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TO: **BOARD OF DIRECTORS**

THROUGH: **PHILLIP A. WASHINGTON** PAW
CHIEF EXECUTIVE OFFICER

FROM: **JOSHUA SCHANK** JZS
CHIEF INNOVATION OFFICER

SUBJECT: **VIABILITY OF HYPERLOOP**

ISSUE

In the May Board meeting, Director Ara Najarian asked the Office of Extraordinary Innovation to research the viability of Hyperloop and to identify Metro's role in developing this technology. This memo provides a summary of the Hyperloop concept as detailed in Musk's whitepaper and recommends that based on the challenges associated with Hyperloop, Metro should stay appraised of Hyperloop technological developments but does not need to play an active role at this time. An overview of the overarching issues within this proposal and a discussion of the current stage of development can be found in Attachment A.

DISCUSSION

In recent years there has been growing interest in pneumatic tube transportation technology. This interest was in large part catalyzed by a white paper published by Tesla and SpaceX CEO Elon Musk in 2013, titled Hyperloop.[i] The paper was written to provide a technological alternative to the California High Speed Rail project. As a result of this publication, two United States based companies were created to develop and test the technology as described within Musk's white paper: U.S. Hyperloop Transportation Technologies and Hyperloop One (formerly Hyperloop Technologies).

The Hyperloop, as described in Musk's whitepaper, is a technological alternative to the high-speed rail technology that is currently being used for the California

high-speed rail project (CHSR). Musk's paper describes a low-pressure pneumatic tube with 28-person capsules that travel through the tube at a maximum of 760 miles per hour.

Musk estimates a $6 billion price tag for a Hyperloop between Los Angeles and San Francisco. This estimate assumes that Caltrans would provide free right-of-way alongside the Interstate 5 Highway and that the tube would be built on above ground pylons, thereby avoiding the need to purchase any land to build the project. The tube would be powered by solar panels on top of the tube; Musk projects that the Hyperloop can generate "far in excess the energy needed to operate."[ii]

According to the whitepaper, a one-way trip between the County of Los Angeles and the County of San Francisco would take 35 minutes. Capsules carrying 28-people would leave approximately every two minutes, but could leave every 30 seconds during rush hour. Based on the $6 billion price tag, projected carrying capacity, and projected operational costs, the whitepaper estimates that a ticket would cost $20 each way.

NEXT STEPS

While the Hyperloop concept and the new development emphasis that has been placed on passenger pneumatic tubes is exciting, it is likely that full technological development and implementation will be much more expensive than projected and will be subject to an unknown development time. The cost projections that are included within Musk's whitepaper are likely far lower than is realistic. Similar low cost estimates on new technologies have been seen before in the transportation industry for technologies such as Maglev or personal rapid transit.

Even if the technologies were implementation ready today, it is very likely that Hyperloop would face the same challenges that CHSR or any other new transportation system faces, which are access to right-of-way and sufficient capital for construction, operation, and maintenance of assets.

Informed by these challenges, it is recommended that Metro stay appraised of the technological developments associated with Hyperloop and similar technologies, but there is no apparent opportunity for Metro to invest time or resources in such an effort at this time

[i] https://www.tesla.com/blog/hyperloop
[ii] https://www.tesla.com/sites/default/files/blog_attachments/hyperloop_alpha3.pdf

Attachment A

Overarching Issues

Musk's proposed Hyperloop is very attractive due to its low projected cost and its high speeds. For comparison, the CHSR project currently has a $68.4 billion cost estimate and a projected travel time of 2 hours and 38 minutes between Los Angeles and San Francisco. However, many industry experts are skeptical about a number of assumptions within the proposal and are well aware of past experiences with new transportation technologies.

Right-of-Way

A challenge of high-speed rail projects, including the CHSR project, is obtaining right-of-way to construct and safely operate the service. Musk's proposal seeks to overcome that barrier by using preexisting state-owned right-of-way along the I-5 corridor. The proposal acknowledges that there would be a number of deviations from the I-5 right-of-way, but there is the expectation that due to the elevated nature of the tube, property owners, and specifically "farmers" are likely to consent to the provision of right-of-way for the Hyperloop.[i]

In part due to the private, for-profit nature of this proposed project, it is unlikely that Caltrans could provide free right-of-way on the I-5 corridor for construction. It is also unlikely that property owners will provide access to their land for free, or potentially at all. The CHSR has faced significant resistance from property owners to sell their land, which may contribute to construction delays.[ii]

Accessing rights-of-way becomes significantly more challenging in metropolitan areas. The currently proposed route would begin in the San Fernando Valley in Sylmar, about 26 miles from Union Station. It is unclear where exactly the Hyperloop station would be in the Bay Area.

Unrealistic Cost Projections

Hyperloop technology is likely viable from a technical perspective, it likely will not economically pencil out after the full capital, operating, and maintaining costs are calculated. This is similar to other transportation technologies such as Maglev high speed rail and personal rapid transit, which have also faced primarily economic barriers to implementation.

