

Grand Theft Auto V - Car upgrades & dynamics

Short link **new-** <https://bit.ly/2IOyCD8>

Introduction

Feel free to skip to the next page if you want to get right into the good stuff.

Who made this document?

Me adding this here is long overdue, my apologies to people to have contributed throughout the years.

This started with me (**CHILLI**) being curious about tuning because it did nothing in GTA San Andreas, so I started testing out wheels. Safe to say it snowballed from there. Not long after a few of the Xbox360 guys found tyre clipping (**Kelevera**, **Crazyman**, **Twilicane(?)**, **Trowa(?)**, sorry it's been ages). That was about it until the next-gen release and PC, with **Nismo97** finding the handling flag responsible for the effect, soon after I found an old-style handling file confirming his find. **Pardonias** contributed to figuring out drag and got really close to cracking engine upgrades until we found the exact formula much later. **Fuksias** finding odd turbo behaviour, later solved with the help of **Adam10603's** scripthook scripts (We also made use of previous work by **IKT**). **OvivoJr** & **Fab.Iceman** for finding per-wheel effects, previously I only knew of per-type (**Supersteppa** assisted when initially finding this). **Morphos** for throwing curveballs with neons, custom tyres and possibly license plates. My driving skills took a long time to become good enough to confirm or deny his suggestions. **Hertzog** for sacrificing his computer hardware in the name of science to figure out how framerate impacts car speed (game only craps out over 120fps, below we found no clear signs of odd behaviour, though other side effects apply). **Da7k** for helping out with model file data, even if that has yet to answer previous questions, any contribution counts. At least we know where not to look as a result.

Oh of course thanks to **Broughy1322** for creating a community where all of us came together, it's impossible to say where any of us would've been without a place to easily chat and play with each other.

Apologies if I forgot any important names in there, that does not mean your contributions were discredited. I simply forgot who contributed what, nothing personal. This document wouldn't be where it is now if it wasn't for all you guys helping out along the way.

And for the love of the gaming gods DO NOT go after any of these people, especially if you're gonna be toxic. Point all criticisms to me, I'm the madman who opened the pandora's box. I do not tolerate sh*tty behaviour from people, keep it classy, constructive and respectful.

Let's get started

On the next page below you'll find a list of topics that will be talked about in this document. I will bring them up in the order they are listed. First by main category, then by sub-category. Some information may get repeated but that is just the nature of the topics that will be covered.

Car Upgrades & Tweaks

LS Customs

Performance Upgrades

- Brakes - stopping power
- Engine - acceleration increase
- Spoiler - traction + downforce increase
- Suspension - lowering + inertia
- Transmission - +1 gear & clutch speeds
- Turbo - gradual acceleration boost

Handling Tuning

- Wheel types + unique models
- Spoiler variants / other cosmetics

Car Dynamics (GTA V vs. the basics)

Car behaviour

- Traction limits
 - Steering
 - Throttle management
 - Braking
- Weight shifting
 - What is it?
 - How to use it?
- Oversteer vs Understeer
 - Different circumstances and conditions

Car components

- Body(rigidbody)
 - Centre of Mass - CoM
 - Rotational inertia
- Tyres/traction
 - Slip angle
 - Traction curve
 - Traction balance
- Suspension
 - Stiffness
 - Damping
 - Max travel
 - Anti-roll-/Sway-bar
 - Roll Centre

Update changes & Testing

Here is a list of changes to the game and stuff that I've tested/want to test.

The description of anything mentioned here is what they **feel** like and not what they actually **affect**. Once an item has been solved or figured out it will be moved to their appropriate category within this document.

Car parts

- *Nothing new for now...*

Other/Misc [Updated as of August 2020][Minor adjustments as of October 2020]

- Added new wheels & early testing to the wheel type section.

Recent updates - here I will list what was most recently changed within this document.

- Added "Street" wheel type table.
- Added new wheels to "Offroads" wheel type table, listed under their own sub-table.

Latest game update changes [Summer 2021]:

- Added new wheel type "Track", with a focus on loose handling (even puts muscles & tuners to shame). If you like your tyres made out of sponge, these are for you.
 - Will probably be a little while before I give these proper testing though, need to get used to the physics change noted below 🙌.
- Car physics on PC are now in line with console versions. I haven't mentioned it much, but ever since the nightclub update (After Hours? forgot the exact name) cars on PC became notably more boaty. The latest update remedies this divergence in the game's physics. This is a game-wide change, so check out old cars that might've felt too boaty in the past.
- Added "Tuner" sub-class of cars, along with a unique low grip tyre enhancement for only those cars. Sadly no new drifting mechanic though. These tyres simply reduce grip and piggyback off how cars can sorta drift under low grip conditions already.
- The new Tuners can also be lowered through the interaction menu to further loosen the grip, similarly to how you'd stance it by damaging the suspension in the past. Damaging the car might no longer be required.
- At the car meet you can both mod and test drive your car in a giant underground garage, neat having a clean-ish testing space. Curse those puddles though, otherwise I could've used it for my testing. Oh well.
- Added party-style modes to the car meet test area, kinda cool. 1v1 duels as well as cannonball run-esque races can be done there. Or checkpoint blitz, for those familiar with Midtown Madness 🔥.

