POLITECNICO
DI TORINO

MASTER'S DEGREE COURSE IN AUTOMOTIVE ENGINEERING

Master's Degree Thesis

Statistical Analysis for the Evaluation of the Loss of Performance in a Touring Competition Car

Academic Supervisor
Prof. Gianfranco GENTA

Candidate
Matteo SELVA S262077

Company Supervisors
Six Engineers
Ing. Francesco BRACCIOTTI
Dott. Gabriele CAMISA

October 2020

Summary

This thesis analyses the factors affecting the loss of performance of a Touring Race Car. The work consists of the identification and validation of a procedure for the characterization of driving styles and circuits.

The procedure identified uses some statistical instrument for the identification of outliers and comparison of different samples. This procedure can select the telemetry data, aggregate them, and consequently compare the different drivers and circuits.

The data used for this research come from the database of the Six Engineers Team. More specifically it is analyzed the 2019 racing season working on telemetry data of the cars assisted by the team: two Seat Leon Cup Racer.

The problem that the cars suffered during the season is related to an extension of the brake pedal stroke and a consequent loss of ability to slow down the car by the driver. The results confirm what was experienced by the engineers of the team during the races. The occurrence of the problem seems to be directly related to the specific braking behavior of the driver and the circuit.

Contents

List of Figures

List of Tables

Chapter 1

Introduction

1.1 Aim of the research

During the 2019 season the team Six Engineers was competing in an Italian Championship called Trofeo Super Cup with two Seat Leon Cup Racer. During some races a technical issue regarding the braking system raised and forced the team to retire the car from the race. The problem was about the drop of pressure inside the braking circuit, with a consequent extension of the brake pedal stroke until the force applied by the driver on the pedal was not anymore able to slow down the car.

The problem was critical on the safety aspect and forced the team to retire multiple times the car, during the season. The technical direction of the team decided to conduct a deeper analysis on the phenomenon. On the pure technical side it was very difficult to find the root cause of the problem, so it was decided to conduct a statistical analysis to confirm some hypothesis presumed by the experience on the field.

The experience gained during the season suggests that the problem arises with some specific pilots, with a very precise driving style, in some circuits with an high demand on the braking system. This thesis will define, with the help of some statistical instruments and practices, the driving style of the pilots and also the demand on the braking system of the different tracks. The aim is to find a correlation between those two factors and the occurrence of the problem starting from the telemetry data of the vehicles.

1.2 Six Engineers, Company Description

Six Engineers is an Italian company specialized in track racing support. The company was born in 2017 from the idea of six young engineers with the passion of Motorsport; during a Master course in Race Engineering they met and founded the company.

Six Engineers works in a strict collaboration with charterers of racing cars for Italian Championships. The highly skilled engineers from the company offer a technical advanced support to drivers and team management. Six Engineers was able through the last years to become one of the most successful team in their championships.

Six Engineers offers a complete team and support to the drivers: from the vehicle set-up, telemetry, race strategy and driver's training until team management. In the last period they also begin to offer specialist courses in telemetry data analysis. [30]

Figure 1.1: Six Enigneers team

1.3 Trofeo Super Cup

Trofeo Super Cup is an Italian Championship promoted by A.S.D. Italia Corse, under supervision of ACI Sport.

Are admitted to the races all types of Touring Cars subdivided into two different divisions according to model and engine. Trofeo Super Cup fits in the Italian racing background as a low cost championship for all the owners and charterers of Touring Cars.

Figure 1.2: Trofeo Super Cup logo

Every race weekend is structured in the following way:

- Two round of 20 minutes of free practice;
- 25 minutes of qualifying;
- Two races of 25 minutes each.

Racing weekends are shared, in most of the cases, with other series and championships and take place on Italian racing tracks. For GT cars the same promoter organizes a different championship, in the same racing weekends, called Supercars Series. [31]

1.3.1 Regulations

Technical Regulation The technical regulation specifies all the technical aspects to be respected in order to participate to the races. This particular document discusses also the safety systems, technical documents and approval and suppliers for spare parts and tires.
The cars admitted to the series are the following:

- Cite Super Production 2015,
- 24hr Special Turismo,
- Seat Leon Cup Racer,
- TCS,
- Super 2000 - WTCC,
- D2,
- Seat Leon Supercopa MKII,
- Alfa Romeo 147 CUP,
- Gruppo A,
- Gruppo N,
- Produzione EVO and Produzione di serie,
- Mini Challenge,
- VSO Gruppi A and N,
- Racing Start and Racing Start Plus,
- E2 Silhouette,
- Clio RS CUP,
- Renault Clio CUP,

- MITJET,
- Vetture Turismo V8,
- Top series,
- E1 Italia Turismo. [18]

Sports Regulation Sports regulation includes all the rules about the sporting side of the competition: from the points assigned per race to the penalties assigned in case of non-fulfilment of specific rules.
For the 2019 season the races were 7 on six different race tracks:

- Autodromo dell'Umbria, Magione;
- Autodromo Internazionale di Franciacorta;
- Misano World Circuit;
- Autodromo Enzo e Dino Ferrari, Imola;
- Autodromo Internazionale del Mugello;
- Adria International Raceways. [17]

Chapter 2

Mention on Vehicle's Braking System

The braking system present in a road car has two main functions: stop the vehicle while it is in motion and keep it still when it is parked. In a race car the second function is marginal to the first, since there are other techniques to keep the vehicle parked: for this reason race cars are normally not equipped with a park braking system. This chapter will deal only with the service braking system used to slow down the car while driving.

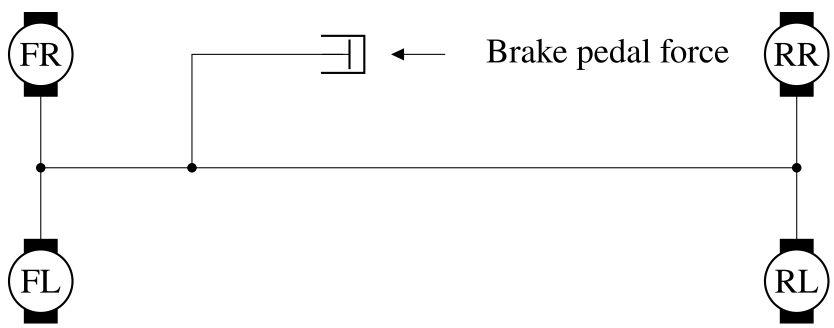


Figure 2.1: Braking Circuit

To reduce the speed of a moving body it is necessary to dissipate the vehicle's kinetic energy through other types of energy. The brakes of vehicles dissipated this energy through friction and heat between two surfaces (one rotating with the wheel, the other fixed). The two surfaces are put in contact by an hydraulic pressure that comes from an hydraulic circuit actuated by the driver through a pedal.

The braking circuit consists in three main different components:

Control components to control the hydraulic pressure (pedal, pump and reservoir);

Transmission components to allow the braking fluid to reach the brakes (circuit);

Actuation components to stop the wheels in motion (brakes).

Usually the hydraulic circuit is split in two different circuits to ensure an adequate braking capacity also if one line fails. The two circuits can be arranged in different ways as shown in the table 2.1. [5] [7] [11]

Type	Circuit 1	Circuit 2
TT	Front axle	Rear Axle
K	FR and RL wheels	FL and RR wheels
HT	All wheels	Front axle
LL	Front axle and RR wheel	Front axle and RL wheel
HH	All wheels	All wheels

Table 2.1: Braking circuit design

2.1 Brake Pump

The intent of the brake pump is to apply an hydraulic pressure to the braking fluid present in the circuit. The brake pump is directly or indirectly actuated by the driver through the brake pedal. Usually in road cars is present a vacuum power brake booster that helps the driver to apply the right amount of pressure in the circuit. This particular aid is not present in race car and the driver has to provide without any assistance the pressure to the brake pump.

The pump is connected to the braking fluid reservoir and to the circuit. One or two different brake pumps can be present in a vehicle. In the first case a single pump provides the pressure to the different circuits, in the second case one pump is present for each circuit.

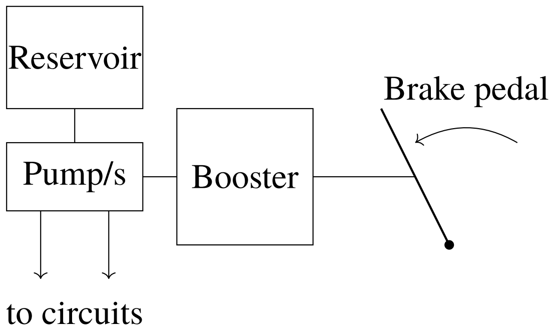


Figure 2.2: Braking system

The brake pump is composed by a cylinder with a piston inside, when the pressure is applied, the piston compresses the fluid. When the pressure is not anymore applied a spring helps the piston to return in the rest position. The technical drawing of a racing brake pump can be seen in figure 2.3: the C letter indicates where the circuit is linked, while the letter R where the reservoir is connected. In the second figure, the red arrow highlights the pressure applied on the brake pedal by the driver. [5] [7] [11]

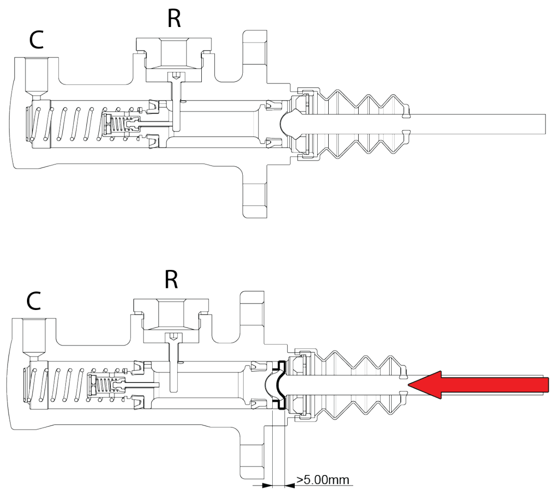


Figure 2.3: Technical drawing of a racing brake pump: AP Racing *CP7198*

2.2 Disc Brakes

Disc brakes are the most used type of brakes in vehicle's applications: they are universally mounted on the front axle and in the last decades the trend is to mount this type also on rear axle. Usually on race cars they are mounted both on front and rear axle; they are different in the dimension of the disc: larger in the front, smaller in the rear.

Disc brakes consist in two different parts:

- One is rotating with the wheel (the disc);
- The second is fixed with respect to the suspension (the caliper and the pads).

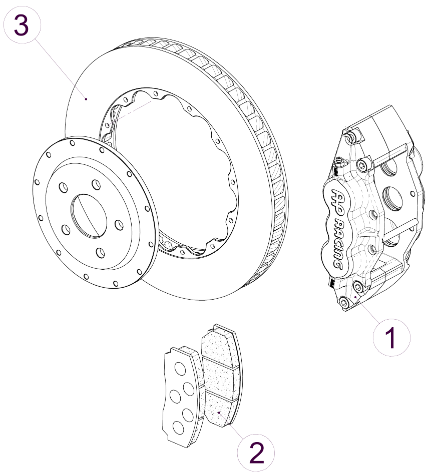


Figure 2.4: Technical drawing of a racing disc brake: AP Racing *P12102*.
1. Caliper, 2. Pads, 3. Disc.

The hydraulic pressure in the circuit activates the cylinder or cylinders present in the caliper, their movement put the pads with the disc dissipating energy trough friction. A spring helps to move back the pads from the disc once the force on the brake pedal is released.

The disc brakes can be of two different type:

- Floating caliper;
- Fixed caliper.

2.2.1 Floating Caliper

In the floating caliper disc brake is present only one cylinder that applies the pressure on the inside pad. Once it is applied, the caliper slides on its mounts and presses also the outside pad. This solution is applied on average road cars since the king-pin offset of the wheel can be reduced and consequently it is cheaper then the fixed caliper. [5] [7] [11]

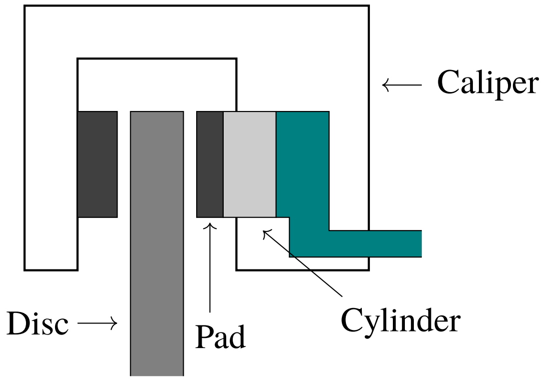


Figure 2.5: Floating Caliper architecture

2.2.2 Fixed Caliper

The fixed caliper disc brake the pads are pressed on the disc by two different cylinders, mounted in parallel. This particular architecture is used in high-end cars and race cars since they ensure higher performances. Usually in the caliper are present several pairs of cylinders, depending on the specific design. [5] [7] [11]

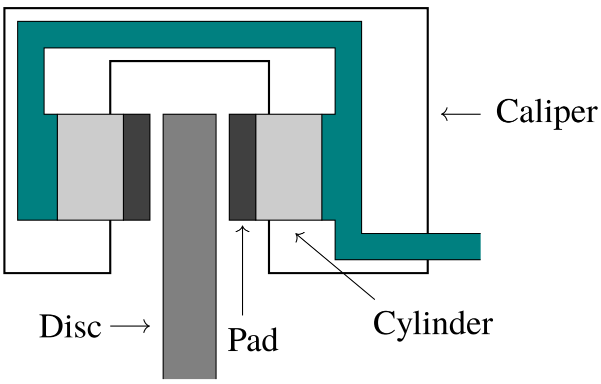


Figure 2.6: Fixed Caliper architecture

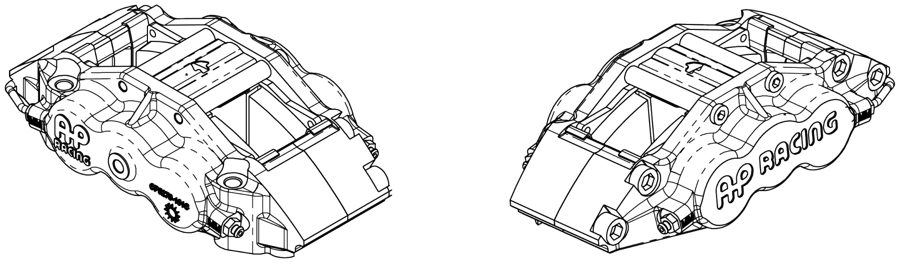


Figure 2.7: Technical drawing of a racing braking caliper: AP Racing *CP5570*

2.3 Brake Control Systems

Forces generated by braking system can heavily affect not only longitudinal dynamics, but also lateral dynamics of the vehicle. For this reason electronically operated control systems can be present in the car to stabilize the vehicle during the drive. In race cars those controls can be present or not depending on the type of vehicle.

Here are listed the main brake control systems that could be present in a vehicle with a brief description:

ABS (*Anti-lock Braking System*) helps to avoid longitudinal slip of the tire during the braking maneuver.

EBD (*Electronic Brake Distributor*) controls the distribution of brake pressure between front and rear axle, in race car this type if control is usually manually operated by the driver.

ESP (*Electronic Stability Program*) used to control and predict vehicle's dynamic behaviour.

2.4 Brake Distributor

The brake distributor allows to unevenly distribute the braking force between the front axle and the rear axle. This is necessary because the vertical load transfer on the front wheel must be higher than the rear wheels to keep the vehicle stable during the braking maneuver.

If the braking force on the rear axle is too large, rear wheels tend to lock during braking, causing a loss of stability. If it is too low, compared to the front axle, the vertical load on the rear wheels can be overcome by the pitch moment applied to the vehicle, with a consequential lift of the rear wheels.

In racing vehicles the brake distributor can be manually actuated by the pilot while he is driving, changing the dynamic performance of the car according to his preference. While in a standard road car this type of control is done automatically by a dedicated brake distributor that tends to replicate the ideal curve of braking pressure between front and rear axle (figure 2.8). [5] [7] [11]

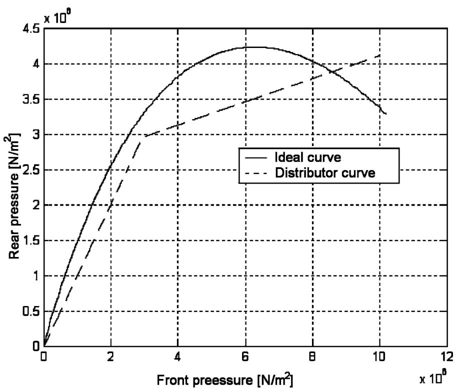
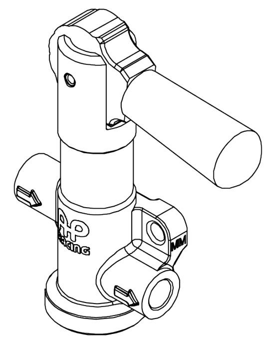
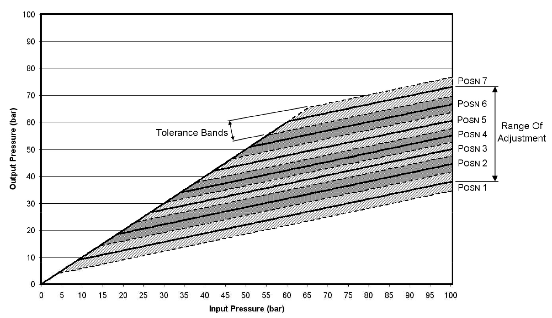


Figure 2.8: Comparison between the ideal distribution curve of braking pressure and the actual distributor curve. [5]



(a) Technical drawing



(b) Input pressure (front axle) vs Output pressure (rear axle)

Figure 2.9: Racing brake distributor: AP Racing *CP3550*

Chapter 3

Vehicle Description

The Seat Leon Cup Racer is a Touring Competition Car derived from the standard model of Seat Leon (*third series*). It is improved from the production model in terms of performance, weight reduction and safety.

(a) Seat Leon Cup Racer (b) Seat Leon, standard model

Figure 3.1: Seat Leon versions compared

The Cup Racer version is equipped with the 2-liter turbocharged with direct fuel injection engine produced by the Volkswagen group: the 2.0 TFSI. The engine is properly tuned to obtain a maximum power of 330 cv and torque of 410 Nm.

The gearbox instead is the same as the standard model: DSG gearbox developed by BorgWarner exclusively for models of the Volkswagen Group. The acronym DSG stands for Direct-Shift Gearbox. The gearbox is a double friction one, equipped with an electronic control system that can be actuated automatically or semi-automatically with the use of a sequential mechanism, mounted on the gear stick or on the steering wheel pads.

On the safety side the Cup Racer is equipped with full a roll bar and a proper racing seat and seat belts. It is also present a fire extinguisher and an air jack. All the safety device are conform to FIA standards.

The racing car is also equipped with a complex set of sensors positioned in order to monitor the operating conditions of the car, both on the side of engine operations (temperatures, pressures, etc.) and chassis operations (brakes, wheel velocity, etc).

From the aerodynamic point of view the Cup Racer has some device such as a rear spoiler and a front splitter. [12] [13] [14] [15] [16]

3.1 Technical Data

In this section all the technical specifications are explained by means of tables and images.

Total weight in race conditions without fuel	1150	kg
Car balance	63,2% *front* - 36,8% *rear*	
Distribution weight/power	3,48	kg/cv

Table 3.1: Seat Leon Cup Racer Weight

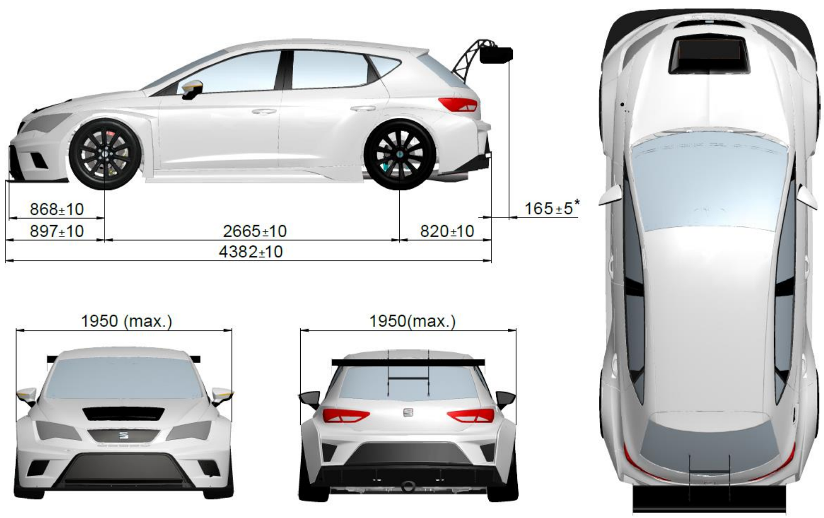


Figure 3.2: Seat Leon Cup Racer Dimensions [14]

In the following table (Table 3.2) are present the dimensions stated by the homologation form and technical manual of the car. Those dimensions are different from the ones of the standard model.

Overall length	4382	mm
Overall bodywork front width	1950	mm
Overall bodywork rear width	1950	mm
Wheel base	2665	mm
Over hang front splitter	897	mm
Over hang front bumper	868	mm
Over hang rear	820	mm
Over hang rear wing	165	mm
Minimum ground clearance	free	

Table 3.2: Seat Leon Cup Racer Dimensions

The Tables 3.3 and 3.4 describes the characteristic of the 2.0L TFSI engine and the DSG gearbox with which is equipped the Seat Leon Cup Racer.

Type	Turbochargerd, 4-cylinder in line	
Fuel supply system	Direct fuel injection	
Displacement	1984	cc
Bore	82,5	mm
Stroke	92,8	mm
Maximum power	330	cv at 6250 rpm
Maximum torque	410	Nm at 4600 rpm
Maximum rpm	6800	rpm

Table 3.3: Seat Leon Cup Racer Engine

Transmission	Front-wheel drive
Gearbox	6-speed DSG
Differential	VAQ, electronically managed
Clutch	Multi disc oil cooled
Shift control	Electronic on steering wheel

Table 3.4: Seat Leon Cup Racer Transmission

In the table below (Table 3.5) it can be found the data about the chassis and suspensions of the car.

Front suspension	McPherson, adjustable in height, toe and camber
Anti-roll bar	Front and rear adjustable
Rear suspension	Multi-link axel, adjustable in height, toe and camber
Front brakes	6-piston callipers, 362 mm steel ventilated discs
Rear brakes	272 mm steel discs
Brake pedal	Unitary with brake balance regulation
Steering system	Full Electrical power steering racks
Rims	Seat sport 10”x18”
ABS	Removed

Table 3.5: Seat Leon Cup Racer Chassis and Suspensions

3.2 Braking System

The braking system is explained in detail since it has a relevant importance in this research.

The Table 3.6 resumes the basic specifications of the system.

Front caliper	AP 6P
Front disc	362 x 32
Front pump	AP 19,1 mm
Front pads	Pagid 5F6
Rear caliper	AP 2P
Rear disc	272x10
Solid Rear pump	AP 22,2 mm
Rear pads	Pagid 5F6
Orange Rear press reducer valve	25 bar
Brake balance	Mechanical

Table 3.6: Seat Leon Cup Racer Brake System

Both front and rear brakes are disc brakes with fixed caliper designed specially for race cars by AP racing, an automotive supplier company.

The braking circuit is a TT type: this means that front and rear brakes are actuated by two different hydraulic circuits. This allows to simply modify the brake balance with the brake distributor. The two circuits have also two different pumps directly connected to the brake pedal.

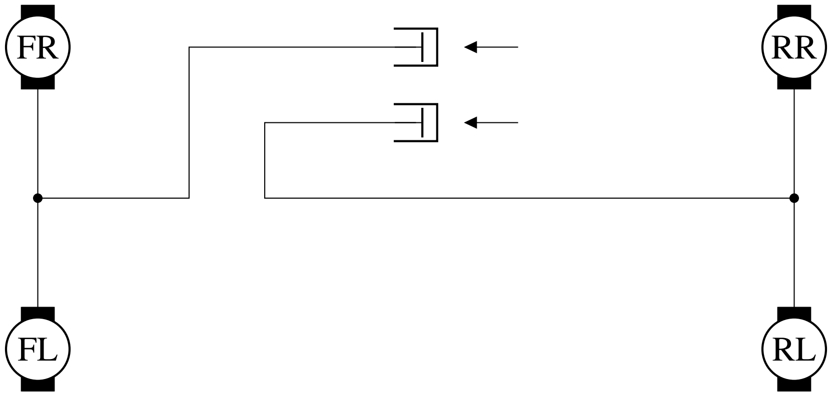


Figure 3.3: Braking Circuit

3.3 Sensors

The car is equipped with a wide set of sensors used to monitor as many as possible aspects in the car. To acquire and display the data a dash-logger is present: the AIM MXG. This device is able to read data coming from its internal sensors (gyro and accelerometer), GPS module and data coming from ECU (other sensors).

Figure 3.4: AIM MXG dash-logger

Some sensors are connected to the BUS of the car and then to the ECU; other sensors, coming from specific modules of AIM, are connected directly to the dash-logger. It is possible to download the data of the sensors directly from the logger through a cable, a memory stick or WiFi connection. In the following subsection it can be found the list of all the data channels that can be downloaded from the car. [26]

3.3.1 Acquisition Channels

The dash-logger is able to acquire and store data coming from the sensors of the vehicle. Channels are of three main types: physical, GPS and mathematical.

Physical Channels Are the one directly related to physical quantities, for example velocity of the wheels and operating temperatures of the engine fluids. Also the flag channels are included in this category.

GPS Channels Those data come from the GPS module directly connected to the dash-logger. GPS is able to give precise informations about the position of the vehicle in a quite continuous way: from the position in every instant it is possible to derive velocities and accelerations.

Mathematical Channels The AIM MXG dash-logger is able to extrapolate also mathematical channels. Those type of data are the one calculated by means of mathematical formulas and equations. Usually those channels are not standard, but are defined by the data engineer of the car.

DATA ACQ NAME	UNIT	DATA ACQ NAME	UNIT
P_TURBO	Pressure (bar)	**T_ENG_AIR**	Temperature (°C)
T_ENG_OIL	Temperature (°C)	**T_ENG_WATER**	Temperature (°C)
T_AIR	Temperature (°C)	**RPM_ENG**	rpm
FLAG_BRAKE	on/off	**P_BRK_FRONT**	Pressure (bar)
P_BRK_REAR	Pressure (bar)	**P_ENG_OIL**	Pressure (bar)
P_ENG_FUEL	Pressure (bar)	**FUEL_LEVEL**	Amount (litres)
POS_PEDAL	Load (%)	**POS_GBX_LEVER**	number
POS_GBX	number	**GEAR**	number
TIP_DOWN	sign	**TIP_UP**	sign
POS_DIF_MAP	number	**T_GBX_OIL**	Temperature (°C)
G_CH_Y	acceleration (g)	**G_CH_X**	acceleration (g)
W_CH	Angular speed (°/s)	**V_WHL_RL**	Velocity (km/h)
V_WHL_RR	Velocity (km/h)	**V_WHL_FL**	Velocity (km/h)
V_WHL_FR	Velocity (km/h)	**A_STE**	Angle (°)
FLAG_FBX_F5	number	**FLAG_FBX_F4**	number
FLAG_FBX_F3	number	**FLAG_FBX_F2**	number
FLAG_FBX_F1	number	**Battery Voltage**	mV
GPS_Speed	km/h	**GPS_Nsat**	**
GPS_LatACC	g	**GPS_LonACC**	g
GPS_Slope	°	**GPS_Heading**	°
GPS_Gyro	°/s	**GPS_Altitude**	m

Table 3.7: Acquisition Channel List

3.3.2 AIM Software

The data acquired by the dash-logger AIM MXG can be downloaded and read on the PC by mean of a specific software. The software used to download the data in the channels is called *AIM Race Studio*, while *AIM Race Studio Analysis* is needed to read and visualize the data.

