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THE POTENTIAL SHORT-TERM IMPACT OF A HYPERLOOP SERVICE BETWEEN SAN FRANCISCO AND LOS ANGELES ON AIRPORT COMPETITION IN CALIFORNIA

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1. INTRODUCTION

In August 2013, the CEO of Tesla Motors and SpaceX, Elon Musk, released a design document for a new high-speed transportation concept: the Hyperloop (SpaceX, 2013). This new system would transport passengers and cargo within pressurized capsules that travel through tubes at similar or higher speeds than air travel. As an example, the proponents of this technology state that the Hyperloop can make a trip between Los Angeles and San Francisco in 35 minutes. Since the release of the original design concepts, many other routes have been considered by dedicated academic teams and consultancy companies, these include: Helsinki-Stockholm (KPMG, 2016), Paris-Amsterdam (Delft Hyerloop, 2016), or Toronto-Montreal (Transpod, 2016). Hyperloop One, the leading company in the development and commercialization of Hyperloop technology, is collaborating with local authorities to carry out feasibility studies for both passenger and cargo routes in the United Arab Emirates (BBC, 2016) and Russia (RT, 2016). At this early stage, however, the costs and timescales of these projects remain unclear.

Leaving aside the debate on the technological feasibility and marketability of the Hyperloop, which still has to overcome more than a few hurdles (DOT, 2016; MTR, 2016), this paper is focused on exploring the impact that such a disruptive innovation would hypothetically have on other transport modes, particularly on air travel. The existing literature on high-speed rail (HSR) is a good reference for the relevant economic and social effects that could apply to the Hyperloop. On top of the well-established impacts on regional population, employment, economic activity, and land values (Sands, 1993), Wang et al., (2016) notes that the "time-space compression" created by HSR can lead to improved regional accessibility and foster economic interactions between regions. Chen et al. (2016) also refers to the impacts of HSR on travel behaviour and household mobility, since improved employment and housing opportunities open the door for residential relocation for many families, particularly if there is a significant gap in salaries or home values between the connected regions (Clark and Davies, 1999).

In regards to the impact of HSR on air transport, Dobruszkes et al. (2014) provides a comprehensive review of studies on HSR-induced intermodal effects and concludes that a substitution effect between airlines and HSR in short-haul routes is generally observed (depending on travel speeds). However, there is also a potential for HSR to feed long-haul routes at hub airports where the frequency of long-haul services is high (also noted by Albalate et al., 2015). Taking this idea a step further, Takebayashi (2015) analysed the possibility of a leakage of demand between airports facilitated by air-rail connectivity. Using a theoretical model, the authors showed that, if a HSR connection was available between two airports of different sizes, a leakage in long-distance passenger demand towards the largest airport will occur. This seems a reasonable effect due to existence of a connectivity gap - not unlike the salary gap mentioned above -, in which the higher number of frequencies and destinations available at larger airports can incentivise air passengers in the vicinity of a small airport to travel to other regions when choosing a point of departure. Thus, improved HSR connectivity can help large airports to capture air-rail transfer passengers from the smaller airports' catchment areas. Empirical proof of these impacts was provided by Terpstra and Lijesen (2014), who analysed the Amsterdam-Brussels and Madrid-Barcelona HSR corridors, as well as the surrounding multi-airport regions. Their analysis is based on a framework that predicts that the catchment areas of airports with intermodal access expand after HSR is introduced. Using a multinomial logit (MNL) model based on access times, fares, and frequencies, they show that, in line with Takebayashi's prediction, the largest airports tend to benefit more from HSR connectivity by capturing demand from their competitors.

Terpstra and Lijesen's empirical estimates brought by the interaction between airports and HSR support the idea that airport catchment areas could be similarly affected by the introduction of the Hyperloop. However, the extent of this impact remains unclear, as the highly disruptive nature of this innovation makes past HSR impact studies not entirely comparable in terms of, for example, travel time savings. Therefore, the main contributions of this paper are to investigate how a hypothetical Hyperloop service between San Francisco and Los Angeles' metropolitan areas could affect the mobility of air passengers by means of air-Hyperloop connectivity, and to determine the implications in terms of airport competition and passenger leakage in long-distance domestic markets within a context of substantial connectivity gaps amongst the main commercial airports in California. In line with previous studies, our working hypothesis is that the largest airport (e.g. Los Angeles International - LAX) stands to benefit the most from a new Hyperloop service.

