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AWD Torque Vectoring

Advanced Vehicle Dynamics

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1 Introduction

The following paper investigated the all-wheel drive (AWD) system developed by Ferrari in their FF. This electronic system developed can take decisions on how much power to deliver to each wheel depending on the environment, for example, if the car was driving over a dirt track the system will send power to the front and to the rear wheels to increase the amount of grip on a loose surface. On the other hand, on a track the system will send all the power to the rear wheels to not lose that sporty feeling.

The dynamic index of the Ferrari FF was compared to other readily available dynamic indexes. Different patents were used to find the torque path of the vehicle, as well as the electronic system layout.

Different situations were assumed and calculated within excel to see how the system will fare in its different setups, in AWD mode and in RWD mode.



Figure 1 – Side View of Ferrari FF (Super Street Network, 2011)

2 Base Vehicle Specification

The following table shows the data used for this paper, in Appendix 1 there is further data about the vehicle which was not used in the paper but can be useful for reference.

The driver weight was taken from a BBC article giving the average weight of a male human. (BBC News, 2010)

The gear ratios were sourced from lecture notes. (Sandford, 2020)

Most of the data was sourced from Ferrari (Ferrari, 2011), the Appendix A has the rest of the base data.

Table 1 – Base Vehicle DATA

Name	Data		Units
Kerb Weight	1880		Kg
Driver Weight	83.6		Kg
Wheelbase	2990		mm
Track	1676		mm
Front Gearbox Ratios + Final Drive	1	8.59	(Sandford, 2020)
	2	4.69	
Rear Gearbox Ratios	1	3.15	
	2	2.18	
	3	1.57	
	4	1.19	
	5	0.94	
	6	0.76	
Final Drive	4.18		
Engine Torque @6000RPM	683		Nm
Front Tyre size	245/35 ZR 20 8.5J x 20"		
Rear Tyre size	295/35 ZR 20 10.5J x 20"		
Traction Coefficients	Wet Ice	0.1	(The Engineering Toolbox, 2020)
	Dry Asphalt	0.9	
	Loose Sand	0.3	
	Rolled Gravel	0.5	

3 Torque Vectoring System

The difference between a torque vectoring system and a more traditional limited slip differential system, the designer of the vehicle could decide how much torque is sent to each wheel depending on electronic sensors, while a limited slip differential acted on account of how much grip each wheel gets. For example, if the vehicle was moving around a left-hand corner the torque vectoring system was able to control the amount of torque sent to each wheel, in this case it sent a larger amount of torque to the outside wheels. While a limited slip differential was not able to react via electronic inputs, the outside wheels for them to produce more torque needed a higher resistance than the inner wheels. One way to control resistance on each wheel via the use of an LSD was with the use of a braking torque vectoring system which controls the resistance of each wheel electronically by detecting understeer and oversteer, consequently applying a dab of the breaks on the lightly loaded wheel, in this case the inner wheel, an increase in torque at that wheel, allowed the differential to transmit more torque to the heavily loaded wheel, Figure 2.

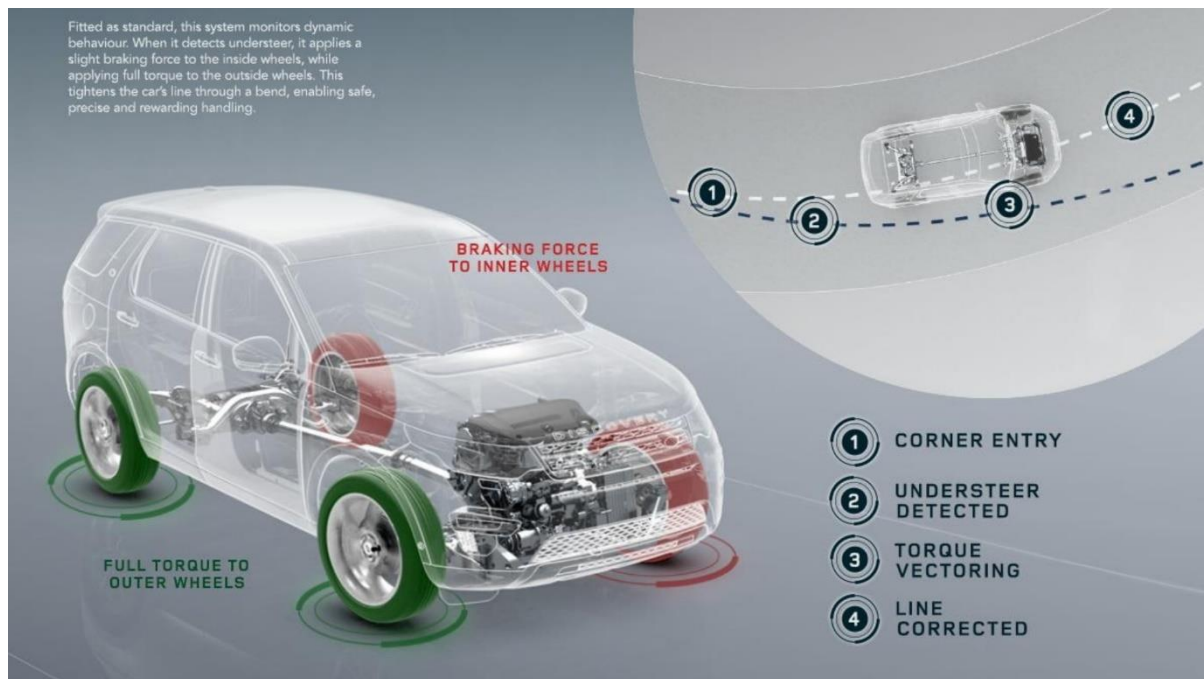


Figure 2 – Brake torque vectoring (Jaguar Land Rover, 2020)

Another example of torque vectoring was when a vehicle front tyres were on a different surface with a lower coefficient of friction to the back, Figure 3, such as ice. The active centre differential sent 90% of the torque to the rear of the car where there is more grip, furthermore the rear differential separated the torque 20% to the left and 80% to the right. (Kiumars Jalali, 2013)