- **Los Santos Customs**

Performance Upgrades

In this section the list of performance related upgrades will be discussed.

In this case performance upgrades refers to parts that will be necessary to make your car faster around a track. So we'll be taking a look at *brakes, engine, spoiler, transmission & turbo*. Suspension will get a mention in here as well. Alright let's get into it.

Power!

The best way to go start going faster is by making our car accelerate faster. To do this we can upgrade the engine, transmission and turbo parts if they're available for the car at hand. While the engine and turbo upgrades are quite straight-forward the transmission needs a bit more explaining.

Engine upgrades permanently increase the acceleration. This is a percentual increase, so cars with a high base value (driveForce) will get the largest increase. For 100% one fifth of the base value will get added onto the base value. This is the proportional increase you will see when upgrading your cars. Do note that there are a few rare cars that get more than a 100% increase but this is a good starting point. Because it's percentual we have to keep in mind that 100% in math is a value of 1. So 50% is 0.5 and so on.

$$acceleration = driveForce + (driveForce * E\% * 0.2)$$

So for example the regular Jester, when fully tuned, gets a driveForce value of 0.36 as shown below.

$$acceleration = 0.3 + (0.3 * 1 * 0.2) = 0.36$$

Turbo upgrade increases acceleration based on context. It is unknown how much turbo adds to the base value, but we do know it's not constant. When you're below 100% throttle input the turbo actually *decreases acceleration*, but when you're at 100% input the turbo pressure will slowly climb and *gradually increase acceleration*. Because the turbo response isn't instant it may actually help to run without a turbo on really tight tracks where you'll rarely be at full throttle. For most tracks you will see a benefit from a turbo, so only remove it/stay stock if you suspect it might help for an upcoming event race or you have multiple cars for different purposes.

[Turbo graph](#)

With the raw power out of the way let's talk about how the transmission upgrade works.

The moment you apply *any* transmission upgrade one extra gear will be added to the gearbox. The gear shift time will be sped up as well, making the car shift between gears faster. The in-game acceleration bar completely lies when looking at this upgrade because it won't actually make you accelerate at a faster rate. It's the other way around; it will make you spend less time *not* accelerating. The extra gear that gets added won't be engaged until you are really close to top speed. Once the final gear is engaged it will make sure you can maintain that top speed even when turning moderate amounts. So when in final gear the car may feel more sensitive to losing traction, requiring extra caution to keep it on the road.

Traction, Braking & Stability!

So now that we know how to go fast it's essential to know how to keep your average speed as high as possible. If we can't stay on the road then all that extra power is of little use to us, so how do we keep things in control? By increasing traction of course.

Spoiler

A lot of cars come with a *spoiler* part or an equivalent. You can tell if a part increases traction by looking at the in-game "traction" bar of the vehicle. There are a few cases where a non-spoiler part adds traction, so keep an eye out for those parts if it has no "spoiler" category. Also keep in mind that the traction bar can be buggy, so ***always*** go with a **non-stock spoiler** when in doubt. With this part attached any actions that make use of the vehicle's traction will be improved. This will allow for turning at higher speeds, more traction when accelerating from a standstill and greater potential braking power. Downforce will also be increased some amount, keeping the car grounded more efficiently.

Brakes

Speaking of braking power, a lot of vehicles come with a "brakes" category of upgrades. Most cars in the game already have brakes more than strong enough, but there are a few cars that need all they can get. This will be talked about more later on in this document. But I do want to point out that you don't always *need* stronger brakes. The more you can avoid breaking traction during braking the faster you will slow down, but also make sure not to apply too little force either or you'll decelerate slower than optimal.