AIM Race Studio It is the software able to download and store on the PC the data coming from the dash logger.

Figure 3.5: AIM Race Studio screenshot

AIM Race studio Analysis To read and visualize the data it is necessary to open AIM Race Studio Analysis. This software is a powerful tool able to organize, visualize and compare different data coming from different vehicles, pilots and circuits. It is also possible to manipulate and export data in different type of files (Matlab, Excel, etc.).

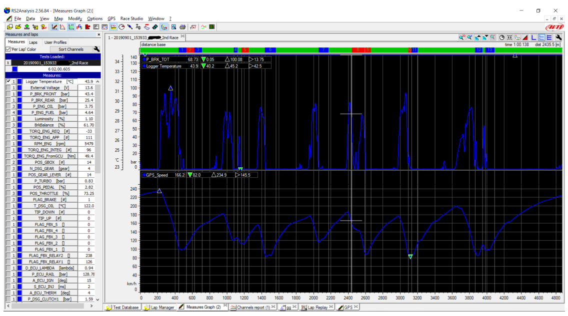


Figure 3.6: AIM Race Studio Analysis screenshot

Chapter 4

Circuits and Pilots

4.1 Circuits

In this section are described all the tracks on which the data were acquired. They are identified by the location of the circuit and not by their name.

4.1.1 Adria

Adria International Raceway is placed alongside the *Adria Kart Track*. This is a short circuit and presents corners with high bending angle after the straights. This characteristic imply that are present zones in which is required heavy braking. [19]

Length	2702	m
Width	12	m
Direction of Travel	Counterclockwise	
Turns	17	

Table 4.1: Adria Data

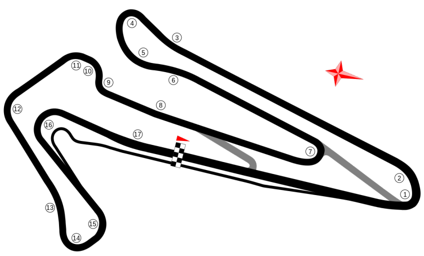


Figure 4.1: Adria Track Map

4.1.2 Franciacorta

The track is located in Lombardia, similarly to Adria has a Karting Track alongside. This track is shorter than Adria and it is characterized by 90° turns and not very long straights. [20]

Length	2520	m
Width	12	m
Direction of Travel	Clockwise	
Turns	12	

Table 4.2: Franciacorta Data

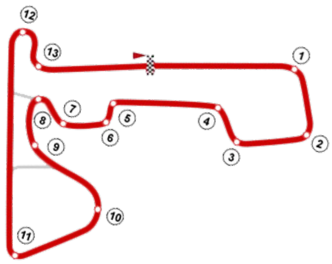


Figure 4.2: Franciacorta Tack Map

4.1.3 Imola

Imola is one of the most famous Italian track; during the past years has hosted international competitions such as Formula 1 and Superbike. It is a long track with three chicanes and long straights; the geographical location allows to have ups and downs that make the circuit difficult to drive. [21]

Length	4909	m
Width	10 - 15	m
Direction of Travel	Counterclockwise	
Turns	21	

Table 4.3: Imola Data

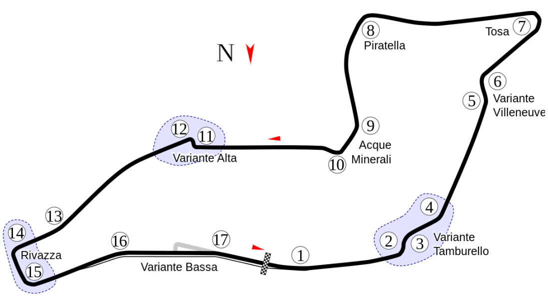


Figure 4.3: Imola Tack Map

4.1.4 Magione

The complete name of the circuit is *Autodromo dell'Umbria* and it is located in Magione (PG). It is the shortes track among the others and presents very frequent braking zones and only one long straight. [22]

Length	2507 m
Width	11 m
Direction of Travel	Clockwise
Turns	11

Table 4.4: Magione Data

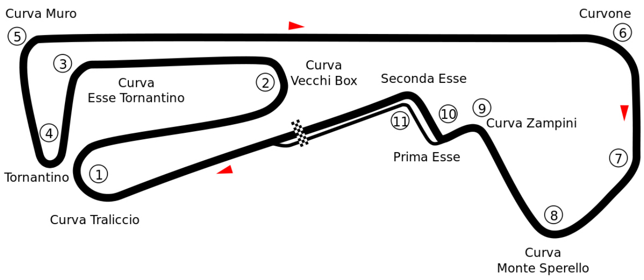


Figure 4.4: Magione Track Map

4.1.5 Misano

The Misano track is located in Misano Adriatico in Emilia Romagna, its complete name is *Misano World Circuit Marco Simoncelli*. It is an International circuit mostly used for motorcycle races. It presents long straights with high bending angle corners.[24]

Length	4226 m
Width	14 m
Direction of Travel	Clockwise
Turns	16

Table 4.5: Misano Data

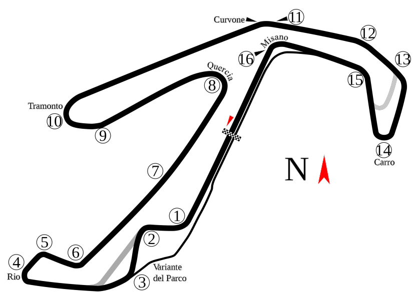


Figure 4.5: Misano Track Map

4.1.6 Mugello

The Mugello Track develops on the Tuscan hills near Florence and is one of the most iconic Italian tracks. It is the longer circuit of the one analyzed and its characteristic is to have very high speed corners with not so many high braking zones. [25]

Length	5245	m
Width	9.6 - 14	m
Direction of Travel	Clockwise	
Turns	15	

Table 4.6: Mugello Data

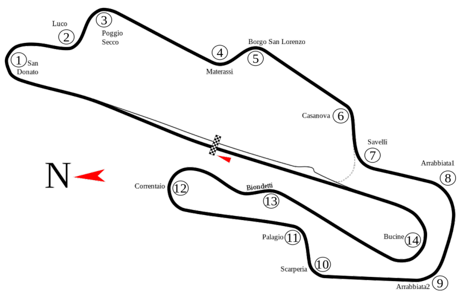


Figure 4.6: Mugello Tack Map

4.2 Pilots

The team Six Engineers for the 2019 season did not have only two drivers, but the driver line up was constantly changing. This phenomenon is frequent in championships where the pilots are not professional drivers, but amateurs.

In order to respect the privacy of all the drivers in this thesis all their names will not be displayed, instead they will be identified by means of alphabetical letters.

Pilots that raced for the team during the 2019 season were 10. Not all the drivers are included in this research according to the indication given by the team. Only the telemetry data coming from 8 pilots are considered in this analysis.

The Table 4.7 summarizes in which circuit every driver has completed at least one session. The sessions considered can come from race weekends (practice, quali and race) or private test sessions, they can be considered different: the Test or Practice sessions are the one in which the driver is testing the car or becoming familiar with the track in a race weekend; in the Qualifying the driver is trying to get a fast lap and in the Race what it is important is the consistency during the whole time.

	drivers							
	A	**B**	**C**	**D**	**E**	**F**	**G**	**H**
Adria		✓					✓	✓
Franciacorta		✓			✓		✓	
Imola		✓				✓		
Magione	✓	✓	✓	✓	✓	✓	✓	✓
Misano		✓			✓			
Mugello		✓						✓

Table 4.7: Drivers and Circuits

Chapter 5

Description of Statistical Instruments

This Chapter describes the statistical instruments used in the procedure of data analysis. Those instruments allow to select, aggregate and compare data coming from different samples.

5.1 Descriptive Statistics

Descriptive statistics is useful to summarize data set by using some statistic indicators such as the mean, standard deviation and variance. This type of analysis is a preliminary one aimed to have a fast and precise evaluation of the data set taken into account.

Minitab ® software provides a command called *Descriptive Statistics* that prints, for every variable in selected, the number of data, the mean, standard deviation for the mean, the standard deviation, the minimum and the maximum, the quartiles and the median. [2] [23]

5.1.1 Mean, standard deviation and variance

Mean The mean is a measure of central tendency and it represents the most likely value for the given data set or the arithmetic average of a set of data.

$$\bar{x} = \frac{\sum_{i=1}^{n} x_i}{n} \tag{5.1}$$

Standard Deviation The Standard Deviation is a measure of dispersion from the mean of a given data set. It is calculated following three criteria: all the data in the data set are taken into account, a single number indicates the typical dispersion and it increases with the increasing dispersion of the data.

The Standard Deviation can be calculated on the sample or on the whole population. The second is less used since it is not always possible to take into account all the population. The one displayed in the equation below (5.2) is the one related to the sample.

$$s = \sqrt{\frac{1}{n-1} \sum_{i=1}^{n} (x_i - \bar{x})^2} \tag{5.2}$$

Variance The Variance is another measure of dispersion and it is the square of the standard deviation. Also for this measure it can be differentiate between the variance for the sample or for the whole population. The following equation (5.3) displays the one for the sample. [2] [4]

$$s^2 = \frac{1}{n-1} \sum_{i=1}^{n} (x_i - \bar{x})^2 \tag{5.3}$$

5.1.2 Quartiles

Quartiles are a specific type of quantiles and they divide the data set into four different parts. The first quartile, Q_1, represents the value that has a quarter of the data below. The second quartile, Q_2, can be identified also as the median: it is the value which has half of the data below and the other half above. The third quartile, Q_3, has three quarters of data below its value. [3]

5.2 Graphical Representations

While working in the statistics field a graphical representation of data is always needed. The various types of graphs give a fast and intuitive representation of the data to be analyzed. For this reason it is important to choose the right way to represent data, according to the wanted outcome of the data analysis.

In this specific case there are present two different graphical representation of data: Scatter Plot and Box Plot.

5.2.1 Scatter Plot

The aim of a scatter plot is to show the relationship between two different variables.

The plot is the combination of the two variables: one displayed on the abscissas and the other one on the ordinates. Every point in the plot corresponds to a specific case to which are related specific values of the two variables.

Usually on the Y-axis is displayed the response variable, while on the X-axis the variable that may be related to the response. [4] [28]

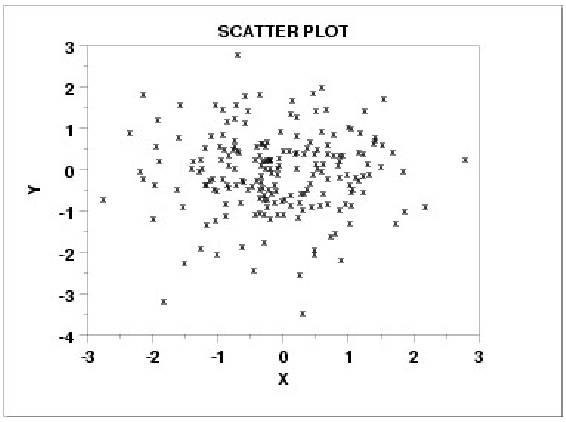


Figure 5.1: Example of a scatter plot with no relationship between the two variables [28]

5.2.2 Box Plot

The Box Plot, or Box and Whiskers Plot, describes several important features of a data set such as location and spread of data. This type of representation it is also useful to compare different data set.

The box plot represents in the same graph for a specific data set the three quartiles, the minimum, the maximum and the outliers. The upper and lower edge of the box represent the range between the first and the third quartiles, while the line inside the box shows the second quartile (50th percentile or median). The two whiskers extends from the lower and upper side of the box to the smallest and largest data point that fall inside the 1.5 interquartile range from the first and third quartiles. The other data points that are not included in this range are classified as outliers. [3] [4] [27]

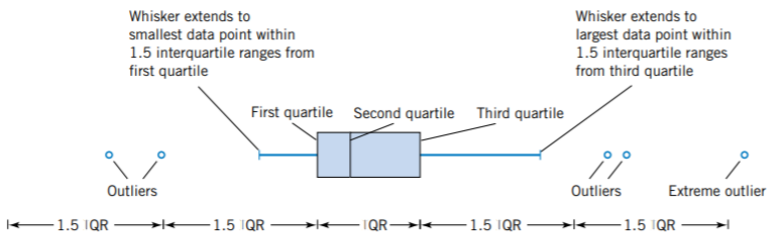


Figure 5.2: Description of a Box Plot [27]

5.3 Outlier Management

Outliers are data inside the set that differ considerably from the rest. They can be treated in several ways and there are many instruments to find and treat them. Those data can lead to an incorrect measurement or they just be bad values inside a data set. For this reason they can affect heavily the analysis, it is necessary to identify and eliminate those observations.

A preliminary analysis can be conducted by the help of a Box Plot, in fact the outliers are idenfied as the values that fall outside the 1.5 interquartile range over the first and above the third quartile. After this first identification, a more precise analysis can be conducted with the help of some specific tools. In this chapter is described the Chauvenet Method used for the identification of outliers in a given set of data. [9]

5.3.1 Chauvenet Method

Chauvenet Method is widely used to detect outliers in a data set.

Chauvenet stated a conventional probability of 50% to have an outlier among n tests. The reference distribution assumed by this method is the Normal Distribution, so the probability to have an outlier is symmetrically split between the lower tail and the upper tail.

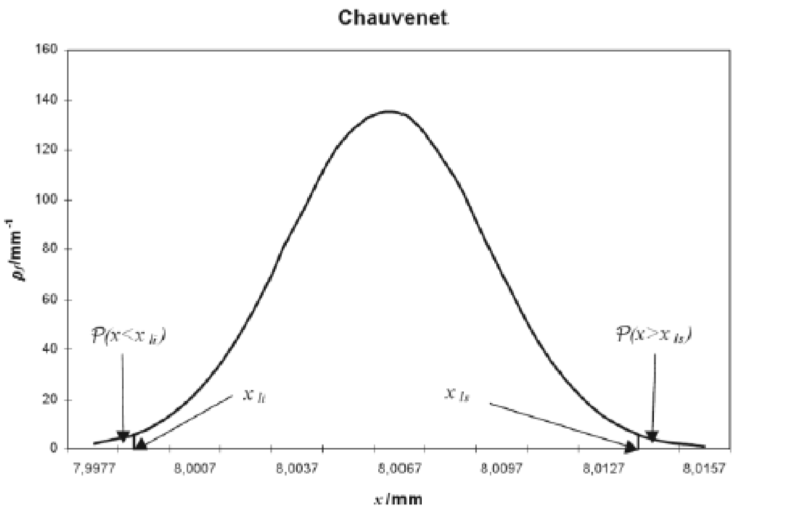


Figure 5.3: Chauvenet Distribution [10]

The probability P_{xL} is calculated using the Equation 5.4; this value is related exclusively on the number of data present in the sample.

$$P_{xL} = \frac{1}{4 \cdot n} \tag{5.4}$$

After having identified the value for probability P_{xL} it is necessary to find out the lower and the upper boundary according to the Normal Distribution.

If the value falls outside those boundaries it is classified as an outlier and then excluded, if it is inside is not considered an outlier.

Once one value is excluded from the analysis the probability P_{xL} is recalculated with the new number of data n and a new interval is found. This loop repeats until all the values are inside the boundaries. [1] [10]

5.4 Two-Sample t-Test for Equal Means

The Two-Sample t-Test for Equal Means is employed in statistics to find whether the means of two data set are equal or not.

For this type of test is employed the Student's t-Distribution, a particular distribution with a single input: the number of data n. Given a specific Confidence Interval, CI, it is possible to evaluate if the two means are different or not.

Definition The procedure for the t-Test for unpaired data (different n) is defined below.

Firstly is needed to define the null hypothesis and the alternative hypothesis.

H_0	$\mu_1 = \mu_2$
H_a	$\mu_1 \neq \mu_2$

The test statistic T is given by the following equation:

$$T = \frac{\bar{x}_1 - \bar{x}_2}{\sqrt{s_1^2/n_1 + s_2^2/n_2}} \tag{5.5}$$

Having previously defined the Confidence Interval it is possible to obtain the Significance level, $\alpha = 1 - \text{CI}$. With the Significance Level, α and the degrees of freedom, ν, using the Student's t-Distribution, it is calculated the critical value $t_{1-\alpha/2,\nu}$.

The null hypothesis is rejected if $|T| > t_{1-\alpha/2,\nu}$, while if $|T| \leq t_{1-\alpha/2,\nu}$ the test fails to reject the null hypothesis. [29]

Minitab results The software Minitab has a proper command called *2-sample t-Test* able to conduct this type of test.

The output of the command is a value called *P-value*.

- If the *P-value* is smaller or equal than the *Significance Level* (P-value $\leq \alpha$) the null hypothesis is rejected: the difference between the means is statistically significant.

- If the *P-value* is larger than the *Significance Level* (P-value $> \alpha$) the test fails to reject the null hypothesis: it cannot be stated that the two means are statistically different. [23]

5.5 Software used for Statistical Analysis

The statistical analysis is conducted with the help of some specific software: Microsoft Excel and Minitab. The first is used for the aggregation of data and for the outlier management, while the second is used for specific statistical analysis.

Chapter 6

Procedure for Statistical Evaluation of Data

In order to evaluate statistically the data it is necessary to define a proper procedure to follow. The procedure has two different steps: in the first one the focus is on the Laptime: it is necessary to exclude the ”bad” laps inside a deifned session. While the second step is aimed to aggregate and compare the examined telemetry data.

An example is done in order to better explain the procedure. The data are coming from the track of Magione and the driver is A.

6.1 Outlier Exclusion Based on Laptime

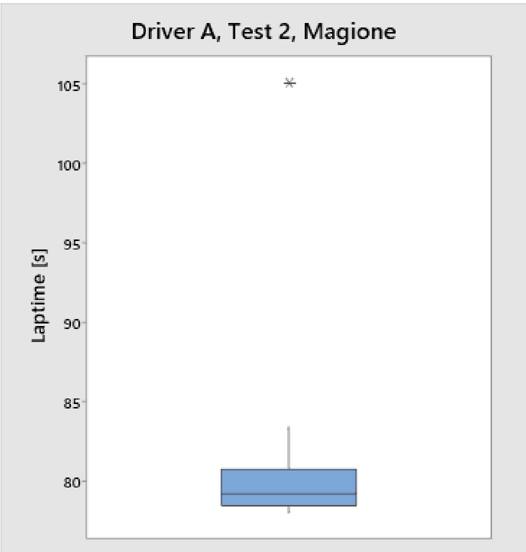
The first step of the procedure is to find the laps from which compare the data. Those ”good” laps are calculated based on every single session: this choice comes from the need to differentiate every typology of session, but at the same time to have a wider set of data possible. A race session is very different, in terms of Laptimes and trend, from a qualifying session; but the driving style of the driver and the characteristics of the track tend to be constant.

6.1.1 Preliminary Evaluation

The first outlier exclusion is a preliminary one: after having done a boxplot it can be seen the outliers according to the 1.5 quartile rule. Once an outlier is evidenced that data is excluded and a new graph is made in order to find all the outliers; this procedure repeats until no new outliers are found.

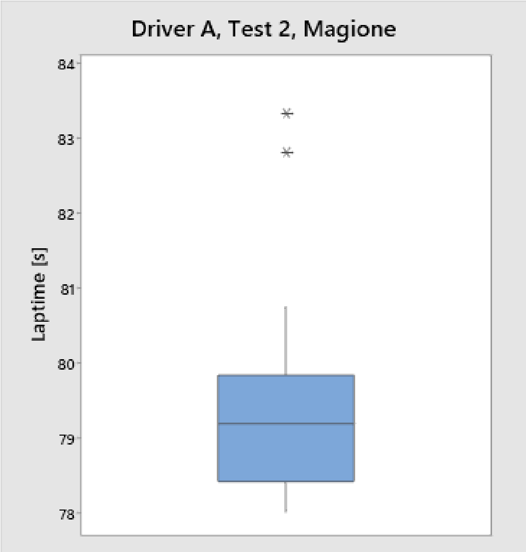
In this preliminary phase are also excluded the laps considered as ”bad” laps: those laps are the one driven under safety car conditions or outlaps and inlaps.

Example The first table shows all the laptimes coming from the Test 2 of Driver A in Magione.



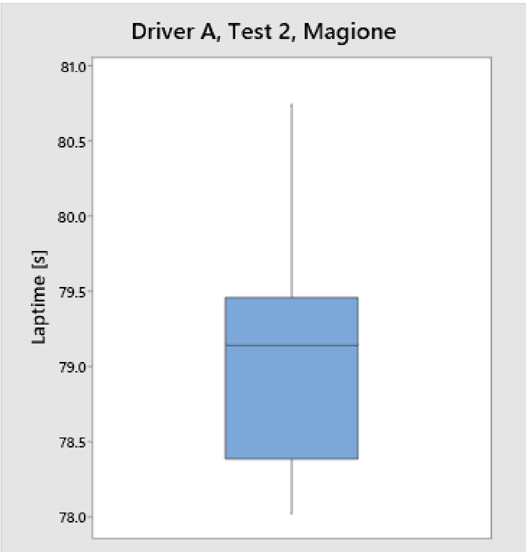
Lap	Laptime [s]
lap 2	83.332
lap 3	79.393
lap 4	79.482
lap 5	78.369
lap 6	78.021
lap 7	79.184
lap 8	78.162
lap 9	78.436
lap 10	79.195
lap 11	80.743
lap 12	78.737
lap 13	79.100
lap 14	79.532
lap 15	82.823
lap 16	105.113

The first step is to exclude the *inlap* (lap 16), that is the last one; once it is excluded a new boxplot is done in order to check if there are other data outside the 1.5 quartile rule.



Lap	Laptime [s]
lap 2	83.332
lap 3	79.393
lap 4	79.482
lap 5	78.369
lap 6	78.021
lap 7	79.184
lap 8	78.162
lap 9	78.436
lap 10	79.195
lap 11	80.743
lap 12	78.737
lap 13	79.100
lap 14	79.532
lap 15	82.823
lap 16	105.113

The new Boxplot evidences two laps outside the range: lap 2 and lap 15. They are now excluded and a new graph is done.



Lap	Laptime [s]
lap 2	83.332
lap 3	79.393
lap 4	79.482
lap 5	78.369
lap 6	78.021
lap 7	79.184
lap 8	78.162
lap 9	78.436
lap 10	79.195
lap 11	80.743
lap 12	78.737
lap 13	79.100
lap 14	79.532
lap 15	82.823
lap 16	105.113

This last boxplot is evidencing that no more ouliers are present and so it can be possible to continue to the next step of the Outlier Exclusion: the Chauvenet Criterion.

6.1.2 Chauvenet Criterion

The Chauvenet Criterion is used to find out if there are present other outliers. The method is explained in section 5.3.1.

Once an outlier is identified, the lower and upper boundaries defined by the method are recalculated until all the data are within the range.

Example After the first outlier management done in section 6.1.1.

Lap	Laptime [s]
lap 2	83.332
lap 3	79.393
lap 4	79.482
lap 5	78.369
lap 6	78.021
lap 7	79.184
lap 8	78.162
lap 9	78.436
lap 10	79.195
lap 11	80.743
lap 12	78.737
lap 13	79.100
lap 14	79.532
lap 15	82.823
lap 16	105.113

Chauvenet table	
Number of Data	12
PxL	0.0208
Lower Boundary	77.497
Upper Boundary	80.562

From the interval derived from the Chauvenet's table it is possible to see that Lap 11 is outside the boundaries. The next step is to exclude that data from the calculation and see if there are other data outside the boundaries with the new interval calculated.

Lap	Laptime [s]
lap 2	83.332
lap 3	79.393
lap 4	79.482
lap 5	78.369
lap 6	78.021
lap 7	79.184
lap 8	78.162
lap 9	78.436
lap 10	79.195
lap 11	80.743
lap 12	78.737
lap 13	79.100
lap 14	79.532
lap 15	82.823
lap 16	105.113

Chauvenet table	
Number of Data	11
PxL	0.0227
Lower Boundary	77.774
Upper Boundary	79974

The last table highlights that no more data are outside the boundaries, with this step the Outlier Management procedure can be concluded.

6.2 Data Aggregation

Once the process of Outlier Exclusion is completed for each set of data, it is necessary to find out if the examined data coming from the different session of the same driver can be aggregated or not. This step in the procedure allows to have bigger set of data to be compared.

The outlier exclusion is conducted on the laptime, while the aggregation deals with the data to be compared: the Maximum Braking Pressure of the lap, the Integral of Braking Pressure on the laptime and the Corrected Integral.

The statistical instrument used to aggregate data is the Two-Sample t-Test for Equal Means, explained in detail in section 5.4.

In order to conduct a correct aggregation of data it is necessary to compare each set of data of each session with all the others. After having collected all the results of the various t-Tests, a matrix is compiled to see if the data of the different session can be aggregated. The key result of the Two-Sample t-Test for Equal Means computed on Minitab is the P-value. Where the P-value is smaller or equal than the significance level (α) the two set of data cannot be aggregated; if the P-value is larger that the significance level the two set of data can be aggregated. The chosen confidence level (α) for this analysis is 5%.

Example For this example are taken into account all the session done by Driver A on the track of Magione. The Table 6.1 is the result of the t-Test for the Integral of the Braking Curve.

	Quali 1	**Quali 2**	**Test 1**	**Test 2**	**Test 3**	**Test 4**	**Test 5**
Race	0.260	0.485	0.946	0.709	0.017	0.480	0.022
Test 5	0.038	0.746	0.315	0.001	0.802	0.042	
Test 4	0.147	0.669	0.805	0.620	0.049		
Test 3	0.030	0.703	0.292	0.003			
Test 2	0.192	0.544	0.943				
Test 1	0.410	0.600					
Quali 2	0.191						

Table 6.1: t-Test result for Integral of Braking Curve, driver A, circuit of Magione

In red in the table 6.1 are evidenced the sessions that cannot be aggregated:

- Quali 1 cannot be aggregated with Test 5 and Test 3;
- Test 2 cannot be aggregated with Test 5 and Test 3;
- Test 3 cannot be aggregated with Race and Test 4;
- Test 4 cannot be aggregated with Test 5;
- Test 5 cannot be aggregated with Race.

6.3 Data Comparison

The last step of the procedure is the comparison of the different data that has been aggregated before. The aim of this last passage is to find whether two different set of data are statistically different or not.

