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by Alexandre Bierley

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Introduction:

Each Vehicle has its own design regarding the driver's needs. A Formula 1 car's purpose is to go as fast as possible around the track where a 4x4 is to be able to climb hills and get out of mud. The 4x4 will get out of the mud happily when the formula 1 has no chances. The formula 1 will fly on the track where the 4x4 will be slow and ineffective. They are simply designed to meet some specific requirements.

The following Technical report will look at how vehicle chassis and suspension design could affect a vehicle behaviour and will deeply explain how. It will start by defining what is vehicle ride comfort and handling all will explain what affects these vehicle characteristics. The report will also take a look at what affects vertical wheel load and will examine how it is affected by going through a series of real-life simulation using tables, formulas and graphs from Microsoft Excel.



Research:



What is ride comfort?

Ride comfort can be defined as how well a person feels in a vehicle while travelling in multiple scenarios. Different people will have different approaches of comfort but general opinion suggest that, the smoother the vehicle is, the more pleasant the ride will feel. The principal cause of discomfort in a vehicle is vibrations (International Ergonomics Conferences, 2004). Vibrations that human internal ear perceives may affect the overall feeling of a person. Generally, vibrations with a frequency between 1 Hz and 1.5 Hz. (Journal of Engineering Research and Application, 2019).



What factor affect ride comfort?

Ride comfort can get affected by diverse parameters such as suspension set-up, vehicle's mass, vehicle's design or tyre profile (Pankaj Vig (2016) What is ride quality & what affects it?). The following technical report is orientated on the mechanical aspect of ride comfort, however, different noises such as exhaust sound, engine sound or the sound of tyres on road surface could also be a source of discomfort for the vehicle occupants.



How these factors affect ride comfort?

Suspension set-up makes a considerable impact on the ride comfort of a vehicle. Assuming that in this case, the suspension system is equipped with a damper unit and spring. The suspension system absorbs most shocks from road disturbances. More precisely, the spring absorbs the shock and the damper unit helps to reduce the natural oscillation effect caused by the shape the spring (Robert Q.Riley, 2020). The natural frequency of a suspension system is settled by the static deflection rate (capacity of a suspension system to compress regarding weight applied to it) (Bin Yu (2019)). Static deflection rate has an impact on ride comfort of a vehicle. During the process, depending on the situation, the suspension system also creates high frequency vibrations that are reflected on the top strut mount of the suspension then on the structure of the vehicle. (Robert Q.Riley, 2020)

The mass of a vehicle has also an impact on ride comfort. In fact, it does not affect ride comfort directly but affects the natural frequency of the suspension system. If taking a completely factory car with suspension system designed for it, when additional mass like passengers or loading the car with luggage is applied to the vehicle, the natural frequency is reduced. It is due to the fact that the suspension system is preloaded and will deal less over-damping. As states Robert Q.Riley "Over-damping (above 100 percent) dramatically reduces ride quality" (Q.Riley, 2020).

Tyres is the only component that creates contact with road surface. The tyre profile has a significant impact on the ride comfort of a vehicle. Larger tyres will have greater side walls and a bigger contact patch than smaller ones. They have a better ability to absorb shocks as it will shape itself around road deformations. On the other hand, smaller tyres, due to the rigidity of their shape will have to climb the deformation which results in a less pleasant ride.

Vehicle wheelbase, wheel track and centre of gravity will also impact ride comfort. In fact, a car with a longer wheelbase tends to pitch less than a car with smaller wheelbase. Same theory for roll effect. A vehicle with a wider wheel track tends to deal less roll effect than a vehicle with a narrower wheel track. The Height of the vehicle directly affects the centre of gravity which impact roll effect as well. Higher vehicles will roll more during cornering than lower ones (Robert Q. Riley, 2020).



What is handling?

Handling could be defined as the ability of a vehicle to perform and react regarding the driver's needs. Handling could also be evaluated while driving in different scenarios such as accelerating, braking or cornering (Policedriver.com, 2015).

What factor affects handling?

