VITTORIA WHITE PAPER

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BICYCLE INNER-TUBE MATERIALS AND APPLICATIONS

BUTYL VS. LATEX VS. TPU, AND HOW TO CHOOSE

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IN MODERN TIMES, THE VAST MAJORITY OF BICYCLES EMPLOY PNEUMATIC TYRES. THE REASONS ARE MANY, WITH PNEUMATIC TYRES OFFERING LOWER ROLLING RESISTANCE, INCREASED LEVELS OF COMFORT, GRIP, AND ADJUSTABILITY, WHEN COMPARED TO AIRLESS TYRE SYSTEMS OF THE PAST.

HOWEVER, WHILE THE BENEFITS OF PNEUMATIC TYRES ARE WELL PROVEN, THEIR METHOD OF HOLDING AIR IS STILL EVOLVING. WHILE MODERN TUBELESS SYSTEMS HAVE BECOME POPULAR, THE CLASSIC INNER-TUBE STILL HOLDS A PLACE IN ANY RIDER'S KIT. WITH INNER-TUBE OPTIONS RANGING FROM CLASSIC BUTYL RUBBER, LATEX, AND TPU, NEVER BEFORE HAS THERE SO MANY OPTIONS TO HELP RIDERS REACH THEIR PERSONAL GOALS.

IN THE PROCEEDING WHITE PAPER, WE REVIEW WHY SPECIFIC INNER-TUBE MATERIALS ARE CHOSEN, AND HOW THOSE MATERIALS PROVIDE PERFORMANCE AND UTILITY FOR RIDERS OF EVERY LEVEL.

INTRODUCTION

→ In the mid-1800s, the first examples of pedal driven bicycles were introduced to the market. Known commercially as "Velocipedes", which blends the Latin terms for "swift" and "foot", these early machines enabled riders to cover more ground, thanks to advancements in crank driven wheels.

However, eventually these Velocipedes came to be casually known as "bone shakers", as a result of the extremely uncomfortable ride the iron wrapped wooden wheels would return for the rider. Despite the efficiency of the machine, riders were desperate to find a way to improve the ride quality.

In 1868, advancements in solid rubber tyres provided a much improved ride, which eventually led to the first air-filled (pneumatic) bicycle tyres, around 1887, providing marked advantages in both speed and comfort. As then, riders of today enjoy the blend of simplicity and utility that an innertube system provides. Innertubes, or simply "tubes" as most enthusiasts refer to them, allow a user to fine tune the internal pressure of tyre, allowing for the desired amount of tyre deformation, based on load and use. In the event of a puncture, tubes are easy to change, can be patched if needed, and are fairly inexpensive to replace if necessary. For all of these reasons, innertubes have withstood the test of time, and are here to stay. As with any technical advancement, there are variations which provide the best performance for the intended use. Over the course of the following White Paper, we will dive deeper into the three main types of tubes available in today's market, as well as the strengths of each.

FIGURE 1. Velocipede, also known as "Bone Shaker"

FIGURE 2. Example of an innertube

CONTENTS

SECTION 1.
TUBELESS VS. TUBES

In recent times, tubeless tyre systems have gained attention and acceptance in performance cycling applications. As with almost any technology in cycling, there are pros and cons to either system, but as "going tubeless" has become a mainstream option, we will take this opportunity to highlight why even tubeless riders should keep an innertube handy. In terms of strengths, tubeless systems offer the ability to reduce rotating weight and friction by removing the tube from the system, while offering increased flat protection with the help of liquid sealant which sits inside the tubeless tyre. In the event of a puncture, the sealant fills the void, often times without the rider even knowing. However, while a tubeless system may sound convenient in use, the same cannot be said of repairing the system in the event of a failure. Unlike changing a simple tube, mending a tubeless system can often pose a challenge on the side of the road or trail. Tubeless tyres fit tighter than non-tubeless compatible versions, as the bead fitment is tasked with providing an air-tight seal. Assuming the user can remove the failed tubeless tyre, they will then have to care for the leaking liquid tyre sealant, which can be messy during a ride. Also, certain tubeless tyre and rim combination may require a compressor to initially seat the tyre on the rim, where a CO_2 cartridge or frame pump may not be effective. In addition, the sealant must be periodically changed, regardless of if the tyre is ever punctured.