The instrument used also in this case is the Two-Sample t-Test for Equal Means (5.4) and the confidence level (α) chosen is 5%.

After having aggregated all the possible data for a single driver on the circuit coming from different sessions it is possible to compare the drivers. If there is evidenced a statistical difference by the data coming from two different drivers it is possible to state that their driving style is different.

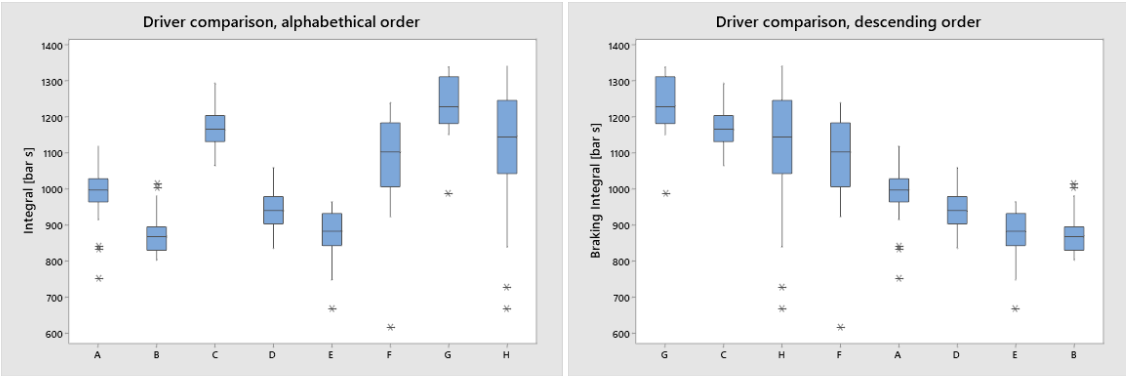
By using the same instrument it is also possible to compare the different tracks in terms of demand for braking system. This will be deeply analyzed in the next chapter.

Example For this last example are taken into account all the aggregated data of the Integral of Braking Pressure from all the pilots on the track of Magione. The table below sorts in ascending order the Mean and relative SE for every pilot of the aggregated data.

Driver	**Mean [bar · s]**	**SE Mean [bar · s]**
E	878.8	12.6
D	950.7	25.6
A	994.3	11.1
B	1079.5	54.1
H	1084.9	52.4
F	1097.7	23.2
C	1160.2	10.8
G	1305.8	80.4

Table 6.2: Mean of the Integral of Braking Curve, sorted in ascending order and relative SE for the mean.

The following plots are Boxplot (see 5.2.2) done in order to see graphically the data of the different pilots, one is in alphabetical order, the other one is in descending order.



(a) Alphabetical order (b) Descending order

Figure 6.1: Boxplots for Integral of Braking Pressure, Magione

The following matrix evidences in green the intersections in which the drivers are not statistically different.

	A	B	C	D	E	F	G
H	0.003	0.000	0.177	0.000	0.000	0.394	0.008
G	0.000	0.000	0.016	0.000	0.000	0.001	
F	0.048	0.000	0.021	0.002	0.000		
E	0.000	0.990	0.000	0.004			
D	0.005	0.007	0.000				
C	0.000	0.000					
B	0.000						

Table 6.3: t-Test for Comparison of Integral of Braking Pressure, circuit of Magione

Chapter 7

Statistical Analysis for the Characterization of the Driving Style

The first step for the statistical analysis is to characterize the different drivers according to their driving style. The driving style is a set of different aspect to consider: how the driver uses the brake and throttle, how he turns the steering wheel and other characteristics. This analysis will deal with the braking behaviour of each driver, since it is necessary to investigate only this aspect.

7.1 Examined Data

The choice of the examined data among all the channels acquired by the Telemetry[1] if fundamental to characterize the braking technique. The data chosen for this analysis is the braking pressure. The braking pressure is acquired by the dash logger by two different sensors: the one concerning the braking pressure on the front wheels and the one for the rear wheels; the unit of measure is bar. Since the attention is on the whole braking system was created a Mathematical Channel (See

[1] See table 3.7 for the complete list of all the channels acquired by the Telemetry.

chapter 3.3.1) called P_BRK_TOT.

$$P\_BRK\_TOT = P\_BRK\_FRONT + P\_BRK\_REAR \tag{7.1}$$

Once the mathematical channel is created it is possible to visualize the data on a window in Race Studio Analysis. The graph displays the data on the y-axis and on the x-axis the meters travelled by the vehicle; it shows one complete lap and on the top of the window it is possible to see the the turns and the straights: the red ones are the right-hander, while the blue ones are the left-hander and the green part is the straight.

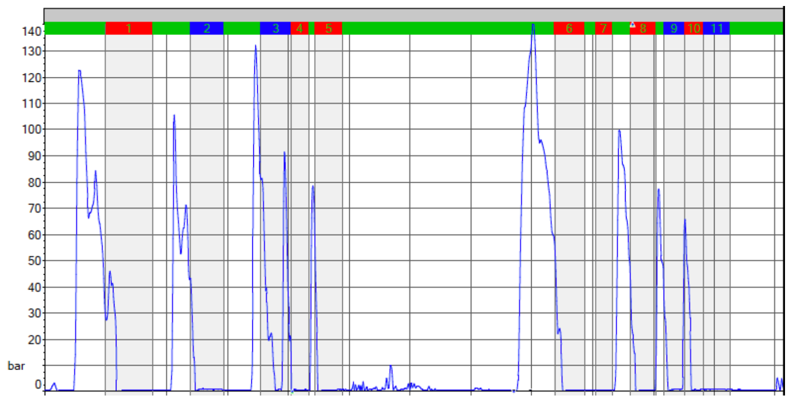


Figure 7.1: Braking pressure Graph

The driving style during the braking maneuver can be defined by a visual analysis on this particular graph: the braking pressure of two different driver can be compared and the differences can be highlighted. To conduct a statistical analysis it is necessary to extrapolate a numerical data from the graph to work on. The data chosen to extrapolate are the following:

Maximum The maximum value of the curve defines how much a driver is pressing on the brake pedal, expressed in bar.

Integral over the time The integral is useful for this analysis since it correlates the amount of braking pressure inside the circuit and the amount of time in which the pedal is pressed. This data is directly related to the amount of energy inserted in the braking circuit and consequently to the amount of heat generated by the brakes. The equation for the integral is the one shown in

Equation 7.2. The unit of measure of this data is bar · s.

$$\int_0^{\text{Laptime}} \text{P\_BRK\_TOT} \quad dt \tag{7.2}$$

In order to compare the different drivers it is fundamental to chose a single circuit on which data are acquired, it is not convenient to compare the data coming from two different circuits. This choice is derived from this hypothesis: it can be plausible that the driving style changes with the circuit since the drivers are not professional one and the subjective aspect regarding the specific circuit is relevant. According to Table 4.7 it is possible to find a circuit in which every driver has completed at least one session: it is the circuit of Magione. All the data are coming from the different session of all the drivers done at this specific track.

7.2 Procedure

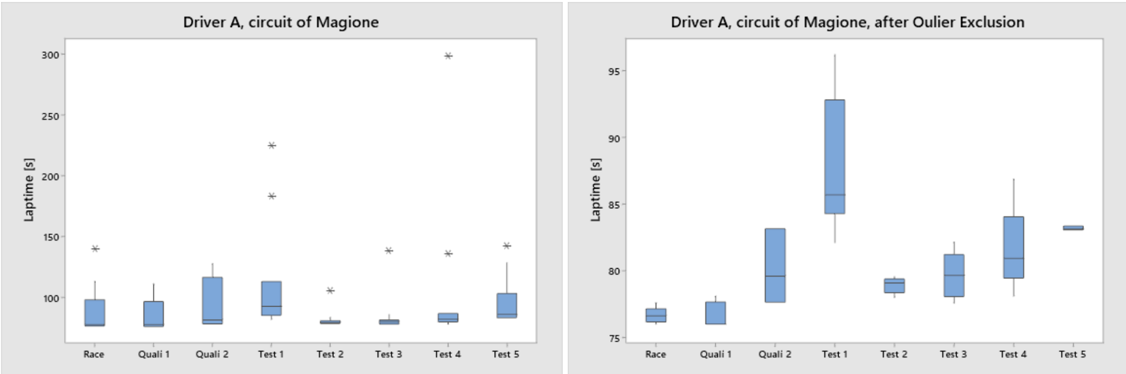
The procedure follows the one discussed in Chapter 6: after a first step of outlier exclusion based on laptimes, the data are aggregated and then compared.Two different and parallel analysis are conducted: the one regarding the maximum value and the one about the integral.

In the tables of outlier exclusion in Appendix A, the excluded values are displayed in red, the superscript near the lap number identifies the step in which the data was classified as an outlier.

1. Qualitative evaluation.
2. Chauvenet Method.
3. *Bad lap*: Safety Car, incident, last lap of the session (in-lap).

In the next Sections every driver is analyzed by following the procedure. For every driver are shown two different Boxplots for the Laptime of every session: one before and one after the outlier exclusion. In those graphs it is possible to see the difference on the scale, that is substantially different. After the Boxplots for the Laptime, the Data Aggregation procedure has to be conducted. In this Chapter the data aggregation is the combination of the Maximum and the Integral of Braking Pressure: atwo sessions can be aggregated only if they do not display statistical different for both the data (Maximum and Integral). After the t-Test results the aggregated data are displayed in a proper table.

7.3 Driver A



(a) Before Outlier Exclusion　　(b) After Outlier Exclusion

Figure 7.2: Boxplots for Laptime, driver A

	Quali 1	**Quali 2**	**Test 1**	**Test 2**	**Test 3**	**Test 4**	**Test 5**
Race	0.928	0.596	0.530	0.649	0.632	0.264	0.030
Test 5	0.064	0.087	0.143	0.020	0.017	0.258	
Test 4	0.362	0.535	0.706	0.213	0.198		
Test 3	0.819	0.417	0.390	0.980			
Test 2	0.811	0.4356	0.402				
Test 1	0.584	0.851					
Quali 2	0.662						

Table 7.1: t-Test result for Maximum Braking Pressure, driver A, circuit of Magione

	Quali 1	**Quali 2**	**Test 1**	**Test 2**	**Test 3**	**Test 4**	**Test 5**
Race	0.260	0.485	0.946	0.709	0.017	0.480	0.022
Test 5	0.038	0.746	0.315	0.001	0.802	0.042	
Test 4	0.147	0.669	0.805	0.620	0.049		
Test 3	0.030	0.703	0.292	0.003			
Test 2	0.192	0.544	0.943				
Test 1	0.410	0.600					
Quali 2	0.191						

Table 7.2: t-Test result for Integral of Braking Curve, driver A, circuit of Magione

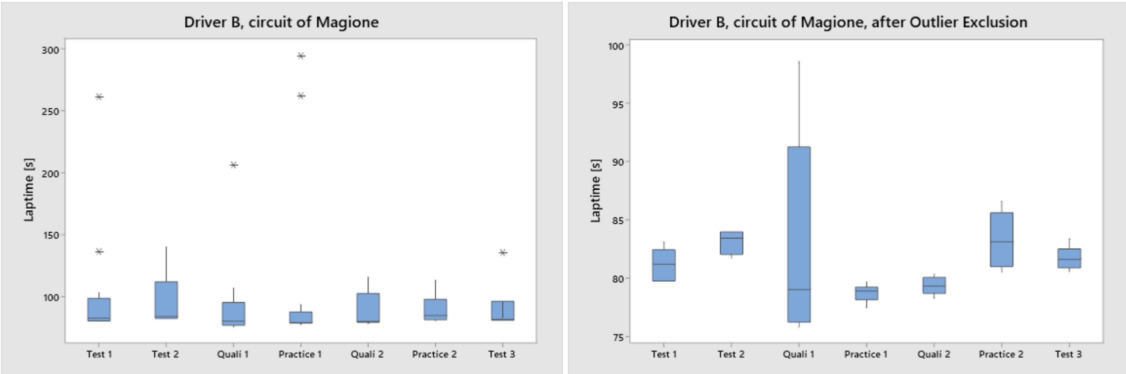
By comparing the two Tables 7.1 and 7.2 it can be seen that the session that can be aggregated are: Race, Quali 1, Quali 2, Test 1, Test 2 and Test 4.

	Lap	**Laptime [s]**	**Max [bar]**	**Integral [bar · s]**
Race	*lap 5*	77.579	85.28	936.70
	lap 6	76.621	89.59	976.00
	lap 7	76.301	84.57	1029.88
	lap 8	76.027	84.30	996.25
	lap 9	76.725	84.42	1004.30
Quali 1	*lap 4*	77.262	75.84	841.16
	lap 5	76.009	87.08	963.85
	lap 6	75.987	87.81	915.04
	lap 7	76.001	92.41	1039.70
	lap 8	78.077	86.41	954.72
Quali 2	*lap 2*	83.160	87.62	1112.27
	lap 3	79.607	81.10	973.79
	lap 4	77.648	84.39	996.14
Test 1	*lap 3*	92.950	74.71	832.91
	lap 4	86.181	77.83	997.14
	lap 5	85.166	81.62	1079.02
	lap 6	96.187	88.3	1118.49
	lap 9	92.498	75.40	750.29
	lap 10	85.242	84.78	991.36
	lap 11	84.011	95.95	1085.41
	lap 12	82.139	91.21	1082.05
Test 2	*lap 3*	79.393	90.02	965.79
	lap 4	79.482	99.44	1000.91
	lap 5	78.369	76.19	996.80
	lap 6	78.021	87.79	1008.66
	lap 7	79.184	75.95	1021.30
	lap 8	78.162	94.32	1026.45
	lap 9	78.436	88.71	1028.16
	lap 10	79.195	90.99	1010.44
	lap 12	78.737	85.62	950.41
	lap 13	79.100	87.45	997.56

	Lap	**Laptime [s]**	**Max [bar]**	**Integral [bar · s]**
	lap 14	79.532	78.09	945.53
Test 4	*lap 2*	85.936	71.40	996.77
	lap 3	86.859	80.23	979.21
	lap 4	82.197	78.48	1023.76
	lap 5	81.981	87.12	1013.63
	lap 6	79.747	88.87	1045.52
	lap 7	79.153	81.83	1026.12
	lap 8	78.133	91.77	1076.66
	lap 9	80.694	92.05	1031.31
	lap 11	80.933	84.54	945.85
	$\bar{x}$		85.16	994.32
	s		6.31	71.07

Table 7.3: Driver A, Magione, Aggregated data

7.4 Driver B



(a) Before Outlier Exclusion (b) After Outlier Exclusion

Figure 7.3: Boxplots for Laptime, driver B

	Test 2	Quali 1	Practice 1	Quali 2	Practice 2	Test 3
Test 1	0.055	0.236	0.307	0.041	0.157	0.856
Test 3	0.062	0.130	0.184	0.037	0.171	
Practice 2	0.557	0.019	0.024	0.012		
Quali 2	0.010	0.108	0.099			
Practice 1	0.010	0.876				
Quali 1	0.007					

Table 7.4: t-Test result for Maximum Braking Pressure, driver B, circuit of Magione

	Test 2	Quali 1	Practice 1	Quali 2	Practice 2	Test 3
Test 1	0.119	0.002	0.000	0.006	0.002	0.187
Test 3	0.807	0.021	0.004	0.022	0.169	
Practice 2	0.224	0.094	0.011	0.086		
Quali 2	0.028	0.944	0.583			
Practice 1	0.005	0.682				
Quali 1	0.027					

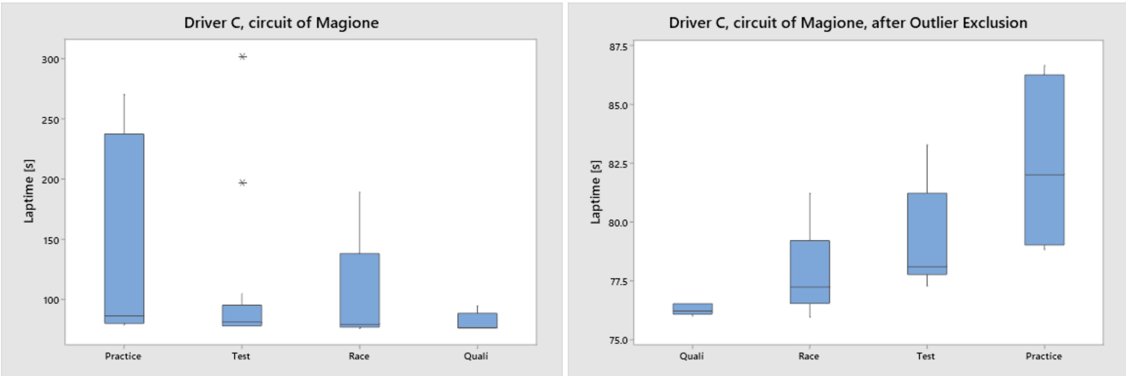
Table 7.5: t-Test result for Integral of Braking Curve, driver B, circuit of Magione

By comparing the two Tables 7.4 and 7.5 it can be seen that the session that can be aggregated are: Test 1, Test 2 and Test 3.

	Lap	**Laptime [s]**	**Max [bar]**	**Integral [bar · s]**
Test 1	*lap 4*	83.043	101.43	883.61
	lap 5	83.070	106.42	874.96
	lap 7	81.848	89.59	874.27
	lap 8	81.182	78.56	806.59
	lap 9	80.643	92.67	849.78
	lap 10	79.703	97.68	844.18
	lap 11	81.739	85.05	815.06
	lap 13	79.805	88.01	822.74
	lap 14	79.706	85.44	832.53
Test 2	*lap 2*	83.997	88.22	862.20
	lap 3	83.867	80.59	889.84
	lap 4	82.961	75.85	912.16
	lap 5	81.718	86.15	1014.60
Test 3	*lap 2*	83.333	88.54	803.64
	lap 3	81.609	96.99	856.49
	lap 4	81.657	84.91	888.45
	lap 5	81.160	95.43	1004.52
	lap 6	80.588	88.93	981.18
	$\bar{x}$		89.47	878.71
	s		7.88	63.77

Table 7.6: Driver B, Magione, Aggregated data

7.5 Driver C



(a) Before Outlier Exclusion (b) After Outlier Exclusion

Figure 7.4: Boxplots for Laptime, driver C

	Race	**Test**	**Practice**
Quali	0.815	0.734	0.001
Practice	0.019	0.020	
Test	0.941		

Table 7.7: t-Test result for Maximum Braking Pressure, driver C, circuit of Magione

	Race	**Test**	**Practice**
Quali	0.902	0.304	0.001
Practice	0.001	0.000	
Test	0.300		

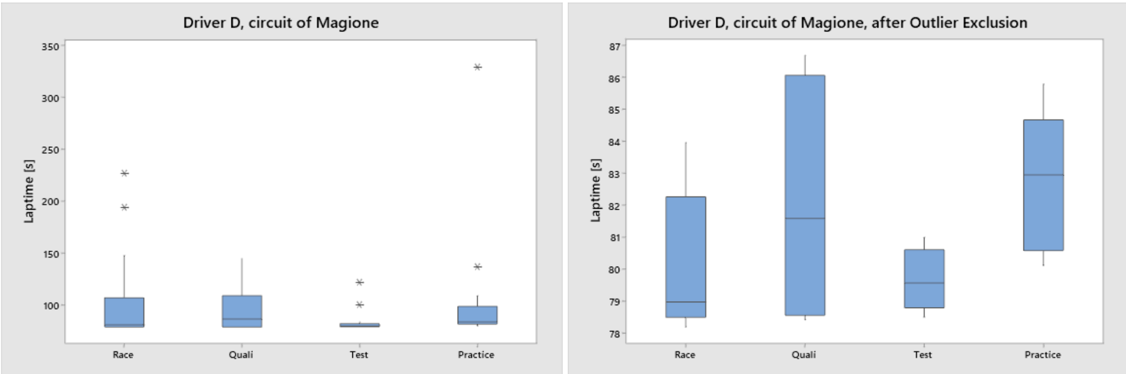
Table 7.8: t-Test result for Integral of Braking Curve, driver C, circuit of Magione

As it can be seen from the Tables 7.7 and 7.8, the session Practice has to be excluded from the aggregation of data.

	Lap	Laptime [s]	Max [bar]	Integral [bar · s]
Quali	*lap 4*	76.533	143.92	1204.31
	lap 5	78.198	130.54	1068.13
	lap 6	76.157	146.66	1123.43
	lap 7	76.522	128.21	1168.50
	lap 8	76.221	147.51	1163.46
	lap 9	76.013	141.41	1178.41
Race	*lap 5*	80.326	112.03	1072.23
	lap 6	79.273	128.26	1079.16
	lap 7	78.451	148.90	1149.27
	lap 8	79.013	136.59	1210.16
	lap 9	76.497	163.92	1236.44
	lap 10	77.088	136.72	1186.67
	lap 11	77.149	139.75	1147.61
	lap 12	76.541	141.01	1179.81
	lap 13	76.546	133.60	1168.99
	lap 14	75.969	166.25	1174.94
	lap 15	77.327	147.10	1158.25
	lap 16	81.218	104.59	1086.30
Test	*lap 7*	78.103	145.88	1065.67
	lap 8	78.164	147.19	1135.03
	lap 9	79.341	145.87	1163.83
	lap 10	77.286	141.88	1224.27
	lap 11	77.668	143.97	1205.97
	lap 12	78.048	148.07	1293.41
	lap 13	77.869	138.47	1239.12
	lap 14	83.279	119.39	1139.35
	$\bar{x}$		139.53	1162.41
	s		13.57	63.77

Table 7.9: Driver C, Magione, Aggregated data

7.6 Driver D



(a) Before Outlier Exclusion (b) After Outlier Exclusion

Figure 7.5: Boxplots for Laptime, driver D

	Quali	Test	Practice
Race	0.586	0.025	0.000
Practice	0.024	0.021	
Test	0.068		

Table 7.10: t-Test result for Maximum Braking Pressure, driver D, circuit of Magione

	Quali	Test	Practice
Race	0.497	0.006	0.000
Practice	0.000	0.001	
Test	0.004		

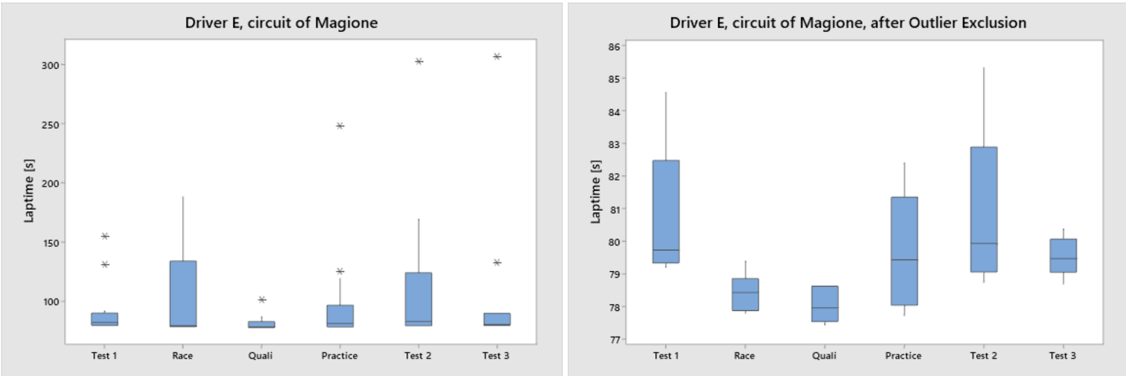
Table 7.11: t-Test result for Integral of Braking Curve, driver D, circuit of Magione

As it can be deducted from the Tables 7.10 and 7.11, the only sessions that can be aggregated are: Race and Quali.

	Lap	Laptime [s]	Max [bar]	Integral [bar · s]
Race	*lap 3*	83.957	86.31	878.52
	lap 4	80.903	88.83	836.26
	lap 5	79.047	97.70	883.03
	lap 6	78.847	107.66	916.85
	lap 7	78.975	104.86	906.00
	lap 8	78.493	104.68	954.50
	lap 9	78.732	103.56	958.34
	lap 10	78.187	111.09	993.48
	lap 11	82.268	107.25	986.46
	lap 13	83.121	102.04	1058.93
	lap 14	78.314	99.95	924.95
Quali	*lap 3*	86.678	117.97	967.87
	lap 5	84.232	97.55	903.58
	lap 6	78.939	98.50	979.14
	lap 7	78.424	99.20	940.54
	$\bar{x}$		101.81	939.23
	s		8.00	55.45

Table 7.12: Driver D, Magione, Aggregated data

7.7 Driver E



(a) Before Outlier Exclusion (b) After Outlier Exclusion

Figure 7.6: Boxplots for Laptime, driver E

	Race	Quali	Practice	Test 2	Test 3
Test 1	0.022	0.000	0.122	0.143	0.527
Test 3	0.413	0.007	0.541	0.612	
Test 2	0.705	0.002	0.871		
Practice	0.878	0.004			
Quali	0.001				

Table 7.13: t-Test result for Maximum Braking Pressure, driver E, circuit of Magione

	Race	Quali	Practice	Test 2	Test 3
Test 1	0.987	0.025	0.750	0.029	0.152
Test 3	0.167	0.006	0.176	0.422	
Test 2	0.0341	0.001	0.049		
Practice	0.770	0.123			
Quali	0.031				

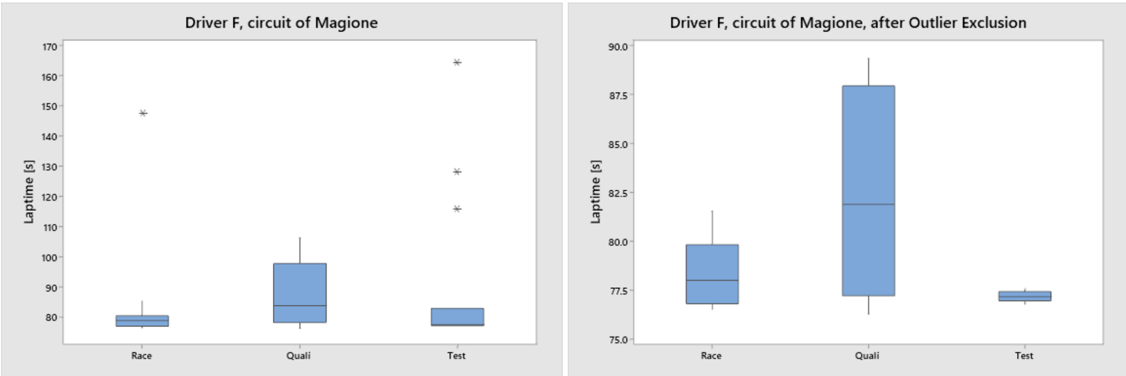
Table 7.14: t-Test result for Integral of Braking Curve, driver E, circuit of Magione

The Tables 7.13 and 7.14 suggest to exclude Test 1, Test 2 and Quali. The remaining sessions to be aggregated are: Test 3, Practice and Race.

