Bike Tech 101: Educating the Consumer on the Best Possible Bike Frame Choice

CONTENTS

Overview

It is shocking, but, pound for pound, a high-performance bicycle or bike frame costs more than even the most exotic sports car. On average, a complete high-end bicycle weighing less than 17 pounds will cost in the neighborhood of $4,000: that's $235 per pound. A $200,000 sports car weighing 3,000 pounds has a per pound cost of $66. If a high-end bicycle were a high-end sports car, it would cost in excess of $700,000! There are some high-end bike *frames* which cost in excess of $5,000: these 2 pound frames would translate to an automobile costing in excess of *seven million dollars!* Obviously, the decision to invest in a high-end bicycle should not be taken lightly, and it's a decision that demands a wealth of information.

For the consumer looking to buy a high-end bicycle or bike frame, the options and the marketing rhetoric can seem overwhelming if not downright intimidating. And, unlike buying a high-end sports or luxury car, purchasing a bike frame can prove immensely challenging. On the one hand, bike frames are products about which many know very little; on the other hand, unlike purveyors of luxury cars, retailers of bike frames are rarely expert resources on the products they sell. More often than not, bike dealers are cohorts with major brands and manufacturers, and it is their job to meet quotas and sell as many bikes as they can.

Starting with one simple truth, we can make the purchase of your next high-end bicycle much simpler. That truth is: not every bike is right for every rider. Forgetting for a moment about the size of the bike, the consumer needs to take an even deeper look at how the bike is manufactured to ensure that they are getting a product they can enjoy, that will maximize their efficiency and performance, and that they can safely handle. This is true whether you are an elite or professional cyclist, or someone who is simply passionate about the craftsmanship of fine bicycles and who enjoys weekend outings on the bike.

Down to Basics

First, when choosing a new bicycle or, more specifically, a new bike frame, there are four crucial qualities that the *individual* consumer needs to address:

1. Frame stiffness (vertical, lateral and torsional)
2. Durability
3. Rider Strengths & Objectives
4. Custom geometry options

1. Frame Stiffness

Stiffness is an over-used and misunderstood term. Properly used, stiffness expresses a bike frame's ability to resist forces (stresses) applied against it. In use, forces are continually being applied against a bike frame, whether just from the weight of the rider (load), or from the stress a rider applies to a frame in the form of kinetic energy--especially during aggressive riding behavior like climbing, sprinting, cornering, and accelerating.

Vertical stresses (stresses from loads in the direction of gravity), lateral stresses (stresses resulting from load in a lateral direction) and torsional stresses (stresses resulting from twisting actions) are applied to the bike due to several factors: rider's weight, height, strength, requirements and geography at any given moment. Note that these dynamic factors are constantly changing due to speed and gravity. So, a cyclist accelerating hard from a stand still, standing up to sprint, cornering at high speed, or climbing a steep grade will generate an enormous amount of vertical, lateral and torsional stress on a frame.

A frame's ability to *properly* resist forces applied against it is one characteristic of a great frame, and a frame is appropriately stiff as it resists these forces. We say "appropriately stiff" because a great frame cannot be so stiff that the kinetic energy put into it by its rider is prevented from setting the bicycle into motion. In other words, a frame cannot be stiff as cement, but neither can it be as flexible as cardboard. The best frame manufacturers realize that there is a fine line between making a bike which is stiff enough to withstand the lateral and torsional stresses which are generated against it *and* the ability for a rider to effectively and efficiently ride. In short, the best frame manufacturers realize that a frame must be "dynamic," or "reactive," qualities which ensure that the frame responds to the energy put into it by its rider.

When a frame is overly resistant (too stiff) to forces applied against it, the frame is referred to as "dead." A dead frame saps energy from its rider, causing them to fatigue quickly and not ride to their full muscular or aerobic potential. On the other hand, a frame that is overly susceptible to forces applied against it is called "soft" or "whippy." This means that the frame is not strong enough to bear up to the stresses applied against it. In this case, the frame fatigues, leading to inefficient transfer of human power and resulting in the quick degeneration of the bike's structural integrity.

How Stiff Should *My* Bike Be?

