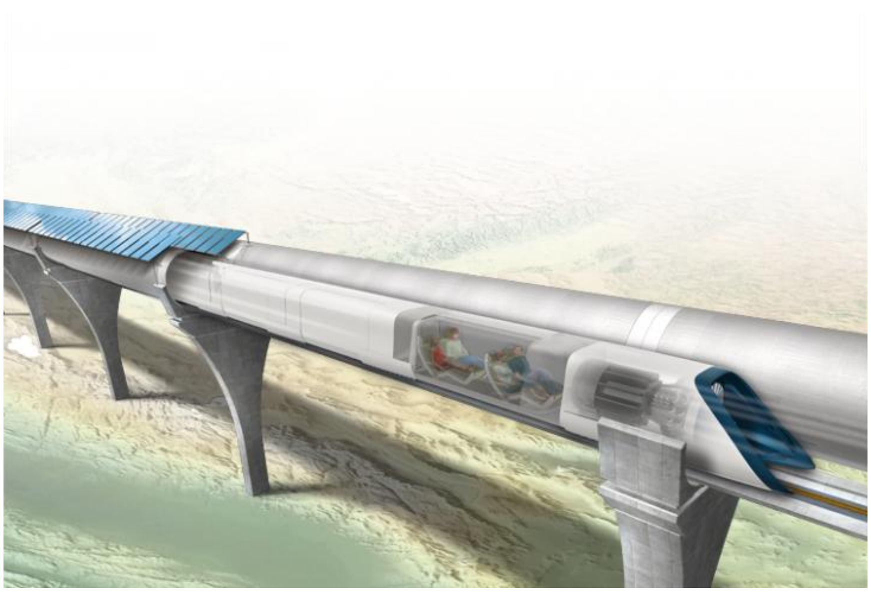
Report

Alternatives Analysis:
California High-Speed Rail and Hyperloop



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Executive Summary

This report is an attempt to analyze the plausibilities and realities of the California High-Speed Rail Project and the 'Hyperloop' project between Southern California and the Bay Area. Extreme care has been given to present unbiased, albeit judicious, critique along dimensions considered standard in the field of regional transportation planning. The five evaluative criteria used in this report are:

(1) Mobility (2) Accessibility (3) Safety
(4) Budget Impact (5) Planning Impact

not necessarily ranked in that order, as will be explained. Accordingly, these five criteria form the analytical sections of this report. Readers with cursory background knowledge about the California High-Speed Rail Project and the Hyperloop design plan are likely acutely aware of how differently they perform in some of these criteria—such as budget, for example. But, transportation projects are rarely chosen based on just one or two quality measurements. This report seeks to assess the complex tradeoffs between the two alternatives by comparing them on a level playing field.[1] The chart on page 3 summarizes this report's findings.

For particulars about the California High Speed Rail Project (CHSRP) in this report the author has made use of California High Speed Rail Authority (CHSRA)'s own published information on route location, station location, operational speed, operational frequency, etc. However, there are not as many equivalent details in the public domain about Hyperloop

alternatives. In order to make direct comparisons between the HSR project and the Hyperloop project in this report, the author has consulted the "Hyperloop Alpha" white paper released by Elon Musk and Tesla Motors in August 2013.[2] Musk and Tesla Motors have since distanced themselves from direct management of the Hyperloop project, instead entrusting it to other locally-based companies including Hyperloop Transportation Technologies and Hyperloop Tech both based in Los Angeles, but we can safely assume that the design efforts of these independent firms will strive for the logistical and spatial goals established by "Hyperloop Alpha."

SUMMARY OF REPORT FINDINGS		
Criterion	**California High-Speed Rail**	**Hyperloop**
Mobility	• Slated to operate at an average of 195 miles per hour (MPH) • Top speed: 220 MPH • But, only after all Phase I improvements are completed (ca. 2029?) • Not a new transportation modal technology, but well-tested	• Slated to operate at an average of about 600 MPH • Top speed: 760 MPH • Unknown when service could begin (cannot operate with a partially-completed track) • Still theoretical but innovative transportation modal technology
Accessibility	• Connects many urban areas, totaling ~19.5 million in population • Planned to connect with many local transit services • Intrinsically linked with regional rail network	• Connects SoCal and Bay Area urban areas, totaling ~15 million in pop. • Unclear whether intermediate stations are truly part of design • No plans currently to link stations to transit or regional rail
Safety	• Technology has potential to be extremely safe with good management • Could have zero grade crossings, but with expensive investments • May reduce 1.56 dangerous car crashes annually	• Still untested, but theoretically very safe • No grade crossings whatsoever (as part of design) • May reduce at least 0.481, but fewer than 1.56, dangerous car crashes annually
Budget Impact	• $68 billion cost, increase from $33 biillion	• Stated to cost $6 billion, likely to truly cost at least $28.3 billion
Planning Impact	• Unknown land use consequences • Unknown land value consequences at stations • Integrable with existing modes; multiple system uses • Incrementable by segments	• Unknown land value consequences at stations • Not integrable with existing modes • Not incrementable