	Lap	Laptime [s]	Max [bar]	Integral [bar · s]
Race	*lap 6*	79.029	94.97	843.95
	lap 7	78.802	107.85	857.23
	lap 8	79.389	100.94	825.83
	lap 9	78.448	95.90	829.18
	lap 10	77.801	102.28	932.50
	lap 11	77.818	109.36	880.26
	lap 12	78.405	95.29	964.97
	lap 13	78.553	93.81	881.16
	lap 14	78.347	104.30	947.68
	lap 15	77.900	95.07	885.38
Practice	*lap 5*	81.855	98.67	905.34
	lap 6	81.16	102.26	954.63
	lap 7	79.04	91.26	937.02
	lap 8	78.087	85.94	928.17
	lap 9	77.727	105.73	933.20
	lap 10	77.911	96.90	859.21
	lap 11	82.397	128.65	956.76
	lap 12	81.188	86.40	666.42
	lap 13	78.445	103.72	910.72
	lap 14	79.820	93.46	889.62
Test 3	*lap 6*	80.374	101.59	826.27
	lap 7	79.965	74.33	748.51
	lap 8	79.450	103.95	905.47
	lap 9	79.490	102.80	880.11
	lap 10	79.168	103.19	862.66
	lap 11	78.699	85.68	840.90
	$\bar{x}$		98.63	878.97
	s		10.08	66.97

Table 7.15: Driver E, Magione, Aggregated data

7.8 Driver F



(a) Before Outlier Exclusion (b) After Outlier Exclusion

Figure 7.7: Boxplots for Laptime, driver F

	Quali	Test
Race	0.498	0.001
Test	0.134	

Table 7.16: t-Test result for Maximum Braking Pressure, driver F, circuit of Magione

	Quali	Test
Race	0.448	0.035
Test	0.224	

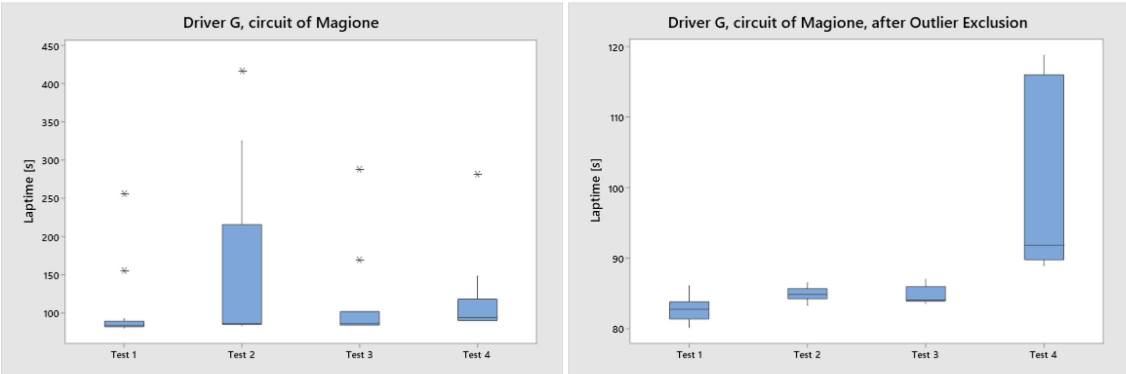
Table 7.17: t-Test result for Integral of Braking Curve, driver F, circuit of Magione

The only session that has to be excluded according to the result of the Tables 7.16 and 7.17 is the Test, while Race and Quali can be aggregated.

	Lap	Laptime [s]	Max [bar]	Integral [bar · s]
Race	*lap 3*	79.101	104.03	973.94
	lap 4	77.415	117.71	1024.53
	lap 5	76.662	119.39	1101.52
	lap 6	76.654	127.76	1184.97
	lap 7	76.532	144.72	1220.15
	lap 8	76.854	120.02	1197.36
	lap 9	77.354	136.47	1239.30
	lap 10	77.476	115.26	1184.14
	lap 11	78.531	119.26	1105.12
	lap 12	79.097	114.56	1133.30
	lap 13	79.765	99.23	1032.01
	lap 14	80.049	100.67	998.79
	lap 15	80.561	107.45	1027.12
	lap 16	81.538	101.35	923.22
Quali	*lap 2*	89.348	63.28	615.01
	lap 3	80.019	114.86	1009.01
	lap 4	76.287	122.70	1131.41
	lap 5	83.767	119.72	1175.13
	$\bar{x}$		113.80	1070.89
	s		17.36	146.86

Table 7.18: Driver F, Magione, Aggregated data

7.9 Driver G



(a) Before Outlier Exclusion (b) After Outlier Exclusion

Figure 7.8: Boxplots for Laptime, driver G

	Test 1	**Test 2**	**Test 3**
Test 4	0.000	0.002	0.003
Test 3	0.359	0.502	
Test 2	0.997		

Table 7.19: t-Test result for Maximum Braking Pressure, driver G, circuit of Magione

	Test 1	**Test 2**	**Test 3**
Test 4	0.000	0.115	0.080
Test 3	0.010	0.236	
Test 2	0.527		

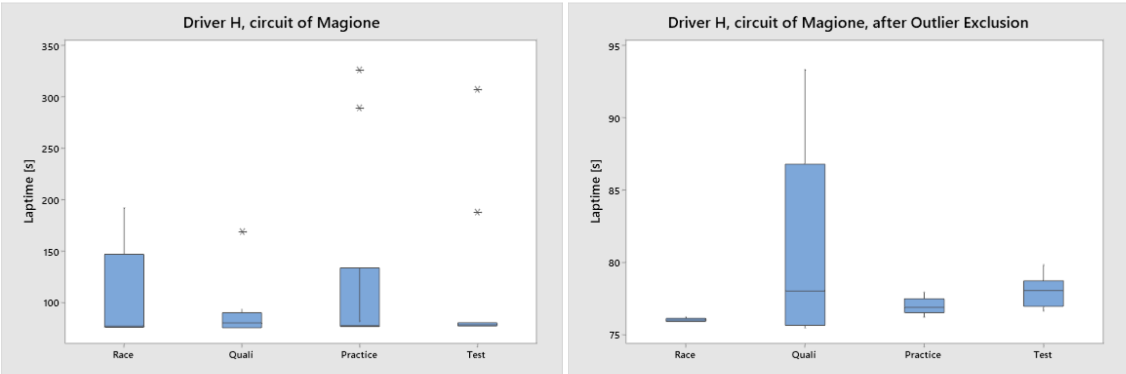
Table 7.20: t-Test result for Integral of Braking Curve, driver G, circuit of Magione

The Tables 7.19 and 7.20 give two possible combinations for the aggregation of data: keep Test 1 and Test 2 or Test 2 and Test 3. The choice between the two combination depends on the larger data set, that is given by the aggregation of Test 1 and Test 2.

	Lap	Laptime [s]	Max [bar]	Integral [bar · s]
Test 1	*lap 3*	86.035	98.70	1151.89
	lap 4	84.972	95.13	1271.86
	lap 5	83.369	102.55	1316.26
	lap 6	83.434	111.13	1309.53
	lap 7	83.160	123.53	1312.66
	lap 8	82.313	112.21	1338.89
	lap 9	81.870	106.22	1186.34
	lap 10	81.581	110.14	1236.07
	lap 12	80.226	107.90	1230.93
	lap 13	80.802	108.99	1154.06
Test 2	*lap 2*	84.821	90.15	1180.50
	lap 4	86.460	85.73	986.71
	lap 5	85.426	131.32	1214.06
	lap 6	84.543	106.79	1226.07
	lap 9	83.348	127.05	1197.86
	lap 10	84.870	118.75	1339.17
	$\bar{x}$		108.52	1228.30
	s		12.63	90.49

Table 7.21: Driver G, Magione, Aggregated data

7.10 Driver H



(a) Before Outlier Exclusion (b) After Outlier Exclusion

Figure 7.9: Boxplots for Laptime, driver H

	Quali	Practice	Test
Race	0.175	0.057	0.461
Test	0.307	0.044	
Practice	0.417		

Table 7.22: t-Test result for Maximum Braking Pressure, driver H, circuit of Magione

	Quali	Practice	Test
Race	0.065	0.008	0.538
Test	0.105	0.008	
Practice	0.712		

Table 7.23: t-Test result for Integral of Braking Curve, driver H, circuit of Magione

According to Tables 7.22 and 7.23 only the Practice session has to be excluded from the aggregation.

	Lap	Laptime [s]	Max [bar]	Integral [bar · s]
Race	*lap 8*	76.017	94.53	1002.47
	lap 9	75.866	96.71	1088.88
	lap 10	75.914	105.32	1190.34
	lap 11	75.942	125.44	1223.88
	lap 12	76.225	122.18	1263.41
	lap 13	76.078	123.42	1289.21
	lap 14	76.140	140.94	1248.78
Quali	*lap 2*	85.945	84.72	839.36
	lap 3	75.739	106.90	1068.09
	lap 4	75.477	115.11	1163.46
	lap 5	75.725	126.22	1340.96
	lap 6	93.330	97.01	726.97
	lap 7	80.321	105.52	1114.75
	lap 8	87.083	98.86	665.60
	lap 9	75.639	98.03	1047.84
Test	*lap 3*	79.833	114.41	1244.21
	lap 4	78.063	123.94	1251.87
	lap 5	78.062	116.53	1278.94
	lap 6	79.257	116.98	1225.93
	lap 7	76.982	114.51	1144.86
	lap 8	78.566	104.12	1197.17
	lap 9	76.889	112.84	1054.70
	lap 10	76.659	110.49	1122.21
	lap 11	78.489	90.40	1038.92
	lap 12	77.471	95.09	986.39
	$\bar{x}$		109.61	1112.77
	s		13.43	170.53

Table 7.24: Driver H, Magione, Aggregated data

7.11 Comparison

In this Section the aggregated data for each driver are compared, both the Integral and the Maximum of Braking pressure.

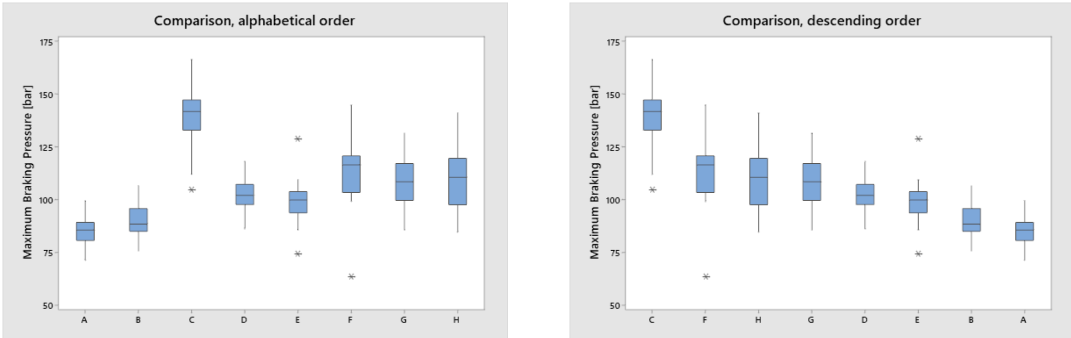
7.11.1 Maximum of Braking Pressure

The following table (Table 7.25) summarize the Mean and the Standard Deviation of Maximum of Braking Pressure for each driver, the rank is intended in the descending order.

Driver	**Mean [bar]**	**StDev [bar]**	**Rank**
A	85.16	6.31	8
B	89.47	7.88	7
C	139.53	13.57	1
D	101.81	8.00	5
E	98.63	10.08	6
F	113.80	17.36	2
G	108.52	12.63	4
H	109.61	13.43	3

Table 7.25: Comparison Table for Maximum Braking Pressure, circuit of Magione

The Boxplots in Figure 7.10 give a graphical representation of the analyzed data, both in alphabetical and descending order.



(a) Alphabetical order (b) Descending order

Figure 7.10: Boxplots for Maximum of Braking Pressure, Magione

It is necessary to see if there is a statistical difference between the data to have a complete view of the results obtained. For this reason in Table 7.26 are present the result of the t-Test for every driver.

	A	**B**	**C**	**D**	**E**	**F**	**G**
H	0.000	0.000	0.000	0.027	0.002	0.398	0.794
G	0.000	0.000	0.000	0.088	0.013	0.315	
F	0.000	0.000	0.000	0.015	0.003		
E	0.000	0.002	0.000	0.273			
D	0.000	0.000	0.000				
C	0.000	0.000					
B	0.050						

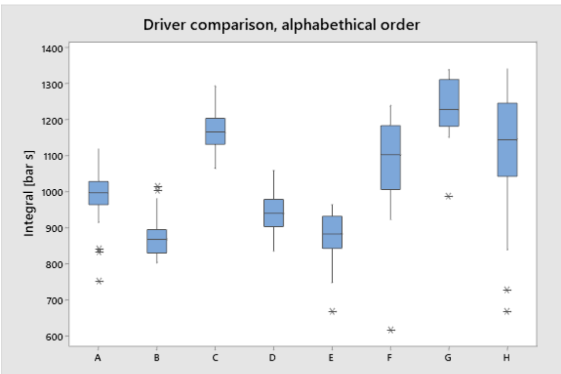
Table 7.26: t-Test for Comparison of Maximum Braking Pressure, circuit of Magione

7.11.2 Integral of Braking Pressure

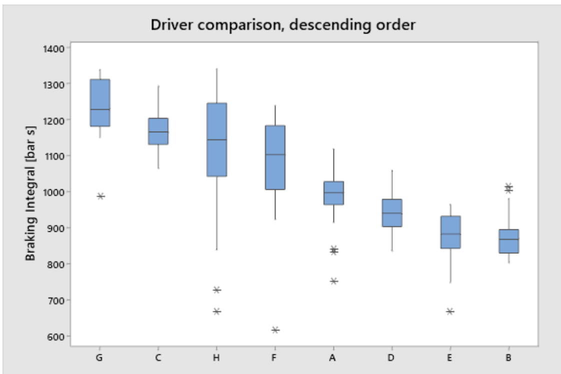
Similarly to what was done in the previous Subsection for the Maximum of Braking Pressure is done in this part for the Integral of Braking Pressure.

Driver	Mean [bar · s]	StDev [bar · s]	Rank
A	994.32	71.07	5
B	878.71	63.77	8
C	1162.41	57.27	2
D	939.23	55.45	6
E	878.97	66.97	7
F	1070.89	146.86	4
G	1228.30	90.49	1
H	1112.77	170.53	3

Table 7.27: Comparison Table for Integral of Braking Pressure, circuit of Magione



(a) Alphabetical order



(b) Descending order

Figure 7.11: Boxplots for Integral of Braking Pressure, Magione

	A	B	C	D	E	F	G
H	0.003	0.000	0.177	0.000	0.000	0.394	0.008
G	0.000	0.000	0.016	0.000	0.000	0.001	
F	0.048	0.000	0.021	0.002	0.000		
E	0.000	0.990	0.000	0.004			
D	0.005	0.007	0.000				
C	0.000	0.000					
B	0.000						

Table 7.28: t-Test for Comparison of Integral of Braking Pressure, circuit of Magione

7.12 Discussion of the Results

The Tables 7.25 and 7.27 give important results for the analysis and the characterization of the driving style. It can be seen that driver C has the highest value for the maximum of braking pressure, but for the integral has the second highest. This implies that the driver has a good braking behaviour, with a lot of pressure applied in the circuit for a relatively short amount of time. On the opposite, Driver G has the maximum value for the integral among all the drivers, while his maximum is only the fourth highest. In this case the pilot applies the force to the pedal in not an optimal way, giving pressure to the system for a larger amount of time.

The whole set of drivers can be split into two groups, according to the result of the analysis: one including Drivers C, F, G and H that has higher values for both the data analyzed (maximum and integral); while the other group with Drivers A, B D and E has a relatively smaller values.

Chapter 8

Statistical Analysis for the Characterization of the Circuits

The aim of this second statistical analysis is to determine the most demanding circuit for the braking system of the car. This characterization is important to classify all the circuits in order to find a correlation between the occurrence of the problem and the different circuits.

According to the Table 4.7 it is possible to find that driver B is the only driver that has completed at least one session in every circuit. For this reason the data of driver B are taken as reference, assuming that his driving style can be considered constant during different races. This statement is confirmed by the experience on track of the Engineers from the company, that followed the driver during the races. The only exception is represented by the last race in Magione: where the driver has changed his braking behaviour thanks to some adjustment. This data will be excluded from the following analysis, in order to achieve a more reliable result.

8.1 Definition of Examined Data

For this analysis it is necessary to find the proper data to consider to gain correct and significant results. The data has to take into account not only the pressure applied to the braking circuit in one lap, but also the length of the circuit, since the total amount of Braking Pressure is directly related to it. For this analysis it not useful to deal with the Maximum of the Braking Pressure, while it is convenient to take into account the Integral of the Braking Pressure over the time.

Starting from the Integral, in order to correlate this data to the specific circuit, it is necessary to apply a correction that takes into account the length of the circuit. This because if the circuit is longer, the integral will be larger. It is fundamental to have a data that it is not affected by the length of the circuit.

The most practical and efficient way to find a proper data to be compared is to divide the Integral of the Braking pressure over the length of the circuits in meters as it can be seen in Equation 8.1.

$$\text{Integral}_{\text{cor}} = \frac{\text{Integral}}{\text{Circuit Length}} \tag{8.1}$$

It can be highlighted that the Corrected Integral has the following unit of measure: bar · s / m; that can be also written as: bar · $(\text{m / s})^{-1}$. This data can be also interpreted as a pressure over an average speed of the vehicle.

In the Table 8.1 are summarized the lengths of the various circuits.

Circuit	**Length [m]**
Adria	2702
Franciacorta	2519
Imola	4909
Magione	2507
Misano	4226
Mugello	5245

Table 8.1: Length of the Circuits

8.2 Procedure

The procedure, also for this part, follows the one properly described in Chapter 6. For the Outlier Exclusion, the number displayed as a superscript near the lap number has the same meaning of the Chapter 7.

Every circuit has a dedicated section in which are displayed with the help of a Boxplot the data before and after the Outlier Exclusion and the table of the aggregated data. The complete tables of data and the excluded outliers can be found in Appendix A.

8.3 Adria

Since only one session was completed on this circuit by driver B, there is no need for aggregating data coming from different sessions. The Table 8.2 show only the laps not excluded in the Outlier Exclusion procedure.

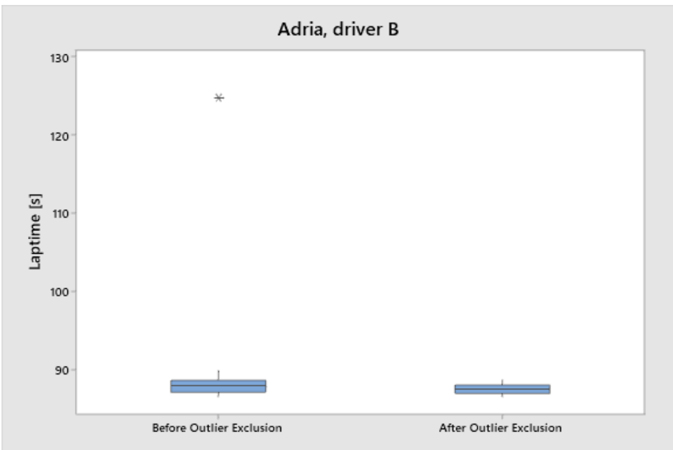


Figure 8.1: Boxplot for Laptime, circuit of Adria

	Lap	Laptime [s]	Integral [bar · s]	Integral$_{cor}$ [bar · s / m]
Practice	*lap 3*	87.117	1174.33	0.435
	lap 4	87.504	1404.72	0.520
	lap 5	86.803	1310.94	0.485
	lap 6	87.497	1280.33	0.474
	lap 7	87.948	1331.68	0.493
	lap 8	86.597	1404.45	0.520
	lap 9	88.651	1642.71	0.608
	lap 10	88.140	1295.36	0.479
	lap 11	87.971	1246.23	0.461
	$\bar{x}$		1343.42	0.497
	s		133.50	0.049

Table 8.2: Driver B, Adria, Aggregated data

8.4 Franciacorta

Also in this only one session was driven by Driver B on this track, so there is no need for aggregating different session's data.

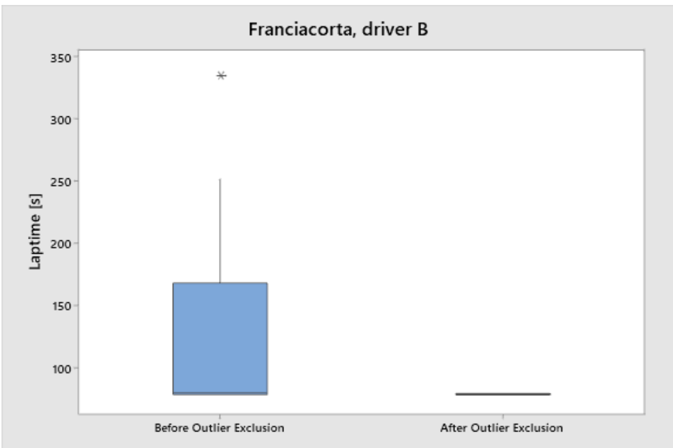


Figure 8.2: Boxplot for Laptime, circuit of Franciacorta

	Lap	Laptime [s]	Integral [bar · s]	Integral_{cor} [bar · s / m]
Race	*lap 4*	79.243	993.39	0.394
	lap 5	79.526	928.59	0.369
	lap 6	79.073	1035.19	0.411
	lap 7	78.279	912.71	0.362
	lap 8	78.125	860.41	0.342
	lap 9	78.347	922.19	0.366
	lap 10	78.470	989.15	0.393
	lap 11	80.073	918.06	0.364
	$\bar{x}$		944.96	0.375
	s		56.24	0.022

Table 8.3: Driver B, Franciacorta, Aggregated data

8.5 Imola

Driver B at Imola completed only one session, so it is not necessary to aggregate data from different sessions. The Table 8.4 shows the data not excluded by the Outlier Exclusion procedure.

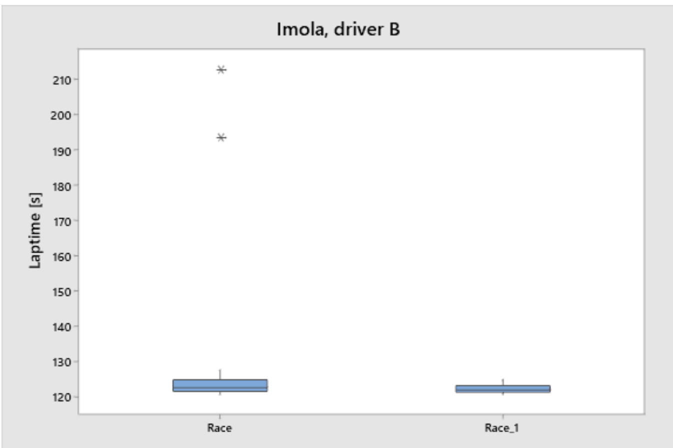


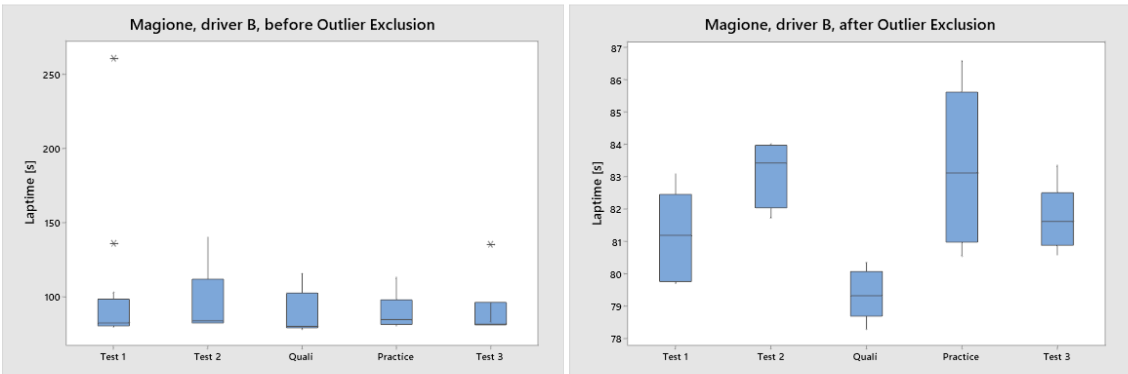
Figure 8.3: Boxplot for Laptime, circuit of Imola

	Lap	**Laptime [s]**	**Integral [bar · s]**	**Integral$_{cor}$ [bar · s / m]**
Race	*lap 4*	121.544	1999.15	0.407
	lap 5	120.787	1568.11	0.319
	lap 6	120.605	1659.38	0.338
	lap 7	121.230	1464.61	0.298
	lap 8	121.937	1260.92	0.257
	lap 9	121.549	1283.10	0.261
	lap 10	122.019	1476.23	0.301
	lap 11	123.156	1369.98	0.279
	lap 12	122.585	1536.08	0.313
	lap 13	123.227	1394.71	0.284
	lap 14	123.889	1273.12	0.259
	lap 15	124.815	1354.93	0.276
	$\bar{x}$		1470.03	0.299
	s		208.07	0.042

Table 8.4: Driver B, Imola, Aggregated data

8.6 Magione

The Team has given specific input to not consider the last race weekend of the season because the driver has changed his driving style. So the used data come from only the first race weekend and from the test sessions.



(a) Before Outlier Exclusion (b) After Outlier Exclusion

Figure 8.4: Boxplots for Laptime, circuit of Magione

	Test 1	Test 2	Quali	Practice
Test 3	0.187	0.807	0.022	0.169
Practice	0.002	0.224	0.086	
Quali	0.006	0.028		
Test 2	0.119			

Table 8.5: t-Test result for Corrected Integral, driver B, circuit of Magione

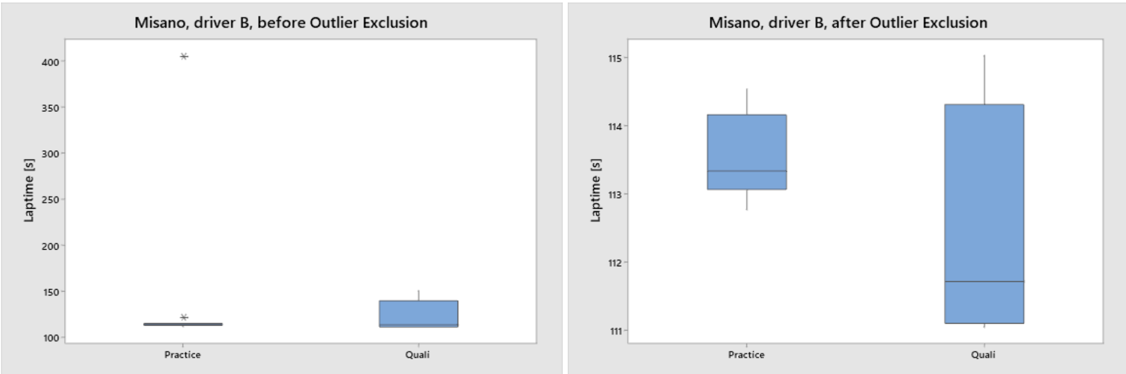
Looking after the Table 8.5 it is possible to conclude that two combinations are possible: Test 2, Practice and Test 3 or Test 1, Test 2 and Test 3. In this case the best set, since it is the most populous one is the second.

