Product Design S-drive

A new bike gearing system – a simple idea that may be difficult to implement.

Building a better bicycle gearbox has been the holy grail for many engineers, inventors, small companies, and major corporations since the bicycle became mainstream. The S-drive concept was such an idea (S for Skillion), conceived in 2016, a simple design that seemed to solve all the issues with current gearing systems for bicycles.

“Build a better mousetrap, and the world will beat a path to your door,” as the saying goes. The phrase was first ‘coined’ by American essayist and philosopher Ralph Waldo Emerson. Though not used until 1889, some years after his death, it has a straightforward meaning: “To create the next big thing, you need a greater idea.” This comment summarizes what underpins the idea of innovation. But these are simple things to utter but can be much more challenging to put into practice.

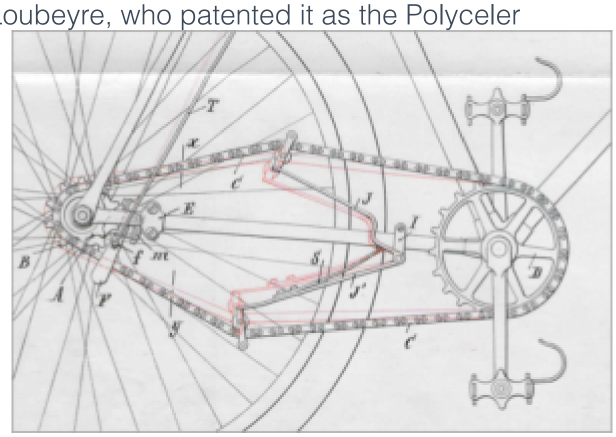
A popular board game Mouse Trap first released in 1963.

Like the board game, the Mouse Trap replaces a simple latch, bait, and trigger with an overly complex system. Replacing the derailleur with modern technology could be the biking equivalent of the Mouse Trap.

Bicycle gears are an essential part of the bicycle, allowing the rider to change pedaling resistance and speed. There are two main bicycle gears: derailleur gears and hub gears. Derailleur gears are the most common type and consist of cogs, or sprockets, attached to the bike frame. The rider shifts the chain between these cogs to change gears. Hub gears are less common and found on some older and specific new bikes. Hub gears are enclosed within the rear wheel hub, and the rider changes gears by shifting a lever on the handlebars. This page explains them well.

A derailleur consists of a cage that holds two pulleys connected to the bicycle's chain. The cage is attached to the bicycle's frame, and the pulleys are connected to the pedals. When pedaling, the chain passes through the cage and around the pulleys. The derailleur moves the cage back and forth so the chain can pass at different speeds. Pedaling faster or slower, depending on the terrain.

The derailleur was invented in 1895 by Frenchman Jean Loubeyre, who patented it as the Polyceler (multispeed).

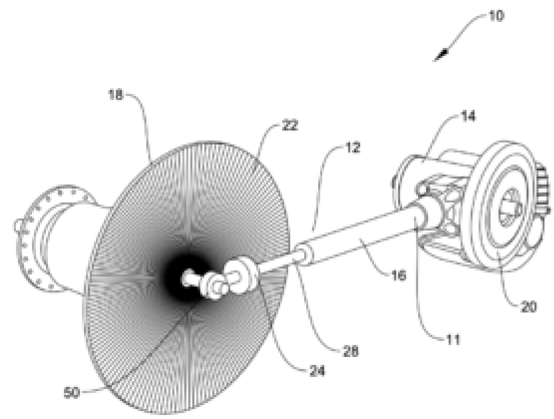


Electronic gear systems are becoming increasingly popular on bicycles as they offer several advantages over traditional mechanical approaches. Electronic gear shifters are very fast to change gears and make very accurate placement of the chain onto the sprocket reducing the chances of missing gear. Such systems offer slight advantages for professional or high-performing road riders but come to a significant price increase between 10 and 20 times more expensive, the cheapest over $400.

There are around 20 million bikes sold in the USA each year, and worldwide it could be 10x that. Also, the emergence of eBikes has surged sales resulting in high annual growth and a compound annual growth rate (CAGR) of 8.2% from 2022 data. The derailleur is the most popular gearing system for bikes as it offers low cost, lightweight, somewhat robust, somewhat easy to maintain, provides a wide range of gear ratios, is very familiar to many riders maintenance people, and is popular with sports teams.