Chart 1: Summary of the following sections in this report. All information derived from the sources cited in each respective section of this report. See the Conclusions & Recommendations section for further analysis.

Introduction

The linear distance between Los Angeles and San Francisco is 347 miles, and their shortest distance by road is 382 miles. 115 passenger flights, 37,890 cars and buses, and 10 passenger trains traverse the distance between Southern California and the Bay Area daily.[3 4 5] By 2030, the interregional transportation corridors of California are projected to carry 65% more travel demand (a total of 2.50 million trips daily).[6]

It is abundantly clear that to handle growth in regional trips, regional transportation capacity in California needs to increase. State policymakers should design ways of increasing efficient and rapid interregional transportation capacity, or otherwise they shall have to identify ways of reducing demand growth or ways to mitigate bottleneck costs (neither of these two latter options are wise planning decisions).

But, capacity expansion within the modes Californians traditionally use will be tremendously expensive. LAX airport is expected to reach its documented capacity threshold of 78.9 million passengers per year by the mid-2020s, and new runways will be needed at both LAX and SFO if new modes of transportation do not at least partially absorb the projected demand growth.[7] Travel on interstate highways in California is increasing at a rate five times the rate of highway capacity expansion.[8] The California Transportation Commission estimated in 2011 with its *Statewide Needs Assessment Report* that $183 billion in infrastructural improvements, including $79 billion for highways and $5 billion for airports, would be needed to meet the state's projected travel demand in 2020; the American Society of Civil Engineers estimated that California needs to spend $365 billion *more* than currently budgeted over the next 10 years to meet demand.[9] A multi-billion-dollar solution is needed, that much is clear. But, California has the unique opportunity to venture into more efficient, more foreign, and more futuristic modes of transportation to meet this looming demand surge.

In 2008, California voters passed Proposition 1A, a statewide referendum delegating tax dollars to the creation of a high-speed rail (HSR) corridor between San Francisco and Los Angeles via several cities in the Central Valley, with strict and ambitious guidelines for the final product coded into the very funding channels supporting the corridor. Although the cost of the project was initially estimated at $33 billion that year when the bonds were approved, that amount has notoriously ballooned to $67.6 billion according to the latest budget plans approved by the California High-Speed Rail Authority (CHSRA), and may be even greater for system expansions to Sacramento and San Diego.[10] The planning process of this rail corridor has been laden with controversy over budget management and right-of-way acquisition hurdles, and seven years later it is the subject of much politicizing.

In response to the technical challenges facing this project, billionaire innovator Elon Musk of Tesla Motors and Space X teamed with engineering associates to propose an entirely new form of transportation technology—a ‘hyperloop’—which according to their estimations could outperform the California High-Speed Rail Project (CHSRP) in several ways. The Hyperloop design calls for an extremely fast, short, windowless maglev train traversing the distance between Los Angeles and San Francisco in a pair of elevated, sealed tube with low air pressure. The white paper “Hyperloop Alpha” released by Musk and Tesla Motors in August 2013 alleges that a hyperloop system could be faster and safer, as well as quicker and cheaper to construct.[11]

The California High-Speed Rail Authority has been accruing public funds from state and federal sources for several years since, and now has around $20 billion in total probable funds by the year 2030 (see the “Budget Impact” section). Construction began with geotechnical tests in

2006 and grade separation construction in Fresno in January 2014; now several projects between Madera and Fresno are underway.[12] Currently community impact meetings are being conducted in several locations around the impacted areas of Los Angeles and Orange Counties, as part of the process of compiling environmental impact reports for all the as-yet non-contracted construction components. And, the land acquisition process is proceeding, at a very slow pace.[13]