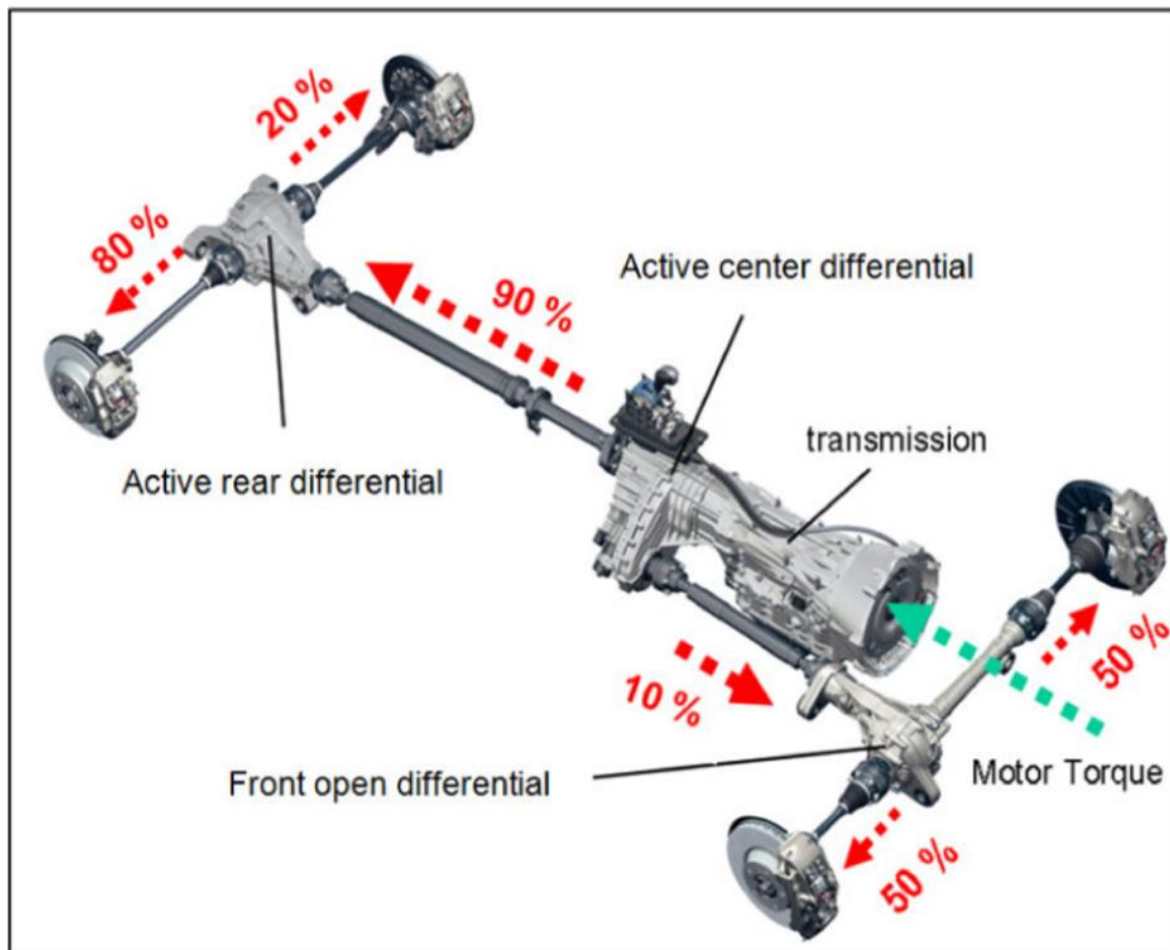


Figure 3 – Torque vectoring for additional traction on low grip surfaces. (Kiumars Jalali, 2013)

Torque vectoring also enables stability control, the torque is distributed along each wheel to generate corrective yaw moment about the vertical axis of the vehicle. This corrective yaw can be generated in different manners: (Kiumars Jalali, 2013)

- Left to Right mode, where the available torque is distributed asymmetrically to the left and right wheels of an axle.
- Front to Rear mode, where the available torque is distributed asymmetrically to the front and rear axles.

Figure 4 shows examples of Left to Right torque vectoring:

In an oversteering situation, as seen in Figure 4-a, the inside wheel on the front axle is transmitted more torque to counter the oversteer.

In an understeering situation, as seen in Figure 4-b, the outside wheel on the rear axle is transmitted more torque to generate the required corrective yaw moment.

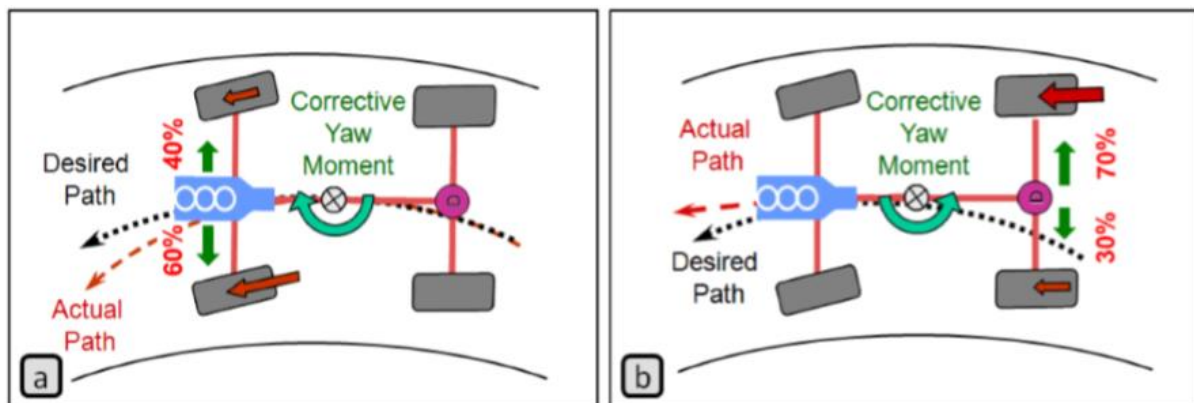


Figure 4 – a) Stability control of an oversteered vehicle through left to right torque vectoring on the front axle, and b) stability control of an understeered vehicle through left to right torque vectoring on the rear axle. (Kiumars Jalali, 2013)

The vehicle investigated in this paper uses a plethora of electronic driving aids, as well as a new state of the art torque vectoring system.

4 Base Vehicle Specification

4.1 Lumped Mass model

A simple lumped mass model of the Ferrari FF was done, a side view photo was used in Solid works and then scaled to the correct size by using the known wheelbase, from there some estimated guesses of the location of the passengers can be done, 1780mm was an approximation, as seen in Figure 5.

Where M_f is Mass Front, M_d is Mass of the drivers and M_r is Mass Rear. The vehicle has 47% of its kerb weight at the front and 53% of its kerb weight at the rear.