	Lap	Laptime [s]	Integral [bar · s]	Integral_{cor} [bar · s / m]
Test 1	*lap 4*	83.043	883.61	0.352
	lap 5	83.070	874.96	0.349
	lap 7	81.848	874.27	0.349
	lap 8	81.182	806.59	0.322
	lap 9	80.643	849.78	0.339
	lap 10	79.703	844.18	0.338
	lap 11	81.739	815.06	0.325
	lap 13	79.805	822.74	0.328
	lap 14	79.706	832.53	0.332
Test 2	*lap 2*	83.997	862.20	0.344
	lap 3	83.867	889.84	0.355
	lap 4	82.961	912.16	0.364
	lap 5	81.718	1014.6	0.405
Test 3	*lap 2*	83.333	803.64	0.321
	lap 3	81.609	856.49	0.342
	lap 4	81.657	888.45	0.354
	lap 5	81.160	1004.52	0.401
	lap 6	80.588	981.18	0.391
	$\bar{x}$		878.71	0.351
	s		63.77	0.025

Table 8.6: Driver B, Magione, Aggregated data

8.7 Misano

For the Circuit of Misano, only two sessions were present in the database. After the Outlier Exclusion procedure it is necessary to compare them with the t-Test.



(a) Before Outlier Exclusion (b) After Outlier Exclusion

Figure 8.5: Boxplots for Laptime, circuit of Misano

	Practice
Quali	0.350

Table 8.7: t-Test result for Corrected Integral, driver B, circuit of Misano

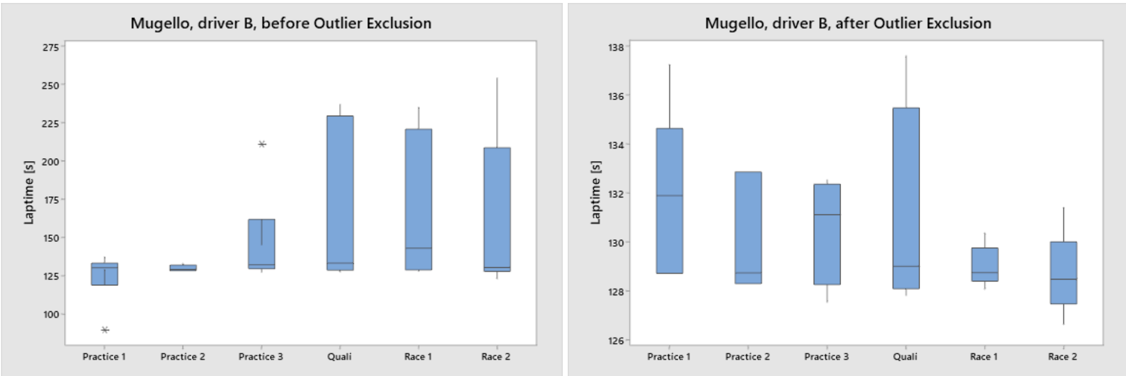
The t-Test states that it is not possible to evidence a statistical difference between the two sessions, so they can be aggregated.

	Lap	Laptime [s]	Integral [bar · s]	Integral$_{cor}$ [bar · s / m]
Practice	*lap 4*	113.992	1421.02	0.336
	lap 5	113.097	1507.77	0.357
	lap 6	114.538	1483.76	0.351
	lap 7	112.772	1382.82	0.327
	lap 8	113.038	1432.78	0.339
	lap 10	114.336	1606.53	0.380
	lap 11	113.213	1534.76	0.363
	lap 12	113.821	1365.45	0.323
	lap 13	113.336	1358.10	0.321
Quali	*lap 2*	111.047	1558.96	0.367
	lap 4	115.028	1369.61	0.324
	lap 5	112.172	1187.67	0.281
	lap 6	111.260	1344.03	0.318
	$\bar{x}$		1427.17	0.337
	s		111.44	0.026

Table 8.8: Driver B, Misano, Aggregated data

8.8 Mugello

Driver B at Mugello completed six different sessions in a race weekend: three practices, one quali and two races.



(a) Before Outlier Exclusion (b) After Outlier Exclusion

Figure 8.6: Boxplots for Laptime, circuit of Mugello

	Practice 1	**Practice 2**	**Practice 3**	**Quali**	**Race 1**
Race 2	0.034	0.623	0.121	0.089	0.151
Race 1	0.339	0.195	0.901	0.527	
Quali	0.855	0.119	0.425		
Practice 3	0.212	0.129			
Practice 2	0.040				

Table 8.9: t-Test result for Corrected Integral, driver B, circuit of Mugello

Results from Table 8.9 evidences two possible options for the aggregation of data. The first possible solution is the one including the following sessions: Practice 2, Practice 3, Race 1 and Race 2; this solution led to a data set whose size is 19. The second solution is represented by the set with Practice 1, Practice 3, Quali and Race 1 with 18 data. It is chosen the most populous combination: the first one.

	Lap	Laptime [s]	Integral [bar · s]	Integral$_{cor}$ [bar · s / m]
Practice 2	*lap 2*	132.852	1211.31	0.231
	lap 3	128.295	1275.08	0.243
	lap 4	128.729	1233.61	0.235
Practice 3	*lap 3*	132.510	1292.70	0.246
	lap 4	127.551	1238.31	0.236
	lap 5	130.345	1309.66	0.250
	lap 6	131.868	1314.04	0.251
Race 1	*lap 6*	128.743	1220.55	0.233
	lap 9	130.345	1391.72	0.265
	lap 10	128.083	1318.32	0.251
	lap 11	128.700	1294.82	0.247
	lap 12	129.155	1240.64	0.237
Race 2	*lap 6*	126.642	1290.53	0.246
	lap 7	128.558	1286.21	0.245
	lap 8	128.390	1104.54	0.211
	lap 9	127.743	1266.92	0.242
	lap 10	131.389	1113.41	0.212
	lap 12	129.534	1254.24	0.239
	$\bar{x}$		1258.70	0.240
	s		69.21	0.013

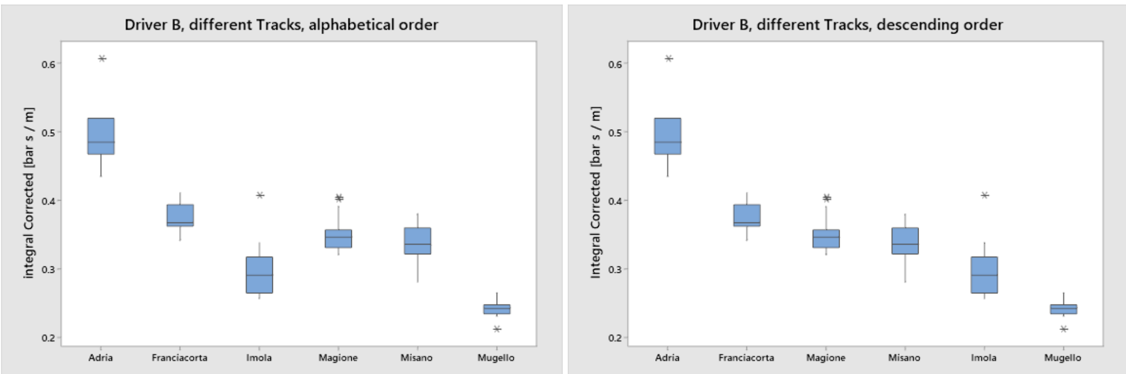
Table 8.10: Driver B, Mugello, Aggregated data

8.9 Comparison

The Table 8.11 summarizes the result obtained in the previous Sections. It shows the Mean and the Standard Deviation of the Corrected Integral ($\text{Integral}_{\text{cor}}$) and the rank of the mean in descending order among all the values.

Circuit	Mean [bar · s / m]	StDev [bar · s / m]	Rank
Adria	0.497	0.049	1
Franciacorta	0.375	0.022	2
Imola	0.299	0.042	5
Magione	0.351	0.025	3
Misano	0.337	0.026	4
Mugello	0.240	0.013	6

Table 8.11: Comparison Table for Corrected Integral of Braking Pressure, driver B



(a) Alphabetical order

(b) Descending order

Figure 8.7: Boxplots for Corrected Integral of Braking Pressure, driver B

	Adria	Franciacorta	Imola	Magione	Misano
Mugello	0.000	0.000	0.001	0.000	0.000
Misano	0.000	0.003	0.015	0.175	
Magione	0.000	0.026	0.002		
Imola	0.000	0.000			
Franciacorta	0.050				

Table 8.12: t-Test for Comparison of Different Circuits, Driver B

The Table of the t-Test evidences that the circuits of Magione and Misano are not statistically different, this means that they can be treated as equal in terms of rank and mean value.

8.10 Discussion of the Results

The results of this analysis are coherent with the experience gained on the track by the team. Adria is the most demanding circuit for the braking system since it is a short circuit with a high number of corners and brakings. Franciacorta has similar characteristics to Adria in terms of circuit length, corners and brakings.

The analysis does not evidenced a statistical difference between Magione and Misano: two different circuits in terms of characteristics. Magione is a short circuit with a lot of high braking consecutive zones in the first and last part; while Misano is longer and has long straights with very tight corners.

Imola and Mugello are not surprisingly at the last position of the ranking in terms of Corrected Integral. They have similar characteristics: long straights, long circuits and few heavy braking zones.

Chapter 9

Validation of the Obtained Results

This chapter will deal with a preliminary validation of the results obtained in Chapters 7 and 8. This final work is aimed at verify if the method and the procedures are confirmed by the analysis of the other data available in the database.

The used set of data for the previous analysis were taken from one single circuit (Magione) and one single driver (Driver B). The simplest and most effective way to verify the results is to take the other drivers that have completed sessions in other circuits and verify if the results follows what was obtained in Chapter 7. In the same way it is possible to verify, for the same driver that has completed session in different circuits, if the results are coherent with the one obtained in Chapter 8.

9.1 Procedure

The procedure follows the one explained and used in the previous chapters. By using the same procedure it is also possible to verify the correctness.

All the tables with the complete set of data and the Outlier Exclusion can be found in Appendix A.

Are treated and examined the data coming from the pilots that have driven in three different circuits: Driver E, G and H. It is dedicated to each driver a specific subsection that shows the data of the different tracks.

9.2 Definition of Examined Data

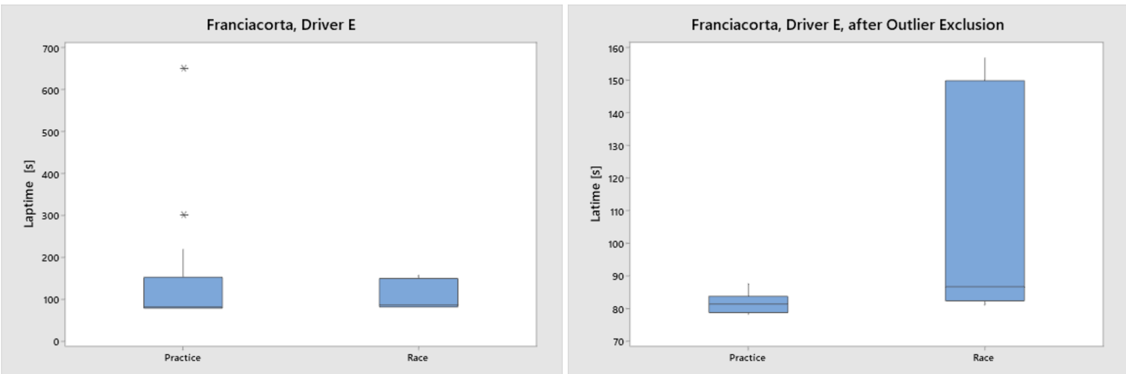
The examined data for this validation is the only Integral of Braking Pressure Corrected (see Equation 8.1). This value it is the one that allows to compare not only the drivers but also the circuits.

9.3 Driver E

In the database of the team are present the telemetry data of Driver E coming from the circuits of Franciacorta, Magione and Misano.

9.3.1 Franciacorta

After having completed the Outlier Exclusion procedure on Laptimes, The Corrected Integral values are tested to see if the two different sessions can be aggregated or not.



(a) Before Outlier Exclusion (b) After Outlier Exclusion

Figure 9.1: Boxplots for Laptime, circuit of Franciacorta, Driver E

	Practice
Race	0.026

Table 9.1: t-Test result for Integral of Braking Pressure, driver H, circuit of Franciacorta

The Table 9.1 shows that the two session cannot be aggregated. Since they have the same number of data it is chosen the one with the smallest value for the standard deviation: the Practice session.

	Lap	Laptime [s]	Integral [bar · s]	$\text{Integral}_{\text{cor}}$ [bar · s / m]
Practice	*lap 2*	84.910	964.64	0.383
	lap 3	87.519	947.04	0.376
	lap 4	83.384	788.96	0.313
	lap 7	81.982	792.08	0.314
	lap 8	78.844	822.96	0.327
	lap 9	80.732	837.43	0.332
	lap 10	82.019	999.75	0.397
	lap 11	78.545	954.14	0.379
	lap 12	78.366	916.12	0.364
	lap 13	79.123	945.77	0.375
	$\bar{x}$		896.89	0.356
	s		78.43	0.031

Table 9.2: Driver E, Franciacorta, Aggregated data

9.3.2 Magione

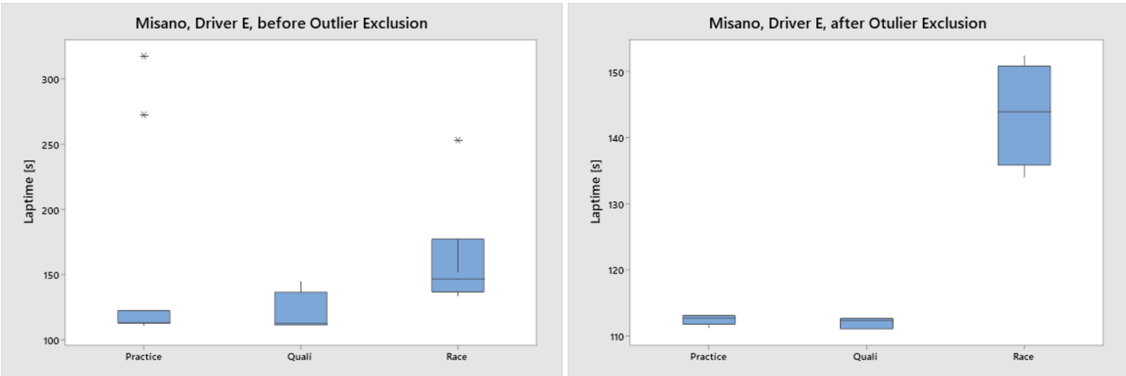
The Outlier Exclusion and Data Aggregation procedure on the data of Magione has been already done in Chapter 7. Below it is reported only the table with the aggregated data; the value of Maximum is not reported, while the Corrected Integral is calculated and added to the Table shown in Chapter 7.

	Lap	Laptime [s]	Integral [bar · s]	Integral_{cor} [bar · s / m]
Race	*lap 6*	79.029	843.95	0.337
	lap 7	78.802	857.23	0.342
	lap 8	79.389	825.83	0.329
	lap 9	78.448	829.18	0.331
	lap 10	77.801	932.50	0.372
	lap 11	77.818	880.26	0.351
	lap 12	78.405	964.97	0.385
	lap 13	78.553	881.16	0.351
	lap 14	78.347	947.68	0.378
	lap 15	77.900	885.38	0.353
Practice	*lap 5*	81.855	905.34	0.361
	lap 6	81.16	954.63	0.381
	lap 7	79.04	937.02	0.374
	lap 8	78.087	928.17	0.370
	lap 9	77.727	933.20	0.372
	lap 10	77.911	859.21	0.343
	lap 11	82.397	956.76	0.382
	lap 12	81.188	666.42	0.266
	lap 13	78.445	910.72	0.363
	lap 14	79.820	889.62	0.355
Test 3	*lap 6*	80.374	826.27	0.329
	lap 7	79.965	748.51	0.299
	lap 8	79.450	905.47	0.361
	lap 9	79.490	880.11	0.351
	lap 10	79.168	862.66	0.344
	lap 11	78.699	840.90	0.355
	$\bar{x}$		878.97	0.351
	s		66.97	0.027

Table 9.3: Driver E, Magione, Aggregated data

9.3.3 Misano

Driver E in Misano took part in one complete race weekend.



(a) Before Outlier Exclusion (b) After Outlier Exclusion

Figure 9.2: Boxplots for Laptime, circuit of Misano, Driver E

The Outlier Exclusion procedure is done also on this data, after that the t-Test is conducted on the values of the Corrected Integral.

	Practice	**Quali**
Race	0.028	0.086
Quali	0.389	

Table 9.4: t-Test result for Integral of Braking Pressure, driver E, circuit of Misano

The result coming from the Table 9.4 evidences that Practice or Race has to be excluded from the aggregation. The most populous set of data is the one represented by the aggregation of Practice and Quali; it is then chosen this set.

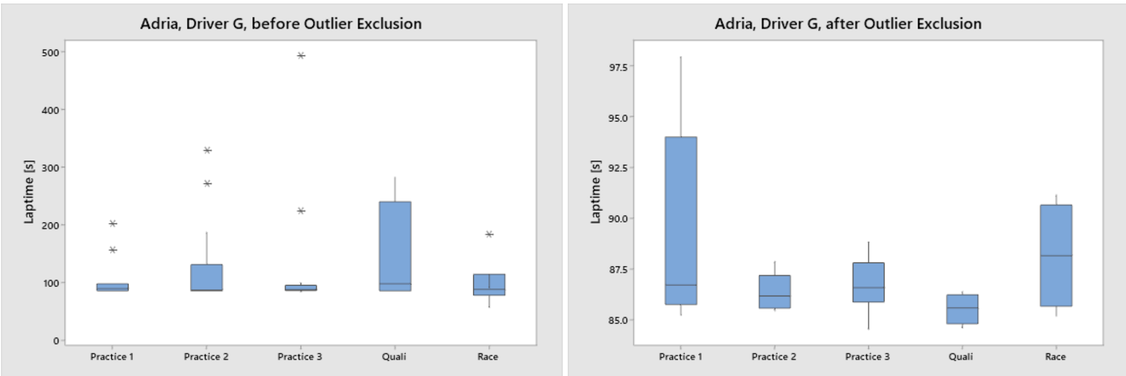
	Lap	Laptime [s]	Integral [bar · s]	Integral_{cor} [bar · s / m]
Practice	*lap 5*	112.772	1343.67	0.318
	lap 6	113.104	1368.30	0.324
	lap 8	111.916	1350.96	0.312
	lap 9	112.661	1309.34	0.310
	lap 10	111.331	1419.38	0.336
	lap 11	113.201	1442.55	0.341
Quali	*lap 2*	111.078	1214.17	0.287
	lap 3	112.692	1345.92	0.318
	lap 4	112.353	1379.05	0.326
	$\bar{x}$		1352.59	0.319
	s		65.82	0.016

Table 9.5: Driver E, Misano, Aggregated data

9.4 Driver G

Driver G has driven for the team on the circuits of Adria, Franciacorta and Magione.

9.4.1 Adria



(a) Before Outlier Exclusion (b) After Outlier Exclusion

Figure 9.3: Boxplots for Laptime, circuit of Adria, Driver G

	Practice 1	**Practice 2**	**Practice 3**	**Quali**
Race	0.002	0.006	0.001	0.011
Quali	0.912	0.427	0.157	
Practice 3	0.165	0.046		
Practice 2	0.325			

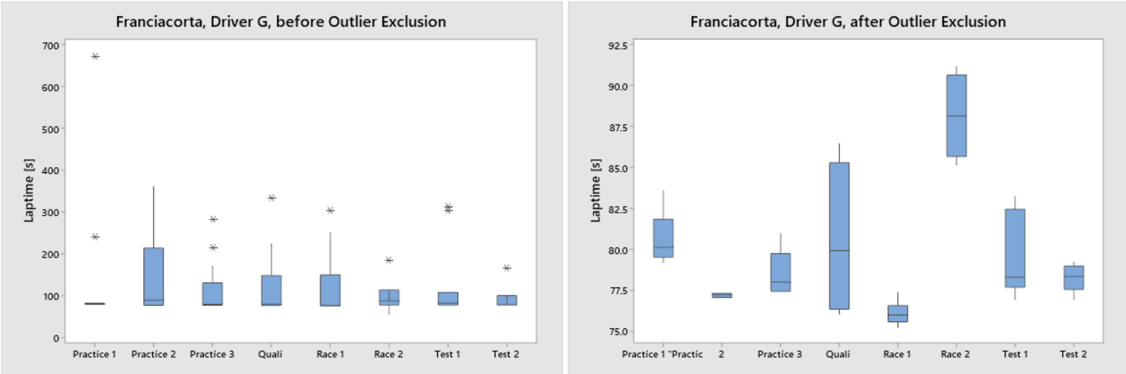
Table 9.6: t-Test result for Integral of Braking Pressure, driver G, circuit of Adria

According to the results displayed in the Table 9.6, the Race session has to be excluded from the aggregation. It is also necessary to exclude one session between Practice 2 and Practice 3, for the criterion used before it is considered the most populous set of data: Practice 3 is then excluded.

	Lap	Laptime [s]	Integral [bar · s]	Integral$_{cor}$ [bar · s / m]
Practice 1	*lap 2*	89.568	1353.55	0.501
	lap 4	97.948	1165.49	0.431
	lap 5	86.717	1413.27	0.523
	lap 6	86.257	1567.90	0.580
	lap 7	93.104	1660.53	0.615
	lap 8	94.897	1460.47	0.541
	lap 9	85.748	1519.93	0.563
	lap 10	85.768	1595.99	0.591
	lap 11	85.244	1688.18	0.625
Practice 2	*lap 3*	87.407	1220.28	0.452
	lap 4	87.853	1395.93	0.512
	lap 5	85.577	1551.7	0.574
	lap 6	85.466	1582.44	0.586
	lap 7	85.582	1522.30	0.563
	lap 8	86.481	1507.14	0.558
	lap 10	86.683	1172.45	0.434
	lap 11	85.867	1435.59	0.531
	lap 13	85.639	1307.88	0.484
	lap 14	87.111	1498.26	0.555
Quali	*lap 3*	86.379	1385.73	0.513
	lap 4	85.389	1607.30	0.595
	lap 7	85.798	1378.26	0.510
	lap 8	84.620	1558.62	0.577
	$\bar{x}$		1458.66	0.540
	s		145.98	0.054

Table 9.7: Driver G, Adria, Aggregated data

9.4.2 Franciacorta



(a) Before Outlier Exclusion (b) After Outlier Exclusion

Figure 9.4: Boxplots for Laptime, circuit of Franciacorta, Driver G

	Practice 1	**Practice 2**	**Practice 3**	**Quali**	**Race 1**	**Race 2**	**Test 1**
Test 2	0.371	0.184	0.203	0.095	0.281	0.587	0.119
Test 1	0.202	0.506	0.401	0.883	0.270	0.026	
Race 2	0.100	0.060	0.063	0.018	0.071		
Race 1	0.707	0.437	0.548	0.197			
Quali	0.149	0.393	0.298				
Practice 3	0.384	0.762					
Practice 2	0.315						

Table 9.8: t-Test result for Integral of Braking Pressure, driver G, circuit of Franciacorta

The Table 9.8 gives the indication that the only Race 2 session has to be excluded from the aggregation of data, while all the other sessions can be aggregated.

	Lap	Laptime [s]	Integral [bar · s]	Integral_{cor} [bar · s / m]
Practice 1	*lap 2*	82.851	1018.29	0.404
	lap 3	81.102	1011.93	0.402
	lap 4	83.572	971.78	0.386
	lap 5	79.791	1089.64	0.433
	lap 6	80.412	1127.86	0.448
	lap 7	80.130	1064.05	0.422
	lap 8	79.496	1128.13	0.448
	lap 10	82.349	950.78	0.377
	lap 11	79.435	1023.12	0.406
	lap 12	79.224	1148.31	0.456
	lap 13	79.780	1158.94	0.460
	lap 14	81.347	1281.55	0.509
	lap 15	79.554	1228.43	0.488
Practice 2	*lap 5*	77.331	1034.01	0.410
	lap 6	77.040	1021.00	0.405
	lap 10	77.089	1105.63	0.439
	lap 11	77.228	1053.35	0.418
	lap 12	77.315	1084.75	0.431
Practice 3	*lap 3*	80.941	1084.22	0.430
	lap 4	79.199	1107.50	0.440
	lap 5	77.885	1055.09	0.419
	lap 6	77.402	1064.96	0.423
	lap 7	77.382	1103.16	0.438
	lap 10	79.705	996.58	0.396
	lap 11	78.004	1087.35	0.432
	lap 12	79.784	1033.87	0.410
	lap 13	77.480	1060.36	0.421
Quali	*lap 3*	86.084	1051.76	0.418
	lap 4	79.477	1090.70	0.433
	lap 5	80.366	925.72	0.367
	lap 6	80.513	1017.85	0.404
	lap 7	77.012	1073.46	0.426
	lap 8	85.049	888.54	0.353
	lap 9	76.394	1136.41	0.451
	lap 11	76.243	1107.17	0.440

	Lap	Laptime [s]	Integral [bar · s]	Integral_{cor} [bar · s / m]
	lap 12	86.461	825.74	0.328
	lap 13	76.059	1141.42	0.453
Race 1	*lap 3*	76.532	1036.30	0.411
	lap 4	77.356	1090.97	0.433
	lap 5	75.252	1017.85	0.404
	lap 6	75.811	1097.76	0.436
	lap 7	76.590	1091.42	0.433
	lap 8	75.500	1010.88	0.401
	lap 9	75.842	1162.73	0.463
	lap 10	76.145	1130.49	0.449
Test 1	*lap 3*	83.226	911.82	0.362
	lap 4	82.461	945.33	0.375
	lap 5	80.037	960.83	0.381
	lap 7	78.297	1082.90	0.430
	lap 8	78.171	1094.97	0.435
	lap 10	77.689	1087.59	0.432
	lap 11	76.986	1149.21	0.456
Test 2	*lap 2*	79.206	1006.86	0.400
	lap 3	76.968	1092.11	0.434
	lap 4	78.776	1191.15	0.473
	lap 5	78.353	1134.60	0.450
	lap 6	78.154	1350.04	0.536
	$\bar{x}$		1070.16	0.425
	s		89.58	0.036

Table 9.9: Driver G, Franciacorta, Aggregated data

9.4.3 Magione

For the data of Magione, the procedure was already done in Chapter 7. It is added to that table the value for the Corrected Integral.

