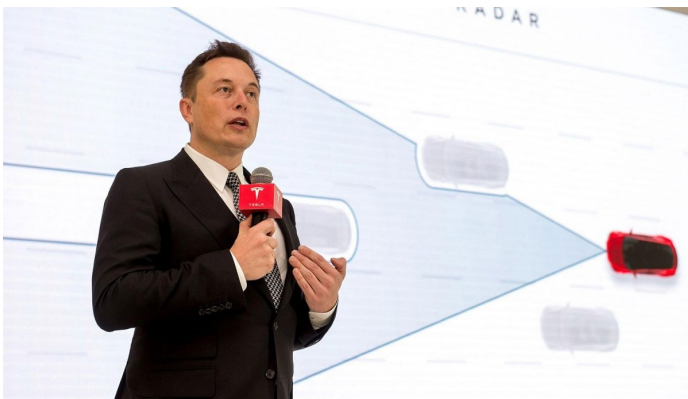


## Why Elon Musk is Throwing Money Down a Hole

### News Article



You have to dig Elon Musk. After taking on electric cars, solar power and rocket ships, Musk has lowered his sights—way down into the dirt. The visionary technologist has decided to inject a bit of innovation into that most prosaic of subjects: tunneling.

Musk wants to speed up an excruciatingly slow process to tunneling's equivalent of the speed of light—about a mile a week. That may sound underwhelming; even a garden snail can cover a mile in less than two days. But a reasonable day for the quaintly-named “tunnel boring machines,” the massive worm-like cylinders known as TBM's that chew their way through rock and dirt, would be 50 feet. The first phase of New York City's Second Avenue subway line, which opened on Jan. 1, 2017, is two miles long. They started digging in 2007.

Faster tunneling would make more practical the type of elaborate projects that Musk envisions—a series of criss-crossing tunnels to relieve congestion on the surface. (This criss-crossing already exists in certain major subway systems worldwide.) And make no

mistake, congestion is a real economic, not to mention psychological, downer. Congestion not only increases travel time and fuel costs and hence the cost of goods, but causes environmental damage, lowers productivity and ultimately GDP. In 2016, according to the traffic data firm INRIX, congestion cost U.S. drivers more than \$295 billion in direct and indirect costs.

“There's no technology that can beat the subway, it's more space efficient, and it can move through a dense corridor more quickly; it can go from a standing start to a pretty good speed in a matter of seconds,” notes Art Guzzetti of the American Public Transportation Association. Right now, there are 15 subway systems in the United States; surely more would be built if there were quicker, less expensive and more efficient ways to do so.

Last year, Los Angeles had the worst congestion in the world, according to INRIX, with the average Los Angeles driver spending 104 hours in congestion.

In fact, it was arguably Los Angeles' famous traffic jams that pushed Musk into the tunneling world. The city had the worst congestion in the world last year, according to INRIX, with each Los Angeles driver spending 104 hours in congestion.

“Traffic is driving me nuts. Am going to build a tunnel boring machine and just start digging,” Musk tweeted on Dec. 17, 2016. Three hours later, as if to set any skeptics straight, he sent a final tweet on the subject: “I am actually going to do this.”

**Tunnel engineers, a pragmatic lot**, are willing to suspend disbelief. “I would never dare to say he's talking nonsense, he's known for ambitious ideas,” says Werner Burger, the head of traffic engineering

## Why Elon Musk is Throwing Money Down a Hole

### News Article

at Herrenknecht, the German company that is the world's largest maker of TBMs.

Musk, one of the world's richest people, helped found PayPal, which he later sold. He runs Tesla Motors, the electric car company, and is chairman of the Tesla subsidiary, SolarCity, the country's largest solar energy services provider. He's also founder and chief executive of SpaceX, which makes reusable rockets and hopes one day to land on Mars. SpaceX is also designing the Hyperloop, Musk's futuristic plan to whisk people through vacuum-sealed tubes at 700 mph, something for which faster tunneling capacity could prove very useful.

A 2015 biography calls him a "modern alloy of Thomas Edison, Henry Ford, Howard Hughes and Steve Jobs."

Musk has so far dug a deep hole some 50 feet wide at SpaceX, headquarters in Hawthorne, California. But certain tunneling projects often have their own set of issues, some of which will never go away no matter how advanced the technology. Like say, a few billion dollars of real estate right over your head.

Anil Parikh was the MTA Capital Construction's senior VP and program executive for the Second Avenue subway project. On a great day he could move his 30-year-old TBM as much as 70 feet, although the average was much closer to 40 or 50 feet. But with some 110,000 people per square mile just above the surface, "we had to monitor every building, and take readings every minute for vibrations."

"There are so many factors in an urban environment," says Parikh, and not just the maze of cables and utilities stuffed underground. "We had to deal with dust concerns, and noise, and carting the muck away. We actually built almost five-story buildings where trucks went in, the doors were shut, and there was soundproofing on the inside of the structure. We called it a muck house, and it's where we loaded the trucks with muck," he explains. "We took pretty extreme measures to keep the community happy."

Parikh said the project's soft costs — the mitigation, the environmental work, the design — ate up 30 to 40 percent of the \$4.5 billion cost. "My contract for the TBM and launch box was just \$340 million," he says, referring to the hole in which the TBM is placed before it begins to tunnel.