In turn, development of the Hyperloop concept has mostly taken place behind closed doors. The two companies Hyperloop Transportation Technologies and Hyperloop Tech were founded in Los Angeles shortly after the release of "Hyperloop Alpha" and took control of the Hyperloop's conceptual and financial development, relying fully on private investment and crowdsourced funds rather than public grants. HTT, however, has a unique employment structure allowing it to minimize R&D costs: all of its 100 engineers work off-site, donating their free time between other unrelated projects to develop the technical concept in exchange for stock options.[14] HTT plans to open a five-mile hyperloop test track in Kern County next year costing at least $100 million, which the company announced in spring 2015 that they were hoping to finance by going public by the end of this year—which they have yet to do.[15] Engineers at both firms anticipate an arrival of an operational hyperloop prototype model still at least a decade away.[16]

Figure 1: The CHSRP and Hyperloop routes compared (map drawn by author). The HSR corridor follows SR-99 through Central Valley and the Hyperloop follows I-5. The Hyperloop route is thus more direct but meets fewer intermediate urban areas between Southern California and the Bay Area.

Mobility

Mobility and accessibility are the two central measurements of a region or a transportation mode's performance in moving passengers. Susan Hanson of Clark University defines mobility in "The Context of Urban Travel" as "the ability to move between different activity sites."[17] Samuel Staley, author of *Mobility First*, defines it as "moving people and goods from place-to-place."[18] According to Todd Litman of the Victoria Transport Policy Institute, mobility "assumes that any increase in travel mileage or speed benefits society."[19] Similarly, Sam Schwartz, the former New York City Department of Transportation chief engineer, allows mobility to simplify into “faster vehicle operating speed” in urban contexts.[20] In our comparison between high-speed rail and the Hyperloop/maglev, since both modes have essentially parallel routes through the Central Valley and have no grade crossings with other modes of traffic, mobility will simply concern operating speed and frequency between any two points on each system.

Proposition 1A dictated that state funds would support a “clean, efficient 220 MPH [miles per hour] transportation system”.[21] The proposition promised “travel from Los Angeles to San Francisco in about 2 ½ hours [2h 40m specifically]”.[22] Funds have passed to the California High Speed Rail Authority conditionally on the achievement of such a system. 220 MPH is an ambitious but not unattainable top speed for a high-speed rail service. This is the approximate high speed of the *AVE* high-speed rail service between Madrid and Barcelona which began service in 2008, as well as some Japanese Shinkansen bullet trains.[23] French TGV service in some areas of Champagne attain speeds above 300 MPH, although regular TGV service even along the fastest routes infrequently surpasses 300 MPH. But currently no HSR system in the world meets the sustained average speed and safety goals stipulated by Proposition 1A.[24] Moreover, the only currently operational high-speed service in the United States—the Amtrak Acela on the Northeast Corridor between Boston South Station and Washington Union Station—has a top speed of 150 MPH, which it maintains “for five or 10 minutes” between Westerly and Cranston, Rhode Island.[25] Its true average speed is around 80 MPH.

It is considerably doubtful whether or not the current California high-speed rail plan to traverse the entire 490-mile San Francisco – Los Angeles route in 2 hours and 40 minutes is feasible. This would require an average speed of 184 MPH. That average in turn implies a top attainable speed much higher than the envisioned 220 MPH, and little or no time allowed for acceleration, rest stops, or potential congestion at the endpoint stations, even CHSRA officers report.[26] Based on this report's calculations, traveling 490 miles in 2 2/3 hours while sustaining a top speed of 220 MPH would require accelerating to that top speed within 26 minutes of departing the first station, decelerating to 0 MPH within the last 26 minutes of the trip, and not stopping or slowing down once during the middle of the trip. Such acceleration is equivalent to 0.0064 *g* in lateral force. The CHSRA attempts to justify this in their business plans by calling for express trains skipping a majority of intermediate stations, and several more local trains serving all stations but on a 3+ hour schedule (see the chart on page 14 of this report).

Many wonder why the corridor chosen by the CHSRA does not follow a shorter and more intuitive route along I-5 and via Tejon Pass, which would only be about 380 miles long.[27] The fine text of Proposition 1A obligates the CHSRP to route through Fresno, Bakersfield, and Palmdale.[28] This adds a minimum of 90 miles to the length of a straight Los Angeles-Bay Area route along I-5. Consequently any California high-speed rail proposal attempting to tap Proposition 1A's ample funding reserves must achieve an average speed of at least 176 MPH and would face the same logistical constraints.

