

Ethan Johnson-1902940. Vehicle Systems

by Ethan Johnson

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Introduction

As quoted by the author of Race Car Engineering & Mechanics;

“The torques and rotations are the secrets of winning races”

Van Valkenburg, P (1976). *Race Car Engineering & Mechanics* pg40

Vehicle balancing has been around since the first vehicle produced, vehicle balancing is used in a number of disciplines, racing and consumer cars will be the focus of this investigation. Vehicles react in many different ways when driving, a few of these movements include;

Squatting (rear lowers front raises)

Diving (Front lowers rear raises)

Rolling

Jacking (vertical movement)

All of these movements are controllable, in this investigation, weight transfer will be harnessed to see what can be changed to improve performance through the corners.



Research



TYRES

Racing and commercial are two polar opposites in vehicle design. Racing is an optimization process to make a vehicle perform for the fastest time on the track. However, commercial design is focused on ergonomics, comfort and safety.

Different systems can be changed to affect vehicle handling and comfort, The first of these is the tyre choice. Tyres are the only contact the vehicle has with the road, therefore a great deal of optimization has been put into them by companies. One of the most important aspects of tyre design is the coefficient of friction, this coefficient dictates how much force the tyre can exert on the road before losing traction.

Standard Tyre Coefficient: 0.8 - 1.0

Race Tyre Coefficient: 1.0 - 1.4

Van Valkenburg, P (1976). *Race Car Engineering & Mechanics* pg8

When a wheel is rotating on the tarmac, the friction generates heat, and this heat is washed out by the airflow until the heat generation and dissipation are equal. This equilibrium is where "the tyre compounder tries to design the tyre to have its highest C_f " (Coefficient of Friction).

Van Valkenburg, P (1976). *Race Car Engineering & Mechanics* pg9

Having the coefficient of friction at the heat transfer equilibrium is good, for racing, where tyres reach high temperatures. But for a road car, this is inadequate since a road car will only be taking slow turns and slow accelerations. Therefore road tyre's friction coefficients are at a lower temperature range, to better help with traction in colder situations. The tread pattern is also a factor in handling for road and race cars alike. A race car will attempt to have the lowest tread profile, this is to reduce the stored heat in the tyre, heat energy is lost energy. On the contrary a road tyre will be designed to have a high tread profile to assist in rain water displacement, and cold grip. In some instances the higher tread profile may help absorb impacts to an extent.

SUSPENSION GEOMETRY

Certain suspension adjustments affect handling and comfort of a vehicle.

Squat and dive are two rotational-longitudinal forces that act on a vehicle. Squat happens when a vehicle accelerates and dive occurs under braking/deceleration. In a racing fraternity, squat and dive can cause instabilities in a vehicle, this is unwanted. Some interesting physics phenomena can be used to combat squat and dive.

For a trailing arm setup, the axle is pivoted and sprung. When the vehicle accelerates, the torque travelling through the axle tries to rotate the pivot arm upwards. When this happens the torque generated meets the load transfer squat, in turn the two forces largely cancel each other out. This negates the effect of squat on acceleration, the anti dive effect on this would be the opposite, the brake torque canceling out the dive effect.

For double wishbone suspension, it is essentially the same setup as the trailing arm. This time however, the pivot point is an imaginary one, located at the intersect between two lines drawn from the wishbone longitudinal angles. The same canceling effect now happens during squat and dive.

Anti-squat and anti-dive both are optimal for racing, but also transmit all of the forces to the driver. A consumer car is built for passenger comfort therefore "many passenger car suspensions (...) amplify the dive in search for softness" Van Valkenburg, P (1976). *Race Car Engineering & Mechanics* pg40. Softness is a large area in vehicle design, therefore compromises on handling can be made to support comfort.

Shock absorbers also play a role in the handling of a vehicle, The shock absorber maintains control over the contact patch during bumps and ruts. If a shock absorber is too soft, it can allow for the chassis to bounce

when the wheels go over bumps. If the absorber is too soft, the tyres may leave the ground when travelling over bumps.  6

Traction Circle Theory

the traction circle is a “way of thinking about the grip that a particular tyre has on the road, how much of it, and how you can use it.” **Technical F1 Dictionary. (2011). Traction Circle.**  8 Fig 1 shows a typical traction circle, the circle represents the maximum traction the tyre can hold with the road before slipping. The two directional arrows represent acceleration/deceleration and left turn/right turn. By drawing a directional arrow from the centre to the outside, a vector can be denoted. Using pythagoras theorem, the maximum lateral and longitudinal G force can be calculated.