There are different factors that could affect handling such as weather conditions, the road surface condition. However, this report will focus on the mechanical aspects of what could affect a vehicle handling. The main factors that have an impact on a vehicle handling are suspension system design, tyres and aerodynamics (Cars direct, 2012).

How these factors affect handling?

The suspension system on a vehicle is designed to absorb shocks from road disturbances as seen previously. The true purpose behind absorbing road deformations is to try keeping maximum contact between the tyre and road surface in all conditions, at all times (Cars direct, 2012). Suspension systems are designed by manufacturers to fit specific requirements and abilities for a certain vehicle. Although, handling can be affected by how stiff or soft the manufacturer designed the system. On the other hand, a worn out, damaged or misaligned suspension components could result in a partial or even complete loss of control of the vehicle (Cars24, 2020). Here are some examples of factors that could affect handling: a worn-out damper unit, worn-out anti-roll bar bushes, a broken suspension spring, an incorrect suspension alignment, a bended suspension arm.

Tyre design also impacts vehicle handling. As seen previously, the choice for bigger tyres will allow a better ride comfort which is the case for most commercial vehicles. However, lower profile tyres will allow better performances. Low profile tyres tend to have smaller side walls which results in a tyre dealing less flexibility when cornering forces are applied to it.

Aerodynamics have a direct impact on stability of a vehicle at higher speed. Manufacturers design cars body shape in order to create downforce while minimising drag coefficient (Patrick E. George (2020) How Aerodynamics work). Downforce is the force that pushes the vehicle downwards at high speed. It contributes to vehicle overall stability and gives a better handling. Less or no downforce on a vehicle will give a less stable driving.

In order to apply the research and show the balance between comfort and handling, real life examples such as road vehicles, supercars and race vehicles are used and compared. A common road vehicle, in its range of use, will need a proportional balance of handling and comfort. As it is used every day in every condition, it needs to be fairly comfortable but also needs to have a good handling for safety purpose. A road vehicle does not need to have great performances however it needs to be efficient and pleasant to drive.

Supercars on the other hand, have a slightly different range of use and will need to meet a different balance of comfort and handling than road vehicles. A supercar needs to show a better handling performance but also need to meet requirements in terms of comfort as it is a faster road vehicle and not a race vehicle.

Race vehicles are design for handling. In its range of use, a race vehicle does not need to meet comfort requirements but needs to have the best handling possible in ever situations.

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Results:

To understanding how a suspension system behaves while the vehicle is experiencing G forces, a series graphs are created from real conditions scenarios using Microsoft Excel.

Base data about the vehicle details is given in order to complete a series of formulas. First step is to calculate static load for each corner. Next step is to calculate aero load with a given velocity (30m/s). The next step is to use formulas to complete the scenarios required. Graphs are plotted and discussed afterwards.



Here is the data base for the vehicle:

Mass	Kg	628.00
Wheelbase	m	2.80
Center of Gravity Height	m	0.36
Static weight Distribution (front)	%	47.00
Static weight Distribution (Left)	%	51.00
CI		-0.62
A	m ²	1.20
Air density	Kg/m ³	1.22
Center of Pressure	% (front)	42.00
Average Track	m	1.62
Maximum G	G	1.50