Within Musk's current cost projections, there is an assumption that the viaducts will cost $8 million per mile. According to researcher Alon Levy, unit costs for viaducts range from $50 million to $80 million per miles.[iii] This suggests that the $8 million per mile projection is extremely low and unrealistic.

Other costs that are not incorporated into the cost estimate are the development costs of prototyping and engineering.[iv] Industry experts including Dan Sperling, founding director of the Institute of Transportation Studies at the University of California, Davis, has commented that "there is no way the economics on that would ever work out."[v] Michael L. Anderson, an associate professor of agricultural and resource economics at the University of California, Berkeley believes that Musk is underestimating the costs "by at least a factor of 10 to 20."[vi]

Higher costs do not necessarily disqualify the technology from providing public benefit. It is possible that this technology could prove valuable, but because it is in the early stages of development it is difficult to identify whether the cost of development is worth the benefits, particularly in the context of unclear projected cost estimates.

Hyperloop Development

Two companies investing in the development of Hyperloop technology have spun off from the concepts in Musk's whitepaper. The following two sections provide an overview of their current progress.

U.S. Hyperloop Transportation Technologies

U.S. Hyperloop Transportation Technologies (HTT) is based in Los Angeles and is a crowd-funded venture. HTT is a collective of approximately 400 engineers from Boeing, SpaceX, and other firms, working in their free time and meeting weekly online in return for stock options.[vii] HTT is currently working on developing a passenger Hyperloop system in partnership with the Slovakian government.

In 2015, HTT announced co-development deals with Oerlikon Leybold Vacuum and the engineering design firm AECOM. Oerlikon is assigning six people to the development team. Each firm is receiving stock options in return for their assistance.[viii] UCLA's Architecture and Urban Design School's 2014-2015 Suprastudio worked with HTT to conceptually develop the large and small-scale issues of possible routes and user experience.[ix]

With the assistance of AECOM, HTT is building five-mile test project in Quay Valley between Los Angeles and San Francisco, in Kings County, as part of a larger eco-village development. The test track is intended to be ready for testing in 2017. HTT is "hoping investors will step up to finance a test track at Quay Valley."[x] The test track is estimated to cost $150 million. The current design has passenger vehicles travelling up to 160 miles per hour and empty vehicles travelling up to 760 miles per hour.[xi]

HTT is anticipated to start funding later in 2016[xii] and CEO Dirk Ahlborn has stated that, "I have almost no doubt that once we are finished, once we know how we are going to build and it makes economical sense, that we will get the funds".[xiii]

Hyperloop One

Hyperloop One (H1) is also a Los Angeles based company and is developing technologies for goods movement in addition to passenger movement. H1 was founded by venture capitalist Shervin Pishevar and former SpaceX engineer Brogan BamBrogan, both of whom have ties to Elon Musk. The CEO is Rob Lloyd, former president of Cisco. Other connections include Jim Messina, deputy chief of staff in the Obama White House between 2009 and 2011. Shervin Pishevar is estimated to be worth in the high hundred millions or low billions.[xiv] Recently, BamBrogan left H1 and sued the company for mismanagement; H1 has responded by suing BamBrogan.[xv]

The company has approximately 150 employees and is in the process of constructing a two-mile test track north of Las Vegas, NV. Their first test took place on a short test track. H1 intends to have a quarter-mile of track with tubes for testing by the end of 2016.

While one article noted that H1 "has the backing of some of the wealthiest people in the world, and could bankroll this itself,"[xvi] in May 2016, H1 obtained $80 million in Series B funding following an initial round of fundraising of $11 million.[xvii] The total now raised is $100 million and funding is coming from a number of new and existing investors.[1]

H1's partners include AECOM; Amberg Group, Swiss transportation infrastructure firm; Arup, a design firm; Bjarke Ingels Group/Big, an architecture firm in New York; Deutsche Bahn Engineering and Consulting, a consultancy for transportation in Berlin; KPMG, an auditing firm; and Systra, a Paris engineering consultancy.[xviii]

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[xv] https://www.wired.com/2016/07/hyperloop-one-fires-back-wild-lawsuit/
[xvi] Cooper, Daniel. (January 29, 2016). What you need to know about Hyperloop. *Engadget*. Retrieved June 15, 2016 from https://www.engadget.com/2016/01/29/what-you-need-to-know-about-hyperloop/.

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[1] Hyperloop One existing investors: Sherpa Ventures, 8VC, ZhenFund, and Caspian Venture Partners; New investors: 137 Ventures, Khosla Ventures, Fast Digital, Western Technology Investment (WTI), GE Ventures, and SNCF, the French National Rail Company (Takahashi).

[xvii] Takahashi, Dean. (May 10, 2016). Hyperloop Technologies raises $80 million for friction-free trains that go 760 mph. *Venture Beat*. Retrieved June 15, 2016 from http://venturebeat.com/2016/05/10/hyperloop-technologies-raises-80m-for-friction-free-trains-that-go-760-mph/.

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