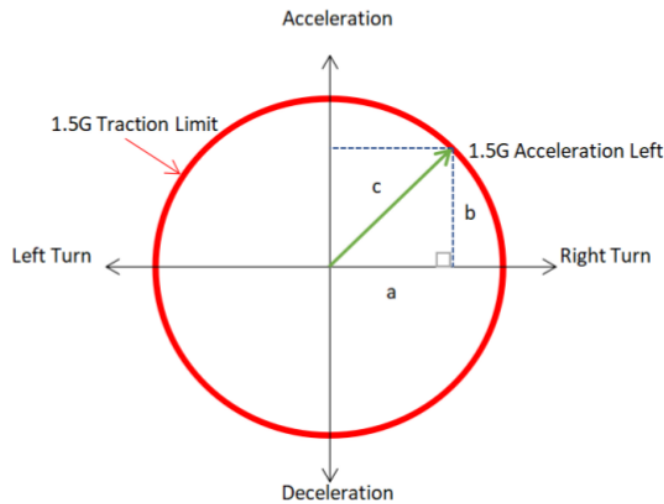


Figure 1:Traction Circle

This is the equation used for the weight transfer calculations

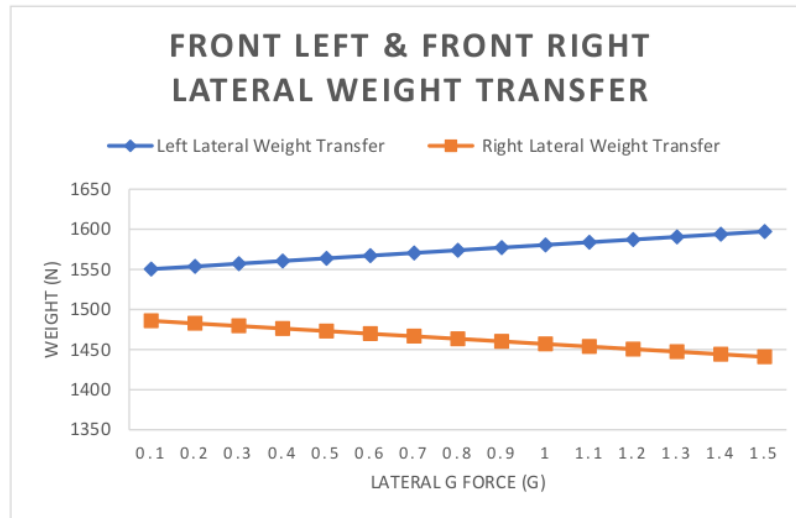
$$CornerWeight + / - \left(\frac{m * G_{lat} * h}{t} \right) + / - \left(\frac{m * G_{long} * h}{w} \right) * Front / rear * left / right - \left(\frac{Cl * \rho * (V^2) * A}{2} \right) = WT$$