To that end, we carried out an exploratory analysis of airport accessibility and catchment areas with the goal to model the choice of departure airport by long-distance domestic airline passengers originating from California. In addition, we also estimated how that choice could be affected by the introduction of the aforementioned Hyperloop service. While the determination of airport catchment areas is usually based on passenger surveys that indicate the place of residence (or stay) of passengers and visitors (CAA, 2011), that approach is not easily scalable to cover the entire Californian airport network. Previous attempts to measure airport catchment areas in large regions, e.g. the European network, use simple geographical criteria, such as Maertens (2012) who defined a 100 km radius around the airports. In a more advanced approach, Lieshout et al. (2015) relied on econometric models based on fares, frequencies, and access times as drivers of passenger choice (Ashford and Bencheman, 1987; Harvey, 1987; Windle and Dresner, 2002; Pels et al., 2001, 2003; Hess and Polak, 2005, 2006). Lieshout et al. (2015) built on a methodology previously developed by Lieshout (2012) to calculate the market shares of Amsterdam Airport in surrounding municipalities based on a simplified Multinomial Logit (MNL) structure. The MNL model links the utility of each travel alternative available to the passenger to a function of route-specific frequencies and generalized travel costs that bundle access times, access costs, airfares, and flight times. This is the approach that we adapt to our case study. The methodology combines publicly available data on airline bookings for June 2015 (obtained from the US Department of Transportation), OAG flight schedules, and additional information on local population and transport accessibility that was compiled using Geographical Information Systems as well as airport-specific passenger surveys available online.

Our results can have implications on the economic impact assessments of Hyperloop services connecting major cities with separate airport systems, as the potential mobility of passengers in long-haul air transport markets should be added to the already established effects on household and work mobility. Quantifying the potential increase in short-term airport competition could help the affected parties in planning their long-term responses to the introduction of the new mode of transport. In particular, this paper can shed light on hidden weaknesses in airport offerings that could become actual threats for passenger leakage in the event of a sudden increase in competition.

The rest of this paper is structured as follows. Section 2 introduces our case study and also describes the methodology to determine airport catchment areas, including the required datasets. Section 3 presents the predicted catchment areas before and after the Hyperloop is introduced and discusses the implications for airports, airlines, and passengers. Finally, Section 4 summarizes the main findings of the paper.

2. DATA AND METHODOLOGY

2.1 Case study and datasets

Our case study focuses on long-distance domestic markets, comprising all itineraries that originate in California and end in another US state, flown during an average week of June 2015[1].

The reason to exclude short-distance travel (i.e. within California) is to focus on routes in which Hyperloop and air travel can act as complements, instead of substitutes, thus facilitating the identification of potential airport leakage effects as discussed in the previous section. The reason to exclude international travel from our study is simply the lack of reliable data on international airfares. The total demand consists of 991,432 airline bookings to 328 destinations obtained from the OAG Traffic Analyser. Figure 1 shows the distribution of California domestic air travel demand per destination state. Half of the passenger demand is concentrated in just nine states, these are (in decreasing order): Texas, Washington, New York, Nevada, Hawaii, Illinois, Florida, and Colorado.

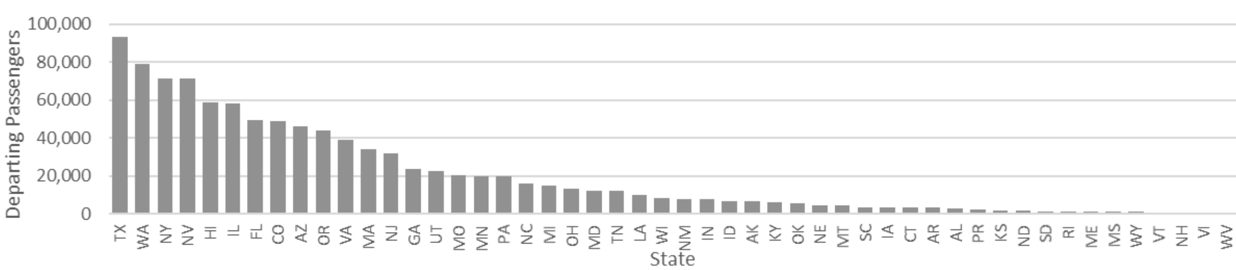

Figure 1. Distribution of California domestic air travel demand per destination state: avg. week June 2015
Sources: OAG Traffic Analyser