Shimano and SRAM and the two leading manufacturers. They dominate the market, and many other manufacturers are run very distant 3rd places. For these reasons, an inventor could be attracted to this idea. With a better bike gearing system, using modern technology, and disrupting the two leading incumbents, any entrepreneur could see the opportunity to exit these two suppliers.

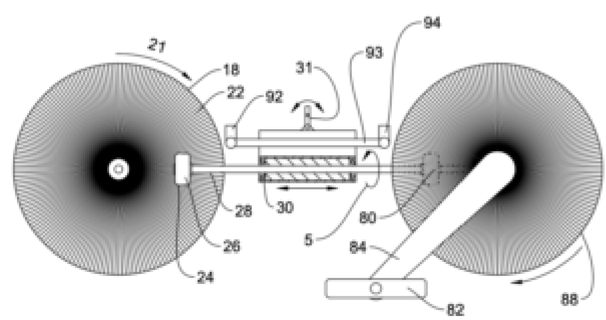
The S-drive concept was invented in 2016. It consists of a flat disk (18 in the diagram) fitted to the rear wheel and a Drive wheel (24) pressing on the Disk 90 degrees to it. Moving the wheel into the center or out to the rim would change the gear ratio. The advantages of this concept are that the gear change is entirely smooth, continuously variable, or sometimes called infinitely variable – as there is no theoretical limit to how small a change can be.



Also, the design allows for power shifting, where the torque of the pedals can be applied during the action; this is a significant benefit over the derailleur that requires the rider to reduce pressure but still rotate the pedals to engage the new gear.

The S-drive concept was further developed to include the following:

- a means of connecting the wheel to the rear wheel by use of a shaft drive
- the incorporation of the Bafang shaft drive and motor system
- a dynamic means of adjusting the pressure of the wheel to the Disk
- a dolly wheel to allow clamping of the wheel to a thin and lightweight disk
- the placement of a secondary disk on the rear wheel for increased gear range
- the use of a single shaft between the front and rear disks
- the inclusion of a steering system to assist the drive wheel in moving in and out without mechanical power
- the addition of a 3rd disk to offer an even more comprehensive gear range and
- the placement of 2 disks beside the rear wheel



One of the critical issues was that the drive wheel would need to be pressed firmly onto the Disk with enough force not to slip. Investigations revealed that a high-toughness rubber for the Drive Wheel and an Aluminium disk would provide enough friction to transmit the torque. A powerful rider can exert enormous force when standing on the pedal; 100nm is a familiar figure; by comparison, a 250cc motorcycle can produce 20Nm. Any slippage will impact the rider's performance and increase wear on the Drive wheel, possibly failing. Also, high force on the Drive wheel to limit slippage will cause high friction, losses, and wear. But when the rider has the bike in motion, the torque drops significantly to around 30Nm, and the high pressure is unnecessary.

To overcome this, a dynamic pressure system was envisaged. This senses the torque the rider produces and adjusts the pressure in real-time – the higher the torque, the higher the force. Torque-sensing was envisaged by a torque sensor either in the crank arms or inbuilt into the bottom bracket, or in the case of an eBike, the current drawn by the motor divided by the rpm. The sensing data was to pass to a computer that controls a motor that turns a jack-screw to adjust the pressure. The Drive wheel pressure, bike speed, wheel position, and other data were also fed to the computer to create a negative feedback loop. With these conceptual problems overcome, the following steps were to submit a patent and build a proof of concept (POC).

For simplicity, we used an existing eBike frame. As Skillion had been designing eBike, we used a Skillion eBike for the basis. We removed much of the rear bracket on the right-hand side and added a disk to the crank and another Disk to the rear wheel. For the POC, the shaft was fixed into position and fitted to turn the rear wheel forward correctly when the pedals rotated forward. To do this, the shaft had to be on the inside of the front Disk and outside of the rear Disk. Check out the video here.

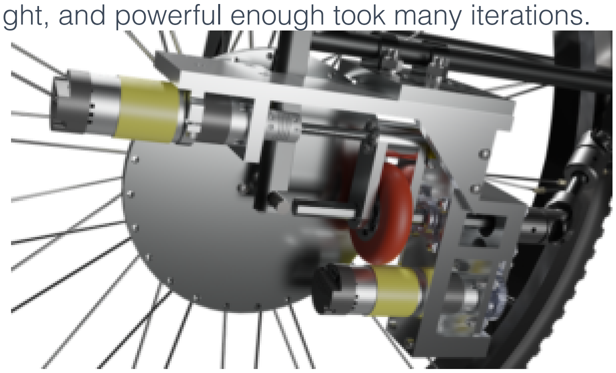
The next step is to work up a detailed design of the S-drive, specifying the exact parts and how they fit together onto a bike. This would flush out any problems with the concept before we build a working prototype.