To a tunneling profession used to the anonymity of the "out of sight, out of mind nature of the underground ... bringing in a proven innovator to something as complex as underground construction is a good thing," says Mike Mooney, whose actual title is the Grewcock Chair Professor in Tunneling at the Colorado School of Mines.

Not that Musk appears to have any idea how he plans to exponentially increase tunneling's so-called advance rate — just that it can be done.

"We're just going to figure out what it takes to improve tunneling speed by, I think, somewhere between 500 and 1,000 percent," he told a Hyperloop design competition at SpaceX headquarters on Jan. 29, adding, almost as an afterthought: "We have no idea what we're doing. I want to be clear about that."

## Why Elon Musk is Throwing Money Down a Hole

### News Article

**Mankind has been building tunnels for thousands of years**, but modern tunneling techniques probably date from the early 19th century, when the Anglo-French engineer Marc

Brunel patented his revolutionary tunneling shield to build his 1,300-foot-long tunnel 75 feet under the river Thames, still the world's oldest underwater tunnel.

Brunel's shield was essentially a movable support structure, a massive, horizontal frame of 36 cells, each cell the size of a worker, open in the back but closed in the front with movable boards. As each workman alternately removed his board and scraped the soil out in front of him, the shield kept the sides and top of the tunnel propped up until they could be lined with a thick layer of bricks.

Today, tunnel engineers have reached new technological heights (or lows): Herrenknecht engineers dug a road crossing more than 300 feet under the Bosphorus Strait to connect the European and Asian sides of Istanbul; the Gotthard Base Tunnel, which runs through the Swiss Alps, is the world's longest traffic tunnel at 35.5 miles. Both opened last year.

Yet despite advances in technology, computerization and automation, all of which have vastly improved the ability of TBM's to move through more and more difficult rock, there remains an elemental quality to the pun-ridden tunneling business. (Musk named his new enterprise "The Boring Company," he revealed in his December tweet. He announced the company's slogan in a second tweet a minute later: "Boring, it's what we do.")

All tunneling involves three basic things, explains Herbert Einstein, a professor of civil and environmental engineering at MIT: excavating the rock or soil, lining the hole with support material like precast concrete segments so it doesn't collapse, and getting rid of the dirt. "And the coordination of these three things is just as important as these three things themselves," he notes.

That's what's happening with a TBM, the custom-made behemoths that almost always sport female nicknames — a nod to Saint Barbara, the patron saint of tunnelers — and can cost up to \$70 million. Often longer than a football field, TBMs are boring increasingly larger cross sections, nearly 60 feet in diameter and counting, enough to stack two lanes of motor vehicles, one in each direction.

"Muck, shove, build and grout," explains Bryan Pennington, the deputy chief program management officer at LA Metro, using the profession's own terms of art for the TBM's four-stage process. "The TBM excavates what's in front of you, we call that 'muck.' Now you have a space where you can move the machine forward, and we call that 'shove,'" he says. Precast concrete is used to build the lining; grout goes behind the lining as a sealant.

**There are two ways for Musk to achieve** his five-to-tenfold increase in the tunneling advance rate. He could come up with an entirely new technology. TBM's, for example, says Mooney, the Colorado School of Mines tunneling professor, were themselves at least a tenfold improvement over earlier tunneling techniques, usually pick and shovel.

There's been research into using lasers to fracture rock, or microwaves to heat the rock to make it easier to fracture. Controlled atomic explosions have been suggested, but that never went anywhere — perhaps

## Why Elon Musk is Throwing Money Down a Hole

### News Article

for obvious reasons.

Or Musk could simply build a better TBM, continuing the myriad, small improvements TBM designers

have been making over the past few decades. “Already there’s been a high frequency of incremental change,” says Herrenknecht’s Burger. For example, cutting-head sizes have consistently increased, climbing from some 25 feet in diameter 15 to 20 years ago to almost 60 feet today, allowing traffic to travel on an upper and lower deck.

Intelligent learning, says Mooney, could help the thousands of sensors on a TBM, including those that control the force of the cutter-head on the soil, to ensure that TBMs always operate at maximum efficiency, maintaining a top speed almost all the time, and not just in short bursts.

A move to so-called continuous tunneling, so the TBM no longer has to stop in order to mount the concrete tunnel lining, but mounts the lining at the same time it’s moving forward, would also enhance tunneling speed. “If you could just maintain the best excavation rates we have today and solve continuous excavation, that’s a five-times increase right there,” Mooney says.

At the least, Musk should bring some much-needed research and development money into an industry that does very little R&D, mostly because there’s no incentive for anyone to pay for it. “I don’t build machines for testing,” says Burger, whose company provides about 40 percent of the TBMs used worldwide. “Every project is a real project.”

**Source: Politico Magazine**

Linea is a results focused Organisational Excellence consultancy with a track record of delivering sustained superior performance that meets and where possible exceeds client expectations.

We combine the credentials of a top tier firm with the depth of expertise and flexibility of a niche practice to support clients in addressing their most pressing organisational issues through the provision of highly professional, innovative, customer focussed solutions which deliver expected business benefits on time every time.

With an exceptional track record of delivering multi-million pound savings for prominent Public and Private Sector clients, our Organisational Excellence approach provides the skills and capability required to support clients to maximise efficiency, improve quality and reduce cost.

**News Articles Ends**