FIGURE 3. An example of tubeless construction.

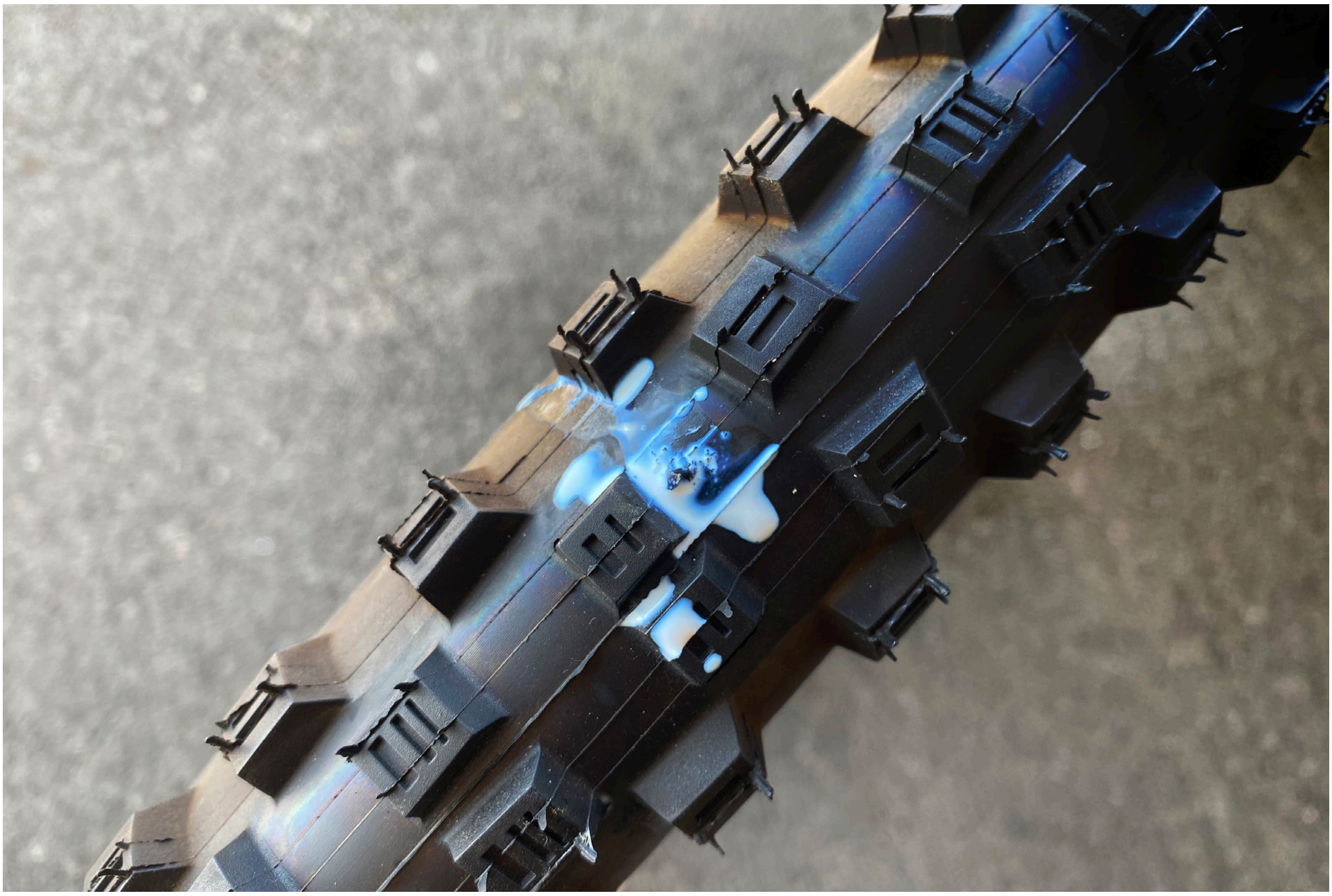

FIGURE 4. Unfixable tyre leaking sealant

Common failure points of a tubeless system include:

- Air-loss at the bead due to cornering load or from impact (aka "burping")
- Rim tape failure
- Expired sealant
- Large punctures which the sealant cannot fix

When a cyclist finds themselves with a failed tubeless system, most often, the solution is to install an innertube, proving once again, that this simple device still has a place, even in the most technical applications. In fact, almost universally, tubeless tyres can be used with an innertube, which led to the widely-used term “tubeless ready” (TLR for short), within the tyre and wheel industry. From a utility perspective, the sheer complexity may make a tubeless system not the best option for certain riders. For example, riders who are looking for a low maintenance option, which (barring punctures) can last almost indefinitely, will most likely be best served using a simple classic innertube. Examples of these applications could be city commuter bikes, or on eBikes where removing a wheel may be more complex. The good news is, if you are a rider who is after higher performance, but without the complexity of going tubeless, modern Latex and TPU performance innertubes offer notable performance benefits, when comparing a standard level Butyl rubber innertubes. In the next section, we will dive deeper into the common tube types, and applications for each.

SECTION 2.
TUBE TYPES: UNIQUE ELEMENTS AND APPLICATIONS

Much as tyre and wheel dimension have changed over time, today's choice in tube types also represents an evolution in utility and performance. At the base of it, all tubes are designed to be a form of elastic bladder, which fills and conforms to the inner volume of the tyre when inflated with air, via the use of an external valve. In today's market, the three most common type of innertubes are made from butyl rubber, latex, and thermoplastic polyurethane (TPU). While butyl and latex innertubes have been around for some time, TPU is a fairly recent addition to this line up. Through this section, we will break down the unique elements and applications of each option, and explore the evolutionary path that innertubes have taken, to increase performance, while maintaining their inherent simplicity.

FIGURE 5. TPU, Latex and Butyl tubes

BUTYL RUBBER INNER TUBES

The most common form of innertubes found today, are made from butyl rubber, which is a synthetic elastomer made by combining isobutylene and isoprene. This material is an excellent choice for innertubes, as it exhibits quite positive shock absorption characteristics for durability, while returning low moisture and gas permeability, to maintain internal pressure. These tubes are known for their classic black color, durability, and low cost, which provide an effective solution for a large population of users. For these reasons, butyl tubes are widely used commercially. For example, these are most likely the tubes found as original equipment on your new bike, or that a shop may use to repair a common flat tyre. In the event of a puncture, butyl tubes are easy to patch using an inexpensive patch kit, which is readily available at bike shops, as well as most hardware stores. These patches are applied using rubber cement, and have a similar elasticity to the tube itself, ensuring a positive repair. As butyl tubes are primarily designed for utility, they come in a wide variety of sizes and wall thicknesses, further broadening their useful range of application. There are "ultralight" versions of butyl tubes, which feature a thin wall, designed for minimizing weight, and maximizing flexibility. Conversely, there are also "thorn-proof" butyl tubes, which employ a thicker wall, designed to minimize punctures. Then, there are also the standard replacement tubes, which are a happy medium of all the above traits. A further variation also includes a "self-sealing" version, which is most commonly made from a standard butyl tube containing a liquid sealing agent, designed to automatically seal small holes when the sealant comes in contact with outside air. Whichever the purpose of the needed tube, there will be a butyl rubber option, and in most cases they will be readily available in your local bicycle shop. However, the simplicity and utility of using butyl rubber tubes does come with some limitations. First, butyl rubber is often not the lightest material for the intended purpose, and this weight is critical as it is rotating weight. In performance applications, this will likely to be a consideration, and is the reason that upgrading the system (via the use of performance tubes or by going tubeless) is so popular. Second, the ultralight versions of butyl tubes use a very thin wall thickness to compensate for weight, which then reduces their durability, whereby negating one of the key strengths of the material in the first place. Third, the level of elasticity of butyl rubber is slightly lower than with some other tube materials, which contribute to increased internal friction between the tube and the inside of the tyre, causing negative effects on rolling resistance in high performance use. Despite these relative potential high-performance limitations, the inherent utility of a standard butyl innertube is hard to beat for normal "everyday" use. If you are a city commuter, and you simply want a low cost option for transportation, or if you are a mountain biker and prefer a thicker thorn-proof tube, butyl rubber innertubes are likely your best option. For these reasons, along with the low cost, butyl rubber innertubes have earned commercial popularity.