Figure 1 Vehicle base data and characteristics

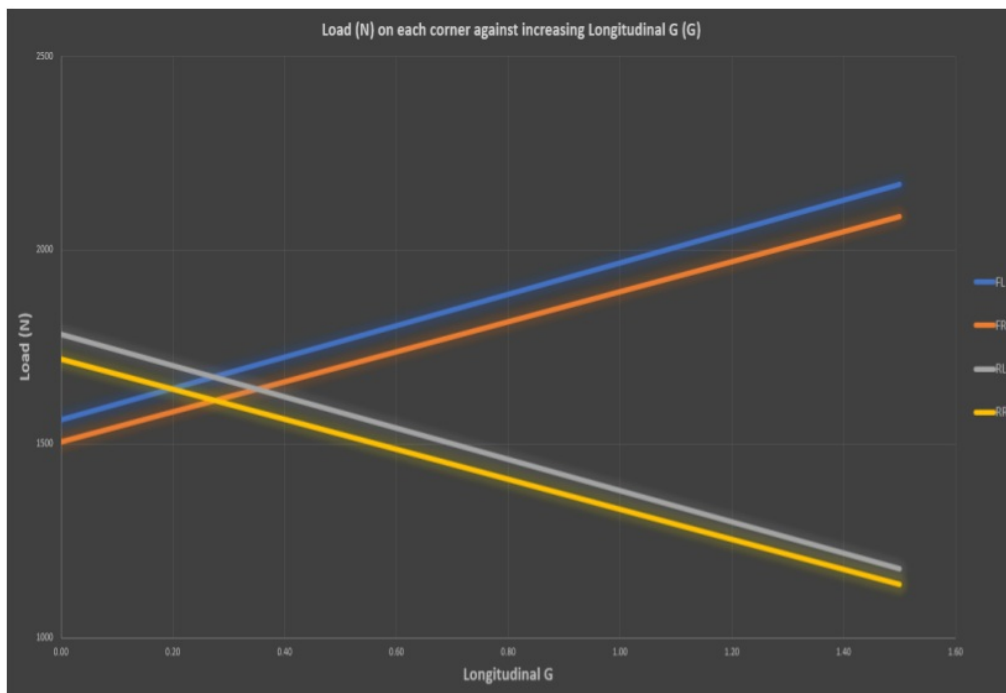


Figure 2: Load on each corner over increasing longitudinal G force

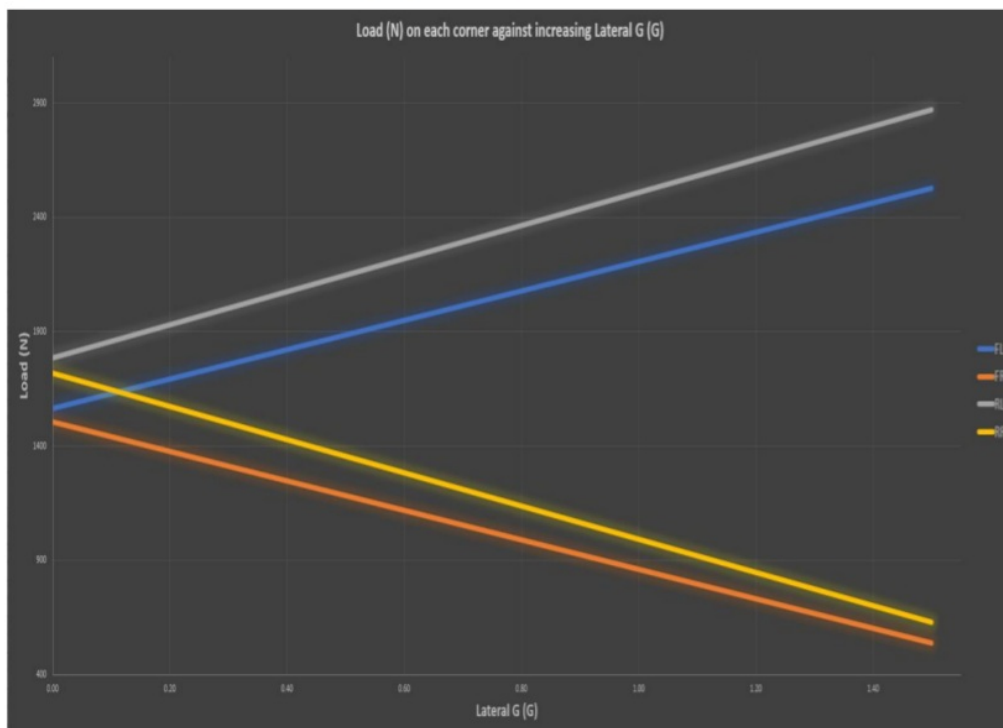


Figure 3: Load on each corner over increasing lateral G force

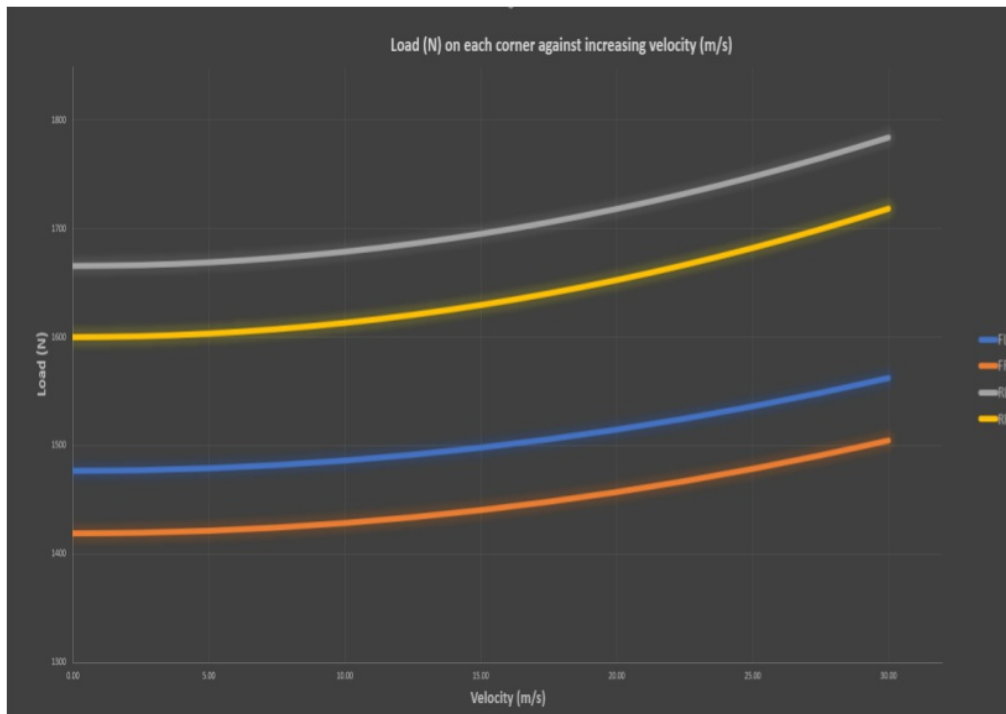


Figure 4: Load on each corner over increasing vehicle velocity

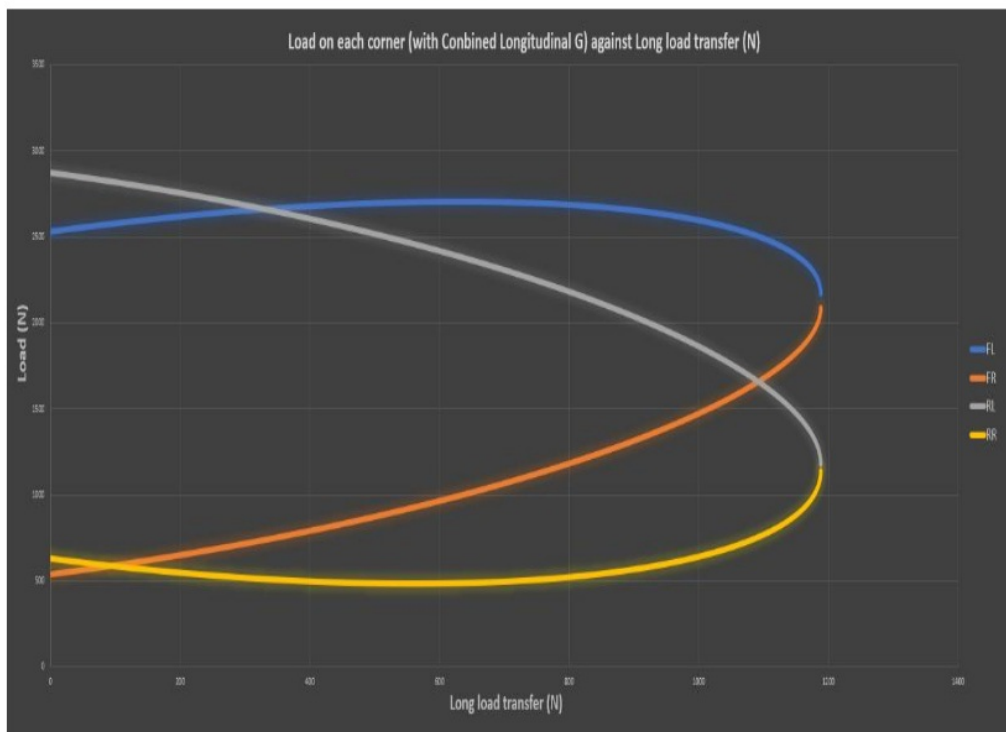


Figure 5: Load on each corner over combined longitudinal load transfer

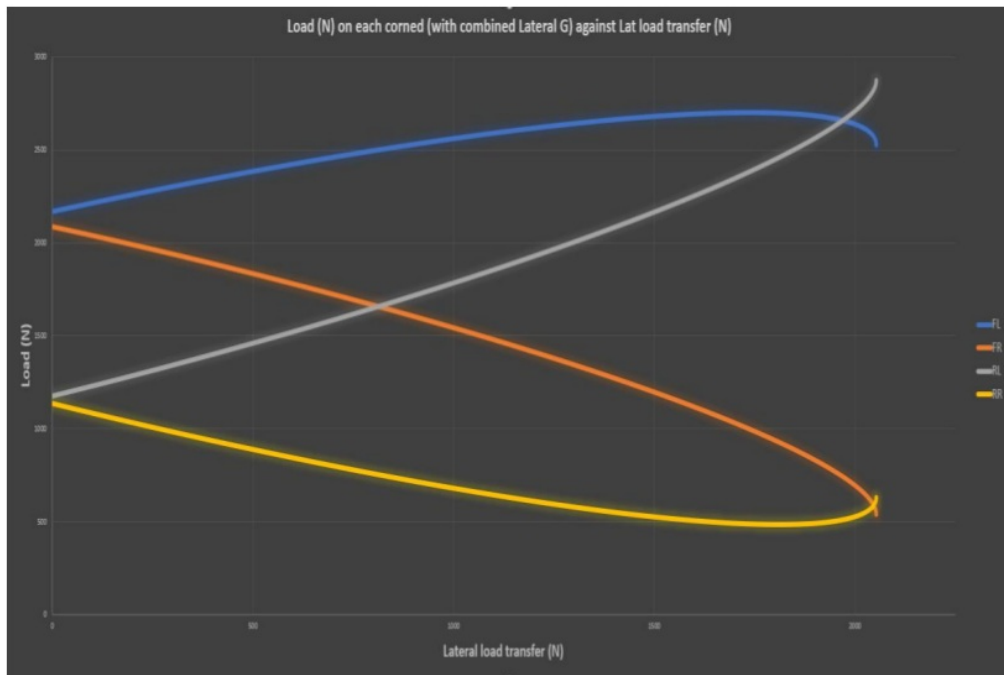


Figure 6: Load on each corner over combined lateral load transfer