However, all things considered, even if we remain skeptical about taking these speed figures at face value we can still conclude that the high-speed rail corridor will vastly improve interregional mobility. In any respect, if the total journey duration from Los Angeles to San Francisco turns out to be in the general vicinity of 3 or 3 1/2 hours, many travelers may still shift their trips onto high-speed rail—consider: that is approximately the duration of a Pacific Surfliner journey from Los Angeles to San Diego, and around 250,000 passengers each year find that service a preferential alternative to driving.[29] The author of this report already commutes regularly between Los Angeles and Oakland on Amtrak's San Joaquin service, which is currently an 8-hour trip including a bus connection. In addition, the several slower local-stop trains

CHSRA plans to schedule on the corridor appear feasible and would boost interregional mobility (see page 14 of this report). Frequency of trains along the HSR corridor is planned to be an average of twelve 1,000-seat trains per hour in each direction for any given point on the system, according to the 2005 EIR/EIS.[30]

The Hyperloop, faster and more frequent, far surpasses the CHSRP in terms of mobility. According to "Hyperloop Alpha," an operational Hyperloop service would sustain a top speed of 760 MPH and an average of about 600 MPH.[31] The entire trip is advertised to be 35 minutes, meaning the top acceleration achieved is 0.5 *g*, or more than three times the acceleration of a normal subway train.[32] [33] The pods' average frequency would be around 1 per every 2 minutes each way, or 1 pod every 30 seconds during peak periods.[34] The Hyperloop also has a much more efficient route through the Central Valley—along the western Coastal Range edge of the valley where there are fewer large urban areas to complicate alignment routing. This is roughly 140 miles shorter in total length than the CHSRP corridor along the east valley edge. The fewer intermediate stops and the lack of significant curvature along its route allow hyperloop vehicles to speed across the landscape much faster—which they do by design anyway, since they run in a fully-grade-separated airtight tube with an internal air pressure of 0.015 psi (1/1000 of Earth's atmospheric pressure).[35] For any rational commuter looking to travel between central Los Angeles and San Francisco and not very choosy about leg room or ticket cost, a 35-minute hyperloop ride clearly beats out a 160-minute high-speed rail ride. And, since the estimated cost of the entire hyperloop project is lower than the $67.6 billion CHSRP, it would seem like a better infrastructure project in dollars-per-trip-hour. But—as the following sections of this report explain—the hyperloop and the CHSRP serve different regional trip networks, boast different maximum passenger capacities, and differ in political feasibility. Speed does not determine which project is ultimately a better choice for California, because mobility is only one of many criteria a project ought to be judged on.

Accessibility

Litman defines accessibility as the "ability to reach desired goods, services, activities, and destinations".[36] In some ways, we can consider accessibility a more crucial evaluative criteria than mobility, for if a system is *fast* but does not serve to link important nodes in a transportation network, people will not use it. Litman argues, "access is the ultimate goal of most transportation," and Susan Handy, director of the Sustainable Transportation Center at UC Davis, stated in her recent presentation at USC "The Future of Travel Demand" that "really the goal is about accessibility, getting people to where they need to be" as opposed to where their ride ends.[37 38] Hanson relates accessibility to the social value of a transportation system: "assessing the equity of a transportation system or a transportation policy requires that we consider who gains accessibility and who loses it as a result of how that system or policy is designed."[39] Although, it is worth observing Staley's warning that "achieving one doesn't necessarily imply giving up the other…mobility provides access, but it is not access. Also, accessibility *does not* provide mobility."[40] Mode choice is "driven by the desire for mobility and its ability to provide as a means for accessing the goods and services we want."

Several of the CHSRP's most important features orient entirely around the goal of accessibility. From its very inception the planning ideal of high-speed rail in California has envisioned a service connecting *multiple* urban areas, not simply Los Angeles and San Francisco. Phase I of the project alone includes stations in 12-15 sizeable California cities, and Phase II is projected to include stops in 10 more. Each additional station is a new departure and arrival point to/from every other point on the proposed system, increasing the system's overall usefulness exponentially. There are 12*11 = 132 distinct departure/arrival station combinations possible in Phase I. And, the potential service market of the CHSRP route connects a larger potential economic market:

- Population of Los Angeles and Orange Counties (2015): 13 million
- Pop. of San Francisco, Alameda, and San Mateo Counties (2015): 2 million
- Pop. served by Los Angeles – Bay Area route (2015): 15 million
- Pop. of Santa Clara, Merced, Fresno, Kings, Tulare, & Kern Counties (2015): 4.5 million
- Pop. served by all Phase I counties (2015): 19.5 million

If ridership proportionally reflects the population of regions containing stations (assuming so for especially fast and cheap modes of ground transportation such as HSR and Hyperloop), then the CHSRP's intermediate stations from Palmdale to San Jose add roughly 30% to its potential travel demand base.