LATEX INNER TUBES

The next material we will review is latex.

As with most trends in the bicycle industry, we simply need to look back in time, in order to see hints of the future. Latex is a natural rubber material, which the earliest innertubes were made from, and which is harvested from trees in liquid form. While the formulation contains other elements, fundamentally, latex can be said to be a naturally based material. In modern times, this same basic material has also been used to formulate new applications, such as high-performance tubular race tyres, which have won countless Olympic and Grand Tour races. Over this span of time, the same basic ingredient, latex, was at the heart of it all.

The intrinsic elastomeric properties of latex give it a performance advantage when used in a bicycle innertube. As the material allows for increased flex and stretch, the propensity for the tyre to deflect from road surface imperfections is reduced, resulting in an overall reduction of rolling resistance. Adding to allure, the natural flex of latex, and resulting increase in performance, does not come at the cost of weight, as latex innertubes are typically on par, if not lighter than the lightest ultralight butyl innertubes. In fact, this is partly due to the reduced all thickness that latex material allows in an innertube, which also contributes in a positive way to the flex described earlier.

In fact, the highly elastic trait of latex is also what makes it potentially less prone to punctures, as often times the material will stretch around the offending puncture item (nail, glass, thorn, etc.), rather than be pierced by it. However, this elasticity can make patching a latex

FIGURE 6. Ultralite, thorn-proof, self-sealing, standard tubes

FIGURE 7. Various latex tubes

FIGURE 8. Image of latex material stretching

elasticity can make patching a latex tube a bit more complex than a butyl tube, if you do get a puncture, as the tube will be more elastic than the patch in most cases. On the topic of air retention, perhaps the most familiar drawback to latex tubes is this very factor. While latex is effective at holding high air pressure for extended rides, users will see a more pronounced drop in pressure over the course of days, due to increased permeability when compared to a butyl innertube. However, as most performance-minded enthusiasts check their pressure before each rider anyway, the topping up of air pressure which latex tubes can necessitate only provide a minor hurdle. Simply put, latex tubes help the tyre to roll faster without many of the common tradeoffs, when compared to standard butyl tubes. Perhaps you are a performance minded rider on a budget, or maybe your favorite wheels are not tubeless ready. Either way, latex innertubes make then an easy and affordable upgrade for any performance minded rider.

TPU INNER TUBES

The third material we will discuss is TPU.

Compared to butyl and latex, TPU is a relatively new material in the innertube world, and recent years has come into favor with performance minded cyclist. The reasons are many, but chief among them is the impressive reduction in weight and rolling resistance, while at the same time increasing puncture protection. This pattern of ideal traits is common between all three tube types, however the use of TPU material allows for considerably increased levels of each, especially when compared to a standard butyl innertube. However, for TPU innertubes, this is merely the beginning of the story. TPU takes the conceptual momentum that latex exhibited by improving performance through elasticity, and brings it to new levels. In fact, the highly elastic TPU material raises performance to levels previously unreached with either butyl or latex, while returning a further reduction in punctures, all while also increasing air retention. It's also worth noting, that these metrics further increase the lower the pressure is used, as the tyre system as a whole experiences increased deformation. In other words, TPU not only improves upon the performance of latex, but also cures the main set-back, by providing a system which is less susceptible to lose air over long periods of time. Aside from performance and convenience, TPU innertubes also take a step toward improving the lifecycle effects of the product. While TPU is not natural in origin like latex, TPU innertubes have the ability to reduce environmental impact during manufacturing through a reduction of raw material, and increase sustainability at end-of-life as they can be recycled for other uses. This means that in practice, potentially less resources are required to produce each tube, and afterwards the TPU option allows for future advantages in the quest for sustainable innertube solutions, bringing the evolution of benefits full circle, and into the modern era. Similar to both butyl and latex tubes, TPU tubes can also be patched, but will require a specific patch kit to do so. All said, this is a relatively minor inconvenience if you are purchasing a patch kit anyway, but worth pointing out to be fair. When comparing the key use for each of the three materials, (butyl, latex, and TPU), all three deliver a means to hold air in a pneumatic tyre system. All three can be patched, and exhibit essentially the same level of difficulty when installing. The TPU option provides a clear benefit on all performance metrics, which returning little comparative downside. Yes, these benefits do come at a cost increase per tube, however the argument could be made that this is still a relatively low cost way to decrease rotating weight, and is a good value especially for the increase in performance when compared to other equipment upgrades. The dollar spent per Watt saved in rolling resistance is nearly impossible to beat when upgrading to TPU tubes, especially when compared to butyl alternatives. As bicycles have evolved into lighter and more efficient machines over time, TPU innertubes represent a similar trajectory with regard to pneumatic tyres. In the end, if you are a rider who seeks the ultimate in performance, and appreciates the simplicity and