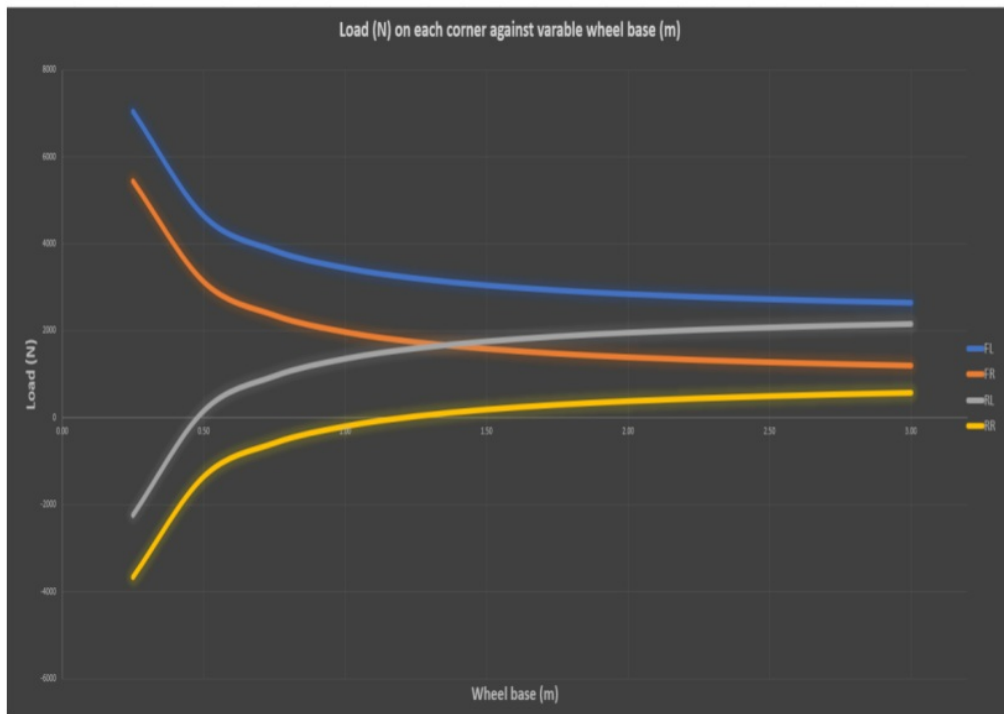


Figure 7: Load on each corner over varying wheel base

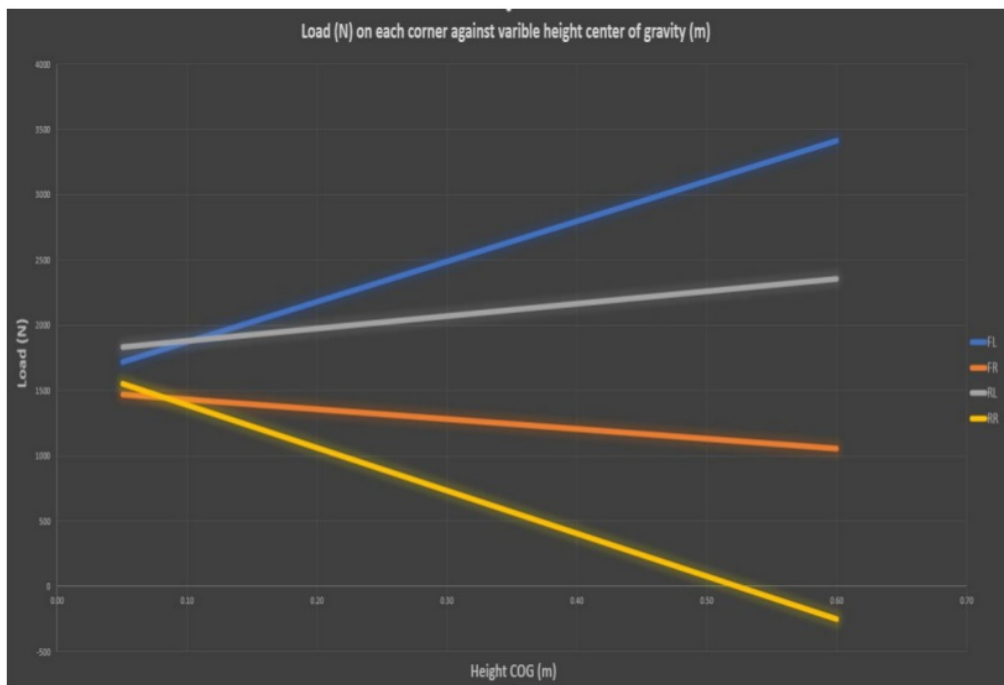


Figure 8: Load on each corner over varying wheel track

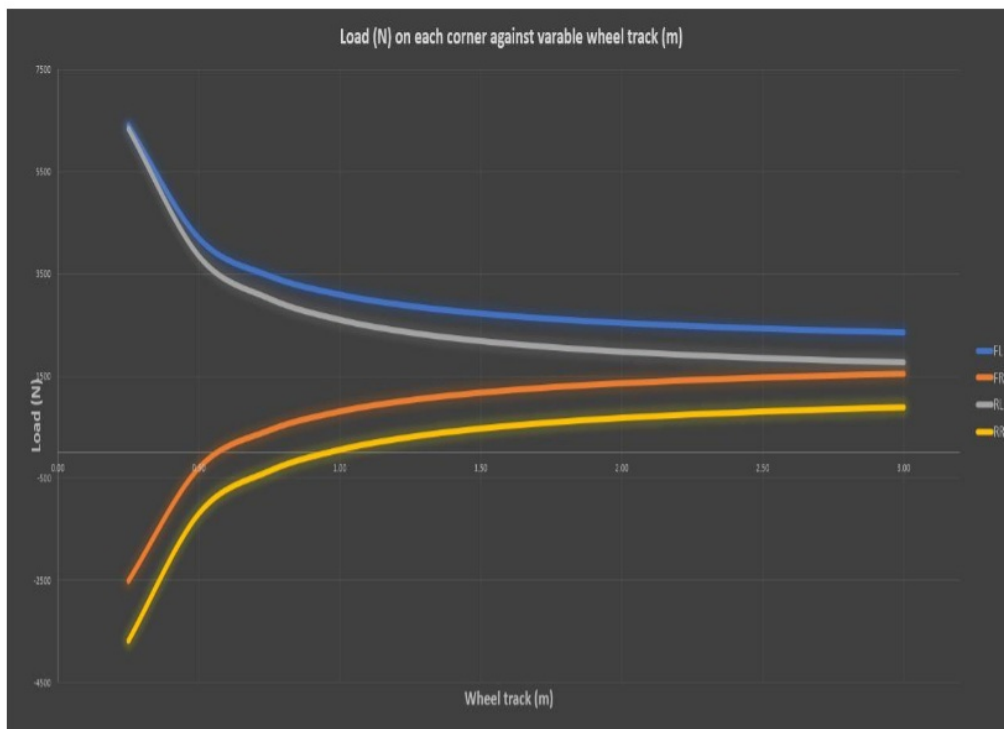


Figure 9: Load on each corner over varying Height COG

Analysis:

Basic Scenarios:

Figure n°2 shows the vertical load (N) on each corner over longitudinal load transfer (N). When simulating an increase of longitudinal G force from 0 to 1.5G at 30 m/s, the graph shows that vertical load transferred to the front of the vehicle