Moreover, the CHSRP stations have been specifically designed to create linkages with local transportation network hubs.[41] In Los Angeles, the corridor will connect directly with Amtrak, Metrolink, and three Metro Rail lines at Union Station; and in San Francisco, the corridor will connect with Caltrain, MUNI, BART, and a new subway line at the Transbay Transit Center. Also, of course, each station will have ample parking for cars and buses—the director of parking at LA Metro is in fact working on the master plan for Union Station's CHSRP expansions.[42] Connectivity between the new HSR service and existing (+ planned) transportation modes increases riders' transportation options and makes riding HSR the rational choice for a larger market of riders.

Lastly, the CHSRP corridor serves rail access beyond passenger HSR service. The new route will close important gaps in the California rail network, including Los Angeles – Bakersfield and Inland Empire – San Diego.[43] The double-tracked route will more than triple the daily cargo capacity of the Union Pacific Tehachapi Pass rail line, which is the busiest single-track main line in the United States.[44] The new gap closings will vastly improve interurban movement of freight and passengers in California.

We can safely assume the Hyperloop project would also link with local transportation at its endpoints. But, this is not presented by the chief designers of the Hyperloop as a design priority, which it ought to be. The merit of the overall system becomes compromised if it is not designed with service interconnectivity in mind, because the real intent of constructing the Hyperloop versus the CHSRP is a pressing need to relieve California transportation infrastructure of present and future capacity stress. Moreover, perhaps the location of each Hyperloop station in Los Angeles and the Bay Area are chosen later in the planning phase and happen to link with local transit—the service would not be useful for passengers traveling from longer distances away from the station, and the Hyperloop has very few stations to compensate for that reality in contrast with the CHSRP. Neither the CHSRP nor the Hyperloop will be built in a vacuum. If getting to stations by other transportation methods is timely and costly and a hassle, the advertised duration and price of a one-way ride is not truly meaningful. Consider, for example, the practicality of funding intense research and development to shorten the duration of a Hyperloop trip from 45 to 35 minutes when taking transit *to* the departure station still might take 60-90 minutes; public money would be far more effectively spent improving local transit.

Lastly, no intermediate stations whatsoever in the Central Valley snubs millions of potential riders and significantly undercuts the project's long-term usefulness. According to the figures presented on the previous page, at least 4.5 million Central Valley residents served by the

CHSRP are not served by the Hyperloop. Although the alignment of the Hyperloop would trace major California transportation network gaps such as the Tejon Pass, it would not “close” these gaps since it would feature no local links with alternative modes enabling smooth transfer of passengers and freight. The Hyperloop thus undermines its own usefulness and longevity as an accessible transportation mode.

PEAK-HOUR SERVICE AND YEARLY CAPACITY										
Service	**California High-Speed Rail (Phase I)**								**Hyperloop**	**Standard Maglev***
Peak-Hour Pattern	1	2	3	4	5	6	7	8		
Freuquency (minutes)	120	60	120	30	30	120	40	40	1/2	15
	Run times from start in minutes									
San Francisco	0	0	0	0	0	0	0		0	0
Millbrae	-	-	13	13	-	-	13		-	-
Palo Alto	20	-	23	-	20	20	23		-	-
San Jose	34	30	38	34	34	34	38		-	-
Gilroy	51	-	55	-	51	-	55		-	-
Merced	-	-	-	-	-	-	89	0	-	-
Fresno	-	-	95	86	-	-		21	-	-
Bakersfield	-	-	133	124	-	-		59	-	-
Palmdale	-	-	-	-	147	139		92	-	-
Sylmar	-	-	-	171	-	159		112	-	-
Burbank	-	-	-	-	171	168		121	-	-
Los Angeles	170	161	188	185	181	177		130	35	82
Alleged capacity per year	**39.9 million****								**7.4 million**	**??**

Chart 2: Peak-hour schedules and the estimated yearly capacity of each system. *=Estimates for maglev speed were approximated by assuming the first and last 19.0 miles are traversed in 8 minutes (exactly as the operational Shanghai maglev train does currently), and then the remaining (350-19=331) miles in between are traversed at the top speed of 270 MPH. Peak operational frequency of 15 minutes on the Shanghai Maglev is also used here.[45] **= Lower bound estimate for yearly ridership on CHSRP at fares set to 77% of market airfare.