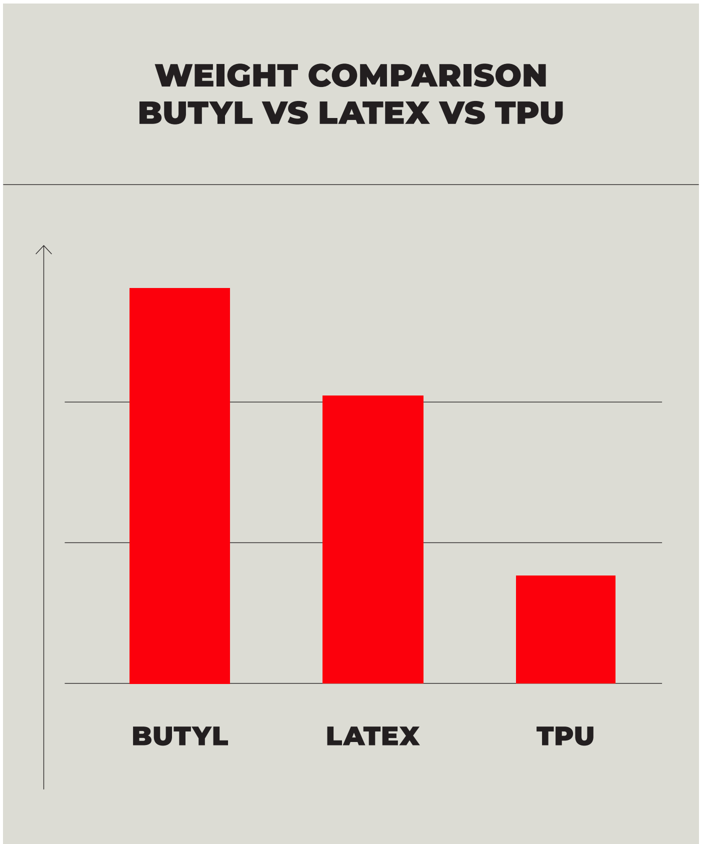

FIGURE 9. Weight comparison data between Butyl, Latex and TPU construction. Based on internal laboratory data on same size using same tyre.