The calculated masses can be seen in Table 2:

Table 2 – Lumped Mass Data

Name	Data	Units
Front Mass (M_f)	883.6	Kg
Rear Mass (M_r)	996.4	Kg
Drivers Mass (M_d)	$2 \times 83.6 = 167.2$	Kg

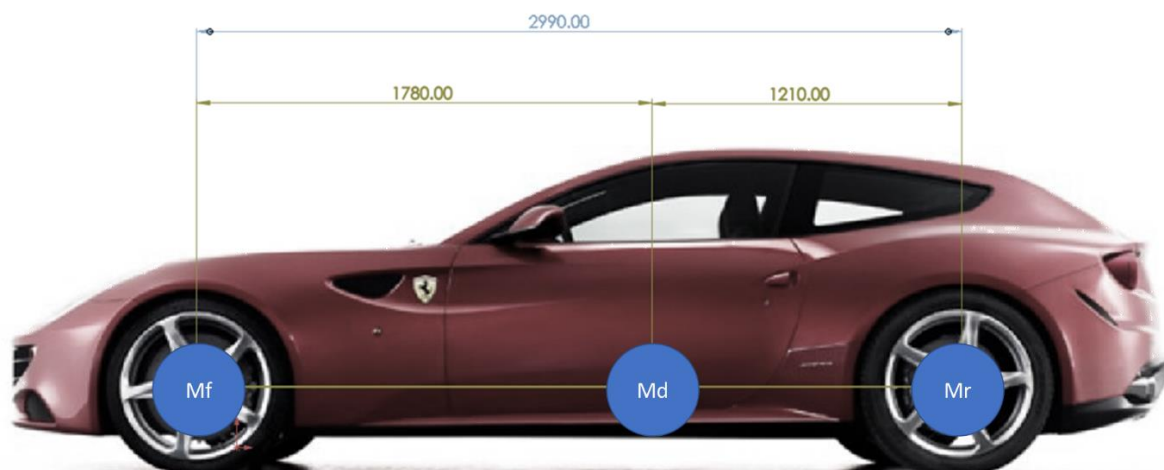


Figure 5 – Lumped mass model of Ferrari FF, measurements shown are in mm.

4.2 Longitudinal Centre of Gravity

The longitudinal COG was calculated by using the different masses and measurements from the lumped mass model in Section 4.1. The following Equation 1 was used to calculate the COG from the vehicle's front axle.

$$COG \text{ position from front} = \frac{M_d * L_a + M_r * Wheelbase}{M_d + M_f + M_r} \quad \text{Equation 1 – COG position}$$

The following table 3 names each measurement:

Table 3 – Naming Convention for measurements.

Name	Data	Units
La	1780	mm
Lb	1210	mm
Lc	1600.56	mm

The COG position with the DATA collected was found to be **1600.56mm** from the front axle, as seen in Figure 6.

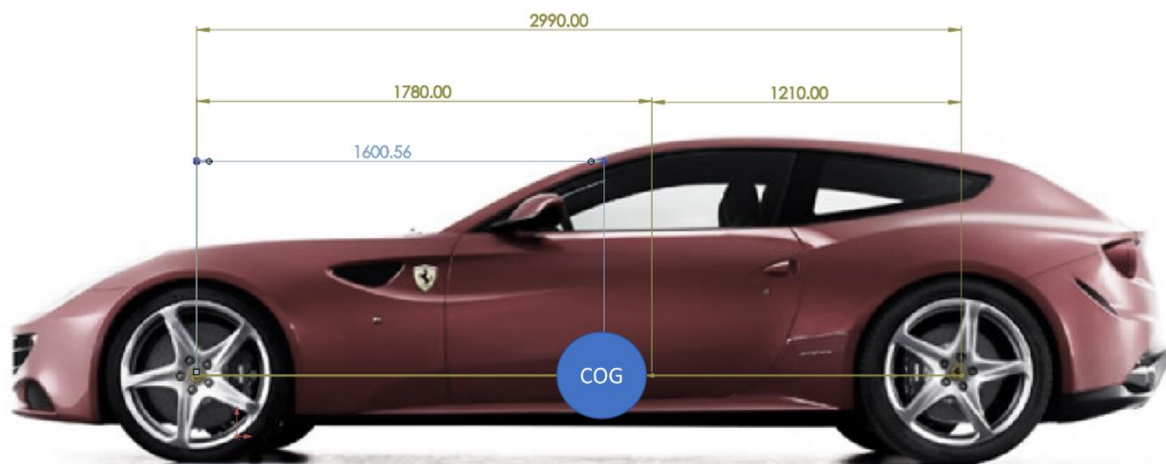


Figure 6 – Centre of Gravity position, measurements are in mm.

The Centre of Gravity is ever so slightly rear bias, it is pretty much in the middle of the vehicle this thanks to the engine being front-mid mounted and most of the weight, 53% at the rear.

4.3 Vehicle Moment of Inertia Z-Z

The vehicle moment of inertia around the Z-Z axis was calculated using the following Equation 2:

$$I_{zz} = (M_f * L_c) + M_d * (L_a - L_c)^2 + M_r * (Wheelbase - L_c)^2 \quad \text{Equation 2 – Moment of inertia}$$

The result of this equation is a moment of inertia of **4192.57 Kg.m²**

This measurement was used in yaw stability control for the torque vectoring system. Other moments of inertia such as roll and pitch were used more often in active suspension control systems and roll over warning systems. (Stijn De Bruyne, 2011)

4.4 Vehicle Internal Conjugate Location

There is a point on a side of the COG where linear acceleration is 0, this point is the inertial conjugate or centre of percussion. (Sandford, 2020)

The inertial Conjugate location was calculated with the following equation 3:

$$\text{Internal Conjugate Location} = \frac{I_{zz}}{\text{Total mass} * L_c} \quad \text{Equation 3 – Internal Conjugate Location}$$

The Location of the internal conjugate from the COG was **1279 mm**, the location can be seen in Figure

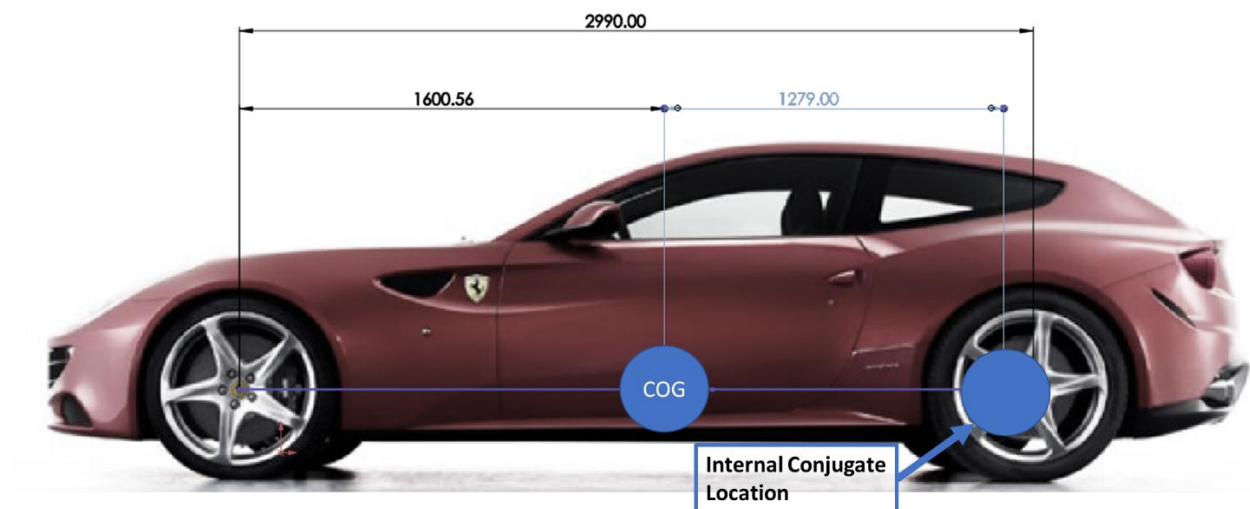


Figure 7 – Internal Conjugate Location, measurements are in mm.