Safety

Safety cannot be left out of this discussion. There is insufficient information to compare the operational safety of high-speed rail and hyperloop systems, but it is possible to compare their effect on traffic fatalities. The CHSRP Phase I is projected to absorb 49.9 million vehicle-miles-traveled (VMT) annually from California roadways by 2030, and 0.0312 serious, severe, critical, or fatal accidents occur for every million VMT on California highways according to the California Highway Patrol.[46] Thus, about 1.56 dangerous car crashes might be prevented by the CHSRP every year. Since the Hyperloop has an annual capacity of 7.4 million passengers to the CHSRP's 24 million, it may absorb between 0.481 and 1.56 dangerous car crashes per year (likely higher on that range, since the average passenger on the Hyperloop would travel a longer distance than the average passenger on the CHSRP).[47] [48] Because of its higher ridership projections, the CHRSP has a larger effect on regional VMT and thus a larger positive safety impact.

It is also worth noting that high-speed rail can have a superb safety record, if built and managed appropriately. Japan Railways proudly boasts that their high-speed Shinkansen trains have maintained a systemwide zero-fatality rate since the system opened in 1964.[49] If the CHSRA can succeed in constructing an entirely grade-separated high-speed rail network with positive train control, both it and the Hyperloop have a feasible chance of achieving similar safety records.

Budget Impact

Constraining an infrastructural project to a certain sensible budget is a fundamental priority of transportation planning, as well as a political asset for planning management. Especially with projects as large as these, public officials would like to see that expenditures do not rise rapidly or inexplicably.

But, with both the CHSRP and the Hyperloop, the final quoted dollar amount is not truly the ultimate 'cost.' Given the tremendous amount of transportation funding the state of

California must allocate within the next few decades (estimated between $183 billion and $550 billion in total by independent sources), each of the two projects discussed here is merely an alternative to other multi-billion-dollar fixes the state would else be forced to complete.[50] The question is thus not cost but cost-effectiveness.

The projected cost of the Phase I + II CHSRP has risen from $33 billion when funding was first apportioned by Proposition 1A to $68 billion (with 10% overall contingency) in 2015.[51] The U.S. Government Accountability Office confirmed the validity of this number after an extensive bipartisan audit.[52] Only roughly $19.8 billion of project funding has been secured or assured through 2030, from sources as summarized:

- $9 billion from Proposition 1A (2008)[53]
- $3.3 billion from federal American Recovery and Reinvestment Act (2010)[54]
- $0.5 billion in state cap-and-trade funds per year. [55]

The CHSRA has already apportioned $6 billion in contracts for the Initial Operating Segment (IOS) between Merced and Bakersfield, and has $4.2 billion remaining of Proposition 1A funds to spend on the IOS as well as the $3.3 billion in federal funds which expire in 2017. One of the main reasons construction of the corridor first commenced in the Central Valley is the fact that the CHSRA could build the most mileage possible between Merced and Bakersfield with these time-sensitive initial funds.[56] This has led the CHSRA to prioritize corridor components which do not serve the most immediate needs of the current California rail network; components such as Palmdale – Bakersfield and Madera – Gilroy connect larger and more crucial gaps in the state rail network but, of course, these links traverse mountainous regions and would not be built in an efficient time frame given the same funding levels.

The CHSRA often reports that estimated construction costs are not actually increasing. The first three construction packages were all contracted below their initial estimated price. It is the contracts, such as Perini/Zachry/Parson Brinckerhoff's contract for Construction Package 1 between Madera and Fresno and Dragados/Flatiron/Shimmick's pending contract for Construction Package 2-3 between Fresno and Wasco, whose projected costs are increasing into their contingency reserves.[57] [58] [59] And, the CHSRA's $67.6 billion estimate is already indexed for inflation, so even with stagnation of construction during the land acquisition process costs are not naturally increasing.[60] Nevertheless, the estimated cost *has* nearly more than doubled from $33 billion in 2008. The reasons for this increase are difficult to accurately discern from the CHSRA's published documents, and also through the forest of politicized commentary on the web, but by researching the contract for Construction Project 1 it appears that unanticipated grade crossing expenditures are at least partly to blame.[61] CHSRA officials in interviews did not supply more specific information on the causes of these recent cost increases.[62]

Considering the $6 billion already apportioned to Central Valley segments as a *sunk cost*, the true cost of moving forward with the CHSRP as planned is $62 billion.