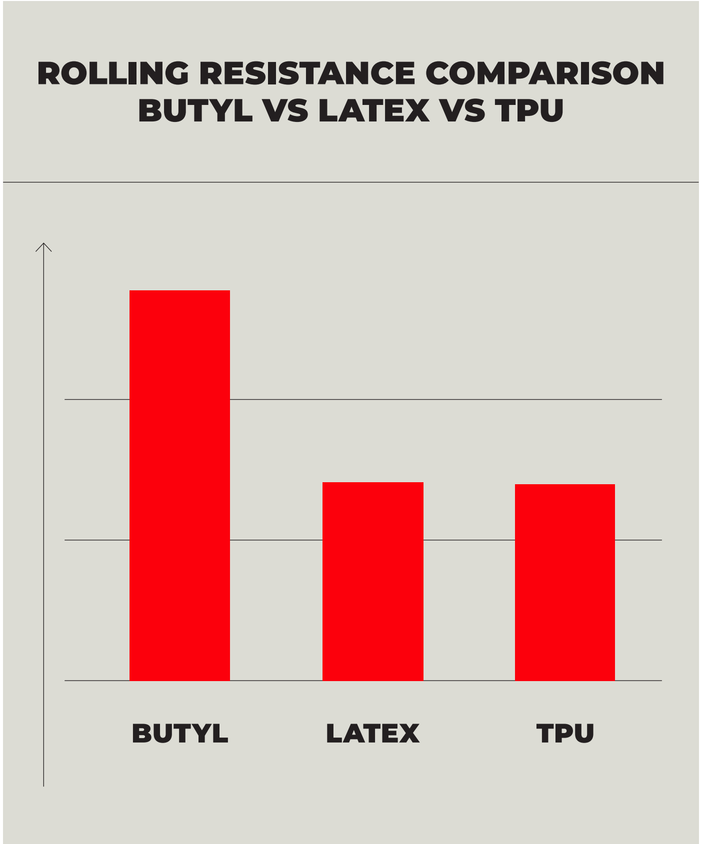

FIGURE 10. Rolling resistance comparison data between Butyl, Latex and TPU construction. Based on internal laboratory data on same size using same tyre.

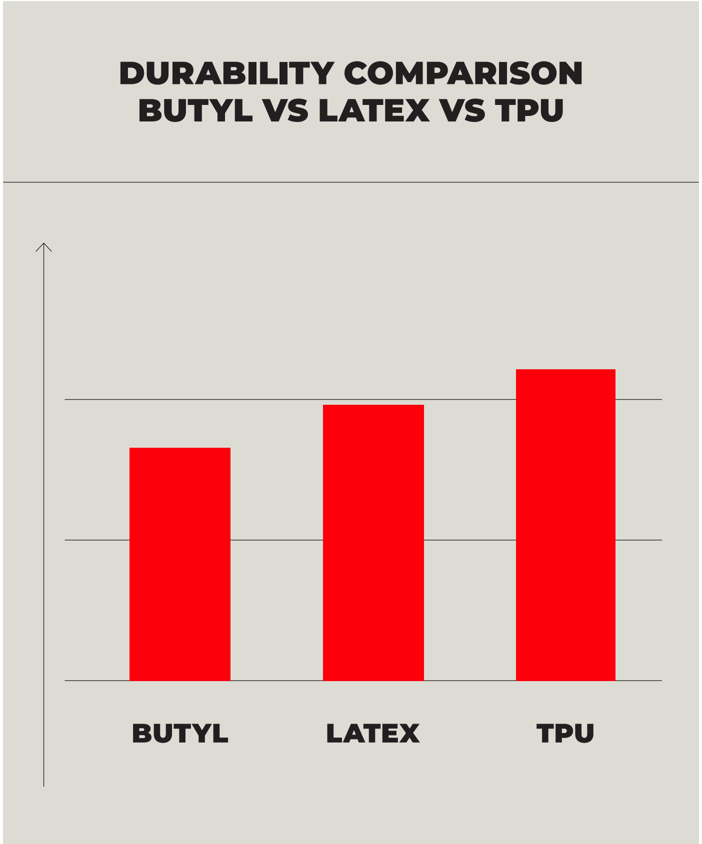

FIGURE 11. Durability comparison data between Butyl, Latex and TPU construction. Based on internal laboratory data on same size using same tyre.

hassle free installation and maintenance of a tube-type system, then TPU innertubes are likely the right fit for you. These traits make the use case for TPU tubes at the upper end of the performance range attractive across all disciplines. In road use, the reduction in rotating weight and rolling resistance will be of highest interest. For gravel and MTB use, the low weight and impressive durability will likely be the top factors. Even the most die-hard tubeless rider will still have a place for a TPU tube in their kit asa spare, due to this option taking up the smallest volume (and again, lowest weight) within their pack. Just as the bicycle itself represents a simple machine which provides engineers and designers a challenge to improve upon, so too does the inherent simplicity of the pneumatic bicycle innertube. The beauty of this product family is the range of materials available, which come from decades of use and evolution within various cycling disciplines. What began as a solution to hold air, evolved into a more durable and reliable form of itself, and eventually became faster and more sustainable in the process. Today's innertube market, which primarily consists of the three tube types we reviewed above, offers something for everyone. The price and durability of the butyl varieties, the balance of performance and value that latex provides, and the ultimate performance across all metrics that TPU offers, all ensure a match for the type of bike or terrain you ride. The three types of tubes reviewed here illustrate not only choices, but also represent evolution. As with most things in the bike world, evolution never sleeps. While it may seem almost impossible to further reduce weight and rolling resistance, it likely won't stop manufacturers from trying. Further advancements for inflation, air retention, and puncture resistance are all likely to be on the list as well, as the next generation of tubes are born. Taking the concept even further, perhaps we will one day reach a point where the air we breath is not the chosen medium for inflation.Through it all, the purpose of innertubes will always be the same; To increase the comfort, reliability, and performance of the simple machine.