[1] The choice of an average week of June is linked to the availability of our flight schedules dataset, from which the air connectivity indicators required for the MNL model are calculated. Using data from sample months/weeks is common in this type of studies (previous papers on airport choice in the Bay Area employ travel surveys carried out in August and October 1995, e.g. Pels et al., 2003; Hess and Polak, 2006). While indeed schedules data is much easier to obtain than passenger surveys, note that we still depend on passenger surveys to calibrate the parameters in our model (See Table 4 below). The passenger surveys used in this paper were carried out in April and July 2015 (LAX) and May 2015 (SFO). Our June sample falls within that interval. Looking at DOT data, we found that the second quarter of the year is the one closest to the annual monthly average for Californian long-distance domestic markets. In spite of that, we recognize that potential seasonal distortions may limit the interpretation of our results. When data becomes available (both airline schedules and passenger surveys), this same study could be expanded to other months.

All these bookings originate from the twelve busiest airports in California, according to annual commercial passenger traffic in 2015 as reported by the US Federal Aviation Administration. All other airports in California serve primarily general aviation. Our sample airports are divided into two regions: Northern California and Southern California. The Northern cluster comprises the following five airports: San Francisco (SFO), Oakland (OAK), and San Jose (SJC) in the Bay Area, as well as Sacramento (SMF), and Fresno (FAT). The Southern cluster comprises the following seven airports: Los Angeles (LAX), Burbank (BUR), Long Beach (LGB), Santa Ana (SNA), and Ontario (ONT) in the Los Angeles Metropolitan Area, as well as Palm Springs (PSP) and San Diego (SAN). Furthermore, we also consider two hypothetical Hyperloop stations: Hyperloop North (HYN), which is located in downtown Oakland, and Hyperloop South (HYS), located in the San Fernando Valley as suggested by SpaceX (2013). Figure 2 shows the geographic location of our sample airports and Hyperloop stations.