4.5 Dynamic Index

Dynamic Index is calculated with the following equation:

$$DI = \frac{I_{zz}}{(Total\ Mass * L_c * (Wheelbase - L_c))} \quad \text{Equation 4 – Dynamic Index}$$

The Dynamic Index was found to be **0.92**

Depending on the DI the vehicle reacts in a certain way: (Sandford, 2020)

- A DI of one is when the centre of percussion is on the rear axle.
- A DI larger than one equals to a very stable vehicle that is reluctant to turn in.
- A DI smaller than one equals to a stable vehicle that turns in okay.
- A DI smaller than 0.8 equals to a very unstable vehicle, turns in too well and is difficult to balance Control.

This Dynamic Index can be compared to other known vehicle Dynamic Indexes.

The closest in terms of wheelbase and dynamic index is the BMW M5, which has a similar weight and wheelbase to the Ferrari FF. This comparison gives the user confidence that the estimated calculated DATA is correct.

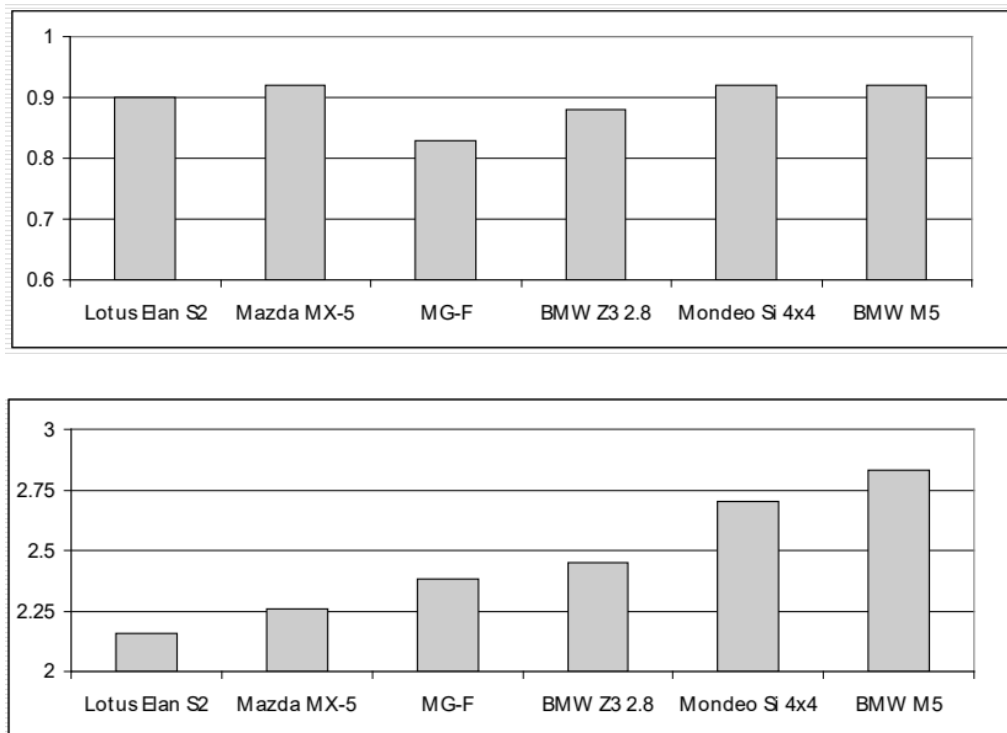


Figure 8 – Dynamic Indexes for other vehicles above, wheelbases below (Sandford, 2020)

4.6 Discussion Base Vehicle Specification

The calculated Data can be seen in the following table

Table 4 – Calculated DATA

Name	Data	Unit
COG position from front (Lc)	1600	mm
Moment of Inertia (Izz)	4192.57	Kg.m ²
Internal Conjugate location	1279	mm
Dynamic Index (DI)	0.92	

The COG was in a mid-rear position, due to the placement of the seats and 53% of the weight was on the rear axle.

The mass distribution of the car highly affects the dynamic index of the vehicle, if the passenger weighed instead of the average 83.6Kg per person, they weighed 200Kg per person the Dynamic Index would be **0.82**, this higher weight in the middle moves the internal conjugate closer to the COG which in turn lowers the Dynamic Index.

The reasoning the Dynamic Index of the vehicle is high (0.92) for a Ferrari, was due to it being a large car with a large wheelbase to accommodate four passengers. In comparison, a MG-F a 2-seater sports car has a much shorter wheelbase and was lighter, as seen in Figure 8, due to this its Dynamic Index is a lot lower, around 0.82.

This is where torque vectoring will help the vehicle dynamics of the Ferrari and attempt to make the vehicle feel more like a supercar.

5 Mechanical Torque Path

A comparison between a current four-wheel drive system and Ferraris connectable four-wheel drive system.

