude exceeds that of the motorcycle, confirming an active and engaged riding style (Cossalter, Lot and Massaro, 2010, section: Stability Analysis).

6.2 Rider Behaviour at Kinsham (Bucci)

Rider behaviour at Kinsham shows adaptation to changes in motorcycle setup, with variations in body movement most apparent during corner entry and mid-corner phases. Following changes to front and rear suspension settings, rider angular motion at turn-in increases, indicating greater rider input to initiate lean when chassis compliance is reduced, which is consistent with rider feedback of difficulties when cornering.

As damping levels increase, rider transitions become less fluid and lean angles are held for shorter durations, suggesting that increased chassis stiffness limits smooth body movement. When no further setup changes are applied, rider behaviour remains consistent, confirming that observed variations are linked to setup changes rather than random variation in riding style.

7. Discussion

The lack of a clear relationship between steering load and roll rate is attributed to experimental limitations rather than a failure of motorcycle dynamics theory, as established analytical models predict such a relationship under ideal measurement conditions (Cossalter, Lot and Massaro, 2010). Rider behaviour observed at Pembrey was consistent with established dynamics theory, with body movement initiating lean prior to motorcycle roll, reinforcing the importance of rider analysis over steering load measurements when interpreting on-track data (Sequenzia et al., 2014).

At Kinsham, increased mechanical stability resulting from setup changes did not consistently improve lap time, reflecting the demands of a low-speed, technical circuit where excessive stiffness can reduce responsiveness. This highlights the need to match geometry and damping choices to circuit characteristics rather than maximising stability alone (Podosek et al., 2023). The observed trade-off between control and responsiveness aligns with experimental suspension studies showing that stiffer damping improves load control at the expense of increased vibration and reduced compliance (Carratù et al., 2018).

8. Recommendations for further work

Further work could be undertaken to improve the quality and scope of the results presented.

For the Bucci platform, future testing should include the measurement of motorcycle angular behaviour, specifically lean angle and roll rate. This would allow setup and geometry changes to be linked more directly to changes in motorcycle attitude during cornering and allow for a more accurate rider analysis.

For the Aprilia RS660, future work should focus on improving test conditions and increasing the size of the dataset. Testing under more consistent surface conditions, combined with requesting the rider to limit body movement and maintain a consistent weight distribution during specific runs, would help reduce non-steering loads acting on the bikes angular behaviour. Increasing the volume of recorded data would allow clearer trends to be identified and improve confidence in assessing the relationship between strain gauge measurements and roll behaviour, and potentially identifying the effect of velocity on this relationship.

9. Conclusions

This study demonstrated how track-acquired data can be used to evaluate motorcycle handling, setup effects, and rider behaviour under real riding conditions. On the Bucci platform, suspension setup changes produced clear and measurable effects on suspension behaviour and front–rear balance, although increased mechanical stability did not consistently improve lap time on a low-speed, technical circuit. Analysis of the Aprilia RS660 showed that handlebar strain data did not provide a reliable representation of steering torque, likely due to non-steering loads and structural compliance. Rider behaviour analysis proved more informative, particularly at Pembrey, where rider body movement consistently initiated lean and strongly influenced motorcycle attitude. Overall, the results highlight the importance of rider input and context-specific setup choices when interpreting motorcycle dynamics data.

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