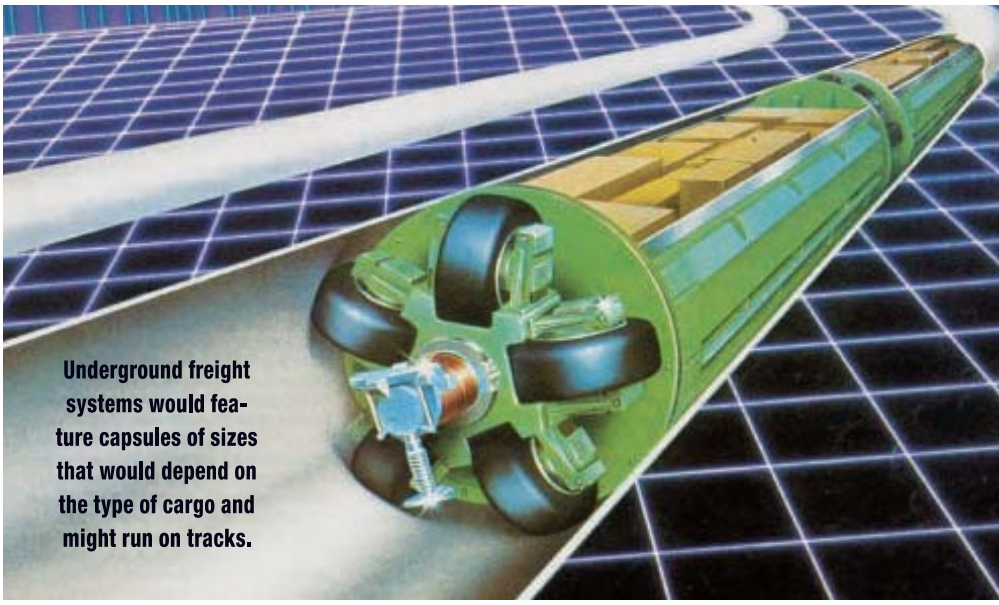
withstanding waves up to 10 m high and hundreds of meters wide.

Mizutani said that the technology has been designed to provide greater reliability and require less maintenance than is the case with other methods. He added that it has been tested extensively and has been shown to work properly in the face of diagonal currents and also to have the ability to withstand debris impacts.

Mizutani further explained that the technology has mainly been tested in straight-line configurations and that additional work will be needed so that it can be used along more complicated shorelines. He declined to predict when or where the system might be deployed, but he said that it has great potential to save money and lives. "We inspected the strength of the components, stability of the base, response against tsunamis, and capability of disaster prevention," he said. "Applications for straight coastal lines are already ready for construction, but in the future it must be improved for installation on curved coastal lines."

—DAVID HILL

MOHAMMAD NAJAFI, PH.D., P.E., F.ASCE/INTERNATIONAL SOCIETY FOR UNDERGROUND FREIGHT TRANSPORTATION



Underground freight systems would feature capsules of sizes that would depend on the type of cargo and might run on tracks.

# Underground Freight Tubes Could Alleviate Congestion on Roads

THE PNEUMATIC TUBE that carries your bank deposit from the drive-through to the teller is serving as the inspiration for an underground freight system that one day could transport tons of cargo without the use of roads or trucks. Researchers at the University of Texas at Arlington have received $247,000 in funding from the Texas Department of Transportation to study the technology, which could confer immense safety, environmental, and cost benefits.

A faculty research team launched the project in April. In addition to

feasibility and impact studies, the 12-month project will include planning and design work. The idea of underground freight shipping has been around for many decades but has been the subject of only limited research, says Mohammad Najafi, Ph.D., P.E., F.ASCE, a civil engineering professor at the University of Texas at Arlington and the leader of the research team. He explains that the time has come to develop the technology as a way of making freight delivery more efficient and lightening the load on increasingly congested and aging roadways.