5.1 Standard Four-Wheel Drive System

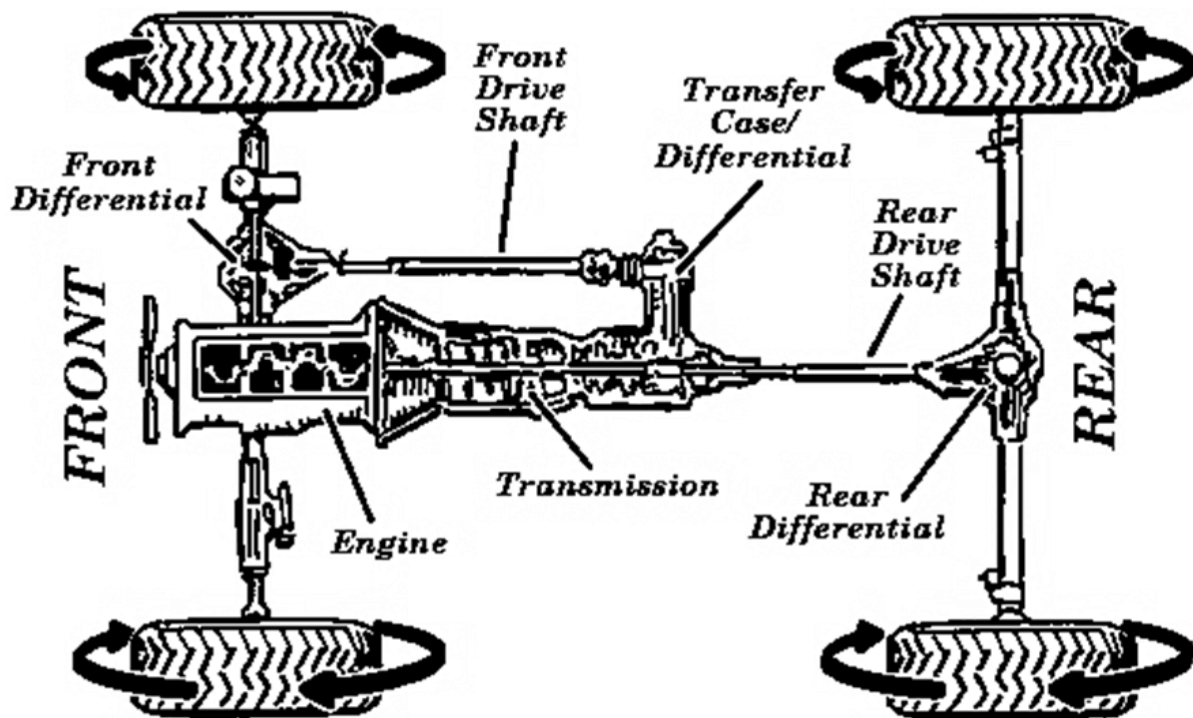


Figure 9 – Four Wheel Drive System (Brett, 2016)

In a four-wheel drive system, the torque goes through a transfer case which separates the power to the front differential and to the rear differential. It is possible with this kind of drive system to tell the car to only send power to the rear wheels and none to the front, as BMW does. This kind of system should not really be used on the road, the transfer case acts pretty much as a locked differential, it is not able to send different speeds to each differential, so when hitting a bend this is not ideal. Many four-wheel drive systems offer low gear ranges providing increased torque so when going over rough terrain and obstacles it would help. (Engineering Explained, 2018)

What BMW has done to compensate for the disadvantages of a standard four wheel drive system, is to implement a multi clutch system within the transfer case, it allows for a different torque split at varying speeds between the front and rear axle, which means the vehicle can go around corners without binding the transfer case. (Engineering Explained, 2018)

5.2 Connectable four-wheel drive system

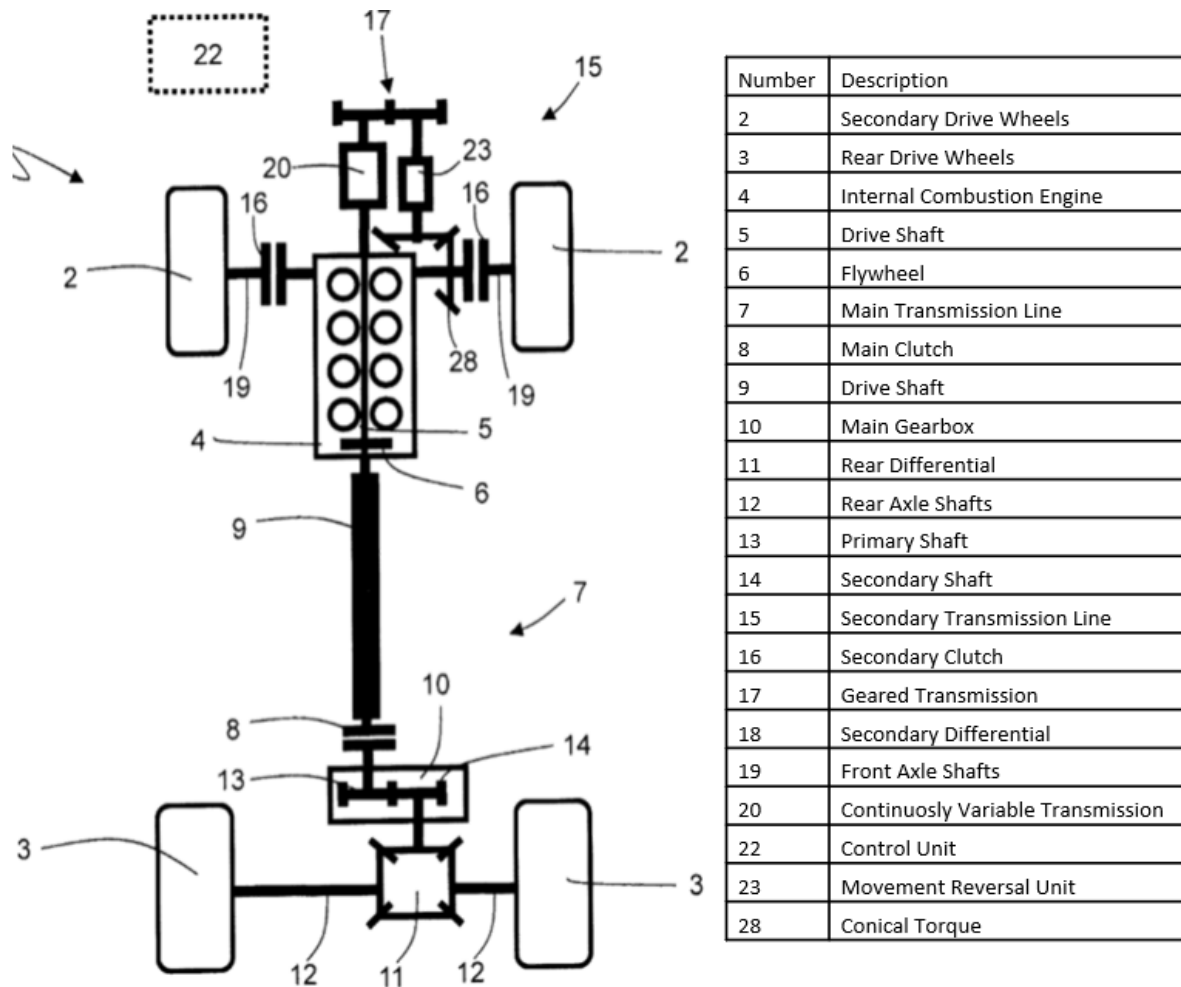


Figure 10 – Connectable Four-Wheel Drive System (Italy Patent No. US9586476B2, 2014)

When the car is on a straight road, the control unit 22 controls the continuously variable transmission 20 of the connectable secondary transmission line 15 in such a way that the output of each secondary clutch 16 always has the same speed as the input of the secondary clutch 16 itself; in this way, the secondary clutch 16 does not work in slipping and has no significant energy dissipation when car is in a straight line. (Italy Patent No. US9586476B2, 2014)