	Lap	Laptime [s]	Integral [bar · s]	Integral_{cor} [bar · s / m]
Test 1	*lap 3*	86.035	1151.89	0.459
	lap 4	84.972	1271.86	0.507
	lap 5	83.369	1316.26	0.525
	lap 6	83.434	1309.53	0.522
	lap 7	83.160	1312.66	0.524
	lap 8	82.313	1338.89	0.534
	lap 9	81.870	1186.34	0.473
	lap 10	81.581	1236.07	0.493
	lap 12	80.226	1230.93	0.491
	lap 13	80.802	1154.06	0.460
Test 2	*lap 2*	84.821	1180.50	0.459
	lap 4	86.460	986.71	0.394
	lap 5	85.426	1214.06	0.484
	lap 6	84.543	1226.07	0.489
	lap 9	83.348	1197.86	0.478
	lap 10	84.870	1339.17	0.543
	$\bar{x}$		1228.30	0.490
	s		90.49	0.037

Table 9.10: Driver G, Magione, Aggregated data

9.5 Driver H

Driver H is the last driver analyzed in this Section, he has completed sessions in the circuits of Adria, Magione and Mugello.

9.5.1 Adria

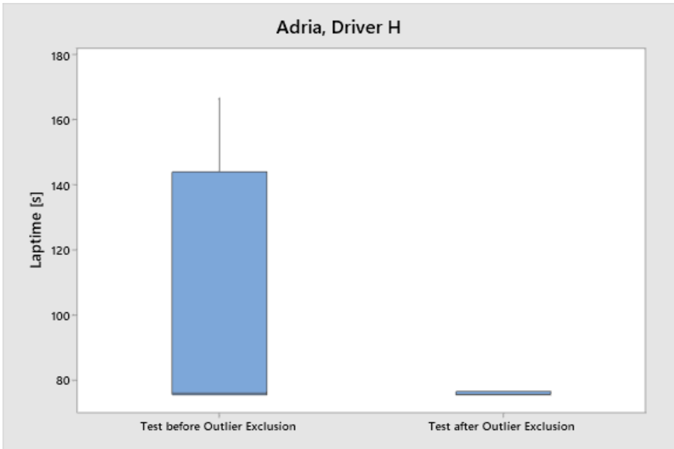


Figure 9.5: Boxplot for Laptime, circuit of Adria, Driver H

Driver H at Adria has completed only one session, so there is no need for aggregating data.

	Lap	Laptime [s]	Integral [bar · s]	Integral_{cor} [bar · s / m]
Test	*lap 2*	76.564	1016.86	0.376
	lap 3	75.484	1080.74	0.400
	lap 4	75.603	1197.88	0.443
	$\bar{x}$		1098.49	0.406
	s		91.81	0.034

Table 9.11: Driver H, Adria, Aggregated data

It is important to highlight that only three laps are considered for this circuit. This very limited set can be relevant for the results.

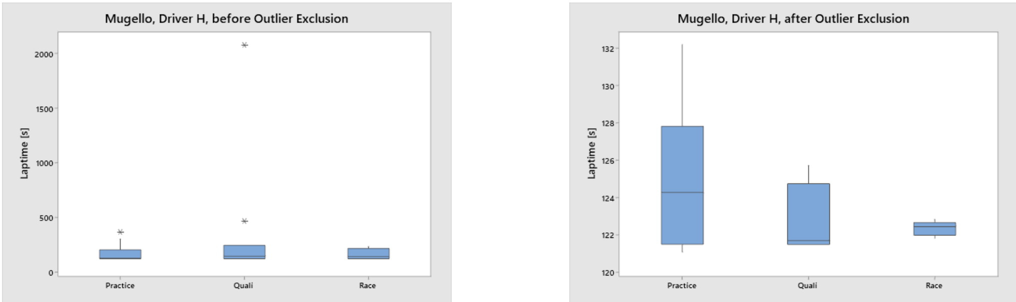
9.5.2 Magione

The Magione data has already been treated in the Chapter 7. Also for this driver, the table is changed in order to display not only the Integral, but also the Corrected Integral.

	Lap	Laptime [s]	Integral [bar · s]	Integral_{cor} [bar · s / m]
Race	*lap 8*	76.017	1002.47	0.400
	lap 9	75.866	1088.88	0.434
	lap 10	75.914	1190.34	0.475
	lap 11	75.942	1223.88	0.488
	lap 12	76.225	1263.41	0.504
	lap 13	76.078	1289.21	0.514
	lap 14	76.140	1248.78	0.498
Quali	*lap 2*	85.945	839.36	0.335
	lap 3	75.739	1068.09	0.426
	lap 4	75.477	1163.46	0.464
	lap 5	75.725	1340.96	0.535
	lap 6	93.330	726.97	0.290
	lap 7	80.321	1114.75	0.445
	lap 8	87.083	665.60	0.265
	lap 9	75.639	1047.84	0.418
Test	*lap 3*	79.833	1244.21	0.469
	lap 4	78.063	1251.87	0.499
	lap 5	78.062	1278.94	0.514
	lap 6	79.257	1225.93	0.489
	lap 7	76.982	1144.86	0.457
	lap 8	78.566	1197.17	0.477
	lap 9	76.889	1054.70	0.420
	lap 10	76.659	1122.21	0.448
	lap 11	78.489	1038.92	0.414
	lap 12	77.471	986.39	0.393
	$\bar{x}$		1112.77	0.443
	s		170.53	0.068

Table 9.12: Driver H, Magione, Aggregated data

9.5.3 Mugello



(a) Before Outlier Exclusion (b) After Outlier Exclusion

Figure 9.6: Boxplots for Laptime, circuit of Mugello, Driver H

	Practice	**Quali**
Race	0.002	0.355
Quali	0.029	

Table 9.13: t-Test result for Integral of Braking Pressure and Integral Corrected, driver H, circuit of Mugello

The two sessions that can be aggregated according to the result of the t-Test shown in Table 9.13 are Race and Quali, while Practice has to be excluded.

	Lap	**Laptime [s]**	**Integral [bar · s]**	**Integral$_{cor}$ [bar · s / m]**
Quali	*lap 4*	121.448	1417.76	0.270
	lap 6	121.532	1191.74	0.227
	lap 9	125.720	1069.38	0.204
	lap 10	123.774	1227.81	0.234
	lap 11	121.694	1262.70	0.241
Race	*lap 6*	122.507	1159.18	0.221
	lap 9	122.440	1202.89	0.229
	lap 10	121.837	1173.44	0.224
	lap 11	122.130	1182.75	0.225
	lap 12	122.816	1152.91	0.220
	$\bar{x}$		1204.06	0.230
	s		90.67	0.017

Table 9.14: Driver H, Mugello, Aggregated data

9.6 Validation of the Results

In order to validate the results it is necessary to subdivide and compare the aggregated data of the previous subsections for the different pilots and for the different circuits. The compared data is the Corrected Integral since it is the only data that allows to compare indistinctly the different drivers and the different circuits.

In the following tables (Tables 9.15 and 9.16) are shown in descending order the results obtained repectively in Chapter 7 and 8.

Driver	**Mean** [bar · s]	**StDev** [bar · s]	**Rank**
G	1228.30	90.49	1
C	1162.41	57.27	2
H	1112.77	170.53	3
F	1070.89	146.86	4
A	994.32	71.07	5
D	939.23	55.45	6
E	878.97	66.97	7
B	878.71	63.77	8

Table 9.15: Comparison Table for Integral of Braking Pressure, circuit of Magione

Circuit	**Mean** [bar · s / m]	**StDev** [bar · s / m]	**Rank**
Adria	0.497	0.049	1
Franciacorta	0.375	0.022	2
Magione	0.351	0.025	3
Misano	0.337	0.026	4
Imola	0.299	0.042	5
Mugello	0.240	0.013	6

Table 9.16: Comparison Table for Corrected Integral of Braking Pressure, driver B

In the next subsections it is analyzed each Driver for the different circuits and each circuit with the different drivers.

9.6.1 Driver E

The first table shows a resume of data in terms of Mean, Standard Deviation and Rank of the three circuits.

Circuit	**Mean [bar · s / m]**	**StDev [bar · s / m]**	**Rank**
Franciacorta	0.356	0.031	1
Magione	0.351	0.027	2
Misano	0.319	0.016	3

Table 9.17: Comparison Table for Corrected Integral of Braking Pressure, driver E

After it is necessary to compare those results with a t-Test, in order to find whether they are statistically different or not.

	Franciacorta	**Magione**
Misano	0.006	0.000
Magione	0.683	

Table 9.18: t-Test for Comparison of Corrected Integral, driver E

The Test evidences that Franciacorta and Magione are not statistically different, while Mugello is different from the two and has a lower value.

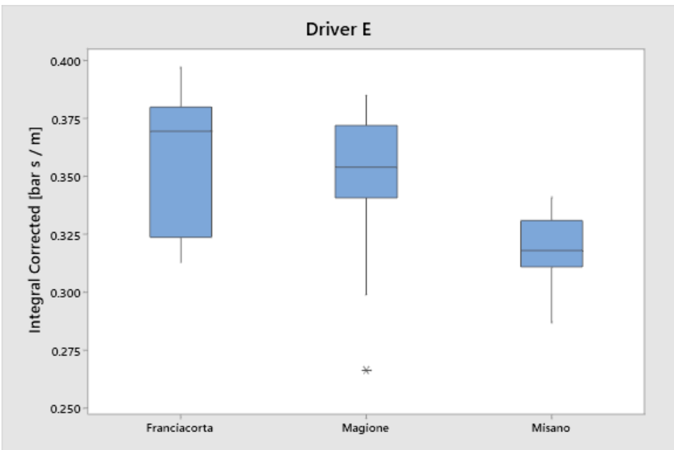


Figure 9.7: Boxplot for Integral Corrected, Driver E

9.6.2 Driver G

Set of data available for Driver G come from three different circuits: Adria, Franciacorta and Magione; the table summarizes the data of those circuits.

Circuit	Mean [bar · s / m]	StDev [bar · s / m]	Rank
Adria	0.540	0.054	1
Franciacorta	0.425	0.036	3
Magione	0.490	0.037	2

Table 9.19: Comparison Table for Corrected Integral of Braking Pressure, driver G

	Adria	**Franciacorta**
Magione	0.002	0.000
Franciacorta	0.000	

Table 9.20: t-Test for Comparison of Corrected Integral, driver G

The Table 9.20 with the results of the t-Test, highlights that all the three circuits are different. The one with the highest value is Adria, then Magione and the one with the smallest value for the Corrected Integral is Franciacorta.

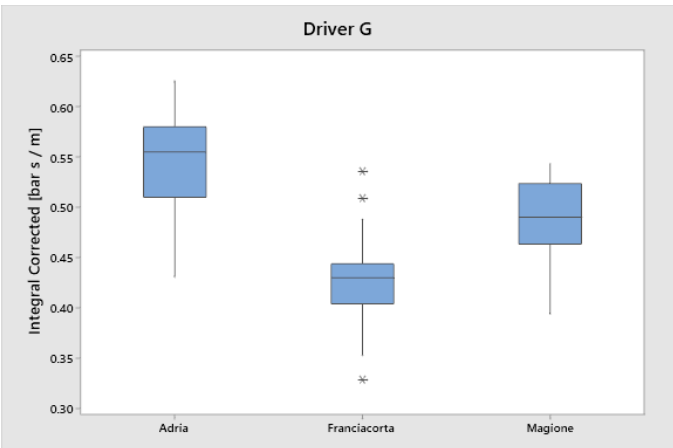


Figure 9.8: Boxplot for Integral Corrected, Driver G

9.6.3 Driver H

Adria, Magione and Mugello are the circuits in which Driver H has completed at least one session. The data relative to the circuit of Adria are only three; the limited umber of available data can heavily affect the results.

Circuit	Mean [bar · s / m]	StDev [bar · s / m]	Rank
Adria	0.406	0.034	2
Magione	0.443	0.068	1
Mugello	0.230	0.017	3

Table 9.21: Comparison Table for Corrected Integral of Braking Pressure, driver H

	Adria	**Magione**
Mugello	0.013	0.000
Magione	0.200	

Table 9.22: t-Test for Comparison of Corrected Integral, driver H

T-Test result evidences that Adria and Magione are not different. Magione is the one with the highest value for the Corrected Integral, followed by Adria and Mugello.

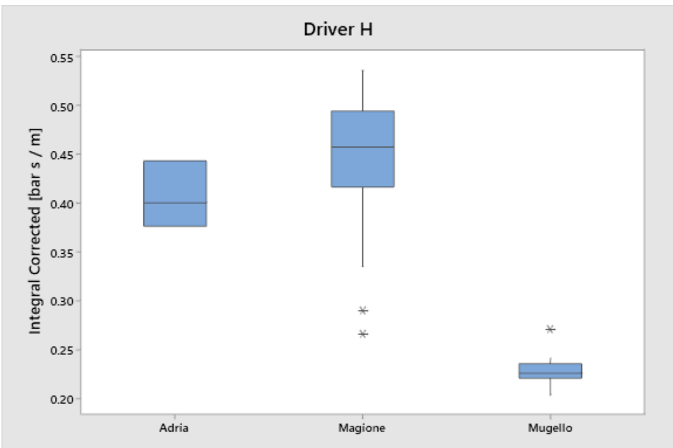


Figure 9.9: Boxplot for Integral Corrected, Driver H

9.6.4 Adria

In Adria, the Drivers B, G and H have completed at least one session. Particular attention has to be done in analyzing the results for Driver H, since it has a very limited number of available data.

Driver	Mean [bar · s / m]	StDev [bar · s / m]	Rank
B	0.497	0.049	2
G	0.540	0.054	1
H	0.406	0.034	3

Table 9.23: Comparison Table for Corrected Integral of Braking Pressure, Adria

	B	G
H	0.016	0.010
G	0.049	

Table 9.24: t-Test for Comparison of Corrected Integral, Adria

Table 9.24 highlights that all the drivers are different for the circuit of Adria. The driver with the highest value of corrected integral is E, then B and H.

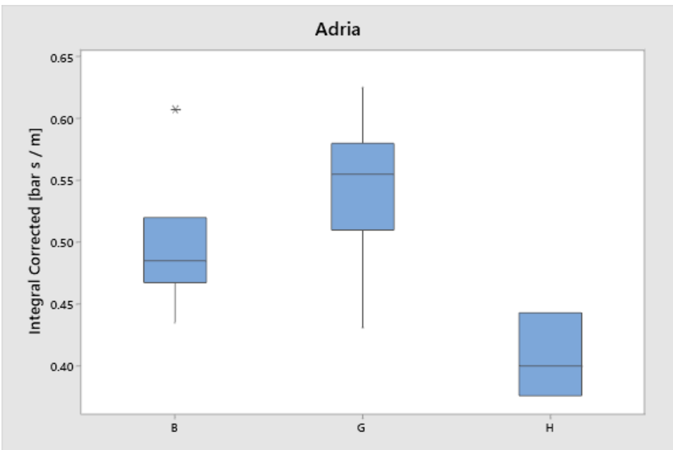


Figure 9.10: Boxplot for Integral Corrected, Adria

9.6.5 Franciacorta

Drivers B, E and G has driven on the circuit of Franciacorta, recording telemetry data for at least one session.

Driver	Mean [bar · s / m]	StDev [bar · s / m]	Rank
B	0.375	0.022	2
E	0.356	0.031	3
G	0.425	0.036	1

Table 9.25: Comparison Table for Corrected Integral of Braking Pressure, Franciacorta

	B	**E**
G	0.000	0.000
E	0.151	

Table 9.26: t-Test for Comparison of Corrected Integral, Franciacorta

T-test evidences that B and E are not statistically different, while G is higher than the two.

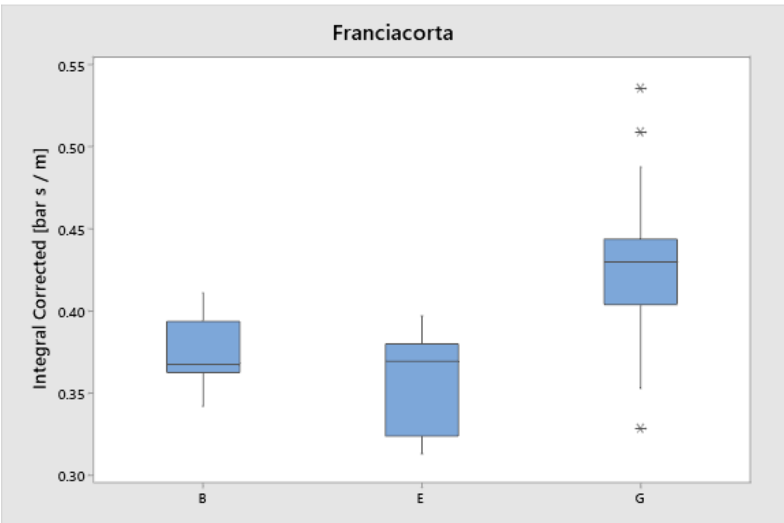


Figure 9.11: Boxplot for Integral Corrected, Franciacorta

9.6.6 Misano

In Misano only two driver has completed the sessions: Driver B and E.

Driver	**Mean [bar · s / m]**	**StDev [bar · s / m]**	**Rank**
B	0.337	0.026	1
E	0.319	0.016	2

Table 9.27: Comparison Table for Corrected Integral of Braking Pressure, Misano

	B
E	0.055

Table 9.28: t-Test for Comparison of Corrected Integral, Misano

The t-Test highlights that the two drivers cannot be seen statistically different.

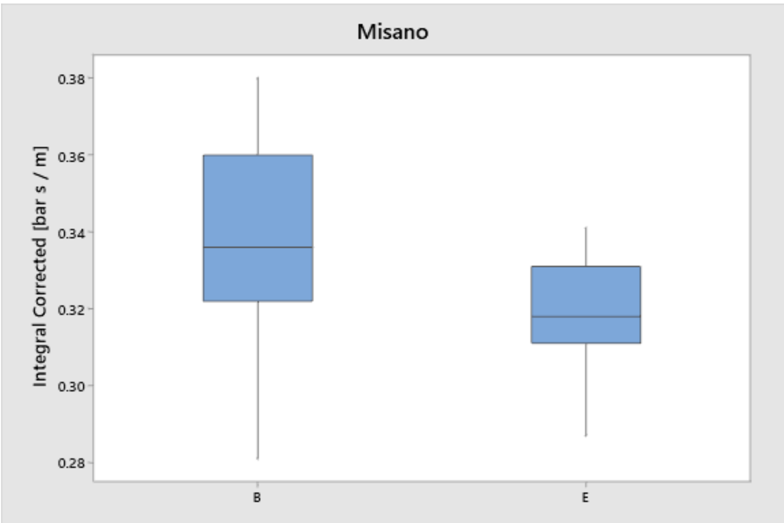


Figure 9.12: Boxplot for Integral Corrected, Misano

9.6.7 Mugello

Driver B and H have completed sessions in the circuit of Mugello.

Driver	Mean [bar · s / m]	StDev [bar · s / m]	Rank
B	0.240	0.013	1
H	0.230	0.017	2

Table 9.29: Comparison Table for Corrected Integral of Braking Pressure, Mugello

	B
H	0.116

Table 9.30: t-Test for Comparison of Corrected Integral, Mugello

Also in this case the t-Test evidences no significant difference among the two drivers.

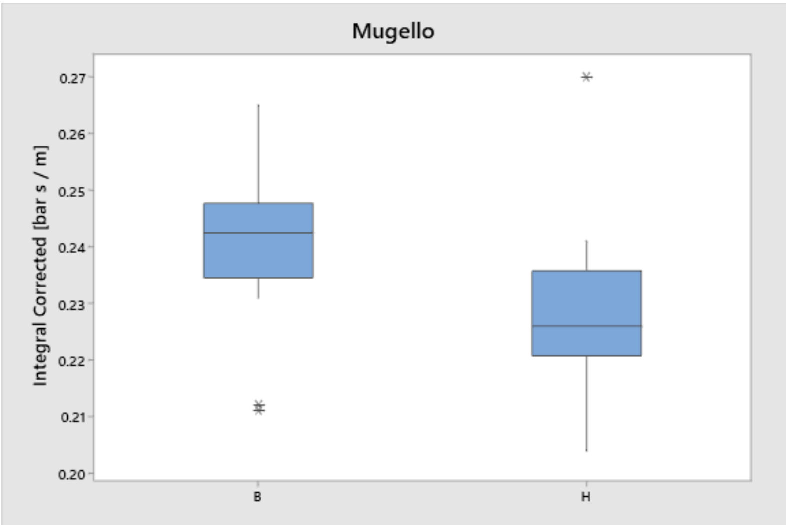


Figure 9.13: Boxplot for Integral Corrected, Mugello

9.7 Discussion of the Results

The result coming from the Validation confirm partially what is stated in Chapters 7 and 8. This section will deal in detail all the comparison between what were the result expected from the previous chapters and the results coming from the above analysis.

Driver E Chapter 8 suggest that Franciacorta has a higher demand for the braking system, measured as the Corrected Integral, than Magione and Misano that are not statistically different. This validation confirms that result, with a minor difference: Franciacorta and Magione does not present a statistically significant difference, while Misano is lower. The order is not changed with respect to the Chapter 8, what is changed is the result of the t-Test.

Driver G Adria is the most demanding circuit also for this driver, while Magione and Franciacorta present and inverted order with respect to Driver B (see Chapter 8). Here Franciacorta is less demanding than Magione.

Driver H The set of measurements coming from the circuit of Adria has a very limited number of data: only 3. This can lead to a possible error in the order of the circuits. In fact for this analysis, in contrast to what stated in Chapter 8 and for Driver G in this Chapter, Adria is demanding as Magione (there isn't a statistical difference between the two). This can be a consequence of the very limited number of data that available for the circuit of Adria. Circuit of Mugello confirms what stated for Driver B in Chapter 8: it is less demanding than Adria and Magione.

Adria Also for the circuit of Adria the anomaly of Driver H seem to have a direct implication. In fact here Driver H has a lower value of Corrected Integral than both Driver G and B. The result concerning Drivers G and B confirms the results of Chapter 7, the Integral of G is higher than the one of B.

Franciacorta and Misano Those two tracks confirms what stated in Chapter 7: in both tracks B and E are not different and in Franciacorta Driver G is higher than both.

Mugello Circuit of Mugello shows another anomaly that involves Driver H. In this track the two Drivers B and H does not present a significant difference, but in Chapter 7 they are different, with the highest value that is the one of Driver H.

Chapter 10

Conclusion

The aim of the research was to find out which are the circuits and the drivers that have an higher probability of occurrence causing the problem to the braking system. During the work a procedure was found and validated, by using some statistical instruments to sort the different pilots and circuits based on the telemetry data gained during a whole racing season.

After having analyzed in Chapter 7 the braking behaviour of the different drivers, the most demanding circuits for the braking system in Chapter 8 and having validated the result in Chapter 9, it is possible to compare what emerges from the analysis with the experience on the track.

The problem on the braking system came forward in the circuit of Adria with drivers G and H, and in the circuit of Magione, with drivers H, C and F.

An important consideration has to be done before analyzing the results: the drivers are non professional pilots and their driving style cannot be considered fully repeatable. It is important to consider that some errors in the analysis and in the validation of the results can arise also for this reason.

Drivers The Drivers that have suffered from the problem are the one that are classified with a more aggressive braking behaviour in Chapter 7, both with high Maximum and Integral of Braking Pressure.

Chapter 9 confirms partially what stated in Chapter 7: Driver H presents some anomalies both in the circuit of Adria and Mugello. This anomalies can not be classified critical because for Adria the set of data is very limited and the circuit of Mugello is a very different circuit in terms of characteristics with respect to Adria, Francicorta and Magione and the driving style can also be affected by the typology of track. Since the drivers are not professional pilots also an anomaly can arise.

Circuits From the analysis conducted in Chapter 8, Adri and Franciacorta are the most demanding circuits, with Magione and Misano being comparable. In Chapter 9, the section dedicated to Driver E, highlights that Magione has an higher demand than Misano.

In fact Magione and Misano are two circuits with different characteristics: Magione is shorter than Misano and has a high frequency of corners, with only one long straight; while Misano has several straights and less corners/length than Magione. The corners of Misano require an higher deceleration than the ones in Magione.

Adria, Franciacorta and Magione are the most demanding circuits for the braking system, it could be necessary to investigate deeper the circuit of Misano to see if it also is an ”high demanding” circuit for the braking system as Magione.

In Franciacorta any driver has suffered the problem during the 2019 season. After this analysis, a particular attention is needed on that track during future sessions or races.

Magione The Magione circuit is the track that was most investigated in the thesis. This can be a good point for making some assumptions and conclusions. The problem came forward with Drivers C, F and H; those drivers are the ones that have the Integral of Braking Pressure that is the second, third and fourth higher. The Driver that has the mean Integral higher than all the other drivers is Driver G. During the test sessions he had not suffered the problem, this can be related to the fact that it was the first time that he drove the car for the team and the sessions were only tests, done in a controlled environment and not a race weekend. The fact that with Driver G the issue came forward in Adria confirms the anomaly in the feedback of the tests in Magione.

It can be noted that all the mean values of the Integral, for the driver that have suffered the problem, were above 1100 bar $\cdot$ s. After having discussed this result with the company supervisors, an important assumption can be stated: it can be plausible that the problem manifests itself when a value of Integral of Braking

Pressure is consistently above a certain threshold. This limit can be assumed, for the circuit of Magione, of about 1100 bar $\cdot$ s. This assumption could be done also for other circuits, but the limited amount of data present in the database cannot guarantee a good result.

10.1 Possible Future Developments

The work done in this research can be continued during the next seasons, the procedure identified enables the team to analyze and store the data in a precise way. This process can be repeated for every session in order to create a database and categorize the braking behaviour of the drivers. The creation of a database can also refine and extend the analysis done for the different circuits.

In order to conduct in the future a more accurate and deeper analysis, both on the driving style and on the circuits, an experimental design of experiment can be set up. With a proper DOE (Design of Experiment) technique it would be possible to get more robust results and check them also with other statistical instruments such as ANOVA (Analysis of Variance) to find the possible interactions between the two factor: driver and circuit.

The procedure investigated in this research had the aim to see on which track and with which driver the problem is more likely to occur. This set of techniques can be replicated also for other problems or other object of investigation by changing the examined data.

The anomalies and imperfections in the procedure and in the validation can lead to some aspects that were not investigated during this research. A possible future argument of research on this topic can be the influence of the weather, both in terms of temperature and humidity. This was not done in this research since it was thought, after some meetings with the company supervisors, that was not relevant for the results in a first exploratory analysis.

Bibliography

[1] W. Chauvenet. *A Manual of Spherical and Practical Astronomy*. Vol. 2. Lippincott, 1863.

[2] Stephen Bernstein and Ruth Bernstein. *Schaum's Outline of Elements of Statistics I: Descriptive Statistics and Probability*. McGraw-Hill, 1998.

[3] Douglas Montgomery and George Runger. *Applied Statistics and Probability for Engineers*. 3rd ed. Wiley, 2002.

[4] William Hines et al. *Probability and Statistics in Engineering*. 4th ed. Wiley, 2003.

[5] Giancarlo Genta and Lorenzo Morello. *The Automotive Chassis, Vol. 1: Components Design*. 1st ed. Mechanical Engineering Series. Springer, 2009.