This is not an altogether easy question to answer and discussing this with a frame expert is ideal, but we can get a good approximation by answering a few questions:

1. How much do you weigh?
2. How tall are you?
4. How long do you like to ride?
5. What are your riding objectives?

How you answer these questions will directly influence how stiff your bike should be. As a general rule, heavier riders should look for stiffer bikes. While "heavier" is a relative term, we tend to think of riders in excess of 185 pounds as heavier. Heavier does not necessarily mean "over weight;" many heavier riders are either tall, or muscular, and it's a function of their size that translates to an increase in weight. A stiffer bike will be able to withstand the forces a heavier rider will generate, both in terms of vertical and lateral stresses, but also in terms of torsional stresses derived from a larger rider's greater explosive power.

Taller riders (in excess of 6'0") will also generate greater stress on a frame from, at least, a lateral stress perspective. The reason for this is that the tubes used in the construction of a larger frame must be longer; to withstand the fulcrum effect, increasingly elongated tube sections must be reinforced, i.e., made stiffer. This can be done in various ways, e.g., butting the tubes, shaping the tubes, or reinforcing them with additional carbon.

If you prefer to do longer rides, especially more relaxed rides, there's no need to run out and purchase the stiffest race frame available. Depending on your size and height, a frame that is too stiff will require a greater amount of energy expenditure from its rider; conversely, a frame that is too soft will inefficiently transfer energy (specifically, power measured in Watts) from the rider to the frame. This, too, will cause the rider to fatigue more rapidly. As each rider has a limited amount of energy for any given ride, how that energy is consumed via transference into the bike frame is a critical factor in pacing, recovery, and efficiency.

Lastly, ask yourself what your riding objectives are. Are you a racer doing shorter events or longer road races? Are you a time trialist? Are you a triathlete, and if so, what distance events do you typically compete in? Or, are you a recreational rider

who enjoys great performance? The answers to these questions will have a significant bearing on not only how stiff your bike frame should be, but even from what materials your frame should be manufactured.

Taking into account your answers to *all* of the above questions will bear directly on how you should choose your frame. Weight and height, while important factors, cannot alone determine how stiff your frame should be. And, contrary to popular opinion, determining what kind of rider you are cannot alone determine how stiff your frame should. Granted, racers may want "stiff" frames, but stiff is relative to the individual, and *how* stiff depends on multifarious factors, including what types of events one races.

A great bike is one which balances and effectively utilizes the stiffness of the medium from which it is made (steel, aluminum, titanium, carbon, or some combination of these) with the power generated by its rider. These media, combined with tube diameters, tube shaping, additional properties in the alloys or additives to the carbon composite, are brought together in world class framesets to deliver optimized stiffness and flexibility to work in harmony with human anatomy.

2. Durability

A crucial question a consumer should ask about a frameset is, "How long is it going to last?" The answer to this question entails several things about the bike, including,

a. How well it is built
b. The quality of materials used in the construction of the frame
c. How well the frame stands up to the cyclist's ride style and anatomy
d. How well it is maintained
e. How often it is ridden

Most cyclists will not average more than a few thousand miles a year. On the other hand, top competitive cyclist may ride 20,000+ miles a year. The higher your average annual mileage, the shorter the life expectancy of your frameset: that's a simple maxim. Having said that, some mediums are better than others for longevity.

All things being equal, titanium is probably the most resilient medium out of which to build a frameset. Ti has incredible resilience against corrosion and, in most forms, provides ample flex without being too soft so that stresses on a properly

constructed frame will do minimal long-term damage. The downside is that Ti is a very difficult medium with which to work, and if it does get damaged, it is very difficult and costly to repair. Ti also provides more flex than many other media, and, while providing a comfortable and almost "cushy" ride, may not be an optimal medium for high-performance cycling or heavier riders. Butting, oversized tubing and shaping of Ti tubes is one way to maximize stiffness on Ti framesets, but a lot of larger and more powerful riders complain about Ti's "marshmallow" or "spongy" feel.

Contrary to almost the entire history of competitive cycling, these days steel is rarely used in high-end bike frame production. However, many small and custom manufacturers still use steel as the metal of choice out of respect for the tradition and art of frame making. Steel rides wonderfully as it can be "tuned" for stiffness and ride quality and it is intrinsically compliant. Steel is also extremely durable and provides good resistance to fatigue. Steel's greatest pitfall, however, is corrosion; for coastal regions or high rust zones, traditional steel alloys should be the last metal of choice. Modern steels, however, which use Niobium instead of Vanadium in the alloying process, are nearly as resistant to corrosion as Ti. The new Niobium steels, like Columbus' Spirit tube set, can be extruded to very thin tolerances (down to .37 mm!) and as such are very light, rivaling the weight of 7000 series aluminum tube sets. Traditional steel tends to be much heavier than alternative media, which means that the rider must exert more energy to ride a steel frame.