The total infrastructural cost of the Hyperloop between Los Angeles and San Francisco is stated by "Hyperloop Alpha" and many proponents to be $6 billion, or more roughly $7.5 billion with additions to carry freight in addition to passengers.[63] [64] With utmost respect to Elon Musk et al, this report's research has found that estimate simply unfeasible. Simple comparison shows this: $6.4 billion was the cost of replacing the eastern span of the San Francisco-Oakland Bay Bridge.[65] Surely, permitting some generality, a 350+ mile twin set of tubes on pylons over mountains and hundreds of urban roadways would cost several times more than a 2.2-mile suspension highway bridge over water. A proposed 40-mile maglev train line between Baltimore and Washington, D.C., is expected to cost at least $10 billion.[66] At that cost-per-mile ratio, the Los Angeles-San Francisco Hyperloop would cost at least $92.5 billion.

Consider the detailed chart on the next page comparing costs between all the project alternatives identified in this report. Even with quite generous comparison to the $67.6 billion CHSRP, the Hyperloop does not truly cost as cheaply as claimed by "Hyperloop Alpha" (and thus many Hyperloop proponents). Its ultimate price tag must at least be $28.3 billion, and that measurement is not even indexed into year-of-expenditure dollars. We can theorize that the reason the Hyperloop most likely would have an 11-digit total cost amount just like the CHSRP is that its foremost advantages over the latter—speed, frequency, ride experience, alignment, etc.—do not address its competitor's most important actual flaws. High land use, construction, and tunneling costs are just as strongly implied in the Hyperloop concept as in the high-speed rail concept.

What inspires greater concern is the lack of a detailed funding plan for the Hyperloop. Mostly, those involved with the Hyperloop plan on private investment carrying the project.[67] The project would be ineligible for Proposition 1A funds since it does not connect Bakersfield, Fresno, and Palmdale; it would also be difficult to market politically to potential public funding sources since the design neglects intermediate urban areas and is not based on thoroughly tested technology. Since the minimum cost of the Hyperloop is truly $28.3 billion or higher, and a half-built Hyperloop system is not useable at all, private investors will be unlikely to completely carry the cost of the project.

COSTS IN BILLIONS (2013 $)					
Expense	**CHSRP Initial Operating Segment***	**CHSRP Phase I***	**Author's Assumptions**	**Hyperloop (Realistic Lower Bound)**	**Hyperloop (Claimed)**
Track Structures and Track	$14.966	$24.431		$13.663	$3.800
➢ Civil	$1.538	$3.170	x 1/3	$1.057	$0
➢ Structures	$12.163	$19.292	x (tunnel mileage Hyperloop / tunnel mileage CHSRP) + Musk's estimate for pylons	$10.696	$3.150
➢ Track	$1.263	$1.967	=	$1.967	$0.650
Stations, Terminals, Intermodal	$0.630	$3.273	Musk's estimate	$0.400	$0.400
Support Facilities: yards, shops, buildings	$0.442	$0.779	x 1/3	$0.260	$0.210
Sitework, ROW, land	$4.881	$12.301	x 1/3	$4.100	$1.000
➢ Real Estate	$1.798	$3.989	Musk's estimate	$1.000	$1.000
Communications & Signaling	$0.529	$0.879	x 1/3	$0.293	$0
Electric Traction	$1.733	$2.879	=	$2.879	$0.140
Vehicles	$0.889	$3.276	Musk's estimate	$0.054	$0.054
Professional Services	$2.750	$5.251	=	$5.251	$0
Unallocated contingency (5%)	$0.955	$1.825	Same percentage (5%)	$1.348	$0.536
Total (in 2013 $)	**$27.775**	**$54.894**		**$28.305**	**$6.000**
Total (in Year of Expenditure $)	**$31.2**	**$67.6**	Same percentage (123%)	**$34.8??**	**??**

Chart 3: Total estimated costs of the CHSRP and the Hyperloop project. Estimates for the CHSRP are based on cost estimates published in the CHSRA 2014 Business Plan (which have not since been surpassed), and estimates for the Hyperloop are based on cost estimates published in "Hyperloop Alpha" plus some interpretation. *= CHSRA estimates include contingency margins of between 10% and 25% on every infrastructure-related cost estimate.

Planning Impact

Beyond servicing California's travel demand needs, a project should minimize negative land use consequences, maximize economic benefit, and improve existing transportation networks.

The CHSRP's largest effect on land use in California is the possibility of rapid urbanization in the Central Valley. The CHSRA views this as a regional benefit but many local community activists have expressed serious concerns that this may negatively impact Central Valley communities.[68] One primary concern is that downtown Fresno and Bakersfield will become commuter suburbs of Southern California and the Bay Area—urban sprawl in an entirely new dimension.[69] In France, new high-speed rail routes prompted significant population growth and development in nearby farmland. So far, the potential impact of the CHSRP upon agricultural land use in the Central Valley is still an open question. The Hyperloop, since it features no stations in the Central Valley, would cause no such land consumption.