Suspension

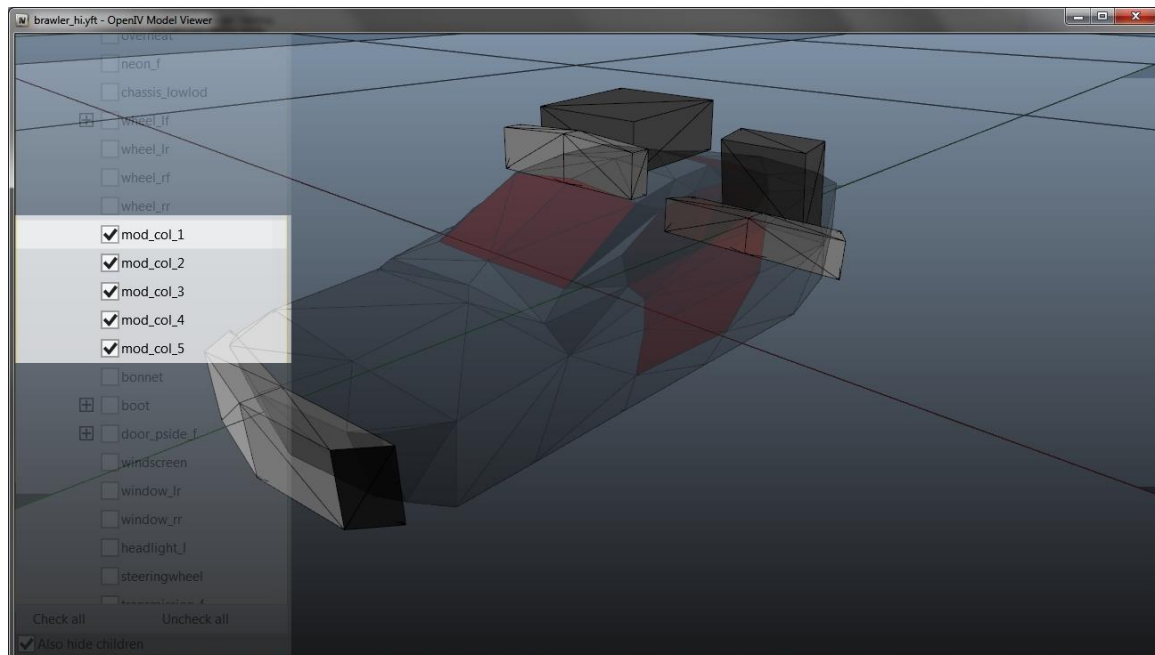
And lastly if the car feels twitchy or unstable, maybe even both, then applying the suspension upgrades might be a good first step. The game is quite quirky, which we'll look into further later on. Suspension upgrades is the first part we'll look at that has its own tradeoffs. Lowering a car will bring the *Center of Mass* (or *CoM* for short) closer to the ground, granting better stability. But the tradeoff is that the more you lower the car the more *inertia* will be applied to the car, meaning that things relating to the steering will feel heavier. This has no negative effects on the car's turning ability, but it may come across as sluggish. The trick here is to find the right balance between responsiveness and stability for your purposes. I greatly encourage experimentation because it's just something you have to do when taking racing to this level and beyond.

Handling Tuning

In this section the list handling related upgrades and parts will be discussed.

Wheel types, unique wheel models, different spoilers and other cosmetics... And I'd like to point out to anyone wanting code proof for all of this stuff that there isn't anything regarding this in the data and config files we've found. Maybe in the future? Who knows. We'll see what happens. But until then, please bare with me as we go along.

Let's start with the least quirky physics-wise. Cosmetics including different spoiler attachments.



On the example picture above I have highlighted parts that, when activated, will change the CoM location of the car. Where the floor grid crosses inside the car is the original CoM location. So when the handling file states a CoM location of 0, 0, 0 this is the point in space it's referring to. Because their game engine interprets 3D space as if it's top-down you get X being left/right, Y front/back and Z up/down.

Visuals vs Physics

What's up with all these rendering bugs? Well, what if I told you they're not bugs?

This is something I hear people ask or bring up from time to time, so I want to get the confusion out of the way right away.

The car in the picture above is the **physical** representation of the Brawler offroad car. This is how the game interprets the car when processing impacts and approximated volume. This is important to know to understand what's going on in games. In this case the Brawler, just looking at the picture above, we can see that it has a front bumper of some kind, 2 objects on the roof, a rear bumper of some kind and another rear attachment. In this case the **visual** models for these are a front bullbar, roof lights + spare wheel, rear bars + spare wheel. What we can gather from this is that what we see more often than not does not quite match what we get.

Now with that out of the way let's move on. The size difference between the car body and said part is what determines how much the CoM moves towards the part at hand.

For example we could approximate that the front bumper is maybe 1/30 of the car. So the CoM would move 3% towards the front. This might not sound like much, but the physics of cars are very sensitive so this change will actually be quite noticeable. Let's imagine the car being 3 metres long. Then the front bumper would move the CoM forward 0.09 of a unit. Again that might not sound like much but when it really comes down to fine control that's significant. And this logic applies to every car part in the game as far as my testing goes. Spoilers, hood scoops, roof racks, shakotan exhausts etc. all have an effect if they have their own collision shape.

Body kits

Let's get some <currently unknown>!

READ THIS - IMPORTANT NOTE

[Recent tests](#) (cred to Pardonias) show that spoilers increase downforce. However [bumpers and skirts](#) (cred to Adam10603) don't seem to have any direct effect on the downforce itself. They adjusting handling still applies, but keep in mind that when I say "downforce" I don't actually mean stick-to-the-floor ability but rather the perceived traction change.

Front bumper and splitters increase or add front downforce. When at high speed this will roughly match the effects you'd get from putting weight in the front, like the Ram air hood on the Ruiner. The difference is that at low speed it handles like as if the CoM was nicely centered. This may restrict front lateral movement.

Side skirts add downforce near the bottom centre of the car, decreasing body roll effects at high speed.

Note that this may partially restrict some of the overall movement of the car but the front/rear traction balance at high speed will remain intact.

Lastly **rear bumper/diffuser** may add some amount of rear downforce. But its more prominent effect is to help with restricting the lateral movement of the rear. It will help with minimizing small amounts of rear skidding but may result in less control over the car once quite severely sideways. This part can help with making the car feel more "on rails" but beware that you get less warning of when the rear might lose traction.