Geaney, A (2017). *Vehicle Dynamics - Race Car Set-Up & Suspension.*  9

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Results

11



12

Figure 2: Front Left & Front Right Lateral Weight Transfer

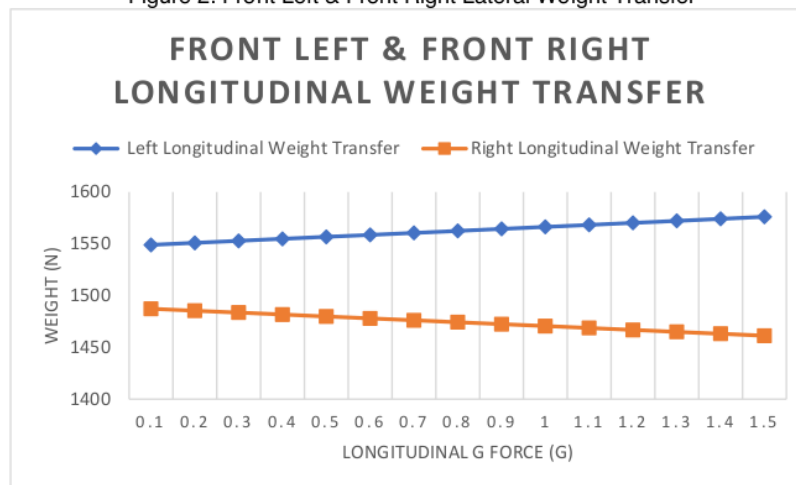


Figure 3: Front Left & Front right Longitudinal Weight Transfer

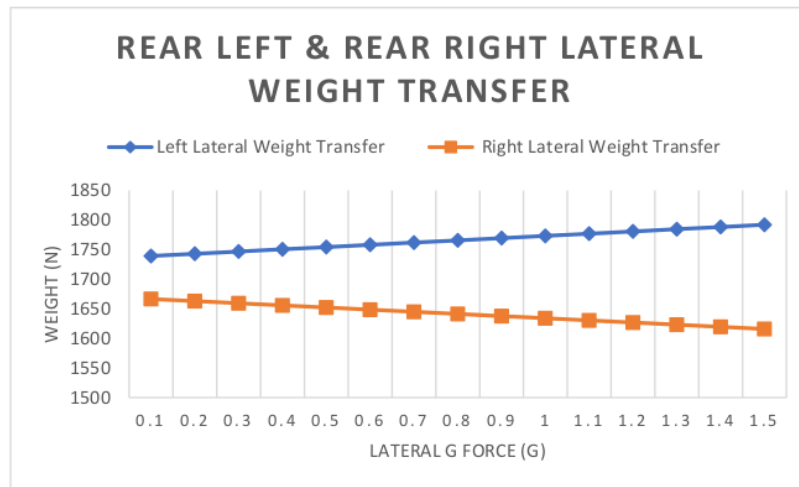


Figure 4:Rear Left & rear right Lateral Weight Transfer

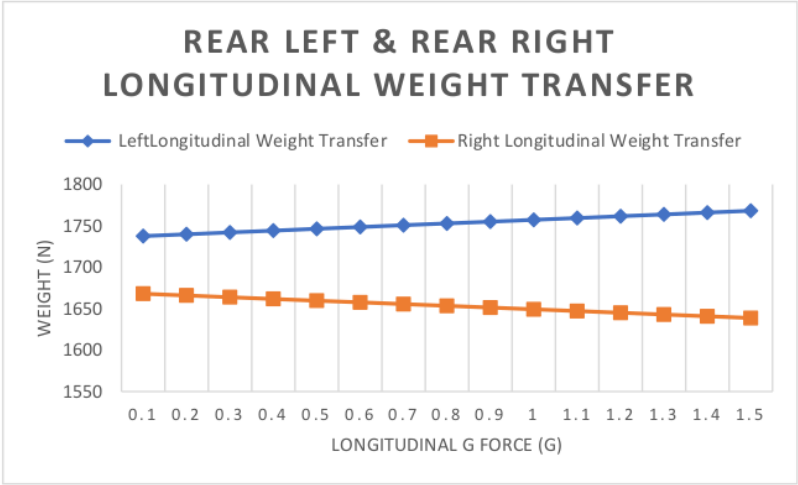


Figure 5:Rear Left & rear right longitudinal Weight Transfer

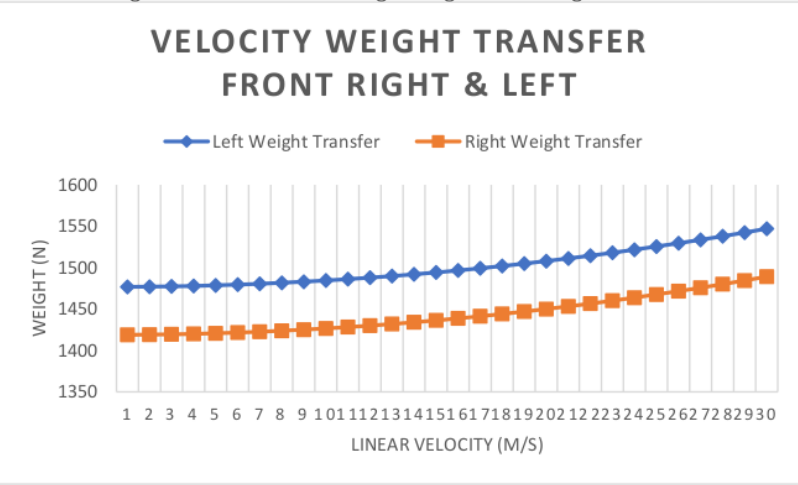