When the car is turning, the control unit 22 controls the continuously variable transmission 20 of the connectable secondary transmission line 15 in such a way that the output of each secondary clutch 16 is always slightly slower than the input of the secondary clutch 16 itself (the output of each secondary clutch 16 rotates more slowly than 50-200RPM with respect to the input of the secondary clutch 16 itself); in this way, the two secondary clutches 16 can be adjusted to compensate for the difference in

the rotation speed between the two front wheels (when turning the front outside wheel rotates faster than the front inside wheel) (Italy Patent No. US9586476B2, 2014)

When the car is turning the transmission ratio of the continuously variable transmission 20 may be lengthened so that the input of each secondary clutch 16 always rotates faster than the output of the secondary clutch 16 itself so as to ensure the correct torque transmission to the front axle in all the radii of trajectory. (Italy Patent No. US9586476B2, 2014)

Only the main clutch and gearbox are made to withstand the full torque of the engine, while the secondary clutches and the CVT are designed to continuously transmit only a fraction of the driving torque. (Italy Patent No. US9586476B2, 2014)

5.2.1 Advantages

- Eliminates almost completely the energy dissipation in the secondary clutches, as the clutches operate in slipping only briefly or when turning and with a modest slip. (Italy Patent No. US9586476B2, 2014)
- The continuously variable transmission can ensure the gear shift under torque eliminating the temporary loss of the four-wheel drive during the shift. (Italy Patent No. US9586476B2, 2014)

6 Clutch pack

There was one clutch pack on each drive shaft at the front.

The engine gives out a max torque of 683Nm at 6000RPM, the front clutch pack can only take about 20% of that torque which equates to 136.6NM, this torque is then multiplied by the overall gear ration of the front box of 8.59 in first gear and 4.69 in second gear, this gives the front clutch pack a torque capacity of 1174.3Nm at 6000RPM in first gear and a torque capacity of 641.015 Nm at 6000RPM in second gear.

The wheel RPM was calculated by dividing the engine RPM with the Overall Ratio, which was the sum of the gear and final drive ratios. The first and second gears in the front gearbox, the first gear was 6% taller than the second gear in the main gearbox ratio and the second gear was 6% taller than the fourth gear in the main gearbox. This produces different wheel speeds at the front two wheels due to these higher ratios.

Table 5 – Calculated Data for Clutch Pack

At 6000RPM			
Gear	Angular Velocity	Power Loss (Kw)	Slip (%)
1	25.36997	29.79	53.16
2	4.137122	4.85	6
3	38.15211	24.45	39.84
4	7.57893	4.85	6

Looking at Table 5, the slip % correlates with the Power applied on to the clutch. For controlling the torque capacity, the slip % increases as Power Loss increases.

An alternative way of calculating torque capacity of a multi clutch system is by knowing the dimensions of the clutch, in more detail the inner and outer diameter, by using the following equation:

$$Torque = \frac{\pi * \mu * P * d1}{8} * N * (d2^2 - d1^2)$$

Equation 5 – Torque capacity alternative

Where μ = friction coefficient; P = Max pressure of material; N = number of clutch surfaces; d1 = inner diameter of clutch; d2 = outer diameter of clutch.

7 Longitudinal acceleration.

The torque going through the front and rear wheels was calculated at 6000RPM as the known engine torque.

The following equations were used for calculating the force acting on the rear of the car, the force acting on the front of the car, the tractive force, and the acceleration.

$$\text{Force from torque} = \frac{T}{\text{Wheel Radius}} (N) \quad \text{Equation 6 – Force acting on wheel from torque}$$

$$\text{Total Force} = \text{Force from Torque} + \text{Normal Force} - \text{Rolling Resistance} \quad \text{Equation 7 – Total Force}$$

$$\text{Tractive Force} = CF * \text{Total Force} (N) \quad \text{Equation 8 – Tractive Force}$$

$$\text{Acceleration} = \frac{\text{Tractive Force}}{\text{Acceleration}} \left(\frac{m}{s^2} \right) \quad \text{Equation 9 – Acceleration}$$

The previous equations were sourced from (The Engineering Toolbox, 2020)

Table 6 – Longitudinal Accelerations depending on if its RWD or AWD.

Traction Coefficient	Gear	Tractive Force RWD (N)	Acceleration m/s ²	Tractive Force AWD (N)	Acceleration m/s ²	Difference %
Wet Ice 0.1	1	3496.53	1.86	4195.04	2.23	18.16
	2	2720.82	1.45	3574.48	1.90	27.12
	3	2233.00	1.19	3031.85	1.61	30.35
	4	1929.12	1.03	2788.74	1.48	36.44
Dry Asphalt 0.9	1	31468.80	16.74	37755.40	20.08	18.16
	2	24487.39	13.03	32170.28	17.11	27.12
	3	20097.02	10.69	27286.69	14.51	30.35
	4	17362.04	9.24	25098.70	13.35	36.44
Loose Sand 0.3	1	10489.60	5.58	12585.13	6.69	18.16
	2	8162.46	4.34	10723.43	5.70	27.12
	3	6699.01	3.56	9095.56	4.84	30.35
	4	5787.35	3.08	8366.23	4.45	36.44
Wet rolled Gravel 0.5	1	17482.67	9.30	20975.22	11.16	18.16
	2	13604.11	7.24	17872.38	9.51	27.12
	3	11165.01	5.94	15159.27	8.06	30.35
	4	9645.58	5.13	13943.72	7.42	36.44

Looking at the results in Table 6 it is obvious that the extra weight at the front of the car helped the car to put down more of its power on to the ground and be able to accelerate of the mark faster than if it was only in its RWD mode.

Looking at Table 7, when the vehicle was in RWD mode it received a larger amount of force overall, while the AWD mode it received a smaller amount. The reasoning the AWD system still works out better is because of the use of the large mass at the front, which equals to 8668.116N extra of force on the front axle. The sum of these forces gives the AWD system an edge on the RWD system.

Table 7 – Engine Force applied to wheels.

Torque on Rear Wheels strictly rear wheel drive					Total AWD		
1	8993.061	Nm	25190.65	N	1	23507.65	N
2	6223.7692	Nm	17433.53	N	2	17301.95	N
3	4482.2558	Nm	12555.34	N	3	11875.74	N
4	3397.3786	Nm	9516.467	N	4	9444.644	N
5	2683.6436	Nm	7517.209	N			
6	2169.7544	Nm	6077.743	N			

8 Yaw moment

A friction ellipse represents a boundary for the maximum forces in the lateral and longitudinal direction. Maximum performance is extracted when the forces are acting on the boundary of these ellipses. When cornering there is a vertical load transfer from the inner wheel to the outer wheel. Which means that for the forces to remain inside the boundaries of the friction ellipse the inner wheel should generate a smaller force. It can be seen in Figure 11 how the Friction ellipse is larger on the right wheels as it turns around a left corner.