It seems like cars that rely on mechanical grip (typically cars with a bit of body roll) benefit very little or even become worse (example: Massacro). However cars that are already planted or have a really low CoM appear to benefit a fair bit from a full kit (example: Jester, Furia) and I greatly recommend giving that a try. If the car becomes a bit stubborn, try removing the rear bumper and try again.

Other cosmetics may have an effect on the CoM placement if they have a collision shape or have been set to affect it otherwise. These parts include Spoilers, roof racks w/ junk, bug catchers and other large components. Exceptions are roll cages (particularly muscle cars that add a gas tank or *stickers, looking at the Dukes*) and neons (weird but oh well). *Tyre smoke* remains untested (by me anyway).

Windows tints are a little hard to pinpoint. But they may slow down the weight shift response the darker you go, primarily front/back transfer like accelerating or braking. *Metal paint* appears to exaggerate the sense of weight, primarily slowing turning rotation of the car.

Extra exception for license plates. This one is particularly interesting because it has no effect on the handling of the car, so no voodoo going on here. Instead it adjusts the steering's stability assist, with

strengths in descending order. So the first plate in the list is the most assisted, gradually decreasing to about (perceived) half assist with the black & yellow plate. This is only really important to keep in mind with cars that respond poorly to turning over bumps (Blackfin comes to mind), as the assist will sort of treat your input as intention. More assist = more auto-corrections to match intended direction..

Wheel types & Uniques

In this section the list of wheel types and unique wheels will be discussed.

Not much to say here for now...

Useful words to know:

- *Traction bias* - The grip difference between front & rear. "Front" means the rear loses a little and the front gains a little, and the opposite for "Rear".
 - *For rear grip the car might feel more "pointy" and front grip more slippery and/or responsive.*
- *Slip angle* - The angle difference between direction of travel vs wheel direction. For the list below an increase means more angle needed to reach peak grip.
 - *Less angle makes the car more responsive but also "on rails" and more angle is looser and possibly more forgiving to sliding.*
- *Anti-roll* - What it sounds like. When increased some traction is sacrificed to offer improved stability in the corners.
 - *No wheel might actually have this. But the real world equivalent is more stable handling while lowering the amount of grip just a tad. There's a sweet spot where the increased stability increases potential. Too soft and you get inefficient use of grip, too hard and it'll be a slippery brick.*

Strength indicators will be used to describe how much the listed effect influences handling. A number between 1 to 5 will be used, including decimals if needed.

Each wheel type has a particular theme to their handling effects it seems. Here are some tips to get you started.

High-ends tend to have a grippy feel to them, good for precision.

Sports are fairly forgiving to sliding, good for aggressive driving styles.

SUVs are somewhere between high-ends and sports.

Muscles can make a car feel a little "loose", or less responsive perhaps.

Tuners are a mix of sports and muscles. Can make cars a bit loose but also reward good car control.

Lowriders for that bling, yo. Generally don't change handling that much.

Offroads for when you're after pure function, looks second. They generally make the handling quite predictable and if a car has tyre clipping these are superior bump absorbers. *Read: noob friendly but not something you'd bring to a car show.*

The unique wheel models

High End	
Shadow	~Neutral (<i>current baseline, for now</i>)
Hyper	
Blade	Traction bias - front x1
Diamond	
Supa Gee	==
Chromatic Z	
Mercie Ch.Lip	
Obey RS	
GT Chrome	
Cheetah RR	
Solar	Traction bias - front x3
Split Ten	
Dash VIP	
LozSpeed Ten	
Carbon Inferno	Anti-roll +1
Carbon Shadow	Anti-roll +1
Carbonic Z	Anti-roll +1
Carbon Solar	Anti-roll +1
Cheetah Carbon R	Anti-roll +1
Carbon S Racer	Anti-roll +1

Lowrider	
Flare	
Wired	~Neutral (<i>current baseline until more are tested</i>)
Triple Golds	
Big Worm	
Seven Fives	
Split Six	
Fresh Mesh	
Lead Sled	
Turbine	Traction bias - rear (moderate)
Super Fin	
Classic Rod	
Dollar	
Dukes	
Low Five	
Gooch	

Muscle	
Classic Five	Anti-roll+
Dukes	Traction bias - front x1
Muscle Freak	
Kracka	
Azreal	Anti-roll bias - front (weak/moderate)
Mecha	
Black Top	
Drag SPL	Traction bias - front (weak/moderate), improved bump stability (dafuq?)
Revolver	Anti-roll - (may decrease more than Five Star, is at least equal)
Classic Rod	
Fairlie	
Spooner	
Five Star	Anti-roll -
Old School	
El Jefe	
Dodman	
Six Gun	
Mercenary	

Offroad	
Raider	Traction bias - forward
Mudslinger	Anti-roll+
Nevis	
Cairngorm	
Amazon	
Challenger	Traction bias - forward & Anti-roll+
Dune Basher	Traction bias - forward+
Five Star	Anti-roll- or neutral, too close to tell for sure
Rock Crawler	Anti-roll+
Mil Spec Steelie	Anti-roll bias - rear+
Summer Update	
Retro Steelie	
Heavy Duty Steelie	Neutral/Understeer
Concave Steelie	Neutral/Understeer
Police Issue Steelie	Neutral/Understeer
Lightweight Steelie	Neutral-ish/Understeer
Dukes	Light Oversteer
Avalanche	Neutral?
Mountain Man	Neutral?
Ridge Climber	Neutral?
Concave 5	Neutral?
Flat Six	Neutral(/Understeer?)
All Terrain Monster	Moderate Oversteer
Drag SPL	Mid/High Oversteer
Concave Rally Master	High-ish Oversteer
Rugged Snowflake	Neutral/Understeer