Aluminum alloys, or matrices, currently make up the greatest number of production road and mountain bikes. Aluminum is often chosen for its remarkable stiffness (depending on the grade, or series, of alloy used), its phenomenal reactivity, its ability to convey a "sense of the road" to its rider, and its incredible light weight. For the last 15 years, the majority of race bikes have been made from aluminum. Aluminum can be machined to very thin tolerances and yet maintain relative stiffness. The tradeoff is a lack of strength and increased brittleness when the tube walls become very thin. Higher fatigue tendencies occur in super lightweight aluminums (like Dedaccai's U2 tubeset), and the longevity of aluminum framesets is somewhat limited (circa 3 to 5 years with moderate usage). Aluminum is also susceptible to corrosion, but is better in high rust areas than steel.

Scandium is a relatively new medium in frame making. Scandium, like its close cousin, aluminum, is used in so-called "metal matrices" which incorporate aluminum, silicon, magnesium, and zinc in various quantities to strengthen the

base metal. Like aluminum, scandium comes in several series: 5000, 6000, and 7000 (see chart below). Unlike aluminum, scandium has a ride and "feel" a bit more like steel and, in principle, can be extruded more thinly than pure aluminum tubesets. On the Periodic Chart of elements, aluminum is number 13, whereas scandium is number 21 and this typically translates to greater vibration absorption, stiffness, and improved resistance to fatigue.

Alloy Series	Main Alloying Elements (Red denotes not used for frame making)
1000 series	Pure aluminum
2000 series	Aluminum and copper. (High strength aluminum used in the aerospace industry)
3000 series	Aluminum and manganese. (Low- to medium-strength alloys, examples of products using these alloys are beverage cans and refrigeration tubing)
4000 series	Aluminum and silicon. (Most alloys in this series are either welding or brazing filler materials)
5000 series	Aluminum and magnesium. (These alloys are used primarily for structural applications in sheet or plate metals - all 5000 series alloys are weldable) Examples include Columbus Altec tubing.
6000 series	Aluminum, magnesium and silicon. (These alloys are heat treatable and commonly used for extrusions, sheet and plate - all are weldable, but can be crack sensitive.) Examples include Easton 6000 and Columbus Airplane tubing.
7000 series	Aluminum and zinc. (These are high strength, hyper-light aerospace alloys that may have other alloying elements added.) Examples include Dedaccai U2, Columbus Starship, and Easton 7000.

Last on the list of frame making media is Carbon. Carbon is currently regarded as "the new steel." It is malleable so it can be stiff, reactive, springy, dead, or whippy, and can be almost infinitely shaped for maximum torsional and lateral stiffness. It is, of course, 100% resistant to corrosion, but repeated intense exposure to ultra-violent rays can be damaging to the carbon fiber cloth fibers.

Carbon also provides unparalleled vibration dampening which translates into reduced fatigue and greater life expectancy. Carbon *can be* extremely lightweight without being susceptible to cracking or "whippyness." Carbon is, however, susceptible to abrasions, and if crashed, chipped, or cut, can have its integrity severely diminished with only minimal opportunity for repair. This vulnerability can be ameliorated with Kevlar and Vectran wrapping of the exterior carbon fibers.

Like titanium, steel, and aluminum, there are various grades of carbon fiber. Perhaps even more than other mediums, the grade and quality of carbon used is an essential facet in the quality, durability, and ride-ability of the frame. For bike frame manufacturing, there are high modulus (HM) and intermediate modulus (IM) carbons, 12K, 3K, 1K and unidirectional carbon weaves, and lately there is CNT (carbon nano-technology). Each carbon has its own unique ride characteristics, and where the carbon tubes originate can have a significant impact on frame quality, ride quality, and frame mannerisms. It is important to note that not all carbon is alike. Even if the look of the carbon weave is the same, the quality of the supplier should be questioned to ensure longevity, safety, and proper ride qualities.

