# Calculation of Mountain Bike Suspension Setup through
# Mobile Image Analysis

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**Abstract**

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# 1   Introduction

## 1.1   Context

A survey carried out by the International Mountain Bike Association shows the average price of mountain bikes owned in Europe to be €2546 (£2206) (IMBA Europe, 2015). Starting at around £1000 (Giant Manufacturing Co. Ltd., 2017), enthusiast level mountain bikes can be purchased with suspension for both the front and rear wheels, known as Full Suspension (FS) bikes. Even at this comparably low cost, the suspension units have multiple adjustments available to tune and personalize how they operate.

To ensure the fork and shock function correctly they must be set up for the rider's weight and intended use of the bike. As this is considered a specialist area, many entry and mid level riders will lack the knowledge of this process or be unsure of how the suspension should operate meaning the rider could use the bike without the suspension set up correctly.

It has been proven that using a FS over a Hard Tail (HT) offers a performance advantage to the rider (Titlestad, Fairlie-Clarke, Davie, Whittaker, & Grant, 2003). However if the suspension fork and/or shock have not been set up, it can be detrimental to the rider's performance and potentially lead to injury. For example, if a shock has too little rebound damping set and the rider goes off a jump, the excessive speed at which the rear of the bike extends can create forwards rotation, causing the rider to go over the handlebars of the bike.

Additionally, an incorrect suspension setup can cause excessive wear and tear on the bike's frame and components. Suspension which is set too soft can allow for bottoming out which expends excess forces into the frame and potentially cracks the frame's structure. Suspension set too hard forces energy, which it would normally soak up, into the wheels and tires causing denting and warping of the wheel rims.

Many bicycle retailers will set up the suspension on a newly purchased mountain bike for the customer on delivery. Most of the time this will be enough to avoid incident but due to the extra weight of the equipment riders use, i.e. helmet, hydration pack, body armor which the customer will not be wearing at the time of delivery, this setup is regularly inaccurate. Furthermore, with some manufacturers choosing direct sales over local retailers (Harker, 2010; Staff, 2015), this setup can be circumnavigated altogether.

Since the birth of the modern smartphone in 2007 brought along by the first generation Apple® iPhone® and introduction of the Android™ mobile operating system, the use of mobile computing in everyday life has grown rapidly. Google™ stated that there were approximately 1.4 active Android users worldwide in 2015 (Callaham, 2015).

The introduction of activity tracking devices and mobile applications such as FitBit (Diaz et al., 2015) and Strava (West, 2015) and their growing popularity (Formosa, 2012) shows that individuals are welcome to the idea of using smartphones to aid or augment their participation in hobbies or sports. Due to this popularity and in a bid to give every rider the ability to setup and tune their own suspension, either at home or

while out on a ride, companies have set about producing small devices (Aston, 2016; Hwang, 2016) and mobile applications (Benedict, 2012) which aid riders in the process.

## 1.2    Mountain Bike Suspension Concepts

The purpose of suspension on a mountain bike is to divert energy from bumps and rough features in a trail away from the rider to improve comfort and performance by maintaining contact between the tires and the ground. This requires the use of a spring and damper, collectively known as a shock absorber, which allows the wheel to move away from the feature when it makes contact and make a controlled return once it has been passed.

### 1.2.1    Travel and Stroke

Travel is the distance which the bike's fork or frame allow the wheel to move in and upward direction. Stroke is the distance that the shock absorber can compress before it bottoms out. Travel is measured in inches or millimeters and can range from 80mm to 210mm. The amount of travel which a bike has normally denotes which discipline it was intended for. Typically less suspension is required for endurance oriented riding and more for aggressive and rough situations.

Table 1: Table of common suspension travels and intended disciplines

| Travel (mm) | Cross Country | Trail | Enduro | Downhill |
|:---:|:---:|:---:|:---:|:---:|
| 80 | ███ | | | |
| 100 | ███ | | | |
| 120 | ███ | ███ | | |
| 140 | | ███ | ███ | |
| 160 | | | ███ | |
| 180 | | | ███ | ███ |
| +200 | | | | ███ |

### 1.2.2    Front Suspension

Front suspension commonly employs a linear telescoping shock absorber, known as a fork due to it's dual sided construction. On nearly all suspension forks the stroke is 1:1 with the potential travel of the wheel. Front suspension is found on all FS and HT bikes.

### 1.2.3    Rear Suspension

Rear suspension uses a shock absorber much smaller than a fork and does not operate on a 1:1 ratio. Bike frames incorporate one or more pivot points and linkages which allows the wheel to move and act as multipliers for the suspension. Rear ratios are expressed as n:1 where n is the distance the rear wheel moves for every 1mm the shock compresses through its stroke. Though this is only the average leverage ratio for the entire travel.