Sport	
Inferno	Traction - rear x2.5
Deep Five	
Lozspeed Mk.V	==
Diamond Cut	==
Chrono	[TESTING] neutral
Feroci RR	Traction bias - front x1 & Slip angle -1
FiftyNine	==
Mercie	
Synthetic Z	
Organic Type 0	[TESTING] Traction bias - front
Endo v.1	
GT One	
Duper 7	
Uzer	
GroundRide	
S Racer	Traction bias - rear & Slip angle -1
Venum	
Cosmo	
Dash VIP	
Ice Kid	
Ruff Weld	[TESTING] Traction bias - front
Wangan Master	[TESTING] Traction bias - front
Super Five	
Endo v.2	
Split Six	[TESTING] - anti-roll+

More below....

SUV	
VIP	
Benefactor	Traction bias - rear
Cosmo	
Bippu	Anti-roll+
Royal Six	
Fagorme	Traction bias - front (mid/strong)
Deluxe	
Iced Out	
Cognoscenti	
LozSpeed Ten	==
Supernova	
Obey RS	
LozSpeed Baller	
Extravaganzo	
Split Six	
Empowered	
Sunrise	
Dash VIP	Traction bias - rear
Cutter	Traction bias - front

More below...

Tuner	
Cosmo	
Super Mesh	==
Outsider	Traction - rear x0.5
Rollas	
Driftmeister	Traction - front
Slicer	Traction - rear(?), friendly to sliding/driftng
El Quatro	
Dubbed	
Five Star	[[maybe anti-roll-]]
Slideways	Traction - front x1
Apex	Traction - front x0.5
Stanced EG	Traction - front x1
Countersteer	Traction - rear x2 & Slip angle -0.5
Endo v.1	Traction- rear
Endo v.2 Dish	Traction - front x2 & Slip angle +1
Gruppe Z	Traction - front x1 & Slip angle +3
Choku-Dori	Traction - rear x3
Chicane	Traction - rear x3
Saisoku	Traction - rear x2 & Slip angle -1
Dished Eight	Traction - rear x2.8
Fujiwara	Traction - rear x3
Zokusha	Traction - front x2 & Slip angle -1
Battle VIII	Traction - front x1 & Slip angle -2
Rally Master	Traction - front x1.5 & Slip angle +2

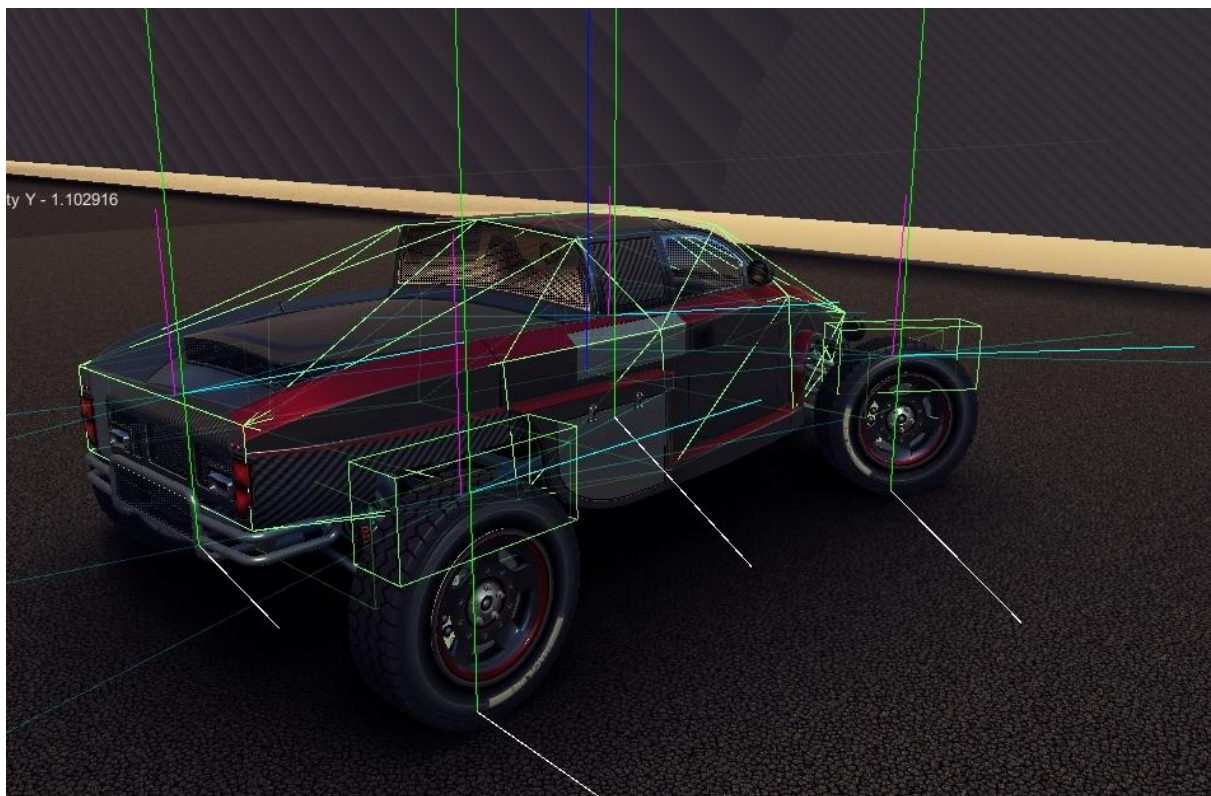
Street	
vv Tuner-sized vv	
Retro Steelie	Rear grip (mid/high)
Poverty Spec Steelie	Rear grip (mid/high)
Concave Steelie	<i>Probably rear grip also</i>
Nebula	Rear grip (mid/high)
Hotring Steelie	Rear grip (moderate)
Cup Champion	Front grip (moderate)
Stanced EG Custom	<i>Very likely front grip</i>
Kracka Custom	Rear grip (strong, can power drift)
Dukes Custom	Rear grip (moderate, hint of power drift)
Endo v.3 Custom	Rear grip (mid/high)
V8 Killer	Rear grip (strong)
Fujiwara Custom	Rear grip (on par or slightly stronger than tuner Fuji)
Cosmo MK II	Front grip (weak)
Aero Star	Front grip (<i>moderate?</i>)
vv Sport-sized vv	
Hype Five	
Ruff Weld Mega Deep	Rear grip (mid/high)
Mercie Concave	<i>Front grip I think, needs revisiting</i>
Sugoi Concave	
Synthetic Z Concave	Rear grip (strong)
Endo v.4 Dished	
Hyperfresh	
Truffade Concave	Rear grip (weak/moderate)
Organic Type II	
Big Mamba	
Deep Flake	
Cosmo MK III	
Concave Racer	Rear grip (mid/strong)
Deep Flake Reverse	
Wild Wagon	
Concave Mega Mesh	