is dramatically increasing. However, vertical load transfer at the rear is dramatically decreasing.

Figure n°3 shows the vertical load (N) on each corner over lateral load transfer (N). When simulating an increase of lateral G Force from 0 to 1.5G at 30 m/s velocity, the graph shows that the vertical load transfer on the Left corners of the vehicle is increasing when load on the right corners is decreasing. 

Figure n°4 shows the vertical load (N) on each corner over velocity (m/s). When simulating an increase of velocity from 0 to 30m/s with no lateral or longitudinal G force, the graph shows that vertical load is gradually increasing in a parallel way.  

Vertical load on corners is transferred regarding where the vehicle mass is transferred. While braking, most of the load is transferred to the front of the vehicle due to the pitch motion (figure 1). While going in a corner, load is transferred side to side in the opposite direction of the cornering direction due to roll motion (Figure n° 2).

While accelerating, aerodynamic load is applied on the vehicle resulting in an equally increasing vertical load on four corners due to the downforce effect (figure n°3). 

Scenarios of combined lateral and longitudinal forces:

The figure n°5 shows the vertical load (N) on each corner over combined longitudinal load transfer(N). Figure n°6 shows the vertical load (N) on each corner over combined lateral load transfer (N). Both graphs help to understand that maximum G force in each axis cannot be reached in the same time. Which means that one force is limiting the other one as one is increasing, the other is decreasing. The vehicle is experiencing higher forces with combined forces due to natural cornering force being added. 