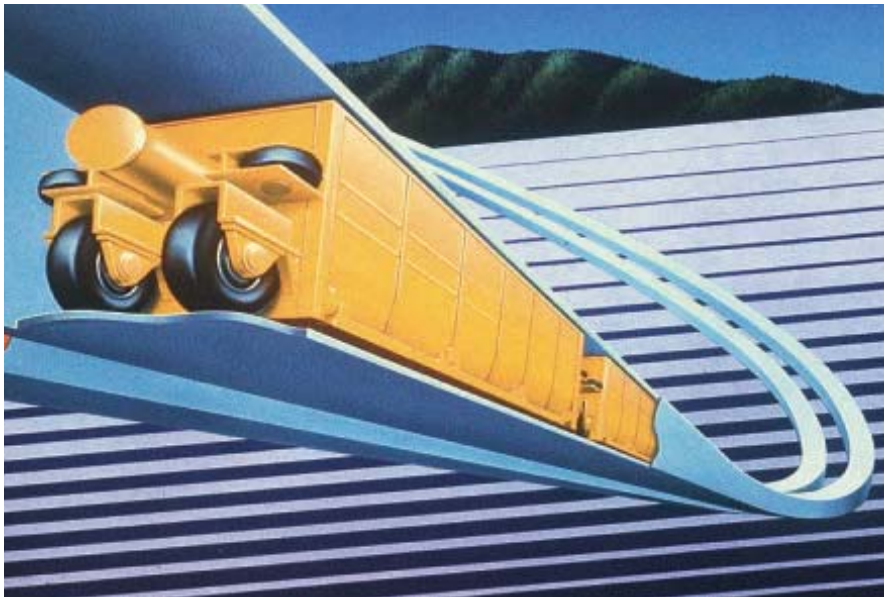
"If we can take some of the traffic off of highways, then they are going to be a lot safer and there will be less damage to bridges and roads," says Najafi, who is also the director of the university's Center for Underground Infrastructure Research and Education. "We would like to include underground freight transportation as part of existing modes of transportation."

Najafi's team includes Siamak Ardekani, Ph.D., P.E., M.ASCE, a civil engineering professor at the university, and Mohsen Shahandashti, Ph.D., A.M.ASCE, a senior lecturer in the civil engineering department. They call their project Integrating Underground Freight Transportation into Existing Intermodal Systems.

More than two-thirds of the commercial goods transported in the United States each year are carried by truck, according to the U.S. Department of Transportation. Total freight activity is expected to increase sharply in the coming decades as the population increases, the amount of goods moved rising from 19.7 billion tons annually in 2012 to 28.5 billion tons by 2040.

Because of their widespread use, commercial trucks are often listed as a leading cause of damage to pavement and roadways and as a major contributor to traffic congestion. Congestion cost the nation's trucking industry an estimated $9.2 billion in operating costs in 2013, according to the American Transportation Research Institute, of Alexandria, Virginia.

Najafi says that an underground freight system would be able to transport cargo in a time frame comparable to that provided by trucks or trains but with greater predictability and lower energy consumption. Goods would be packed into unmanned capsules and transported through underground tubes at a speed of about 45 mph.



Goods would be loaded on unmanned capsules that could reach speeds of 45 mph.

"The energy that this system is going to use is basically one-fourth that of a railroad and one-tenth that of trucks," he says. "And, of course, it doesn't pollute the air and is safer, more reliable, and more secure."

The researchers are considering numerous designs for the system, which they say could be powered pneumatically, electrically, or via an electromagnetic system. It could be built to varying sizes depending upon cargo loads, with small packages transported in tubes 3 ft square in cross section and 12 ft long, larger cargo in tubes 5 ft square in cross section and 12 ft long, and the largest freight in tubes 10 ft square in cross section and 20 ft long.

**Such systems would provide savings in the long run by reducing energy costs and increasing efficiency.**

Under the last scenario, Najafi envisions a subway-sized capsule that would have wheels, run along a track, and lend itself to loading or unloading at terminals that would also service trucks. Ideally, tunnels would be constructed in existing state rights-of-way beneath interstate highways and other major roads and would convey goods to airports, warehouses, and distribution centers.

The first phase of the project will include planning and design, as well as analyses of construction methods, costs, environmental ramifications, and financing methods.

The final two phases of the project could include laboratory testing of a model at the Center for Underground Infrastructure Research and Education's facility at the university.

Najafi contends that trenchless tunneling, propulsion, automation, and unmanned vehicle technologies are all sufficiently advanced to make the project a reality. He says the idea has been explored by researchers in Europe, China, Japan, Canada, and, to a lesser extent, the United States but that officials have typically balked at the cost of constructing a major tunnel network.

Najafi acknowledges that while underground freight systems would carry substantial initial costs, such systems would provide savings in the long run by reducing energy costs and increasing efficiency. He hopes to persuade skeptics that the technology can revolutionize the freight industry and help to address an untenable situation on the nation's highways. —DAVID HILL

MOHAMMAD NAJAFI, PH.D., P.E., F.ASCE/INTERNATIONAL SOCIETY FOR UNDERGROUND FREIGHT TRANSPORTATION