Figure 6:Velocity Weight transfer
front right & left

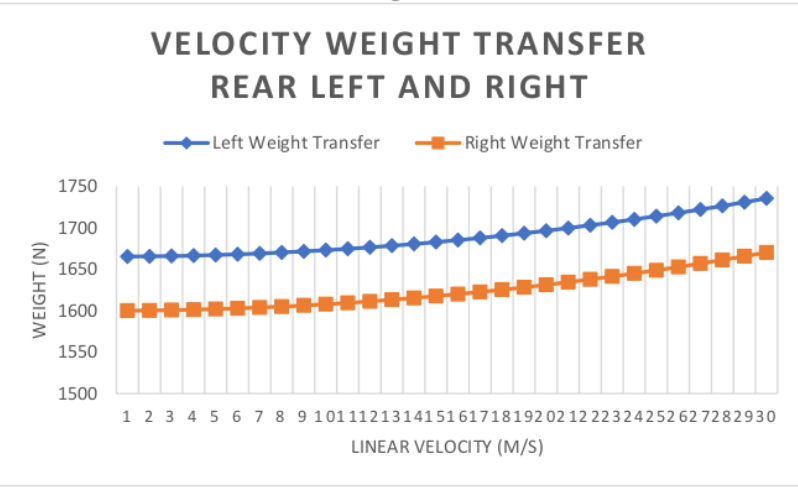


Figure 7:velocity weight transfer
rear left and right



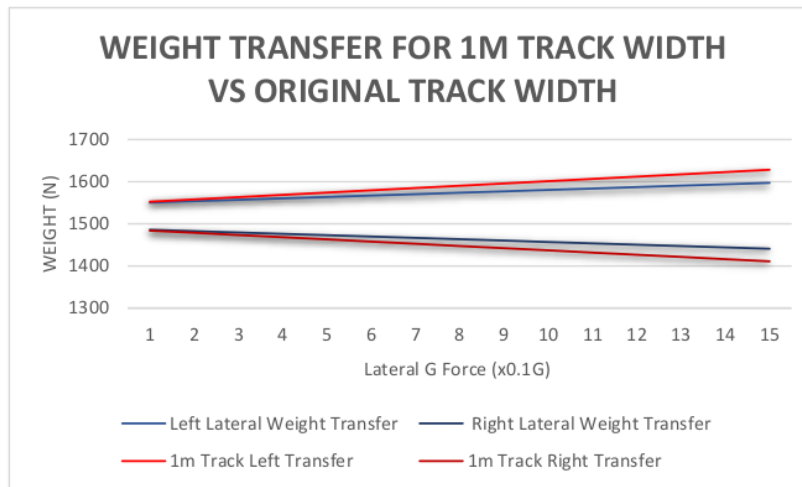


Figure 8: Weight Transfer For 1m Track Width vs Original Track Width

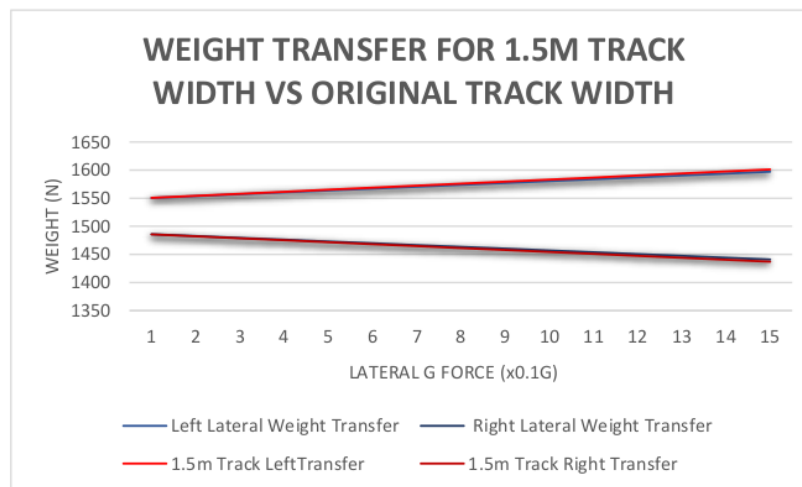


Figure 9: Weight Transfer For 1.5m Track Width vs Original Track Width

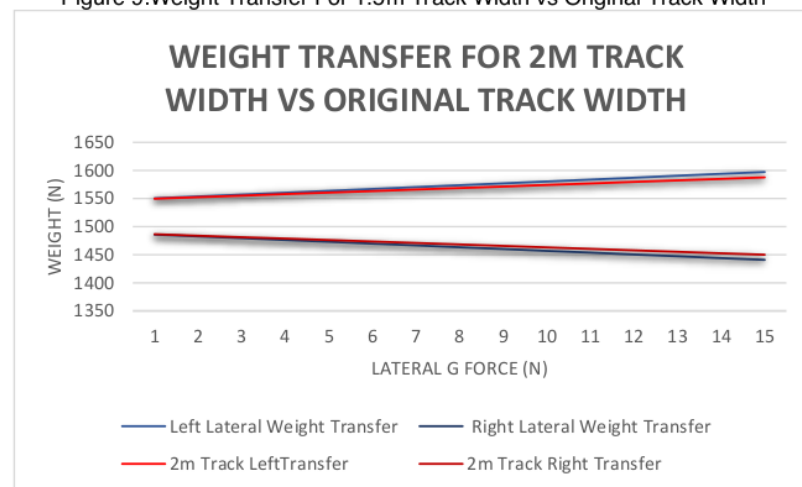


Figure 10:Weight Transfer For 2m Track Width vs Original Track Width

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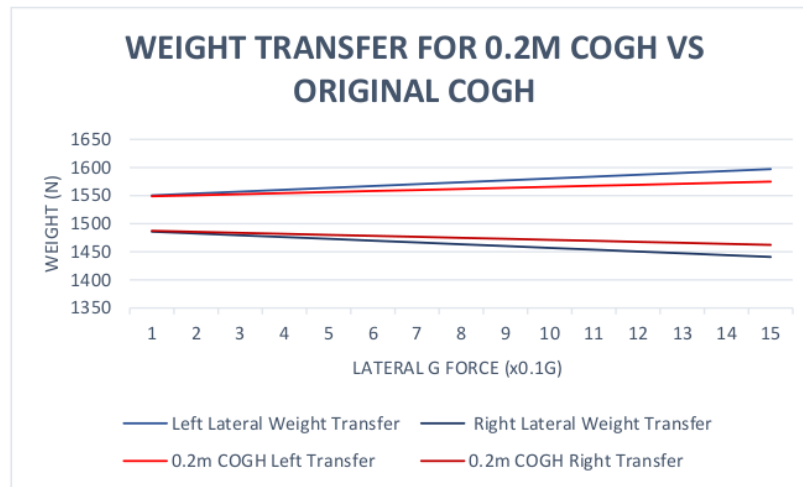