But, in other aspects, the CHSRP has several positive planning consequences. Since it has so many alignment components, portions of the high-speed rail corridor can be built and integrated into the current rail network one-by-one. This makes the CHSRP both *incrementable* and *integrable*, which are significant practical advantages over the Hyperloop as an infrastructural project. More political bodies are likely to lend their support to progress on projects with localized and incrementable components, and the greater rail network of California will realize significant gains from gap closures (refer to the prior section, "Accessibility").

Conclusions & Recommendations

"*Given the typical shortfall of good evidence relative to theory and speculation when it comes to assessing a smart practice, there is a danger of unwarranted optimism. Indeed, a common criticism of the best practices research tradition is that it becomes excessively enthusiastic about* *what appear to be good ideas before their worth is sufficiently tested.*" ~Eugene Bardach

All the aforementioned criteria must be assessed in conjunction. Choosing the best regional infrastructure project for California is not simply a battle to see which is fastest, or the most direct, or the cheapest. It was also never the intention to plan a new transportation mode "better" than flying or driving, as the innovators behind the Hyperloop concept get wrong.[70] Mode split depends on trade-offs involving the convenience of different alternatives.[71] An ideal solution to the travel demand crisis facing California must implicate many more communities than Los Angeles and San Francisco, and must maximize regional connectivity for every dollar spent. An ideal solution should also include mechanisms of political feasibility, such as clear funding sources and support among key policymakers.

Despite its alignment, scheduling, and cost-efficiency flaws, the California High Speed Rail Project capitalizes on the features most needed in a new statewide transportation project: connectivity between California communities of different sizes, integrability with the existing transportation network, service incrementability over time, public funding feasibility, and passenger-capacity-per-dollar performance. While the Hyperloop clearly outperforms any high-speed rail train in terms of speed and possibly also in *total* cost, its design does not address these other critical facets. On the measure of capacity-per-dollar ratio alone, the California High Speed Rail Project is a better investment. However, there are ways to improve the CHSRP's budgetary performance so its greatest flaws are minimized.

Based on the evidence presented in this report, these following steps are recommended for future management of the CHSRP:

(1) Outstanding construction contracts for rail components in the Central Valley with already-secured funding should be awarded as soon as possible. Construction of Package

1 is already underway thanks to Tutor-Perini/Zachry/Parsons, but the contracts for Construction Packages 2-5 seem close to completion and ample state funding is already apportioned. The only major next step forward is formal approval. Having these outstanding contracts awarded to contractors would make the most use of funds the CHSRA has already obtained, some of which expire in 2017. In addition, these rail segments could integrate seamlessly one-by-one with existing San Joaquin Amtrak service once completed to offer an immediate service improvement.

Effectively, the cost of this step is $0.

(2) High-speed rail funds not tied to specific project components should in the future be allocated chiefly to projects that close major transportation gaps such as Bakersfield – Palmdale and Gilroy – Merced. Prioritizing the approval of Draft EIRs and EIRs for these segments, rather than progressing on all segments of the high-speed rail corridor simultaneously, would ensure that the CHSRP's most important foundations are built soonest when funding is still not a tremendous scarcity. This planning method stresses thinking about regional marginal benefits and risks first.

The cost of this step may be between $9.4 billion and $28.4 billion, minus the amount of funds already obtained by CHSRA.[72]

(3) These aforementioned gap closure segments should be designed for immediate interoperability with Amtrak services between Los Angeles and the Bay Area. Having slow, 8-hour one-seat service between those regions by 2020 that could be made gradually faster to 160-minute service by 2030 through other improvements is a strategic plan, because it would maximize statewide political approval and safeguard against the possibility of future funding shortages. After attainment of one-seat service is guaranteed,

other components of the CHSRP may be incrementally added to the statewide funding schedule.

The ultimate cost of this step may be up to $62 billion, minus the cost of step (2). But, the extent of this step is discretionary.

Endnotes

1. There has in fact been a "third" mode proposal for this same corridor worth mentioning: maglev train. But, in all sincerity, the routing and funding plans for an LA-SF maglev train are not yet concrete enough for in-depth planning analysis. Additionally, the maglev proposal is too remarkably similar to the Hyperloop to warrant substantive comparison—the Hyperloop itself is merely a shorter, faster maglev train in a vacuum tube. Nevertheless, on select criteria when the difference between hyperloop and maglev are considerable, this report is crafted to diffentiate between them and juxtapose different data.
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