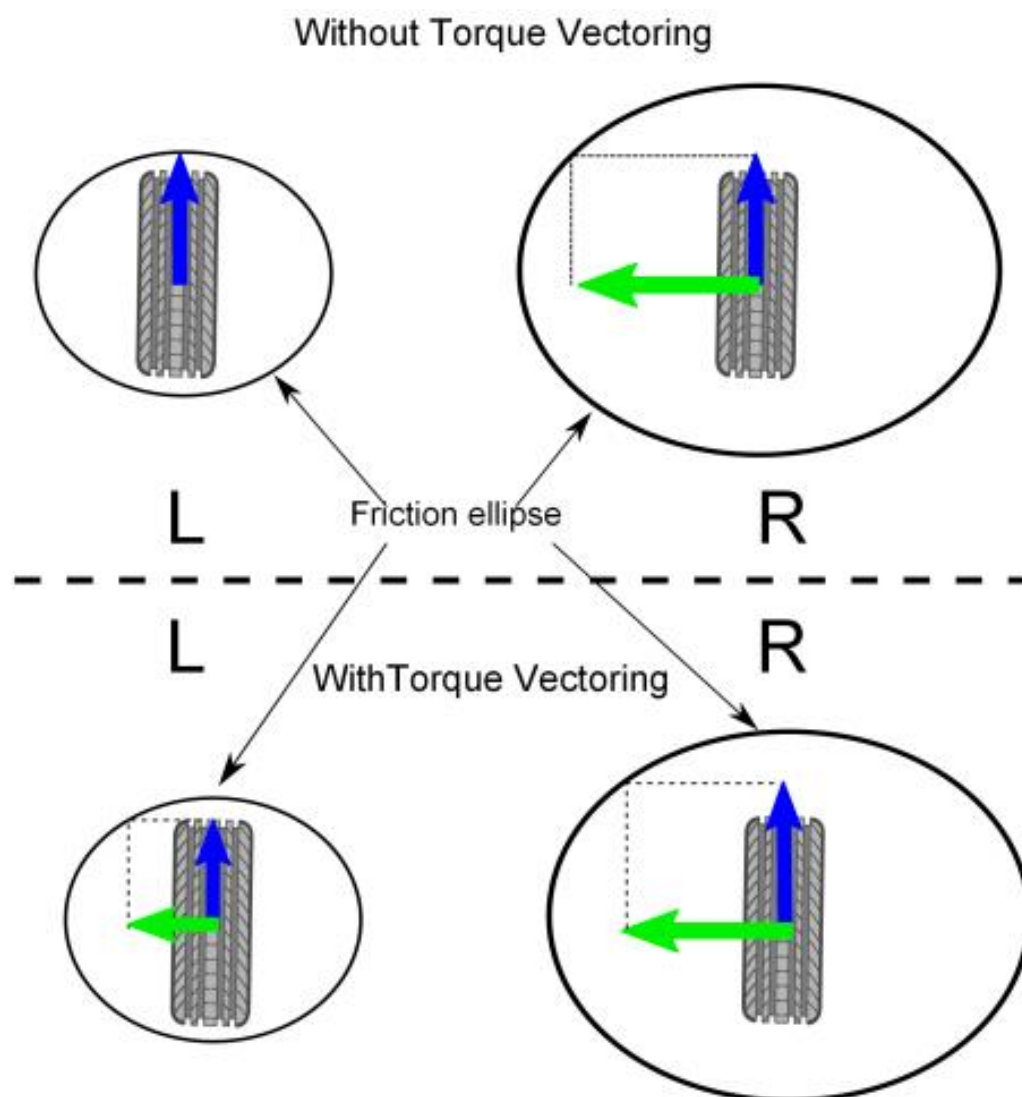


Figure 11 – Friction Ellipse around a left corner.

8.1 Calculations

Some assumptions have been made, the vehicle is travelling on a 25m radius corner at steady state with a speed of 50 KPH and has a COG height of 0.6m. The track of the vehicle is 1.676m

The following equations were used:

$$\text{Centripetal Acceleration} = \frac{\text{speed}^2}{\text{radius}} \quad \text{Equation 10 – Centripetal Acceleration}$$

$$\text{Yaw Rate} = \frac{360}{\text{sec/lap}} \quad \text{Equation 11 – Yaw Rate}$$

$$\text{WT} = \frac{\text{COG height} * \text{mass} * \text{acceleration}}{\text{track}} \quad \text{Equation 12 – Weight Transfer}$$

$$\text{Yaw moment} = \text{Force on wheel} * \frac{\text{Track}}{2} \quad \text{Equation 13 – Yaw Moment}$$

$$\text{Rotational Acceleration} = \text{Yaw Moment} * \text{Moment of Inertia} \quad \text{Equation 14 – Rotational Acceleration}$$

These Equations were sourced from past exams and lecture notes (Sandford, 2020)

From these equations the calculated data can be seen in Table 8.

Table 8 – Yaw moment calculated data

Speed	13.5	m/s
centripetal acceleration	7.29	m/s/s
Circumference	157.0796	m
	11.63553	sec/lap
Yaw rate	30.93972	deg/s
Weight each wheel	4610.7	N
WT	2453.198	N
Left Side	7063.898	N
Right Side	2157.502	N
Difference between left and right	4906.396	N
Yaw Moment	4111.56	Nm
Rotational Acceleration	0.979106	rads/sec/sec