AIR RETENTION COMPARISON BUTYL VS LATEX VS TPU

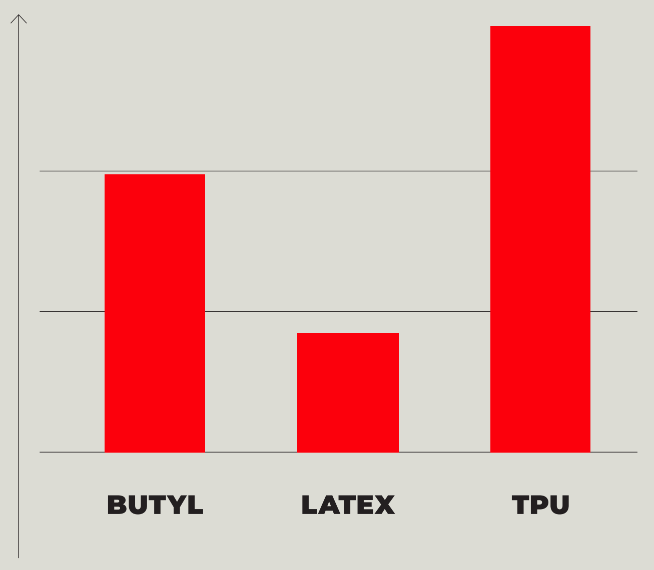

FIGURE 12. Air retention comparison data between Butyl, Latex and TPU construction. Based on internal laboratory data on same size using same tyre.

COST COMPARISON BUTYL VS LATEX VS TPU

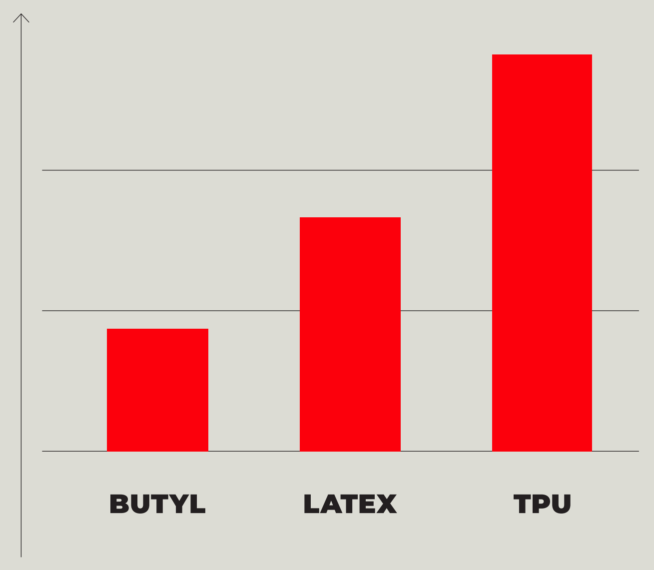

FIGURE 13. Cost comparison data between Butyl, Latex and TPU construction. Based on internal laboratory data on same size using same tyre.

COMPARING BUTYL RUBBER, LATEX AND TPU INNER TUBES

	BUTYL RUBBER	LATEX	TPU
SPEED	★★★	★★★★★	★★★★★
DURABILITY	★★	★★★	★★★★
LIGHTWEIGHT	★★	★★★	★★★★★

FIGURE 14. Comparison table showing Speed, Durability and Lightweight of the 3 tube types