NOTE: in the cycling industry, it's a good estimate that at least 95% of the carbon frames on the market are mass-produced in Taiwan, China, North Africa, Romania, or Mexico. Very few carbon frames are made in the country in which the manufacturer resides. This is no exception even for some of the most recognizable and prestigious names in cycling. To the best of our knowledge, the only reputable carbon frame manufacturers building their products 100% in-house are Cyfac, Time, Serotta, Parlee, Calfee, and Guru. This is not to detract from or discredit other manufacturers who outsource their carbon frames; rather, it is a fact that is frequently obscured from the consumer.

Carbon framesets come in one of three varieties: lugged, monocoque, and miter-joint. Lugs on carbon bikes can be made of carbon, or any other metal matrix; monocoque frames are one-piece molded frames; and jointed bikes have their main tubes connected at angles which are then typically wrapped in more carbon or Kevlar. A frame can actually be a combination of any of these three processes, as well. If the frame comes from a reputable manufacturer, there is no real advantage to having one type of carbon frame over another. In principle, a genuine monocoque frame (which is extremely rare!) should have fewer flex points as there are no points of jointing tubes: the frame is quite literally made in one single mold. Monocoque frames can, in principle, also be lighter than lugged or

miter-jointed frames due to their lack of additional joining materials and bonding agents.

3. Rider Strengths & Objectives

Last, but not least, for a consumer's consideration in choosing a new frame is his or her riding style and strengths. There are basically three rider types who will be considering a performance bike:

a. Occasional recreational
b. Avid recreational
c. Racer

The occasional recreational rider will ride upwards of 500 to 1000 miles in one year. They are not aggressive riders, do not climb a lot of hills, and do not ride at high rates of speed. However, they may very much appreciate the qualities of fine riding bikes. Because they will not severely stress a bike, and will not ride their bikes in inclement weather, the best options for them will be Ti, steel, or full carbon bikes. The comfortable ride qualities of these frames override other considerations for performance and durability.

The avid recreational rider will ride anywhere from a couple thousand to 20,000+ miles in a year. They can be dedicated weekend riders, or even daily riders or commuters. In some cases, nothing may separate an avid recreational cyclist from a racer other than the fact that an avid recreational rider does not race. These riders can prove to be the most difficult group to satisfy. Racers and occasional recreational cyclists fit pretty definite patterns of ride behavior (and for racers, physiology) which makes choosing a bike with or for them relatively easy; avid recreationalists, on the other hand, come in an infinite range of possibilities, sizes, ride styles, and other requirements.

In determining the proper frame for an avid recreational rider, the following needs to be assessed:

--Do they enjoy climbing?
--Do they enjoy high speed rides and sprints?
--Do they have good core strength?
--How much do they weigh?
--Do they prefer longer or shorter rides?
--What are their riding goals?

--Where do they live?

If they enjoy climbing, they will be looking for a relatively lightweight bike. But, do not let lightness be the ultimate factor. Ultra-lightweight bikes may come at the price of sacrificing stiffness, durability and control of the bike, and, when push comes to shove, a bike which is slightly heavier but more reactive in the bottom bracket but stiffer in the chain- and seat-stays will always climb better, and it may behave better for smaller or very lightweight riders. For these riders, look to carbon, aluminum, or scandium framesets with reinforced bottom brackets and oversized down tubes.

It's important to note that lightweight production frames are not optimal in all conditions or for all riders. Smaller and petite riders (under 130 pounds) may find lightweight bikes difficult to maneuver, jittery, and susceptible to road vagaries. This should be kept in mind if you want to purchase your bike based on weight. Also, larger riders, or those in excess of 180 pounds, will also be challenged by lightweight production frames. A larger rider will simply over-burden a 15 pound bike in much the same way an adult would over-burden a small pony. Lightweight frames are meant to be agile, quick, sure-footed, and better for climbing, hence they are designed with more slight physiologies in mind. If you are more petite, or if you are larger, and are determined to ride a lightweight bike, you should consider having your frame custom manufactured by a reputable builder who knows how to custom tune carbon tubes or who uses size-specific, butted tubing in their build process. This will improve the frame's handling, reactivity, and durability.

High speed cruisers and those who enjoy long, casual rides will benefit from the comfort of Ti and steel. Nothing truly compares to the comfortable ride of Ti, with the possible exception of some high-end Niobium steel bikes. Moreover, to conserve energy stores of non-trained cyclists (like cruisers and occasional riders), the vibration absorbing properties of Ti and steel will slow down the rate of fatigue caused by high-frequency vibrations and rougher road surfaces.