Car Dynamics - realism vs GTA

In this section I will explain to the best of my ability why the cars in the world of GTA V behave they way they do and why handling tuning matters. Be sure to check out [Broughy1322's Vehicle Info Spreadsheet](#) and look at the “handling data (full) tab” to easier follow along what’s going to be talked about. Plus all the info on there is really useful for all sorts of purposes, I recommend taking a look to learn more about overall car performance. And with that, let’s get started!

Car behaviour

- Traction limits
 - Steering
 - Throttle management
 - Braking
- Weight shifting
 - What is it?
 - How to use it?
- Oversteer vs Understeer
 - Different circumstances and conditions



This is a picture of the debugger I made when working on a car physics project of my own.

First off I want to say that I’m not an engineer, nor am I a professional race driver. So naturally not every little thing will be correct but I’ll do my best to remain as accurate as possible.

Let’s begin with traction limits. This is probably the most important part in racing land vehicles because if you can’t transfer force between the car and the ground there will be no meaningful

movement. We need a good way to push against the ground to get moving and for cars we take using wheels for granted. So let's look into the core behaviour of rubber tyres.

Game tech & good-to-knows

Before we start to dig into how and why the cars behave the way they do in the world of GTA V we must get familiar with common terminology and how most games, including GTA, treat the physical body of a car. The picture above is to help visualize how some things are calculated, just in case my descriptions and explanations come across as a bit vague or strange. Or it helps understanding how it all works in practise, you decide.

The first thing we need to get out of the way is that, because of a common standard, vehicles in games tend to be very advanced hovercrafts. The wheels don't actually exist in terms of being a physical entity. The reason for this is because it's incredibly difficult to get springy objects to behave predictably, without needing an immense amount of geometry and/or far too heavy calculations to work without chugging along at a low framerate. It worked for games like Rigs of Rods (from 2005) and BeamNG Drive (still in development at the time of writing this, largely made by the same people) because they could dedicate most of the processing power to the physics alone. But in games like GTA there's far too much going on to do this. So nearly all of the games out there make use of either *ray-casting* or *convex-casting*, the latter being used in GTA IV & V.

But before we go any further the lingo used when talking about games has to be understood, so here's a glossary of words that will be used:

Math variables & functions

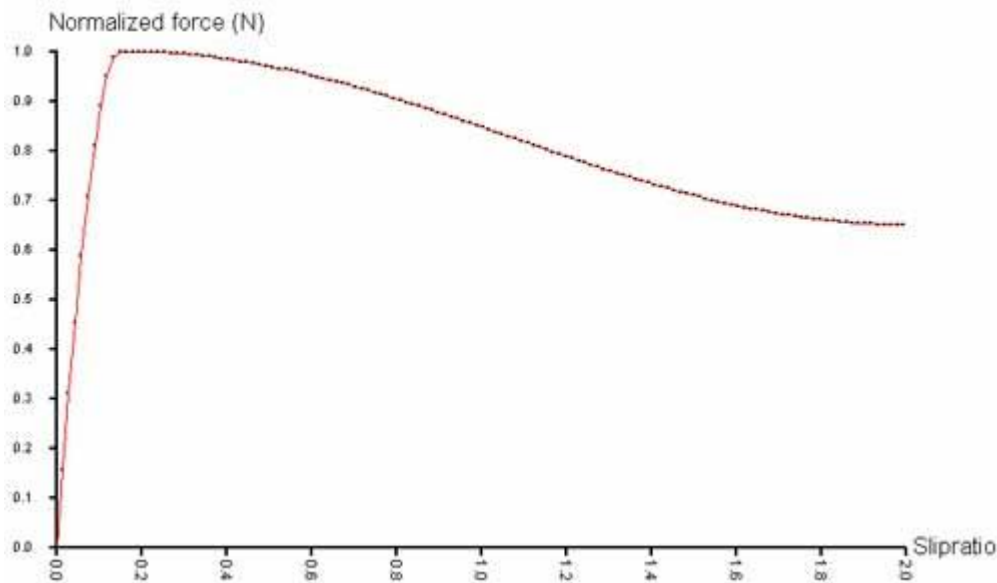
- **Vector** - a position, rotation or direction described by numbers. For 3-dimensional space a Vector3(X, Y, Z), holding 3 numbers, is used. For example Vector3(0, 0, 1) is one way to describe a direction pointing along the Z-axis of something, like the world or the local space of an object.
- **World/Local space** - world-space is exactly what it sounds like, where in the world something is. Local-space however is using the centre and orientation of an object instead of the world. For example if a car flips the local "up" is where the roof is pointing. In this case the up-direction is pointing down in world-space because the car is flipped.
- **Cross product** - this is easiest described as the "left-hand rule". This is used to find out in which direction a perpendicular direction ends up between two *vectors*. [More on that can be found here.](#)

Physics terms

- **Slip** - the speed difference between two objects. Used to describe how much two objects are sliding against each other.
- **Slip angle** - used as an approximation of tyre flex and slip. This is the angle difference of the wheel forward vector and wheel velocity vector.
- **Static/Dynamic friction** - static friction is the force an object can resist before starting to slide against a surface. Dynamic friction is the force an object applies when sliding against something, no longer being stationary.
- **Normal** - or "surface normal", the direction vector of a surface.
- **Ray/Convex-casting** - a common technique used in all areas of games to detect surfaces. Used in shooters to detect a hit, used in AI to "see" the player or in our case to check if a "wheel" is within reach of touching a surface. If something intersects this imaginary

line/volume some data will be returned like the hit point, surface normal, surface/object type and sometimes even more.

Traction limits



This graph is an example of what a friction curve of a tyre may look like. It being “normalized” means that its highest value will equal 1.0 and everything else will be between 0 and 1. This is done so it can be used as a kind of “template” rather than the final values.

Without delving into, let alone speculating, about the calculations taking place for this, I have come up with an approximation to work out traction limits. I'll keep it straight to the point or this is gonna be way too long.

So what I do is multiplying the acceleration (*driveForce*) and deceleration (*brakeForce*) by ~10. Then you need to take their respective biases into account, so multiply by whatever is the highest bias for the front or rear. For example if a vehicle has a *driveBias* of 0.3, that means 30% goes to the front and 70% to the rear. In this case 70% is higher, so that's a decimal value of 0.7. When you've done this for both acceleration and deceleration you're good to go to compare the forces vs. traction limits.

Let's take the Jester Racecar for example, so we got:

driveForce = 0.31 = ~3.1

driveBias = 0.2

***driveTotal* = 3.1 * 0.8 = 2.48**

brakeForce = 0.95 = ~9.5

brakeBias = 0.51

***brakeTotal* = 9.5 * 0.51 = 4.845**

tractionMax = 2.57

From here we can work out how likely it is that we either get wheelspin or lockup.

So we got a *driveForce* of 2.48 against a *traction* of 2.57. The *driveForce* is less, so there's little to no risk of wheelspin. And for *brakeForce* we got 4.845 against 2.57, which is significantly higher. Looks like even stock brakes will be more than enough for the Jester Racecar, so based on this I wouldn't bother upgrading the brakes at all.

Now I don't own a Jester RC nor have I done so in the past. But from experience with other cars this method seems to be close enough to make a fairly educated guess before wasting in-game money.

Weight Shifting

What is it?

Weight shifting, in short, is referring to the suspension and tyres working together to alter the handling of the car based on lateral, longitudinal and vertical forces. For example when turning right the weight will be shifted to the left, putting more pressure on the left wheels and in turn less on the right wheels. The same applies during acceleration and braking, where accelerating will put more pressure on the rear and braking will put more pressure on the front (assuming we're traveling forward relative to the car).

To get a better understanding let's break down what's actually going on mechanically. First we can take a look at the tyres and how their friction behaves. GTA, among nearly every single other game involving driving, assumes that more pressure against the surface will increase the friction coefficient of the tyre but only to a certain point. This explains why you get more traction when driving through a banked corner, but doesn't entirely explain the behaviour I described above. To get the bigger picture the suspension needs to be added to the mix.