Figure 11: Weight Transfer For 0.2m COGH vs Original COGH

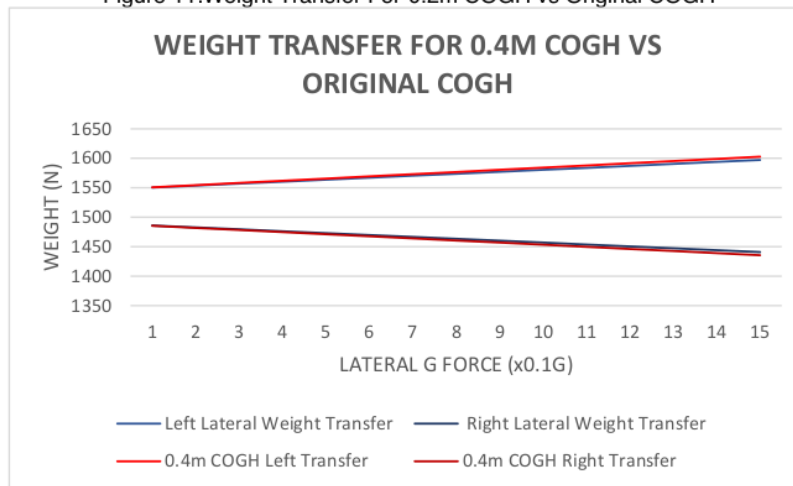


Figure 12: Weight Transfer For 0.4m COGH vs Original COGH

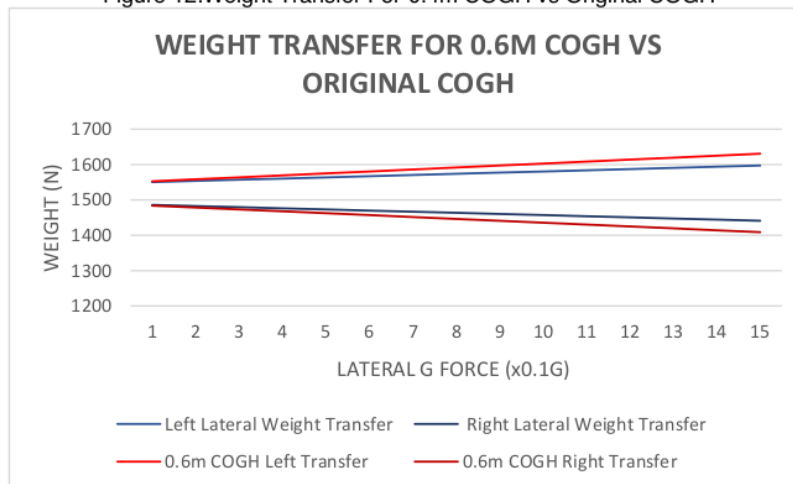


Figure 13: Weight Transfer For 0.6m COGH vs Original COGH

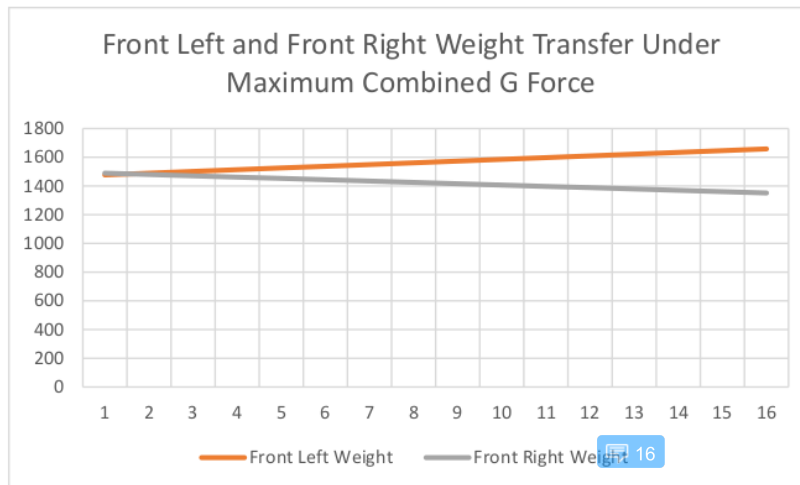


Figure 14: Front Left and Front Right Weight Transfer Under Maximum Combined G Force