4. Do I Need Custom Geometry?

It's hard to quantify how many people *need* custom geometry (custom frames). How many would like to have them is probably an easier question to answer. Only a very small percentage of the riding population actually needs a custom frame, and of that population we can identify two types of persons:

1. Those who need a 650 (smaller circumference wheel) bike
2. Those who need a custom 700 (standard circumference wheel) bike

While they may seem unfashionable, 650 bikes fill a much needed niche in the world of cycling. 650 bikes were popular in the early to mid-90s among triathletes but became extremely passé among road cyclists. In fact, for road riders, 650 bikes didn't become unfashionable for any reason other than the industry as a whole found it too costly to manufacture a bike that a smaller percentage of the population would choose to purchase. Moreover, with the advent of sloping top tubes and so-called compact geometries, it became easier (and cheaper and more profitable) for manufacturers to fit a greater number of riders on a smaller selection of frame sizes. As manufacturers stopped offering 650 frames, parts manufactures—in particular wheel manufacturers—cut back or stopped production of 650 wheels altogether.

All these economic considerations trended towards the fate of the 650 bike, and along with that fate came a stigma: the 650 bike became seen in some sense as inferior or for less-than-capable riders. Nothing could be further from the truth. In fact, in the 80s and early 90s, it wasn't at all uncommon to see even diminutive European professionals (like Chiappucci) riding a 650 bike.

So why ride a 650 bike? In principle (and as a matter of a very high-level explanation), smaller riders tend to be candidates for 650 frames. By smaller, we mean persons in stature under 5'5". Certainly, not every person 5'5" or under needs a 650 bike, and in fact we've seen persons 5'10" for whom a 650 was the best option.

A 650 bike enables two things for the rider whose physiology demands such frame qualities: a shorter top tube and a steeper head tube angle. One problem with 700 bikes for smaller riders (or even medium sized riders with very short torsos) is that the top tube can only be so short (circa 51 centimeters) before the rider will start to experience toe-overlap. Toe-overlap occurs when the axle of the front wheel is sufficiently close to the rider such that the rider's toe in the 3 o'clock position is susceptible of rubbing the front tire. With a top tube length in excess of ca. 51.5 centimeters, the possibility of toe-overlap is diminished, so long as the rider's physiology and the head tube angle of the frame are pretty standard. However, some manufacturers try to accommodate smaller riders by making their bikes with 51 cm top tubes or *shorter* by slacking the head tube angle, which effectively pushes the front wheel away from the rider. While intuitively this may

seem feasible, the result is a bike that handles like a chopper, not a high-performance machine. It also makes for bikes that are unstable at high speeds, which do not descend well, and are not agile.

As there are very few frame manufacturers building production 650 frames, *custom* 650 frames have become very popular. But why would one need a custom 700 frame?

Candidates for custom 700 frames are, like those for 650 frames, restricted to custom geometry because their physiologies cannot be accommodated by standard frame options. For instance, medium height to taller individuals with extremely short torsos may need a 650 bike with a top tube short enough to accommodate their upper body. Additionally, the head-tube height on a production 700 frame that otherwise has the right dimensions may be too short. In such cases, "stack height"—a series of carbon or aluminum spacers placed on the steer tube of the fork between the bottom of the stem and the top of the head tube—is an option to raise the front end. But, there are limits to this, typically 3 or at the very most 4 centimeters is acceptable.

Of course, other considerations may drive a consumer towards a custom frame. For instance, a tall but lanky rider may prefer a frame that is not as stiff as production options; conversely, a more petite rider may opt for a stiffer frame than is offered by production options. For professional athletes who focus on one discipline, e.g., the time trial, a custom geometry frame is sure to enhance the rider's performance by precisely positioning them for optimized muscle usage, critical prolonged power output, maximized oxygen intake and blood circulation, and reduced chance of joint damage.

Summary

In short, the decision to purchase a high-end bicycle frame should be a well-informed decision based on research and discussions with a knowledgeable professional. If you want your money's worth in addition to all the advantages of purchasing a truly high-end frame, you're probably not well suited buying a bike based on marketing, copying what the pros ride, or wanting what your neighbor rides. Each person is an entirely unique individual with physiological traits unlike anybody else: these traits absolutely must be taken into consideration when purchasing one of the world's premier and most technologically advanced bicycle frames.