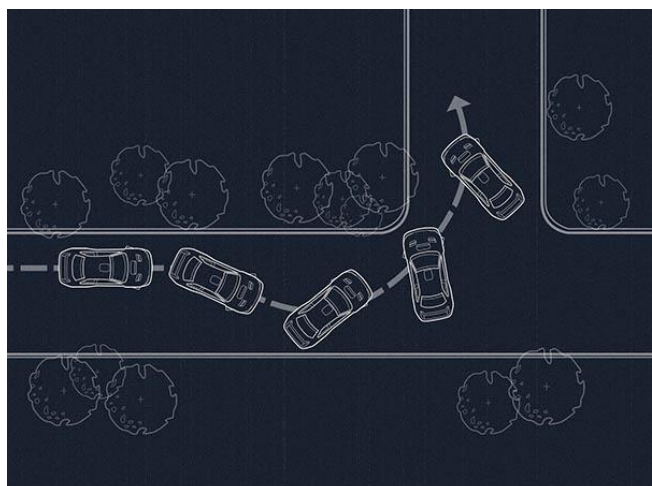
Suspension does as the name implies, it suspends the car above the ground. It does this by pushing against the ground with a force stronger than gravity, until the suspension has extended to the point where the car neatly sits some distance above the ground and the forces equal out. This happens because the springs want to be extended but are forced to contract under the weight of the vehicle. But as our friend Newton figured out in his [Laws of Motion](#) a force on one object has the opposite effect on the other. Since the ground will remain stationary the vehicle will get repelled because of what's known as a *normal* force. This is the same force that increases the pressure against a tyre and increases its friction coefficient. Let's put this all together.

When cornering the wheels will apply a force in the opposite direction of travel near the ground. Because this point is generally below the CoM of the vehicle it will cause body roll. The suspension responds by putting more pressure on the outside, because it is now closer to the ground and thus the springs apply more force against the ground and those wheels get more traction. In turn the inside will end up being lifted, resulting in less pressure against the ground and those wheels will lose traction.

So how to use weight shifting?

Well the truth is that you can never not use it because it's an integral part of physics. When you accelerate off the starting line you're already making use of it. However a few maneuvers have gotten names associated with them. Just as an example I'll describe one of the most famous.

Scandinavian Flick is when you slide a car around a turn without getting wheelspin or pulling the handbrake.



The maneuver is pulled off by turning away from the corner (step 1 and 2) by then rapidly turning towards the corner (step 3) causing the car to become unsettled (step 4) and result in a drift (step 5). It's worth noting that the faster you are going the more sensitive the car will become to movements like this, which is why swerving at high speed can be quite risky. What's happening internally is that the traction gets increased on the wheel pair closest to the corner before turning in. Because the car will be turning in very rapidly the outside wheels won't have enough traction to stop the car's rotational movement in time, resulting in a slide. Speaking of sliding, this moves us on to the last part of this section.

Oversteer vs Understeer & various conditions for each

You might have heard people talk about how a car has lots of understeer or how oversteer keeps causing problems. These two terms refer to when a car no longer has equal traction between the front and rear wheels.

Understeer is when the car refuses to turn as much as desired or expected. This is most common on cars with FWD or AWD as the front wheels will accelerate and take away some of the cornering ability. But it can happen to any type of car running any kind of configuration, it's just more common in some than others. It can happen by turning in too sharply, causing the front wheels to lose traction because the slip angle becomes too high.

Oversteer is when the car turns in far too much and ends up going sideways. This is the most common on cars with RWD as the rear wheels may cause the rear to come loose and cause a slide. It can also happen to AWD cars depending on the circumstances as cars with an all-wheel-drive configuration shares a bit of both FWD and RWD characteristics.

These two scenarios can happen for multiple reasons and I've come up with a quite simple way to look at each. Let's categorize 2 vastly different car setups and how you can experience both understeer and oversteer on both.

- **Front-heavy car**
 - *Oversteers* when within traction limits as there's more pressure on the front.
 - *Understeers* when beyond traction limits as the front is heavier and wants to go first.
- **Tail-heavy car**
 - *Understeers* when within traction limits because there's less pressure at the front.
 - *Oversteers* when beyond traction limits as the rear is heavier and wants to go first.

Or as Clarkson from TopGear said about Porsche's cars, driving one is like throwing a sledgehammer with the handle first and how it simply doesn't work. He's referring to how the engine and transmission is in the back, causing the car to have massive understeer until it suddenly snaps and spins around similarly to throwing a hammer. The heavy part of the object receives less resistance vs mass than the light part of the object, causing the heavy end to end up in front of the direction of travel. If we consider the wheels our resistance this fits nicely into how cars behave.

There are some ways we can exploit weight shifting to momentarily match the setups mentioned above. By braking we'll end up shifting the weight forward, causing the car to behave as if it's front-heavy. This is why you can sometimes experience what's known as braking oversteer. Likewise cars that experience a lot of squatting during acceleration may feel understeer-y as the car now more closely matches a tail-heavy car. This is typically why AWD cars tend to understeer some amount during acceleration because the front wheels lose cornering traction from both the acceleration force and less pressure against the ground.