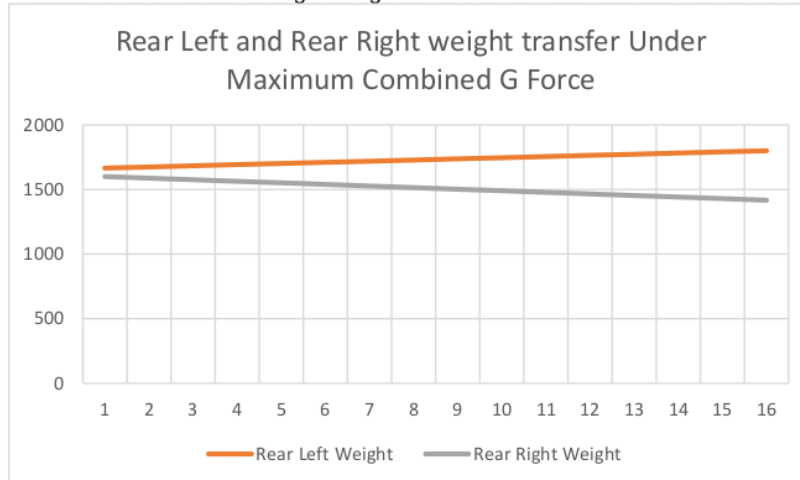


Figure 15: Rear Left and Rear Right weight transfer Under Maximum Combined G Force

Analysis

In the moment of weight transfer for Fig 2, the vehicle is negotiating a right-hand turn, this is therefore causing a weight transfer from right to left. As the graph shows, there is a fairly linear trend in the increase and decrease of weight for each wheel. These figures mirror each other, this is evidence that the weight removed from one wheel, is directly proportional to the weight gained by the other. This is also demonstrated my Figs 3,4&5. There is an increased difference between each two corner weights when comparing the first two data points with the last.  17

The velocity variable weight transfer graphs (Fig6&7) show a much different pattern, the weight on all four corners increases when the velocity increases. This would be impossible had it not been for the aero lift calculations included. This means that the aero lift is pushing down on the vehicle as the velocity is increasing. The weight of the right side of the vehicle matches the original weight of the left once at the extremities.  18

Figs 8,9&10 show how the weight transfer is affected by narrowing or widening the wheelbase. Starting with fig8, it is evident that narrowing the wheelbase to 1m has increased weight transfer significantly. It is to be expected however, a narrow base of an object decreases stability, since the centre of gravity has less to overcome to roll. Fig9 shows the track increased to 1.5m, since the original track is 1.62m, it is unsurprising that the weight transfer is not much higher. Fig10 shows a 2m track width, this width would only be used in the most extreme of race cars. The graph shows a marginal improvement over the original weight transfer, but unlike what may be expected to be an opposite to Fig8, is actually only a slight improvement on the weight transfer. This shows that the track is not directly correlated to the transfer of weight.  19

Figs 11,12&13 all show the effects of changing the centre of gravity height have on the weight transfer of the vehicle. Fig 10 shows an impressive reduction in weight transfer from right to left when the centre of gravity is only 0.2m from the ground. Fig12 similar to Fig9 is very similar due to the COGH value being almost the same. Fig13 shows a proportionally opposite increase to weight transfer as to that of Fig11, hence showing a linear proportion between centre of gravity height, and weight transfer.

Figs 14 & 15 are related to the traction circle theory explained previously, As the maximum combined G force is 1.5 the variable will be changing from 0 to 1.5G in 0.1G steps. In Fig 14 the weight transfer is around 200N from right to left around 50N less than the lateral transfer calculations. Fig 14 is similar to Fig 2 since the weight transfer pattern is the same. It is expected that the two graphs would be very similar since the longitudinal and lateralG forces were equal.  20

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Conclusion

As demonstrated by the generated graphs, it is clear that changing the Height of the centre of gravity is more effective, thus more important to reduce weight transfer. By only reducing the COGH by 160mm, the total weight transfer lowered from 91N to only 26N. whereas widening the wheelbase by 500mm only reduced the weight transfer by 10N. This shows that it is more effective to adjust COGH than it is to widen the track width.  22

It is not possible to achieve 1.5G both longitudinally and laterally with this vehicle, as the maximum combined G is 1.5, to make a triangle showing the values of longitudinal and Lateral G force, Glong and Glat would have to equal <1.5 . If Glong and Glat were both at 1.5G that would result in the vector being greater than the friction coefficient. In real world terms, this results in the car losing grip and sliding off on a tangent to the bend.

This investigation has shown the large differences a minute change can make to a vehicle, there is great potential to tune a vehicle for comfort or racing. Industries are working to make the two polar setups work in consumer vehicles to give that performance edge to the driver.  23

Bibliography

-  24
Alexander, D. (2015). *Chassis Tuning With Dampers – A hard look at shock absorbers and their effects on handling*. Available:
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Ethan Johnson-1902940. Vehicle Systems

GRADEMARK REPORT

FINAL GRADE

54/70

GENERAL COMMENTS

Instructor

A good range of sources used within the report. Use the UWTSD Harvard Referencing guide to look at how to cite correctly the formatting of reference lists.