Every entrepreneur knows the wows of trying to raise capital. Despite the POC and the patent pending, it was not until 2020 that progress was made. Not through raising capital but because of the COVID-19 pandemic.

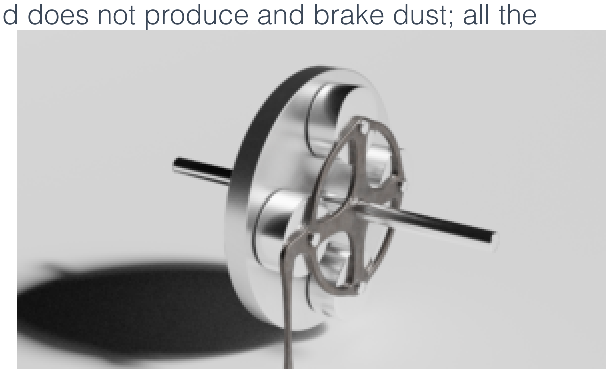
Heading into May 2020, we reached out to multiple universities offering internships. We were delighted to find some excellent students available, as their internships with other companies had been canceled. Over the summer months (May-August), we brought on four mechanical and one electronic engineering intern and were even supported by an aerospace engineer at Boeing. The S-drive concept was developed into a 3D CAD design in SolidWorks, along with first-order mechanical design engineering.

Again, the design was based around the Skillion eBike design with a 1000-watt motor and fat bike tires with a single rear disk. As we were using an eBike, power for the motors that control the position and pressure motor and the motor controller and computer would be drawn directly from the eBike battery. Designing the motor configuration to be compact, lightweight, and powerful enough took many iterations.

One major issue that kept coming up was the wear on the drive wheel. We had an intern figure out the best materials to try, but we could not predict how they would perform in real life. To solve this, we decided to build a test jig to test drive wheels. This became a side project. The test Jig consisted of an eBike motor from our fleet of eBikes and mounting jig to hold the derive Disk and Drive wheel, and the design of a braking system to apply load to the Disk. The chosen braking system was a disk (another disk) and electromagnets that induce eddy currents in the wheel based on the Current into these magnets. The higher the Current, the more resistance a Dynamometer has. The advantage of this system is that it is easy to control by passing in the controlling Current from a power supply and does not produce and brake dust; all the energy is dissipated as heat into the Disk.



The disk choice was steel, as this produced eddy currents with high resistance to magnetic fields, dissipating the energy as heat. It is due to the grainy nature of steel rather than more amorphous metal like aluminum.



Throughout the design, we kept our eye on the issue of wear on the Drive Wheel. We designed the S-drive with an easy means of swapping it out and created a business model around a subscription that included replacing Drive Wheels – turning an issue into an opportunity!

We were excited to complete the summer with a solid design, including the motors, materials, BOM, and test jig details. The plan was focused on making it work reliably. In many cases, we over-engineered parts so that they did not break under any circumstances, which led to a larger and heavier design than we had idealized. The next step is to build a working bench prototype of the system and test the drive wheels and disks in real life. The key outcome would be to determine such details as:

- the wear of the drive wheel
- speed and responsiveness of the system
- reducing size and weight
- finding weaknesses in the design
- creating the motor controllers and software
- production viability
- commercial viability

This required significant investment in skilled engineering resources as we headed into 2021, the opportunity to employ qualified interns dried up as many companies adjusted to COVID and hired remotely. The need for capital to move forward could not be solved, and Skillion focussed its resources on other areas, and we had some issues with the USPTO regarding the patent – see Case Study S-drive patent. It remains to be seen if the S-drive is a better mouse trap or more like the Mouse Trap game. We found a few risks that could not be mitigated without further development, including:

- wear and slippage of the drive wheel
- size and weight of the system drive and pressure motor
- the complexity and power requirements
- the difficulty fitting the design to other bikes
- the costs of the system
- the unclear need on the market for a CVT

These are not insurmountable but offer a StartUp significantly high risk, often too high for investment.

There are many examples where increased complexity can succeed. A Hybrid car is one example; it requires not only a gas engine and transmission but also an electric motor/generator and battery. The Toyota Prius has been on the market for many years and is popular in a niche market.

Another example is with eBikes, which require a motor, electronics, and battery, and the addition of weight and cost.