[6] Giancarlo Genta and Lorenzo Morello. *The Automotive Chassis, Vol. 2: System Design*. 1st ed. Mechanical Engineering Series. Springer, 2009.

[7] Lorenzo Morello et al. *The Automotive Body, Vol. 1: Components Design*. 1st ed. Mechanical Engineering Series. Springer, 2011.

[8] Lorenzo Morello et al. *The Automotive Body, Vol. 2: System Design*. 1st ed. Mechanical Engineering Series. Springer, 2011.

[9] Douglas Montgomery, Elizabeth Peck, and Geoffrey Vining. *Introduction to Linear Regression Analysis*. Wiley, 2012.

[10] Giulio Barbato, Alessandro Germak, and Gianfranco Genta. *Measurement for Decision Making*. Società Editrice Esculapio, 2013.

[11] Giancarlo Genta et al. *The Motor Car: Past, Present and Future*. 1st ed. Mechanical Engineering Series. Springer, 2014.

[12] *Seat Leon Cup Homologation Form*. Seat Sport and FIA. 2015.

[13] *Seat Leon Cup Racer Technical Info*. Seat Sport. 2015.

[14] *Seat Leon Cup Racer Technical Manual*. Seat Sport. 2015.

[15] *Seat Leon Cup Racer Workshop Manual*. Seat Sport. 2015.

[16] *Seat LCR TCR DSG User Manual*. Seat Sport. 2017.

[17] *Supercup 2019: Sports Regulation*. ACI Sport. 2019.

[18] *Supercup 2019: Technical Regulation*. ACI Sport. 2019.

[19] *Adria Circuit Website*. `http://www.adriaraceway.com/`. Accessed: October 5, 2020.

[20] *Franciacorta Circuit Website*. `https://www.franciacortakartingtrack.com/`. Accessed: October 5, 2020.

[21] *Imola Circuit Website*. `http://www.autodromoimola.it/`. Accessed: October 5, 2020.

[22] *Magione Circuit Website*. `https://www.autodromomagione.com/`. Accessed: October 5, 2020.

[23] *Minitab Support Website*. `https://support.minitab.com/`. Accessed: October 5, 2020.

[24] *Misano Circuit Website*. `https://www.misanocircuit.com/`. Accessed: October 5, 2020.

[25] *Mugello Circuit Website*. `https://mugellocircuit.com/`. Accessed: October 5, 2020.

[26] *MXG 1.2, MXP, MXS 1.2 User Guide*. AIM Sportline.

[27] *Nist Engineering Statistics Handbook: Box Plot*. `https://www.itl.nist.gov/div898/handbook/eda/section3/boxplot.htm`. Accessed: October 5, 2020.

[28] *Nist Engineering Statistics Handbook: Scatter Plot*. `https://www.itl.nist.gov/div898/handbook/eda/section3/scatterp.htm`. Accessed: October 5, 2020.

[29] *Nist Engineering Statistics Handbook: Two-Sample t-Test for Equal Means*. `https://www.itl.nist.gov/div898/handbook/eda/section3/eda353.htm`. Accessed: October 5, 2020.

[30] *Six Engineers Website*. `https://www.sixengineers.com`. Accessed: October 5, 2020.

[31] *Trofeo Super Cup Website*. `https://www.trofeosupercup.it`. Accessed: October 5, 2020.

Appendices

A. Outlier Exclusion Tables

Driver A

Magione

Lap	Laptime [s]	Max [bar]	Integral [bar · s]
lap 2 [1]	139.872	75.22	1151.34
lap 3 [2]	83.067	73.27	961.53
lap 4 [2]	79.153	73.38	944.27
lap 5	77.579	85.28	936.70
lap 6	76.621	89.59	976.00
lap 7	76.301	84.57	1029.88
lap 8	76.027	84.30	996.25
lap 9	76.725	84.42	1004.30
lap 10 [1]	112.983	76.11	571.20

Table 1: Driver A, Race, Magione

Lap	**Laptime [s]**	**Max [bar]**	**Integral [bar · s]**
lap 2 [2]	100.045	54.40	547.79
lap 3 [2]	86.100	62.70	668.01
lap 4	77.262	75.84	841.16
lap 5	76.009	87.08	963.85
lap 6	75.987	87.81	915.04
lap 7	76.001	92.41	1039.70
lap 8	78.077	86.41	954.72
lap 9 [2]	110.891	52.78	862.85

Table 2: Driver A, Quali 1, Magione

Lap	**Laptime [s]**	**Max [bar]**	**Integral [bar · s]**
lap 2	83.160	87.62	1112.27
lap 3	79.607	81.10	973.79
lap 4	77.648	84.39	996.14
lap 5 [3]	127.699	83.83	1565.08

Table 3: Driver A, Quali 2, Magione

Lap	**Laptime [s]**	**Max [bar]**	**Integral [bar · s]**
lap 2 [2]	113.556	58.22	727.61
lap 3	92.950	74.71	832.91
lap 4	86.181	77.83	997.14
lap 5	85.166	81.62	1079.02
lap 6	96.187	88.3	1118.49
lap 7 [1]	225.063	71.72	1635.70
lap 8 [2]	111.627	81.92	692.46
lap 9	92.498	75.40	750.29
lap 10	85.242	84.78	991.36
lap 11	84.011	95.95	1085.41
lap 12	82.139	91.21	1082.05
lap 13 [1]	183.066	63.11	1378.94

Table 4: Driver A, Test 1, Magione

Lap	**Laptime [s]**	**Max [bar]**	**Integral [bar · s]**
lap 2 [1]	83.332	83.22	951.87
lap 3	79.393	90.02	965.79
lap 4	79.482	99.44	1000.91
lap 5	78.369	76.19	996.80
lap 6	78.021	87.79	1008.66
lap 7	79.184	75.95	1021.30
lap 8	78.162	94.32	1026.45
lap 9	78.436	88.71	1028.16
lap 10	79.195	90.99	1010.44
lap 11 [2]	80.743	76.50	938.20
lap 12	78.737	85.62	950.41
lap 13	79.100	87.45	997.56
lap 14	79.532	78.09	945.53
lap 15 [1]	82.823	73.53	854.76
lap 16 [1]	105.113	66.16	1502.28

Table 5: Driver A, Test 2, Magione

Lap	Laptime [s]	Max [bar]	Integral [bar · s]
lap 2	81.208	74.30	984.16
lap 3	82.138	75.75	1042.03
lap 4	79.663	85.97	1055.47
lap 5	81.253	83.45	1071.63
lap 6	78.062	90.62	1053.57
lap 7	78.665	94.15	1012.80
lap 8	81.350	82.68	995.19
lap 9	78.296	87.45	1077.68
lap 10	80.071	80.70	1074.89
lap 11	77.601	91.24	1061.26
lap 12	80.631	94.07	1140.26
lap 13	77.657	96.36	1069.36
lap 14 [2]	85.678	80.36	866.39
lap 15	78.081	90.40	974.02
lap 16 [1]	137.906	51.24	911.51

Table 6: Driver A, Test 3, Magione

Lap	Laptime [s]	Max [bar]	Integral [bar · s]
lap 2	85.936	71.40	996.77
lap 3	86.859	80.23	979.21
lap 4	82.197	78.48	1023.76
lap 5	81.981	87.12	1013.63
lap 6	79.747	88.87	1045.52
lap 7	79.153	81.83	1026.12
lap 8	78.133	91.77	1076.66
lap 9	80.694	92.05	1031.31
lap 10 [1]	299.146	80.95	3434.04
lap 11	80.933	84.54	945.85
lap 12 [1]	135.53	38.58	961.46

Table 7: Driver A,Test 4, Magione

Lap	Laptime [s]	Max [bar]	Integral [bar · s]
lap 2 [1]	128.239	42.41	582.57
lap 3 [1]	106.945	43.62	658.05
lap 4 [2]	92.179	59.52	862.93
lap 5 [2]	88.881	64.47	974.92
lap 6 [2]	87.035	62.44	1039.95
lap 7 [2]	84.847	72.86	1046.75
lap 8	83.334	68.97	1037.20
lap 9	83.149	80.65	1063.21
lap 10	83.391	80.91	1039.02
lap 11	83.020	80.96	1026.47
lap 12	83.124	78.73	1051.55
lap 13 [1]	142.312	57.73	1094.72

Table 8: Driver A, Test 5, Magione

Driver B

Adria

Lap	Laptime [s]	Integral [bar · s]	Integral_{cor} [bar · s / m]
lap 2 [2]	89.858	1132.16	0.419
lap 3	87.117	1174.33	0.435
lap 4	87.504	1404.72	0.520
lap 5	86.803	1310.94	0.485
lap 6	87.497	1280.33	0.474
lap 7	87.948	1331.68	0.493
lap 8	86.597	1404.45	0.520
lap 9	88.651	1642.71	0.608
lap 10	88.140	1295.36	0.479
lap 11	87.971	1246.23	0.461
lap 14 [1,3]	124.841	1206.43	0.446

Table 9: Driver B, Practice, Adria

Franciacorta

Lap	**Laptime** [s]	**Integral** [bar · s]	**Integral$_{cor}$** [bar · s / m]
lap 2 [1]	157.333	1937.25	0.769
lap 3 [1]	87.253	1448.87	0.575
lap 4	79.243	993.39	0.394
lap 5	79.526	928.59	0.369
lap 6	79.073	1035.19	0.411
lap 7	78.279	912.71	0.362
lap 8	78.125	860.41	0.342
lap 9	78.347	922.19	0.366
lap 10	78.470	989.15	0.393
lap 11	80.073	918.06	0.364
lap 12 [1]	84.456	794.57	0.315
lap 13 [1]	200.073	1760.81	0.699
lap 14 [1]	250.769	1443.39	0.573
lap 15 [1, 3]	334.303	1510.22	0.599

Table 10: Driver B, Race, Franciacorta

Imola

Lap	Laptime [s]	Integral [bar · s]	Integral$_{cor}$ [bar · s / m]
lap 2 [1]	212.978	1370.47	0.279
lap 3 [1]	127.513	2032.87	0.414
lap 4	121.544	1999.15	0.407
lap 5	120.787	1568.11	0.319
lap 6	120.605	1659.38	0.338
lap 7	121.230	1464.61	0.298
lap 8	121.937	1260.92	0.257
lap 9	121.549	1283.10	0.261
lap 10	122.019	1476.23	0.301
lap 11	123.156	1369.98	0.279
lap 12	122.585	1536.08	0.313
lap 13	123.227	1394.71	0.284
lap 14	123.889	1273.12	0.259
lap 15	124.815	1354.93	0.276
lap 16 [1, 3]	193.512	1045.73	0.213

Table 11: Driver B, Race, Imola

Magione

Lap	Laptime [s]	Max [bar]	Integral [bar · s]	Integral$_{cor}$ [bar · s / m]
lap 2 [1]	103.009	67.03	871.49	0.348
lap 3 [2]	86.198	82.92	1038.55	0.414
lap 4	83.043	101.43	883.61	0.352
lap 5	83.070	106.42	874.96	0.349
lap 6 [1]	261.294	70.21	2608.08	1.040
lap 7	81.848	89.59	874.27	0.349
lap 8	81.182	78.56	806.59	0.322
lap 9	80.643	92.67	849.78	0.339
lap 10	79.703	97.68	844.18	0.338
lap 11	81.739	85.05	815.06	0.325
lap 12 [1]	97.092	92.56	573.07	0.226
lap 13	79.805	88.01	822.74	0.328
lap 14	79.706	85.44	832.53	0.332
lap 15 [1, 3]	136.057	43.90	693.64	0.277

Table 12: Driver B, Test 1, Magione

Lap	Laptime [s]	Max [bar]	Integral [bar · s]	Integral$_{cor}$ [bar · s / m]
lap 2	83.997	88.22	862.20	0.344
lap 3	83.867	80.59	889.84	0.355
lap 4	82.961	75.85	912.16	0.364
lap 5	81.718	86.15	1014.60	0.405
lap 6 [2, 3]	140.071	76.78	1093.27	0.436

Table 13: Driver B, Test 2, Magione

Lap	Laptime [s]	Max [bar]	Integral [bar · s]
lap 2	92.286	94.20	943.59
lap 3	79.014	91.89	1041.36
lap 4	76.234	100.96	1120.48
lap 5	75.818	105.07	1279.81
lap 6	75.852	105.66	1174.79
lap 7 [1]	206.402	92.23	1862.50
lap 8	87.935	93.01	724.29
lap 9	77.347	98.84	1002.68
lap 10	91.236	96.22	1091.96
lap 11	98.495	97.59	1408.68
lap 12	80.153	77.45	982.53
lap 13	78.826	97.89	1104.18
lap 14 [2]	106.881	83.00	1135.20

Table 14: Driver B, Quali 1, Magione

Lap	Laptime [s]	Max [bar]	Integral [bar · s]
lap 2 [1]	93.209	63.42	933.37
lap 3 [1]	82.163	78.54	1007.33
lap 4	79.006	104.88	1098.27
lap 5	78.887	86.99	1085.19
lap 6	77.477	91.76	1165.72
lap 7	78.536	106.16	1379.54
lap 8	77.767	97.59	1113.02
lap 9	78.824	103.26	1097.68
lap 10	79.060	92.10	1044.84
lap 11 [1]	294.926	96.50	4016.45
lap 12	79.389	88.78	1001.85
lap 13	79.648	89.92	979.63
lap 14 [1]	262.056	58.83	1215.15

Table 15: Driver B, Practice 1, Magione

Lap	**Laptime** [s]	**Max** [bar]	**Integral** [bar · s]	**Integral$_{cor}$** [bar · s / m]
lap 2 [2]	109.257	80.42	1014.72	0.405
lap 3 [2]	82.447	104.41	1250.50	0.499
lap 4	79.778	118.04	1173.49	0.468
lap 5	79.090	121.33	1168.83	0.466
lap 6	80.347	108.24	972.88	0.388
lap 7	79.316	88.58	990.22	0.395
lap 8	78.281	105.58	1067.35	0.426
lap 9 [3]	115.632	78.96	962.42	0.384

Table 16: Driver B, Quali 2, Magione

Lap	**Laptime** [s]	**Max** [bar]	**Integral** [bar · s]	**Integral$_{cor}$** [bar · s / m]
lap 2 [2]	97.949	59.11	849.42	0.339
lap 3	86.558	76.23	1013.18	0.404
lap 4	84.644	81.83	985.52	0.393
lap 5	83.105	94.10	929.37	0.371
lap 6	81.395	86.74	1017.37	0.406
lap 7	80.542	87.31	929.80	0.371
lap 8 [2, 3]	112.909	81.80	1038.51	0.414

Table 17: Driver B, Practice 2, Magione

Lap	**Laptime** [s]	**Max** [bar]	**Integral** [bar · s]	**Integral$_{cor}$** [bar · s / m]
lap 2	83.333	88.54	803.64	0.321
lap 3	81.609	96.99	856.49	0.342
lap 4	81.657	84.91	888.45	0.354
lap 5	81.160	95.43	1004.52	0.401
lap 6	80.588	88.93	981.18	0.391
lap 7 [1, 2, 3]	135.452	47.52	827.35	0.330

Table 18: Driver B, Test 3, Magione

Misano

Lap	Laptime [s]	Integral [bar · s]	Integral$_{cor}$ [bar · s / m]
lap 2 [1]	120.594	1424.49	0.337
lap 3 [2]	115.841	1491.84	0.353
lap 4	113.992	1421.02	0.336
lap 5	113.097	1507.77	0.357
lap 6	114.538	1483.76	0.351
lap 7	112.772	1382.82	0.327
lap 8	113.038	1432.78	0.339
lap 9 [2]	111.803	1294.08	0.306
lap 10	114.336	1606.53	0.380
lap 11	113.213	1534.76	0.363
lap 12	113.821	1365.45	0.323
lap 13	113.336	1358.10	0.321
lap 14 [1, 3]	405.858	3638.18	0.861

Table 19: Driver B, Practice, Misano

Lap	Laptime [s]	Integral [bar · s]	Integral$_{cor}$ [bar · s / m]
lap 2	111.047	1558.96	0.367
lap 3 [2]	135.893	1141.83	0.270
lap 4	115.028	1369.61	0.324
lap 5	112.172	1187.67	0.281
lap 6	111.260	1344.03	0.318
lap 7 [3]	150.751	1237.94	0.293

Table 20: Driver B, Quali, Misano

Mugello

Lap	**Laptime** [s]	**Integral** [bar · s]	**Integral$_{cor}$** [bar · s / m]
lap 2	137.217	1450.56	0.277
lap 3	132.033	1339.34	0.255
lap 4	131.881	1287.22	0.245
lap 5	128.706	1310.48	0.250
lap 6	128.715	1296.59	0.247
lap 7 [1,3]	89.504	1021.82	0.195

Table 21: Driver B, Practice 1, Mugello

Lap	**Laptime** [s]	**Integral** [bar · s]	**Integral$_{cor}$** [bar · s / m]
lap 2	132.852	1211.31	0.231
lap 3	128.295	1275.08	0.243
lap 4	128.729	1233.61	0.235
lap 5 [3]	129.478	1153.63	0.220

Table 22: Driver B, Practice , Mugello

Lap	**Laptime** [s]	**Integral** [bar · s]	**Integral$_{cor}$** [bar · s / m]
lap 2 [2]	145.532	1067.54	0.204
lap 3	132.510	1292.70	0.246
lap 4	127.551	1238.31	0.236
lap 5	130.345	1309.66	0.250
lap 6	131.868	1314.04	0.251
lap 7 [1,3]	210.746	998.61	0.190

Table 23: Driver B, Practice 3, Mugello

Lap	Laptime [s]	Integral [bar · s]	Integral$_{cor}$ [bar · s / m]
lap 2	129.128	1335.48	0.255
lap 3 [2]	236.657	948.54	0.181
lap 4	137.571	1219.67	0.233
lap 5	128.878	1412.50	0.269
lap 6	127.826	1341.42	0.256
lap 7 [3]	227.011	1798.69	0.343

Table 24: Driver B, Quali, Mugello

Lap	Laptime [s]	Integral [bar · s]	Integral$_{cor}$ [bar · s / m]
lap 2 [3]	225.569	1467.56	0.280
lap 3 [2]	134.953	1489.90	0.284
lap 4 [2]	179.858	1291.58	0.246
lap 5 [3]	217.240	815.90	0.156
lap 6	128.743	1220.55	0.233
lap 7 [2]	151.187	1053.40	0.201
lap 8 [3]	222.038	748.74	0.143
lap 9	130.345	1391.72	0.265
lap 10	128.083	1318.32	0.251
lap 11	128.700	1294.82	0.247
lap 12	129.155	1240.64	0.237
lap 13 [3]	234.909	1071.38	0.204

Table 25: Driver B, Race 1, Mugello

Lap	**Laptime [s]**	**Integral [bar · s]**	**Integral$_{cor}$ [bar · s / m]**
lap 2 [3]	237.321	1192.11	0.227
lap 3 [2]	135.929	1414.32	0.270
lap 4 [2]	143.874	1270.31	0.242
lap 5 [1]	253.977	840.02	0.160
lap 6	126.642	1290.53	0.246
lap 7	128.558	1286.21	0.245
lap 8	128.390	1104.54	0.211
lap 9	127.743	1266.92	0.242
lap 10	131.389	1113.41	0.212
lap 11 [1]	230.220	1490.14	0.284
lap 12	129.534	1254.24	0.239
lap 13 [3]	123.328	797.60	0.152

Table 26: Driver B, Race 2, Mugello

Driver C

Magione

Lap	**Laptime [s]**	**Max [bar]**	**Integral [bar · s]**
lap 2 [1]	94.644	102.74	874.44
lap 3 [1]	84.383	122.66	1081.48
lap 4	76.533	143.92	1204.31
lap 5	78.198	130.54	1068.13
lap 6	76.157	146.66	1123.43
lap 7	76.522	128.21	1168.50
lap 8	76.221	147.51	1163.46
lap 9	76.013	141.41	1178.41
lap 10 [3]	92.710	152.95	1005.44

Table 27: Driver C, Quali, Magione

Lap	**Laptime [s]**	**Max [bar]**	**Integral [bar · s]**
lap 2 [1]	138.281	95.18	1329.66
lap 3 [1]	88.475	115.72	1240.53
lap 4 [2]	83.162	120.45	1145.65
lap 5	80.326	112.03	1072.23
lap 6	79.273	128.26	1079.16
lap 7	78.451	148.90	1149.27
lap 8	79.013	136.59	1210.16
lap 9	76.497	163.92	1236.44
lap 10	77.088	136.72	1186.67
lap 11	77.149	139.75	1147.61
lap 12	76.541	141.01	1179.81
lap 13	76.546	133.60	1168.99
lap 14	75.969	166.25	1174.94
lap 15	77.327	147.10	1158.25
lap 16	81.218	104.59	1086.30
lap 17 [3]	157.676	57.47	655.09
lap 18 [3]	177.241	59.27	694.01
lap 19 [3]	139.300	54.35	673.40
lap 20 [3]	189.081	37.61	374.53

Table 28: Driver C, Race, Magione

Lap	**Laptime [s]**	**Max [bar]**	**Integral [bar · s]**
lap 2 [1]	104.545	83.75	1104.29
lap 3 [1]	92.342	96.56	1175.82
lap 4	83.123	108.59	1180.62
lap 5 [1]	302.438	150.16	1486.36
lap 6 [2]	86.954	147.32	1005.54
lap 7	78.103	145.88	1065.67
lap 8	78.164	147.19	1135.03
lap 9	79.341	145.87	1163.83
lap 10	77.286	141.88	1224.27
lap 11	77.668	143.97	1205.97
lap 12	78.048	148.07	1293.41
lap 13	77.869	138.47	1239.12
lap 14	83.279	119.39	1139.35
lap 15 [1, 3]	197.300	121.95	2301.16

Table 29: Driver C, Test, Magione

Practice, Magione

Lap	**Laptime [s]**	**Max [bar]**	**Integral [bar · s]**
lap 2 [2]	109.489	113.21	950.19
lap 3	86.131	99.94	994.24
lap 4	83.552	118.16	1016.79
lap 5 [3]	270.249	123.37	2047.96
lap 6	80.463	115.71	1052.05
lap 7 [3]	270.319	130.04	2493.82
lap 8	86.653	123.03	873.24
lap 9	79.095	140.08	1017.83
lap 10	78.838	112.37	1002.10
lap 11 [3]	226.702	92.91	1083.62

Table 30: Driver C, Practice, Magione

Driver D

Magione

Lap	Laptime [s]	Max [bar]	Integral [bar · s]
lap 2 [1]	147.788	73.52	730.50
lap 3	83.957	86.31	878.52
lap 4	80.903	88.83	836.26
lap 5	79.047	97.70	883.03
lap 6	78.847	107.66	916.85
lap 7	78.975	104.86	906.00
lap 8	78.493	104.68	954.50
lap 9	78.732	103.56	958.34
lap 10	78.187	111.09	993.48
lap 11	82.268	107.25	986.46
lap 12 [1]	107.032	68.42	532.38
lap 13	83.121	102.04	1058.93
lap 14	78.314	99.95	924.95
lap 15 [1]	227.243	65.65	406.29
lap 16 [1, 3]	194.358	21.81	293.81

Table 31: Driver D, Race, Magione

Lap	Laptime [s]	Max [bar]	Integral [bar · s]
lap 2 [2]	109.083	74.49	537.95
lap 3	86.678	117.97	967.87
lap 4 [2]	144.562	83.01	1414.90
lap 5	84.232	97.55	903.58
lap 6	78.939	98.50	979.14
lap 7	78.424	99.20	940.54
lap 8 [3]	98.628	104.51	1228.45

Table 32: Driver D, Quali, Magione

Lap	**Laptime [s]**	**Max [bar]**	**Integral [bar · s]**
lap 2 [1]	99.679	91.89	730.39
lap 3 [2]	83.395	83.15	861.27
lap 4	80.991	102.96	809.85
lap 5	80.754	84.26	784.00
lap 6	80.561	77.38	828.82
lap 7	79.403	98.36	831.55
lap 8	79.186	92.28	876.03
lap 9	78.711	93.94	833.25
lap 10	78.500	94.03	876.86
lap 11	79.781	77.10	829.09
lap 12	79.739	89.07	833.21
lap 13	78.815	84.89	860.77
lap 14 [1, 3]	121.753	85.69	723.64

Table 33: Driver D, Test, Magione

Lap	**Laptime [s]**	**Max [bar]**	**Integral [bar · s]**
lap 2 [1]	108.814	64.58	512.52
lap 3 [2]	88.793	72.09	841.29
lap 4	85.791	79.15	796.25
lap 5	85.522	74.46	718.19
lap 6	83.825	72.03	699.43
lap 7 [1]	329.543	77.55	1700.95
lap 8	82.948	83.25	748.14
lap 9	83.012	86.60	639.81
lap 10	82.590	87.41	760.19
lap 11	80.841	80.73	789.31
lap 12	80.319	81.26	784.09
lap 13	80.119	85.42	773.74
lap 14 [1, 3]	136.728	78.40	648.69

Table 34: Driver D, Practice, Magione

Driver E

Franciacorta

Lap	Laptime [s]	Max [bar]	Integral [bar · s]	Integral_{cor} [bar · s / m]
lap 2	84.910	93.88	964.64	0.383
lap 3	87.519	95.23	947.04	0.376
lap 4	83.384	102.65	788.96	0.313
lap 5 [1]	299.892	99.49	4372.82	1.736
lap 6 [1]	651.889	94.60	4442.33	1.764
lap 7	81.982	75.05	792.08	0.314
lap 8	78.844	84.85	822.96	0.327
lap 9	80.732	79.77	837.43	0.332
lap 10	82.019	98.55	999.75	0.397
lap 11	78.545	110.38	954.14	0.379
lap 12	78.366	105.05	916.12	0.364
lap 13	79.123	114.93	945.77	0.375
lap 14 [1, 3]	218.713	83.88	1452.50	0.577

Table 35: Driver E, Franciacorta, Practice

Lap	Laptime [s]	Max [bar]	Integral [bar · s]	Integral_{cor} [bar · s / m]
lap 2 [3]	150.891	99.58	893.49	0.355
lap 3 [3]	147.021	80.56	792.82	0.315
lap 4	86.799	73.80	1114.05	0.442
lap 5	88.165	72.08	950.76	0.377
lap 6 [3]	153.587	85.27	719.88	0.286
lap 7 [3]	156.756	54.23	507.35	0.201
lap 8 [3]	146.935	72.04	591.26	0.235
lap 9	86.569	92.10	1063.50	0.422
lap 10	83.605	72.34	892.79	0.354
lap 11	82.131	80.00	842.81	0.335
lap 12	81.580	93.82	914.49	0.363
lap 13	81.176	92.51	1019.71	0.405
lap 14	82.252	83.62	1021.80	0.406
lap 15	83.868	91.29	1150.14	0.457
lap 16	82.632	83.53	970.58	0.385
lap 17 [3]	153.424	75.08	758.78	0.301

