



Tracking Straight

BY JAN HEINE



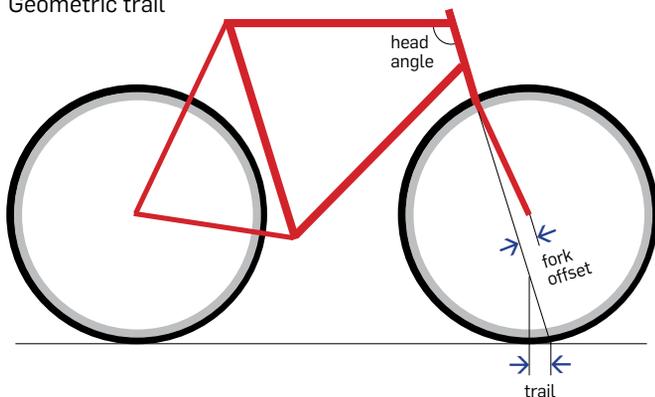
→ EVERY cyclist wants a bike that goes straight with ease, corners with precision, and carries a load without upsetting the handling. Whether your bike can do these things depends on its front-end geometry. There are several interacting variables that can be balanced against each other to give your bike specific handling characteristics.

The best-known factor is geometric trail, usually called “trail” for short. To visualize your bike’s geometric trail, project the steering axis to the ground. The distance between that spot on the ground and the center of the front wheel’s contact patch is the geometric trail. How much trail a bike has is determined by three factors:

- Head angle: A steeper head angle shortens the trail.
- Fork offset: More fork offset moves the tire contact patch forward and decreases trail.
- Wheel size: The larger the wheel, the farther the axle is from the ground. Then the inclined steerer axis intersects the ground farther forward, making the trail longer.

At first sight, it appears that a bike will be more stable if

Geometric trail



it has more trail. The forward motion of the bike tends to drag the wheel back in line. This is true in corners where the amount of trail determines your bike’s mid-corner stability. A bike with too little trail will not hold its line well. A bike with

too much trail feels like it is cornering on rails, making it difficult to adjust your line if the corner suddenly tightens or you have to avoid a pothole in mid-corner.

When going straight, more trail does not make the bike more stable. Here, a second factor is more important — wheel flop. When you turn a bicycle’s fork, the front of the bicycle lowers. This is called wheel flop, and it is caused by the inclination of the steerer axis and the offset of the front wheel from that axis. It means that the bike’s steering is balancing on top of a needle. Even the slightest deviation from a straight-ahead route tends to turn the handlebars further. Gravity pulls the front of the bike downward, and to get lower, it has to push the fork into a rotating motion. A similar principle is used on refrigerator doors: They close by themselves under their own weight.

Think of wheel flop as power steering. It makes it easier to turn the handlebars, especially at low speeds. Too little wheel flop and the bike will be hard to steer; too much, and it will veer off course at the slightest provocation. This is especially noticeable when you go uphill at low speed. A bike with too much wheel flop tends to weave, making it difficult to ride in a straight line.

Wheel flop is proportional to trail. More trail also means more wheel flop. A bike with more trail is more stable due to the trail, but also veers off course more easily due to the extra wheel flop. You can see how the two tend to cancel each other out on the straightaways. In corners, the fork does not point straight and wheel flop is less of a factor so the stability of the trail predominates.

Wheel flop also is influenced by the head angle of the bike. The shallower the head angle, the more wheel flop the bike has. This enables us to select how much wheel flop we want in our bike, independent of trail. If we need more wheel flop, we use a shallower head angle. If we want less wheel flop, we steepen the head angle.

Wheel flop depends on the weight that rests on the front of the bike. A heavy refrigerator door moves more quickly than a light one and slams closed unless you adjust

the hinges. In the same way, we need to adjust the bike's geometry for the weight it carries.

Excess wheel flop can be a problem, especially on tandems. Most of the captain's weight is on the front of the bike. If you don't adjust the geometry to account for this, the captain will have to fight the tendency of the steering to veer off course. Add to that the stoker's movements, which also tend to throw the tandem off course, and captaining a poorly designed tandem can be hard work. The solution is simple: Adjust the geometry to reign in the wheel flop, and your tandem will handle like a good single bike.

On single bikes, rider position plays a similar role. A more upright position puts less weight on the front, resulting in less wheel flop. To compensate, remember, you want just the right amount of "power steering" — a shallower head angle increases the amount of wheel flop. This is what many call a "relaxed" geometry.

Another factor that often is overlooked is the stabilizing influence of the tire. The wider the tire, the more stable the bike will be. It's not just that wider tires tend to be heavier, which increases the gyroscopic stability of the front wheel. Even with tires of equal weight, the wider tire makes the bike more stable. This phenomenon is called pneumatic trail, and its causes remain poorly understood. What matters to us is that the wider tire acts like extra trail. To make up for this extra stability, bikes with wider tires should have less geometric trail than bikes with narrower tires.

The diameter and weight of the tires and rims also influences the bike's stability. Larger or heavier tires and rims have greater rotational inertia and thus make the bike more stable. That is why a 29-inch mountain bike feels much more stable than one with 26-inch wheels.

What does all this mean in practice? For racing bikes with narrow tires, it's of relatively little importance. Wheel flop and trail cancel each other out, and bikes with 30 mm or 60 mm of trail, or anything in between, handle in a remarkably similar fashion.

Once you add a load, things become more complicated. With a rear load, you reduce the weight on the front of the bike. To compensate, you want a shallower head angle that increases the wheel flop slightly. I believe this is why British riders, whose bikes tend to have geometries with shallow head angles, prefer to carry their loads on the rear. If you put a load

on the front of such a bike, it requires a lot of attention to keep it from veering off-line.

With a front load, you need a very different geometry. Because the load turns with the fork, it has two effects. At high speeds, the inertia of the load tends to stabilize the steering so you decrease the trail to make the bike more nimble. At low speeds, the load wants to rotate around the inclined steerer axis so you also steepen the head angle to reduce the force the load exerts on the steering. French bikes tended to have such geometries, and the

French were the first to realize that the front is the logical place to carry most of your load. On such a bike, riding no-hands with a full touring load is easy. Because there is no rear load to act as a "tail wagging the dog," the bike reacts with greater precision to your steering inputs.

Tandems should also have steeper head angles, less wheel flop, and less trail. My favorite tandem — and I have ridden more than a dozen different ones — has a 74-degree head angle and just 30 mm trail. You need wide tires with plenty of pneumatic trail to make such a geometry work, but wide tires make a lot of sense on tandems anyway. On most tandems, my shoulders get sore after just a few hours of riding, yet I captained my favorite machine for 52 hours almost non-stop in the 765-mile Paris-Brest-Paris ride without feeling any extra fatigue compared to riding the same event on a single bike.

The beauty is that bikes can be made to handle very similarly, no matter whether they are racing bikes, loaded touring bikes designed to carry 40 pounds of gear, or even tandems. It requires more than simply sticking a front rack on an "all-rounder" bike or using a "neutral" geometry on a tandem, but when it's done right, all bikes can have the same stability when going straight, the same precision when cornering, and the same ease of riding no-hands.

This article is the result of more than 10 years of research into the science of bicycles, which has been published in more detail in *Bicycle Quarterly* magazine, bikequarterly.com. 



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