The research section is very well written and demonstrates that you have a good level of knowledge and understanding on this topic. You could also have thought about aerodynamics and the effects of wear and tear.

Good analysis, though there is an issue with some of your graphs lacking axis titles. Some of the information included in your conclusion could have been included earlier to help analyse the data more. Due to some issues with your calculations, your graphs are wrong and therefore so is the analysis.

This is generally a well written and presented report. The language and terminology use is to a high standard. There are just a few areas that need to be proof checked before submitting.

PAGE 1

PAGE 2

PAGE 3



Comment 1 | Literature

The citation would just be (Van Valkenburg, 1976) - you don't need the whole reference

The citation would just be (van Varenburg, 1970) - you don't need the whole reference.



Comment 2 | K & U Subject

Good concise introduction.

PAGE 4



Comment 3 | K & U Subject

Some introduction to this section before going into the individual sections.



Comment 4 | Prof Prac

No capital letter needed.



Comment 5 | K & U Subject

Very good section on tyres.

PAGE 5



Comment 6 | K & U Subject

Again a very good description of suspension but have you thought about wear and tear and what effect that might have.



Comment 7 | Prof Prac

Capital letter needed



Comment 8 | Literature

Should just be (Author, year) and in the same size font.



Comment 9 | K & U Subject

When including equations in a report you need to explain what the different letters mean? i.e. m, h, t etc.



Comment 10 | K & U Subject

What about aerodynamics have you thought about how this effects the handling / comfort as well.

PAGE 6



Comment 11 | C&I Skills

Add some text at the beginning of the abstract to explain where the results come from

Add some text at the beginning of the chapter to explain where the graphs came from.



Comment 12 | C&I Skills

Values are correct for the reasons explained on your excel but the trend is correct.

PAGE 7

PAGE 8



Comment 13 | C&I Skills

You could have combined the rear and front graphs and had all four wheels on the same graph.

PAGE 9



Comment 14 | Prof Prac

This could have been caused when you submitted but be careful of formatting.

PAGE 10

PAGE 11



Comment 15 | Prof Prac

Same issue as above

PAGE 12

PAGE 13



Comment 16 | C&I Skills

Your axes have no labels and while I can see that the y-axis is the load, I can not work out what the x - axis is?

PAGE 14



Comment 17 | C&I Skills

Good explanation



Comment 18 | C&I Skills

Good.



Comment 19 | Prof Prac

Leave a space between paragraphs.



Comment 20 | C&I Skills

Due to an issue with your calculation your graphs are not correct. If the Long and Lat G's were calculated correctly, you would have seen that the results curve and cross, demonstrating how the load changes across the lat and long directions.



Comment 21 | C&I Skills

Nowhere so far have you explained how it isn't possible to achieve 1.5G in both directions.

Figure 1 shows it but you haven't explained it.

NOTE - I can see you do explain this in your conclusion but I think it would have been good to include it earlier.

PAGE 15



Comment 22 | C&I Skills

Well observed.



Comment 23 | C&I Skills

Good conclusion.

PAGE 16



Comment 24 | Literature

The reference list should be in alphabetical order and the citations should be (Author, Year).

Use the UWTSD Harvard Referencing Guide to help you in the future.

LITERATURE

Excellent 70-84%

(including reading, referencing, academic conventions and academic honesty)

OUTRIGHT FAIL 0-29%	Little or no evidence of reading and/or reliance on inappropriate sources. Views and findings mostly unsupported and non-authoritative. Referencing conventions used incoherently or largely absent.
UNSATISFACTORY 30-39%	Poor engagement with essential reading. No evidence of wider reading. Reliance on inappropriate sources, and/or indiscriminate use of sources. Heavily reliant on information gained through class contact. Inconsistent and weak use of referencing.
SATISFACTORY 40-49%	Engagement with a limited range of mostly relevant and credible sources but with some reliance on information gained through class contact. Some omissions and minor errors. Referencing conventions evident though not always applied accurately or consistently.
GOOD 50-59%	Engagement with an appropriate range of literature, including sources retrieved independently. Some over-reliance on texts rather than other sources. Referencing may show minor inaccuracies or inconsistencies.
VERY GOOD 60-69%	Engagement with a wide range of literature, including sources retrieved independently. Selection of relevant and credible sources. Generally sound referencing, with no/very few inaccuracies or inconsistencies.
EXCELLENT 70-84%	Engagement with an extensive range of relevant and credible literature. Consistently accurate application of referencing.
EXCEPTIONAL 85-100%	Exceptional engagement with an extensive range of relevant and credible literature. High-level referencing skills consistently applied.

K & U SUBJECT

Excellent 70-84%

Knowledge and Understanding of Subject. Extent of knowledge and understanding of concepts and underlying principles associated with the discipline.