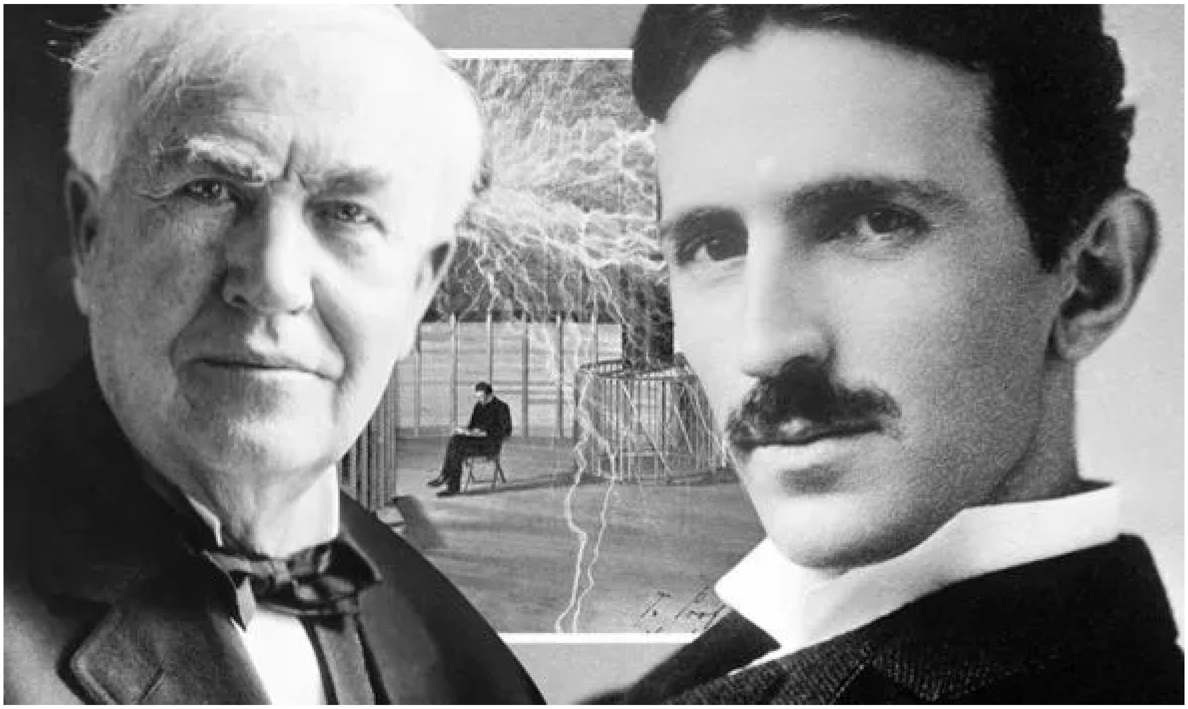
The key to both successes is that the benefit-to-cost ratio for the consumer is positive. With the Prius, the gas mileage is over double that of a regular car at 58 mpg versus 25 mpg (2004). Then there is the value of being environmentally conscious and an early adopter.

With eBikes, it is similar to the value of being more people who can ride and keep up, and you can go faster and further and have more fun!

There is no formula to bring an invention to success. Nichola Tesla was a brilliant engineer, scientist, and inventor who died impoverished. Thomas Edison was a prolific inventor who profited from his products enormously.

If there is one thing to learn, it is to constantly “keep your eyes on the prize,” figure out how the invention can be realized as a commercial success, and check it regularly as you work through conceptualization, proof of concept, design, and patent filing. We stopped the S-drive at this point due to a lack of funds. The next step would be a working prototype. The question is, should we?

(*) The numbers in the Case Study are illustrative only and not intended to be accurate.



Pete Cooper is a CEO and Program Manager with 20+ years of diverse experience as a Program Manager and eight years as a CEO. His career started as a design engineer and grew to the executive level. He has worked in various fields, including Software Development, AI/ML, Product Design Aviation, App development, RF design, Electronics Design, Mechanical Design, Telehealth, Semiconductors, IoT, and more.

Pete is a thought leader in applying Program Management methodology as a CEO. He has received recognition for overseeing complicated projects in various sectors. He holds an Engineering Degree, MBA, an Airline Pilot's Licence, and multiple Program Management Certifications, including FAIPM.

At Skillion, where Pete is the CEO, we pride ourselves on our ability to implement and educate Program Management woven into our customer projects. If you need more than a technical solution managed end to end, don't hesitate to contact us today to learn more.

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