As all rear suspension designs are different and the rear wheel must rotate around the main pivot, or in some cases virtual pivot, as opposed to moving linearly, the frame will behave differently through its travel and depending on the type of shock it is using. Because of this the average ratio is normally dismissed in favour of a leverage curve.
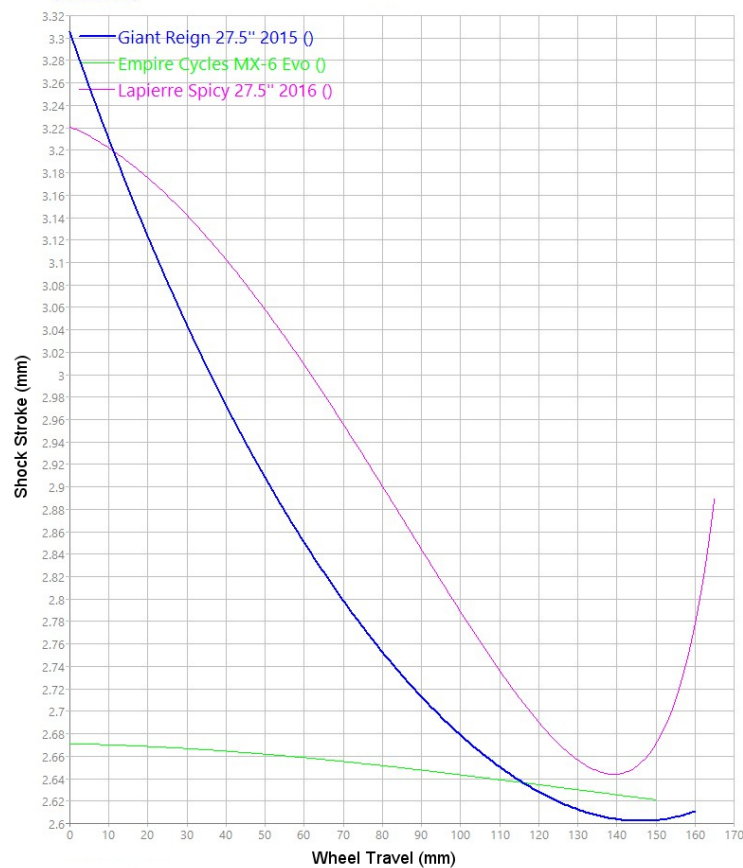


Figure 1: Leverage curves of three modern suspension designs

Figure 1 shows the leverage curves of three modern suspension designs. Each of these designs has between 150mm and 170mm of travel and uses the 27.5 inch wheel size however it can be seen that their suspension hosts drastically different characteristics.

The Virtual Pivot Point (VPP) design of the Giant Reign (shown blue) has an initial falling rate, meaning the shock can be compressed easily, but slows down and even rises slightly towards the end of its travel. This means the suspension will feel soft most of the time but feel stiffer on large compressions. This is emphasised by the horst link system of the Lapierre Spicy (shown magenta) which has a large rise at the end of its travel.

In contrast, the curve of the single pivot Empire MX-6 Evo (shown green) is considered linear. This is due to the MX-6 having only one pivot and swinging arm, as opposed to multiple pivots and linkages of the VPP and horst link designs, so there is an almost direct input from the rear wheel to the shock.

### 1.2.4   Sag

Sag is the amount that the suspension sits into its travel when the rider is in their neutral position, it is calculated using the rider's weight, available travel, and intended riding style. Sag is required so the suspension is able to drop into holes as well as soak up bumps. To adjust sag, the stiffness of the spring must be adjusted as required. This is done by changing the air pressure when using an air spring or replacing the coil and adjusting the spring pre-load on traditional coil shocks.

### 1.2.5   Damping

Suspension damping is carried out by forcing oil within the shock absorber through an arrangement of holes in the absorber's damping circuit. Reducing the size or number of holes making the travel of oil through the circuit slower and therefore increases the damping effect making compression or rebound slower.

**1.2.5.1   Compression Damping**   This is applied while the shock absorber is being compressed. More damping forces the wheel to remain in contact with the ground which makes the suspension feel stiffer. Too much compression damping can make the suspension too stiff so it does not soften bumps or rough sections correctly. Too little can cause the suspension to "blow through" its travel prematurely potentially leaving none when it would be required.

**1.2.5.2   Rebound Damping**   This is used to control the speed at which the shock absorber extends once it has been compressed. An optimal setting will allow the suspension to track the ground, returning after a bump as well as dropping into any holes. Too much rebound damping causes the suspension to return slowly and sometimes pack down meaning the absorber gradually runs out of travel. Too little can cause the suspension to buck the rider and lead to an accident.

**1.2.5.3   High and Low Speed Damping**   Depending on the manufacturer and model of the shock absorber, the unit can include up to two adjustable speeds for each damping circuit making four adjustable damping settings in total. High speed adjustments are used in high impact situations such as large jumps or drops, compression tends to be set softer to remove impact and rebound slower so rider has time to recover and the bike is not made unstable.

Low speed adjustments are used against small movements such as rider weigh shifts or long, slow compressions. Optimally compression is set stiffer as this type of feature can use a lot of travel and rebound damping set faster to deal with multiple features in quick succession.

# 2   Literature Review

# 3 Approach

# 4   Results

# 5 Critical Evaluation

# 6    Conclusion

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# Acronyms

**FS** Full Suspension. 5, 6, *Glossary:* full suspension

**HT** Hard Tail. 5, 6, *Glossary:* hard tail

**VPP** Virtual Pivot Point. 7, *Glossary:* virtual pivot point

# Glossary

**Fork** The front suspension unit on a mountain bike. 5, 6

**Full Suspension** A mountain bike with both front and rear suspension. 5

**Hard Tail** A mountain bike with only front suspension. 5

**Horst Link** A suspension system utilising a pivot point located near to and below the rear wheel axle. 7

**Rebound Damping** Controls the speed at which a suspension unit extends once it has been compressed. Less damping means the unit extends faster. 5, 8

**Shock** The rear suspension unit. Only found on full suspension mountain bikes. 5–7

**Single Pivot** A suspension system which rotates around a physical main pivot point. 7

**Stroke** The distance a shock absorber can compress before bottoming out. 6

**Travel** The distance a wheel can move before bottoming out. 6

**Virtual Pivot Point** A rear suspension utilising an upper and lower link to create a simulated pivot a physical one would be impossible. 7