OUTRIGHT FAIL 0-29%	Major gaps in knowledge and understanding of the basic underlying concepts and principles of the subject matter. Inclusion of irrelevant material. Substantial inaccuracies
UNSATISFACTORY 30-39%	Gaps in knowledge of the basic underlying concepts and principles, with flawed or superficial understanding. Some significant inaccuracies and/or irrelevant material.
SATISFACTORY 40-49%	Limited knowledge and understanding of the basic underlying concepts and principles within the subject area. Some elements may be missing
GOOD 50-59%	Knowledge of the basic underlying concepts and principles is accurate with a good understanding of the field of study but lacks depth and/or breadth.
VERY GOOD 60-69%	Competent knowledge of the basic underlying concepts and principles. Exhibits very good understanding

EXCELLENT 70-84% Excellent knowledge and understanding of the basic underlying concepts and principles of the subject.

EXCEPTIONAL 85-100% Exceptional, detailed knowledge and understanding of the basic underlying concepts and principles

C&I SKILLS

Exceptional 85-100%

(Evaluate underlying concepts and principles of a subject and interpret qualitative and quantitative data in order to develop lines of argument and make sound judgements.)

OUTRIGHT FAIL 0-29% Wholly or almost wholly descriptive work. Little or no evaluation of the underlying concepts and principles. Failure to develop arguments, leading to illogical or invalid judgements. Minimal or no use of evidence to back up views.

UNSATISFACTORY 30-39% Largely descriptive work, with superficial evaluation of the underlying concepts and principles. Weak interpretation of data, flawed development of arguments and judgements. Information accepted uncritically, uses generalised statements made with scant evidence and unsubstantiated opinions. Ideas sometimes illogical and contradictory

SATISFACTORY 40-49% Limited attempt at evaluation of the underlying concepts and principles, tending towards description. Can interpret qualitative and quantitative data but with some errors. Some evidence to support emerging arguments and judgements but these may be underdeveloped or with a little inconsistency / mis-interpretation.

GOOD 50-59% Good evaluation of the underlying concepts and principles. Can interpret qualitative and quantitative data, with minor errors. An emerging ability to use evidence to support the argument. Mostly valid arguments and logical judgements.

VERY GOOD 60-69% Sound evaluation of the underlying concepts and principles. Can interpret qualitative and quantitative data accurately. Ability to devise arguments using evidence to make mostly appropriate and valid judgements.

EXCELLENT 70-84% Excellent evaluation of the underlying concepts and principles. Can interpret qualitative and quantitative data accurately and with some insight. Excellent ability to devise arguments using evidence and make appropriate and valid judgements

EXCEPTIONAL 85-100% Exceptional evaluation of the underlying concepts and principles based evidence. Outstanding interpretation of qualitative and quantitative data. Exceptional ability to devise arguments using evidence and make wholly appropriate and valid judgements

PROF PRAC

Excellent 70-84%

(Communicate the results of their study/work accurately and reliably, and with structured and coherent arguments; the qualities needed for employment requiring the exercise of some personal responsibility within a structured and managed environment.)

OUTRIGHT FAIL 0-29% Work is poorly structured, disorganised, inaccurate and/or confusingly expressed. Very weak use of language and/or very inappropriate style. Failure to work effectively individual or as part of a group. Little or no evidence of the skills for employment requiring the

exercise of some personal responsibility.

UNSATISFACTORY 30-39%	Work is poorly presented in a disjointed manner. It is loosely, and at times incoherently, structured, with information and ideas often poorly expressed. Weak use of language and/or inappropriate style. Flawed approach to individual or group work, meeting only partial obligations to others. Limited evidence of the skills for employment requiring the exercise of some personal responsibility.
SATISFACTORY 40-49%	Mostly ordered presentation and structure in which relevant ideas / concepts are reasonably expressed. Work may lack coherence and/or accuracy in places. Can work as part of a group, meeting most obligations to others but perhaps with limited involvement in group activities. Demonstrates the basic skills for employment requiring the exercise of some personal responsibility, with some areas of minor weakness.
GOOD 50-59%	Mostly coherent, organised and accurate work, in a suitable structure and is for the most part clearly expressed. Can work effectively independently and/or as part of a team, with clear contribution to group activities. Demonstrates the skills for employment requiring the exercise of some personal responsibility, with some areas of strength and some of minor weakness.
VERY GOOD 60-69%	Work is accurate, coherent, fluent, well-structured and organised. Can work effectively independently and/or as part of a team, with very good contribution to group activities. Demonstrates very good skills for employment requiring the exercise of some personal responsibility, with just occasional minor weakness.
EXCELLENT 70-84%	Work is coherent, very fluent and is presented professionally. Can work effectively independently and/or as part of a team, with an excellent contribution to group activities. Demonstrates excellent skills for employment requiring the exercise of some personal responsibility with an appetite for further development.
EXCEPTIONAL 85-100%	Work is accurate, exceptionally coherent, very fluent and presented well. Can work effectively independently and/or as part of a team, with an exceptional contribution to group activities. Demonstrates exceptional skills for employment requiring the exercise of some personal responsibility with an appetite for further development