Scenarios of varying chassis data:

Figure n°7 and n°8 graphs show that when simulating a variation of dimensions on both horizontal axis of the vehicle (longitudinal axis for wheel base and lateral axis for wheel track), the vertical wheel load is shared in the opposite way to the specific weight distribution of the vehicle. On lower wheel base dimensions, the two front wheels are getting significantly higher wheel load when the rear wheel are getting negative vertical load. As weight is distributed 47% at the front and 53% at the rear.

Same phenomenon is visible when simulating variations of wheel track dimensions. On lower wheel track dimensions, graph shows that more vertical load is applied to the left corners compare to the right ones. In this case, wheel load is shared accordingly to specific weight distribution as weight distribution is 51% on left side and 49% on right side.

Figure n°9 shows the wheel load (N) on each corner over varying height centre of gravity (m). When simulating a change on height centre of gravity, the graph shows that at lower values the vertical wheel load is dramatically lower than with higher values.

Changes in chassis dimensions have serious impacts on vehicle behaviour as well as weight distribution. The load transfer is the main actor in vehicle handling as it affects the vertical load on each corner regarding of external forces applied to the vehicle.

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Conclusion: 19

Chassis and suspension systems are designed by manufacturers according to purpose and use of every vehicle. A road vehicle will have different standards than a race vehicle (depends on driver requirements). Vehicle ride comfort and handling are indirectly linked as they are affected by the same components (tyres, spring, damper, chassis design). However, one could affect and limit the other one (comfort vs handling). Chassis design also affect the handling balance as it has an effect on pitch, roll and yaw which influences the repartition of vertical load on the wheels on the vehicle.

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References:



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FINAL GRADE

59/70

GENERAL COMMENTS

Instructor

Your research is from a wide range of sources and is well embedded within the report.

Look at the UWTSD Harvard Referencing Guide on how the reference list should be constructed - it should be in alphabetical order.

Your research section is outstanding and clearly shows you have a very good understanding of the topic. My only advice is that some images would have been useful to help support your statements.

Your analysis of the graphs is really good and you make some clear points. There are couple of areas where the explanation given could be clearer but generally a really good job. Well done.

This is a very well put together report. I would suggest proof reading more thoroughly as the main issues are grammar issues. Remember you can ask others to proof read for you.

Really nice piece of coursework. Well done.

PAGE 1

PAGE 2

PAGE 3



Comment 1 | Prof Prac

should read

...around the track, where as a 4x4



Comment 2 | Prof Prac

Formula 1 should have a capital letter.



Comment 3 | K & U Subject

Really good introduction that sets the scene of the report well.



Comment 4 | Literature

References are really well embedded within this report. Well done.



Comment 5 | K & U Subject

Good explanation.



Comment 6 | Literature

Reference missing?



Comment 7 | K & U Subject

Again a really good explanation.



Comment 8 | Prof Prac

Would be better as;

Manufacturers design car body shapes...



Comment 9 | Prof Prac

used?



Comment 10 | K & U Subject

Really good that you have compared the different types of vehicles as well.

PAGE 7



Comment 11 | C&I Skills

Good introduction to the results.

PAGE 8

PAGE 9

PAGE 10

PAGE 11



Comment 12 | C&I Skills

All your graphs are well produced and are included at a size that is easy to read.

PAGE 12



Comment 13 | C&I Skills

What way is the car turning, you haven't included this?



Comment 14 | C&I Skills

Good.

At what quantitative rate are they changing?



Comment 15 | C&I Skills

Vehicle mass can't physically move - maybe a better description is needed.



Comment 16 | C&I Skills

Good.



Comment 17 | K & U Subject

Brilliant understanding.



Comment 18 | C&I Skills

Really good overview of how characteristics can change handling behavior.



Comment 19 | Prof Prac

Should be on a new page.



Comment 20 | C&I Skills

Good overview of what you have researched and discovered.



Comment 21 | Literature

Good range of sources.

Reference list construction could be improved.

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

Exceptional 85-100%

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	Excellent 70-84%
(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	Exceptional 85-100%
(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