9 Control algorithms, sensors, and potential vehicle dynamic improvements.

9.1 Sensors used (Italy Patent No. US 2011/0087410 A1, 2011)

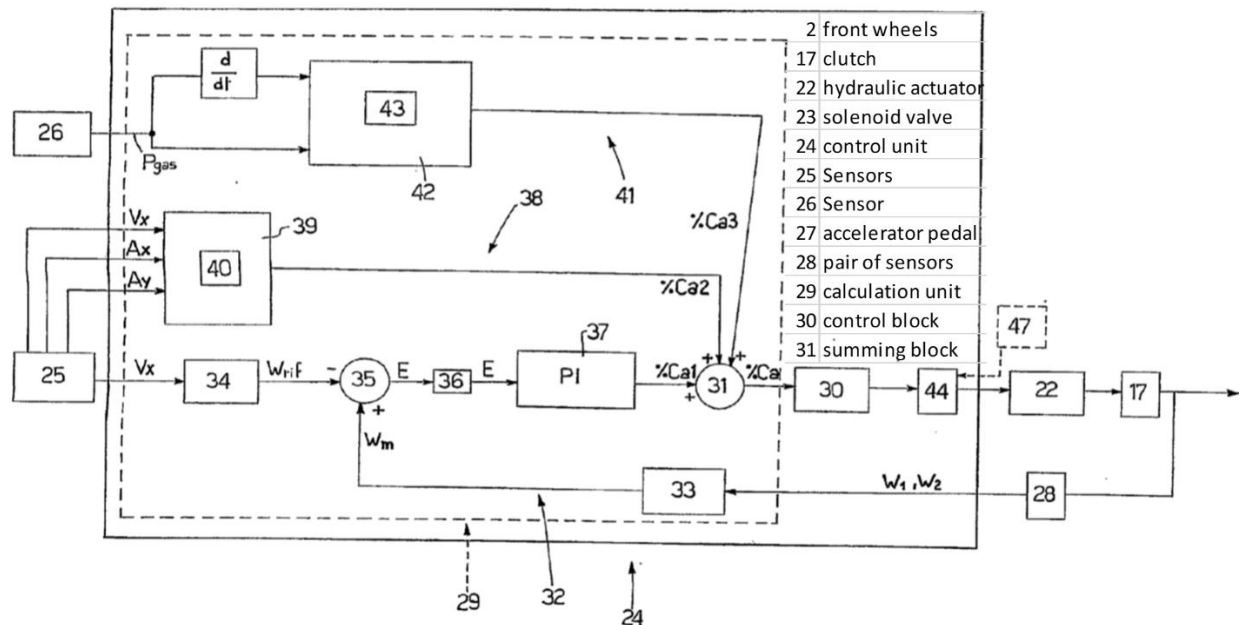


Figure 12 – Example Diagram of sensors used within the torque vectoring system (Italy Patent No. US 2011/0087410 A1, 2011)

A plurality of sensors detects in real time the values of physical quantities of the car which represent the dynamic parameters of the car, these values are then sent to the control unit. The values detected are the longitudinal speed, longitudinal acceleration, and transversal acceleration.

Furthermore, sensor 26 detects the position of the accelerator pedal in real time, for controlling the output of torque by the engine. This information was then sent to the electronic control unit.

Lastly, sensors 28 are fixed to drive axles detect the speed of rotation of the rear wheels. This information is then sent to the electronic control unit.

With all this information the control block has is calculated by the calculation unit, which then calculates an answer in real time and then decides how much torque the clutch should send to the front wheels.

Three different mappings are stored in calculation block 39. Map for high grip conditions (dry) , map for medium grip conditions (water) and map for low grip condition (ice). This grip condition can be determined by the driver using a selector, or it can be automatically determined. Some functions are ABS (brake anti-lock system), ESP (electronic stability control) and ASR (driving wheel anti-slip).

9.2 Handling

A potential improvement for vehicle handling is the use of 4-wheel steering. This kind of steering is useful in low speed manoeuvrability and high-speed stability. This is achieved with a rear suspension control unit by maintaining the centre line of the vehicle tangential to the turning path, to hold zero slip angle at the centre of gravity. This kind of steering when entering a bend, vehicle response is improved when the rear wheels are delayed in comparison to the front wheels, while on a sudden lane change such as in a Moose Test, the earliest lateral displacement is achieved by moving both wheels at the same time. The electronic system can implement this by having two different control algorithms which can detect when the vehicle is entering a corner or if it is performing a sudden lane change. (Landreau, 1989) (Jurgen Ackermann)

10 Conclusion

Ferrari produced this vehicle, because the public was steering towards a larger roomier kind of car with which they could do large distances and carry comfortably 4 people, but without losing its sporty feeling, therefore the AWD system was implemented to help move the bulk of the vehicle which due to its size was a lot bigger than a traditional Ferrari, for example a Ferrari 458, and with the use of torque vectoring help the vehicle traction off different surfaces and go around corners a lot easier. The Ferrari FF was a hit and was sold out in its first year. They produced 800 a year for 5 years which equals to a total of 4000 vehicles. (Ciferri, 2011)

The evolution of the Ferrari FF, the GTC4 Lusso gained rear wheel steering and Ferraris Slip Side Control setup working with the electronic differential and dampers. The Lusso also features a dial which alters the setting of the car ice mode, wet, Comfort and Sport. It also has a bumpy road mode which softens the dampers and gives a better ride. (Auto Express, 2018)

The Porsche Panamera Turbo S is one of the direct competitors to the Ferrari FF, it also features a AWD system which works in the following way. A multi plate clutch regulates power to the front and rear of the car. Sensors are constantly checking rotation speeds of all wheels, the longitudinal and lateral accelerations, and the steering angle. If the rear wheels start spinning a greater portion of force is sent to the front wheels by a larger engagement to the multi plate clutch. On bends propulsion force is only sent to the front wheels. (Porsche, 2020)

For the Cayenne and the Macan uses the same technology but optimised towards off roading. (Porsche, 2020)

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12 Appendix A – Base Vehicle Data

All the following information was sourced from the Ferrari website (Ferrari, 2011)

Dimensions and weight		X
LENGTH	193.2 in (4907 mm)	
WIDTH	76.9 in (1953 mm)	
HEIGHT	54.3 in (1379 mm)	
WHEELBASE	117.7 in (2990 mm)	
FRONT TRACK	66.0 in (1676 mm)	
REAR TRACK	65.4 in (1660 mm)	
KERB WEIGHT*	4145 lb (1880 kg)	
DRY WEIGHT*	3946 lb (1790 kg)	
WEIGHT DISTRIBUTION	47% front - 53% rear	
BOOT CAPACITY	15.9 cu ft (450 l)	
FUEL TANK CAPACITY	24 US gal - 20 UK gal (91 litri)	
Tyres and rims		X
FRONT	245/35 ZR 20 8.5 J x 20"	
REAR	295/35 ZR 20 10.5 J x 20"	
REAR WINTER	285/35 ZR20 10.5 J x 20"	

Brakes X

FRONT	15.7 x 1.5 in (398 mm x 38 mm)
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REAR	14.2 x 1.26 in (360 mm x 32 mm)
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Engine X

TYPE	V12 - 65°
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TOTAL DISPLACEMENT	382.13 cu in (6262 cc)
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BORE AND STROKE	3.70 x 2.96 in (94 mm x 75.2 mm)
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MAXIMUM POWER**	486 kW - 660 CV at 8.000 rpm
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MAXIMUM TORQUE	683 Nm - 504 lbft(70 kg)m at 6.000 rpm
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MAXIMUM REVS PER MINUTE	8000 rpm
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SPECIFIC OUTPUT	77 kW/litre - 105 CV/litre
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COMPRESSION RATIO	12.3:1
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Performances X

MAXIMUM SPEED	208 mph (335 km/h)
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0-62 MPH (0-100 KM/H)	3.7 sec
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0-124 MPH (0-200 KM/H)	11 sec
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0-62 MPH (0-100 KM/H)	114.8 ft (35 m)
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DRY WEIGHT/POWER RATIO	2.7 kg/CV
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Fuel consumption / co2 emissions (ece+eudc)*** X

FUEL CONSUMPTION (EUROPEAN MARKET VERSION)	15.4 l/100km
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CO2 EMISSION (EUROPEAN MARKET VERSION)	360 g/km
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