Table 36: Driver E, Franciacorta, Race

Magione

Lap	Laptime [s]	Max [bar]	Integral [bar · s]
lap 2 [2]	91.662	69.38	789.40
lap 3 [2]	86.428	88.28	899.49
lap 4	84.560	77.05	870.10
lap 5	83.678	88.70	886.93
lap 6 [1]	130.891	74.33	1587.54
lap 7 [2]	89.995	68.09	702.86
lap 8	82.079	96.07	930.49
lap 9	80.064	103.94	927.00
lap 10	79.302	86.41	903.37
lap 11	79.35	105.49	912.26
lap 12	79.694	86.76	805.89
lap 13	79.767	83.84	872.57
lap 14	79.637	91.28	856.07
lap 15	79.210	94.81	880.14
lap 16 [1, 3]	154.943	57.14	1304.18

Table 37: Driver E, Test 1, Magione

Lap	**Laptime [s]**	**Max [bar]**	**Integral [bar · s]**
lap 2 [1]	134.104	84.24	802.17
lap 3 [1]	87.115	97.56	1096.55
lap 4 [1]	83.232	93.66	966.73
lap 5 [2]	80.612	88.00	857.46
lap 6	79.029	94.97	843.95
lap 7	78.802	107.85	857.23
lap 8	79.389	100.94	825.83
lap 9	78.448	95.90	829.18
lap 10	77.801	102.28	932.50
lap 11	77.818	109.36	880.26
lap 12	78.405	95.29	964.97
lap 13	78.553	93.81	881.16
lap 14	78.347	104.30	947.68
lap 15	77.900	95.07	885.38
lap 16 [1]	83.462	89.28	722.97
lap 17 [3]	147.592	60.49	612.88
lap 18 [3]	177.709	82.82	630.99
lap 19 [3]	138.441	78.90	706.96
lap 20 [3]	187.965	42.42	451.05

Table 38: Driver E, Race, Magione

Lap	**Laptime [s]**	**Max [bar]**	**Integral [bar · s]**
lap 2 [1]	86.879	93.00	774.75
lap 3	78.638	105.88	827.27
lap 4	78.624	105.34	938.95
lap 5	77.444	119.89	991.39
lap 6	77.909	115.62	979.96
lap 7	77.961	121.73	960.82
lap 8	78.312	122.82	967.51
lap 9	77.541	121.36	992.01
lap 10 [1, 3]	100.919	115.58	702.70

Table 39: Driver E, Quali, Magione

Lap	**Laptime [s]**	**Max [bar]**	**Integral [bar · s]**
lap 2 [1]	118.882	40.06	506.2
lap 3 [1]	89.272	71.52	908.95
lap 4 [1]	248.397	78.26	3218.55
lap 5	81.855	98.67	905.34
lap 6	81.16	102.26	954.63
lap 7	79.04	91.26	937.02
lap 8	78.087	85.94	928.17
lap 9	77.727	105.73	933.20
lap 10	77.911	96.90	859.21
lap 11	82.397	128.65	956.76
lap 12	81.188	86.40	666.42
lap 13	78.445	103.72	910.72
lap 14	79.820	93.46	889.62
lap 15 [1, 3]	125.135	68.98	839.60

Table 40: Driver E, Practice, Magione

Lap	**Laptime [s]**	**Max [bar]**	**Integral [bar · s]**
lap 2 [1]	111.202	54.17	386.75
lap 3	81.440	117.98	974.15
lap 4	79.375	102.52	769.78
lap 5	80.679	91.59	776.98
lap 6 [1]	169.247	75.60	991.59
lap 7	85.313	81.71	717.23
lap 8 [2]	89.988	117.82	1036.20
lap 9 [1]	302.696	45.25	3685.08
lap 10	84.344	94.37	775.85
lap 11	79.933	108.11	821.35
lap 12	78.861	92.86	828.16
lap 13	79.255	93.68	821.86
lap 14	78.751	103.04	863.68
lap 15 [1, 3]	162.817	71.88	1285.95

Table 41: Driver E, Test 2, Magione

Lap	Laptime [s]	Max [bar]	Integral [bar · s]
lap 2 [2]	89.912	78.03	874.78
lap 3 [2]	85.642	75.16	830.77
lap 4 [2]	83.213	88.12	864.34
lap 5 [1]	307.367	89.31	4370.9
lap 6	80.374	101.59	826.27
lap 7	79.965	74.33	748.51
lap 8	79.450	103.95	905.47
lap 9	79.490	102.80	880.11
lap 10	79.168	103.19	862.66
lap 11	78.699	85.68	840.90
lap 12 [1, 3]	132.201	46.72	640.90

Table 42: Driver E, Test 3, Magione

Misano

Lap	Laptime [s]	Max [bar]	Integral [bar · s]	Integral_{cor} [bar · s / m]
lap 2 [2]	122.431	101.92	1239.05	0.293
lap 3 [2]	118.678	122.12	1311.63	0.310
lap 4 [2]	114.989	91.82	1332.84	0.315
lap 5	112.772	128.20	1343.67	0.318
lap 6	113.104	104.16	1368.30	0.324
lap 7 [1]	317.486	122.37	3630.79	0.859
lap 8	111.916	133.37	1350.96	0.320
lap 9	112.661	116.81	1309.34	0.310
lap 10	111.331	125.41	1419.38	0.336
lap 11	113.201	119.29	1442.55	0.341
lap 12 [1, 3]	272.407	87.47	1405.16	0.333

Table 43: Driver E, Misano, Practice

Lap	**Laptime** [s]	**Max** [bar]	**Integral** [bar · s]	**Integral$_{cor}$** [bar · s / m]
lap 2	111.078	117.70	1214.17	0.287
lap 3	112.692	109.61	1345.92	0.318
lap 4	112.353	113.31	1379.05	0.326
lap 5 [3]	144.418	114.56	1284.88	0.304

Table 44: Driver E, Misano, Quali

Lap	**Laptime** [s]	**Max** [bar]	**Integral** [bar · s]	**Integral$_{cor}$** [bar · s / m]
lap 2	149.401	79.26	994.01	0.235
lap 3	143.936	66.67	1085.88	0.257
lap 4	152.286	69.98	985.72	0.233
lap 5	134.122	90.63	1321.12	0.313
lap 6	137.588	76.63	1264.15	0.299
lap 7 [3]	253.215	78.04	1028.1	0.243

Table 45: Driver E, Misano, Race

Driver F

Magione

Lap	Laptime [s]	Max [bar]	Integral [bar · s]
lap 2 [1]	147.465	86.64	740.00
lap 3	79.101	104.03	973.94
lap 4	77.415	117.71	1024.53
lap 5	76.662	119.39	1101.52
lap 6	76.654	127.76	1184.97
lap 7	76.532	144.72	1220.15
lap 8	76.854	120.02	1197.36
lap 9	77.354	136.47	1239.30
lap 10	77.476	115.26	1184.14
lap 11	78.531	119.26	1105.12
lap 12	79.097	114.56	1133.30
lap 13	79.765	99.23	1032.01
lap 14	80.049	100.67	998.79
lap 15	80.561	107.45	1027.12
lap 16	81.538	101.35	923.22
lap 17 [1, 3]	85.210	106.06	754.49

Table 46: Driver F, Race, Magione

Lap	Laptime [s]	Max [bar]	Integral [bar · s]
lap 2	89.348	63.28	615.01
lap 3	80.019	114.86	1009.01
lap 4	76.287	122.70	1131.41
lap 5	83.767	119.72	1175.13
lap 6 [3]	106.138	125.96	1437.14

Table 47: Driver F, Quali, Magione

Lap	**Laptime [s]**	**Max [bar]**	**Integral [bar · s]**
lap 2 [1]	115.641	79.09	472.25
lap 3 [1]	82.831	105.79	1170.36
lap 4	77.468	140.72	1302.43
lap 5	77.226	152.56	1267.96
lap 6	77.557	143.77	1237.13
lap 7	76.963	135.60	1185.22
lap 8	77.170	129.90	1166.35
lap 9	76.809	120.74	1174.00
lap 10 [1]	164.365	124.34	1666.17
lap 11 [1]	82.048	123.12	1007.96
lap 12 [1]	78.380	129.29	1054.97
lap 13	77.390	129.20	1112.51
lap 14	77.130	126.49	1044.79
lap 15	76.950	132.43	1143.94
lap 16 [1, 3]	128.087	105.04	1115.68

Table 48: Driver F, Test, Magione

Driver G

Adria

Lap	Laptime [s]	Max [bar]	Integral [bar · s]	Integral$_{cor}$ [bar · s / m]
lap 2	89.568	95.58	1353.55	0.501
lap 3 [1]	155.226	98.40	1729.20	0.640
lap 4	97.948	86.86	1165.49	0.431
lap 5	86.717	124.23	1413.27	0.523
lap 6	86.257	136.60	1567.90	0.580
lap 7	93.104	123.53	1660.53	0.615
lap 8	94.897	149.12	1460.47	0.541
lap 9	85.748	142.50	1519.93	0.563
lap 10	85.768	127.40	1595.99	0.591
lap 11	85.244	136.23	1688.18	0.625
lap 12 [1,3]	202.563	118.87	1238.25	0.458

Table 49: Driver G, Adria, Practice 1

Lap	Laptime [s]	Max [bar]	Integral [bar · s]	Integral$_{cor}$ [bar · s / m]
lap 2 [1]	112.976	52.21	742.71	0.275
lap 3	87.407	84.25	1220.28	0.452
lap 4	87.853	132.15	1395.93	0.512
lap 5	85.577	132.75	1551.7	0.574
lap 6	85.466	120.42	1582.44	0.586
lap 7	85.582	118.00	1522.30	0.563
lap 8	86.481	116.11	1507.14	0.558
lap 9 [1]	271.772	120.19	2330.38	0.862
lap 10	86.683	96.55	1172.45	0.434
lap 11	85.867	121.05	1435.59	0.531
lap 12 [1]	329.381	123.67	3683.52	1.363
lap 13	85.639	109.98	1307.88	0.484
lap 14	87.111	128.95	1498.26	0.555
lap 15 [1,3]	186.537	53.13	1054.60	0.390

Table 50: Driver G, Adria, Practice 2

Lap	**Laptime** [s]	**Max** [bar]	**Integral** [bar · s]	**Integral$_{cor}$** [bar · s / m]
lap 2	87.817	104.78	1310.37	0.485
lap 3	85.702	108.64	1253.96	0.464
lap 4	84.553	109.64	1352.55	0.501
lap 5 [1]	493.343	118.27	2769.28	1.025
lap 6 [1]	91.409	133.17	1460.05	0.540
lap 7	88.824	137.57	1668.95	0.618
lap 8 [1]	99.110	125.77	1393.72	0.516
lap 9	87.577	153.31	1792.51	0.663
lap 10	86.585	168.4	1954.40	0.723
lap 11	87.804	139.45	1965.79	0.728
lap 12	86.552	137.92	1767.80	0.654
lap 13	86.043	138.52	1773.26	0.656
lap 14 [1, 3]	223.434	117.90	2052.93	0.760

Table 51: Driver G, Adria, Practice 3

Lap	**Laptime** [s]	**Max** [bar]	**Integral** [bar · s]	**Integral$_{cor}$** [bar · s / m]
lap 2 [3]	104.229	83.75	1066.56	0.395
lap 3	86.379	141.72	1385.73	0.513
lap 4	85.389	143.76	1607.30	0.595
lap 5 [2]	97.955	149.30	1538.79	0.570
lap 6 [1]	273.951	139.66	2794.83	1.034
lap 7	85.798	130.80	1378.26	0.510
lap 8	84.620	144.86	1558.62	0.577
lap 9 [3]	281.933	139.71	2221.62	0.822
lap 10 [3]	206.633	138.15	1578.70	0.584

Table 52: Driver G, Adria, Quali

Lap	**Laptime** [s]	**Max** [bar]	**Integral** [bar · s]	**Integral$_{cor}$** [bar · s / m]
lap 2 [3]	183.844	90.53	1459.79	0.540
lap 3	89.229	114.79	1121.05	0.415
lap 4	87.095	108.17	1149.31	0.425
lap 5	85.205	88.47	1196.26	0.443
lap 6	91.138	112.93	1318.68	0.488
lap 7 [3]	57.297	134.80	878.93	0.325

Table 53: Driver G, Adria, Race

Franciacorta

Lap	**Laptime** [s]	**Max** [bar]	**Integral** [bar · s]	**Integral$_{cor}$** [bar · s / m]
lap 2	82.851	110.14	1018.29	0.404
lap 3	81.102	118.69	1011.93	0.402
lap 4	83.572	114.09	971.78	0.386
lap 5	79.791	133.56	1089.64	0.433
lap 6	80.412	138.71	1127.86	0.448
lap 7	80.130	123.75	1064.05	0.422
lap 8	79.496	130.26	1128.13	0.448
lap 9 [1]	671.950	119.31	2343.04	0.930
lap 10	82.349	95.11	950.78	0.377
lap 11	79.435	116.58	1023.12	0.406
lap 12	79.224	111.98	1148.31	0.456
lap 13	79.780	117.96	1158.94	0.460
lap 14	81.347	100.53	1281.55	0.509
lap 15	79.554	130.51	1228.43	0.488
lap 16 [1, 3]	239.089	88.09	1905.33	0.756

Table 54: Driver G, Franciacorta, Practice 1

Lap	**Laptime** [s]	**Max** [bar]	**Integral** [bar · s]	**Integral$_{cor}$** [bar · s / m]
lap 2 [1]	238.586	73.53	1253.10	0.497
lap 3 [1]	89.710	117.66	969.00	0.385
lap 4 [3]	359.779	127.37	3065.56	1.217
lap 5	77.331	116.62	1034.01	0.410
lap 6	77.040	134.61	1021.00	0.405
lap 7 [1]	164.440	109.90	1286.21	0.511
lap 8 [1]	110.817	67.73	841.22	0.334
lap 9 [3]	351.828	64.56	1282.53	0.509
lap 10	77.089	131.84	1105.63	0.439
lap 11	77.228	135.47	1053.35	0.418
lap 12	77.315	146.13	1084.75	0.431
lap 13 [2]	77.747	139.36	1006.88	0.400
lap 14 [1,3]	189.549	84.20	1160.75	0.461

Table 55: Driver G, Franciacorta, Practice 2

Lap	**Laptime** [s]	**Max** [bar]	**Integral** [bar · s]	**Integral$_{cor}$** [bar · s / m]
lap 2 [1]	281.967	116.79	1281.50	0.509
lap 3	80.941	101.43	1084.22	0.430
lap 4	79.199	121.25	1107.50	0.440
lap 5	77.885	129.26	1055.09	0.419
lap 6	77.402	137.42	1064.96	0.423
lap 7	77.382	137.06	1103.16	0.438
lap 8 [1]	170.011	122.34	1039.50	0.413
lap 9 [1]	92.161	55.49	756.98	0.301
lap 10	79.705	113.08	996.58	0.396
lap 11	78.004	114.35	1087.35	0.432
lap 12	79.784	120.45	1033.87	0.410
lap 13	77.480	129.29	1060.36	0.421
lap 14 [1,3]	215.066	102.54	1539.66	0.611

Table 56: Driver G, Franciacorta, Practice 3

Lap	Laptime [s]	Max [bar]	Integral [bar · s]	Integral_{cor} [bar · s / m]
lap 2 [1]	222.767	64.09	2086.19	0.828
lap 3	86.084	74.93	1051.76	0.418
lap 4	79.477	133.58	1090.70	0.433
lap 5	80.366	97.76	925.72	0.367
lap 6	80.513	125.72	1017.85	0.404
lap 7	77.012	139.60	1073.46	0.426
lap 8	85.049	115.43	888.54	0.353
lap 9	76.394	148.55	1136.41	0.451
lap 10 [1]	332.580	137.52	2077.46	0.825
lap 11	76.243	134.07	1107.17	0.440
lap 12	86.461	80.16	825.74	0.328
lap 13	76.059	139.97	1141.42	0.453
lap 14 [1, 3]	210.168	89.53	895.61	0.356

Table 57: Driver G, Franciacorta, Quali

Lap	Laptime [s]	Max [bar]	Integral [bar · s]	Integral_{cor} [bar · s / m]
lap 2 [3]	84.076	105.32	1295.59	0.514
lap 3	76.532	114.15	1036.30	0.411
lap 4	77.356	123.39	1090.97	0.433
lap 5	75.252	131.32	1017.85	0.404
lap 6	75.811	124.13	1097.76	0.436
lap 7	76.590	130.89	1091.42	0.433
lap 8	75.500	117.47	1010.88	0.401
lap 9	75.842	122.79	1162.73	0.463
lap 10	76.145	128.51	1130.49	0.449
lap 11 [1]	102.351	105.28	758.77	0.301
lap 12 [1]	198.634	63.29	860.76	0.342
lap 13 [1]	249.625	38.44	520.76	0.207
lap 14 [1, 3]	303.432	50.56	977.11	0.388

Table 58: Driver G, Franciacorta, Race 1

Lap	**Laptime** [s]	**Max** [bar]	**Integral** [bar · s]	**Integral$_{cor}$** [bar · s / m]
lap 2 [3]	183.844	90.53	1459.79	0.580
lap 3	89.229	114.79	1121.05	0.445
lap 4	87.095	108.17	1149.31	0.456
lap 5	85.205	88.47	1196.26	0.475
lap 6	91.138	112.93	1318.68	0.523
lap 7 [3]	57.297	134.80	878.93	0.349

Table 59: Driver G, Franciacorta, Race 2

Lap	**Laptime** [s]	**Max** [bar]	**Integral** [bar · s]	**Integral$_{cor}$** [bar · s / m]
lap 2 [2]	88.975	87.96	830.40	0.330
lap 3	83.226	86.81	911.82	0.362
lap 4	82.461	124.21	945.33	0.375
lap 5	80.037	117.41	960.83	0.381
lap 6 [1]	302.932	118.23	3001.57	1.192
lap 7	78.297	127.50	1082.90	0.430
lap 8	78.171	129.12	1094.97	0.435
lap 9 [1]	313.509	121.58	2626.11	1.043
lap 10	77.689	124.05	1087.59	0.432
lap 11	76.986	128.61	1149.21	0.456
lap 12 [3]	108.477	123.60	1174.91	0.466

Table 60: Driver G, Franciacorta, Test 1

Lap	**Laptime** [s]	**Max** [bar]	**Integral** [bar · s]	**Integral$_{cor}$** [bar · s / m]
lap 2	79.206	132.96	1006.86	0.400
lap 3	76.968	149.21	1092.11	0.434
lap 4	78.776	146.52	1191.15	0.473
lap 5	78.353	139.51	1134.60	0.450
lap 6	78.154	155.11	1350.04	0.536
lap 7 [3]	164.208	131.42	1652.52	0.656

Table 61: Driver G, Franciacorta, Test 2

Magione

Lap	**Laptime [s]**	**Max [bar]**	**Integral [bar · s]**
lap 2 [1]	92.083	66.17	947.58
lap 3	86.035	98.70	1151.89
lap 4	84.972	95.13	1271.86
lap 5	83.369	102.55	1316.26
lap 6	83.434	111.13	1309.53
lap 7	83.160	123.53	1312.66
lap 8	82.313	112.21	1338.89
lap 9	81.870	106.22	1186.34
lap 10	81.581	110.14	1236.07
lap 11 [1]	255.889	106.87	3489.96
lap 12	80.226	107.90	1230.93
lap 13	80.802	108.99	1154.06
lap 14 [1, 3]	155.237	107.90	1353.58

Table 62: Driver G, Test 1, Magione

Lap	**Laptime [s]**	**Max [bar]**	**Integral [bar · s]**
lap 2	84.821	90.15	1180.50
lap 3 [1]	417.237	93.99	2545.63
lap 4	86.460	85.73	986.71
lap 5	85.426	131.32	1214.06
lap 6	84.543	106.79	1226.07
lap 7 [1]	324.808	115.11	2322.47
lap 8 [1]	90.703	80.99	903.67
lap 9	83.348	127.05	1197.86
lap 10	84.870	118.75	1339.17
lap 11 [1, 3]	179.237	121.74	1217.22

Table 63: Driver G, Test 2, Magione

Lap	**Laptime [s]**	**Max [bar]**	**Integral [bar · s]**
lap 2	83.878	77.88	1018.18
lap 3	83.979	79.86	1122.30
lap 4 [1]	287.255	82.03	2054.10
lap 5 [2]	96.999	81.62	972.93
lap 6 [2]	101.934	165.48	1344.02
lap 7	84.710	106.25	1001.27
lap 8	87.003	103.64	1081.08
lap 9	84.070	108.74	1150.12
lap 10	83.601	115.51	1225.82
lap 11	85.981	117.03	1240.54
lap 12 [1, 3]	169.426	109.81	1326.45

Table 64: Driver G, Test 3, Magione

Lap	**Laptime [s]**	**Max [bar]**	**Integral [bar · s]**
lap 2 [2]	147.731	53.71	976.50
lap 3	100.767	47.80	813.80
lap 4	118.715	64.47	1140.43
lap 5	93.827	54.82	799.88
lap 6	91.108	68.79	894.00
lap 7	116.033	64.98	1240.91
lap 8	89.761	81.58	958.04
lap 9	117.099	84.28	1254.88
lap 10	91.840	80.96	916.78
lap 11	90.373	98.94	1054.06
lap 12	89.726	87.70	1014.20
lap 13	88.979	73.85	1019.58
lap 14 [1, 3]	281.743	73.39	1643.25

Table 65: Driver G, Test 4, Magione

Driver H

Adria

Lap	Laptime [s]	Max [bar]	Integral [bar · s]	Integral_{cor} [bar · s / m]
lap 2	76.564	91.97	1016.86	0.376
lap 3	75.484	119.50	1080.74	0.400
lap 4	75.603	118.03	1197.88	0.443
lap 5 [3]	166.459	86.70	828.76	0.307

Table 66: Driver H, Adria, Test

Magione

Lap	Laptime [s]	Max [bar]	Integral [bar · s]
lap 2 [3]	148.624	71.97	758.53
lap 3 [2]	77.609	107.77	1006.74
lap 4 [1]	93.071	105.21	892.89
lap 5 [1]	158.21	42.54	420.35
lap 6 [1]	146.717	50.58	357.41
lap 7 [1]	120.311	77.06	446.34
lap 8	76.017	94.53	1002.47
lap 9	75.866	96.71	1088.88
lap 10	75.914	105.32	1190.34
lap 11	75.942	125.44	1223.88
lap 12	76.225	122.18	1263.41
lap 13	76.078	123.42	1289.21
lap 14	76.14	140.94	1248.78
lap 15 [2]	76.922	132.89	1267.58
lap 16 [2]	76.662	118.49	1243.00
lap 17 [1]	91.678	99.14	846.23
lap 18 [1]	175.28	46.48	319.62
lap 19 [3]	192.237	22.40	309.92

Table 67: Driver H, Race, Magione

Lap	**Laptime [s]**	**Max [bar]**	**Integral [bar · s]**
lap 2	85.945	84.72	839.36
lap 3	75.739	106.90	1068.09
lap 4	75.477	115.11	1163.46
lap 5	75.725	126.22	1340.96
lap 6	93.33	97.01	726.97
lap 7	80.321	105.52	1114.75
lap 8	87.083	98.86	665.60
lap 9	75.639	98.03	1047.84
lap 10 [1, 3]	169.063	86.84	655.17

Table 68: Driver H, Quali, Magione

Lap	**Laptime [s]**	**Max [bar]**	**Integral [bar · s]**
lap 2	77.332	92.40	1006.54
lap 3	76.221	111.28	1069.54
lap 4 [2]	81.855	89.00	1126.22
lap 5	76.939	98.40	1092.96
lap 6	76.639	104.52	1032.04
lap 7 [1]	289.698	100.29	2229.09
lap 8	77.937	88.28	922.29
lap 9 [2]	79.240	89.56	946.82
lap 10	76.872	101.11	1047.89
lap 11 [1, 3]	326.057	105.64	1990.96

Table 69: Driver H, Practice, Magione

Lap	Laptime [s]	Max [bar]	Integral [bar · s]
lap 2 [1]	307.193	137.32	7534.43
lap 3	79.833	114.41	1244.21
lap 4	78.063	123.94	1251.87
lap 5	78.062	116.53	1278.94
lap 6	79.257	116.98	1225.93
lap 7	76.982	114.51	1144.86
lap 8	78.566	104.12	1197.17
lap 9	76.889	112.84	1054.70
lap 10	76.659	110.49	1122.21
lap 11	78.489	90.40	1038.92
lap 12	77.471	95.09	986.39
lap 13 [2]	81.259	96.79	991.73
lap 14 [1, 3]	187.906	92.23	1480.01

Table 70: Driver H, Test, Magione

Mugello

Lap	Laptime [s]	Max [bar]	Integral [bar · s]	Integral_{cor} [bar · s / m]
lap 2 [1]	365.930	76.18	1731.48	0.330
lap 3	127.402	85.93	1130.09	0.215
lap 4	127.824	91.17	1081.44	0.206
lap 5	124.280	88.28	1044.99	0.199
lap 6	122.756	99.03	1052.60	0.201
lap 7 [1]	302.344	84.32	1267.88	0.242
lap 8	132.197	71.96	917.39	0.175
lap 9	121.096	104.66	1051.95	0.201
lap 10	121.499	100.37	1059.74	0.202
lap 11 [3]	172.605	113.19	853.22	0.163

Table 71: Driver H, Mugello, Practice

Lap	**Laptime** [s]	**Max** [bar]	**Integral** [bar · s]	**Integral$_{cor}$** [bar · s / m]
lap 2 [1]	2078.068	94.09	3282.38	0.626
lap 3 [2]	144.814	84.48	929.24	0.177
lap 4	121.448	120.51	1417.76	0.270
lap 5 [3]	204.881	124.59	996.22	0.190
lap 6	121.532	121.84	1191.74	0.227
lap 7 [3]	246.044	120.11	1918.04	0.366
lap 8 [3]	225.330	61.11	429.24	0.082
lap 9	125.720	113.63	1069.38	0.204
lap 10	123.774	106.87	1227.81	0.234
lap 11	121.694	121.28	1262.70	0.241
lap 12 [3]	461.891	77.76	2111.74	0.403

Table 72: Driver H, Mugello, Quali

Lap	**Laptime** [s]	**Max** [bar]	**Integral** [bar · s]	**Integral$_{cor}$** [bar · s / m]
lap 2 [3]	234.686	23.03	227.81	0.043
lap 3 [1]	127.025	89.57	1070.49	0.204
lap 4 [3]	184.260	110.80	761.01	0.145
lap 5 [3]	220.181	50.83	322.87	0.062
lap 6	122.507	109.52	1159.18	0.221
lap 7 [1]	155.322	104.78	744.59	0.142
lap 8 [3]	223.676	24.44	147.93	0.028
lap 9	122.440	95.63	1202.89	0.229
lap 10	121.837	101.55	1173.44	0.224
lap 11	122.130	107.69	1182.75	0.225
lap 12	122.816	97.00	1152.91	0.220
lap 13 [3]	207.171	52.54	579.87	0.111

Table 73: Driver H, Mugello, Race