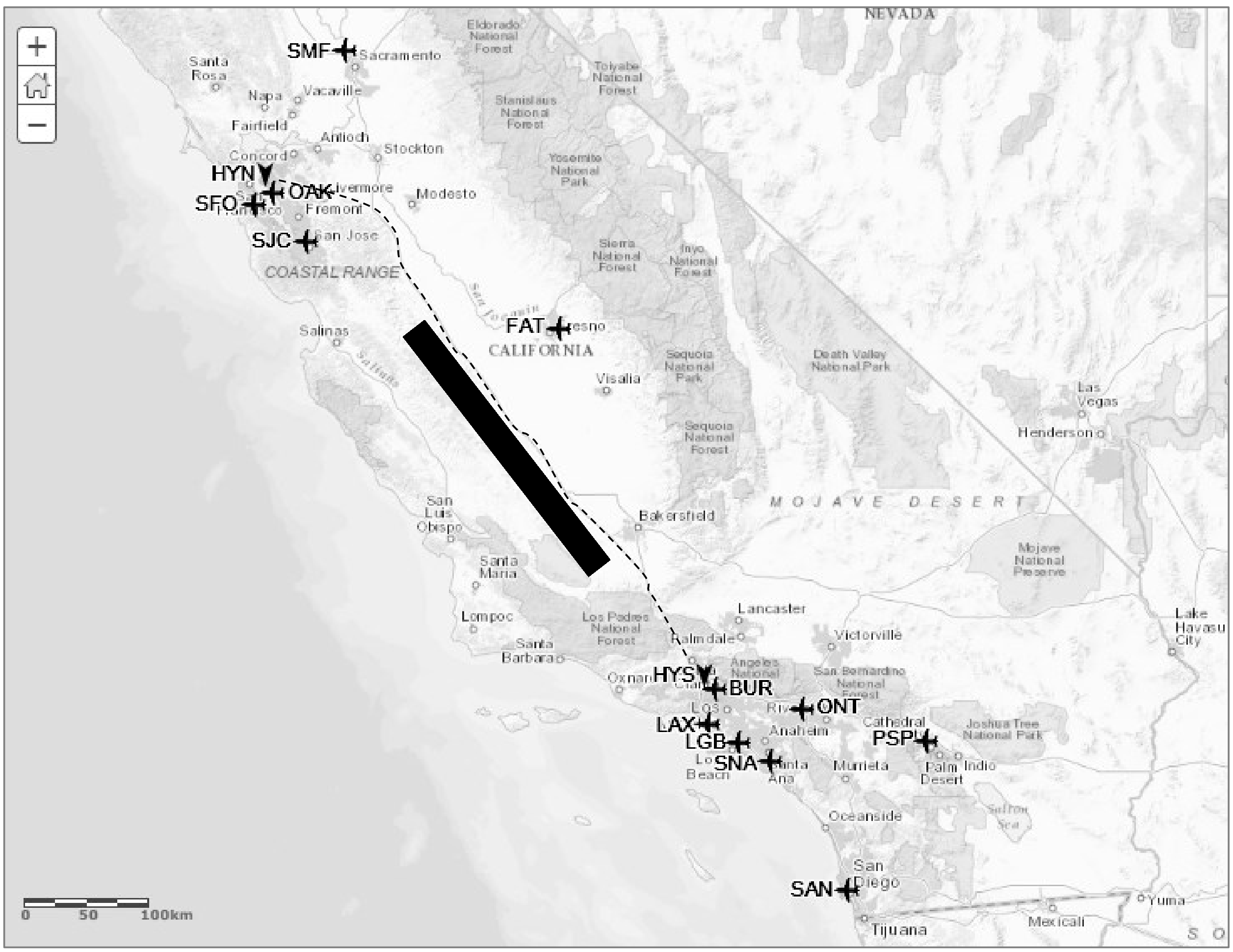

Figure 2. Sample airports and hypothetical Hyperloop stations
Sources: SpaceX (2013), Own elaboration.

Table 1 provides a few traffic and connectivity statistics for our sample airports in long-distance domestic markets. When evaluating the level of air travel connectivity offered by the different regions and airport systems, we consider both the combined total weekly frequencies (i.e., flight departures) as well as the number of different non-stop destinations served. For the purposes of this paper, the main message is that South California and Los Angeles have better overall long-distance air travel connectivity than North California and the San Francisco Bay Area, thus indicating the existence of a connectivity gap that supports the hypothesis that passenger leakage between North and South California could be observed if a high-speed Hyperloop service linked both regions. For example, all Bay Area airports combined serve 59 different non-stop destinations, while by flying non-stop from Los Angeles (even exclusively from LAX) one could reach up to 81 destinations in other US states. In addition, the total non-stop frequencies (weekly departures) is also 38% higher in Los Angeles than in the Bay Area which suggests increased choice for passengers in terms of departure times. In spite of that, a demand leakage in the opposite direction could also be observed between the airports that are closest to the hypothetical Hyperloop stations: OAK and BUR. Residents or visitors in the San Fernando Valley with improved accessibility to OAK may wish to travel North for an increased choice of frequencies and destinations, with respect to those provided at Burbank. These opposing connectivity gaps make difficult to predict what the net effect on passenger transfer flows could be.

Table 1. Overview of sample airports: average week June 2015

Airport	*Total departing passengers*	*Total frequencies*	*Non-stop destinations*
San Francisco (SFO)	224,326	2,760	51
Oakland (OAK)	64,044	766	32
San Jose (SJC)	58,556	718	22
Sacramento (SMF)	53,583	670	20
Fresno (FAT)	8,695	152	7
Total Bay Area	**346,926**	**4,244**	**59**
Total North	**409,204**	**5,066**	**59**
Los Angeles (LAX)	328,333	4,409	81
San Diego (SAN)	131,316	1,447	40
Santa Ana (SNA)	59,379	645	14
Ontario (ONT)	21,868	306	9
Burbank (BUR)	19,757	312	7
Long Beach (LGB)	16,211	187	9
Palm Springs (PSP)	5,274	120	9
Total Los Angeles metro	**445,548**	**5,859**	**81**
Total South	**582,138**	**7,426**	**81**

Sources: OAG Traffic Analyser, OAG Schedules Analyser.

These airports are assumed to serve passengers originating from the 1,541 zip-code areas located within three hours driving time from any of them. The selected zip-code areas have 37.7 million Californian residents (data for 2014), on top of an unaccounted number of visitors, the vast majority of them living or staying in places where more than one departure airport is available to commence their long-distance travel.

2.2 Baseline scenario

Passengers are assumed to make a choice of departure airport given their place of residence (or stay), ultimate destination, and other factors related to the attractiveness of each travel alternative. To the extent access time is a key driver of demand for a particular departure airport, modelling passenger choice will allow us to determine the catchment areas of each of our sample airports and how these catchment areas could be affected by the introduction of the Hyperloop. To that end, we adapt the simplified Multinomial Logit (MNL) structure proposed by Lieshout (2012) and Lieshout et al. (2015). U_{zod} denotes the log-utility (i.e., attractiveness) of a travel alternative involving origin airport o (also referred as departure airport), for passengers in the market from zip-code z to destination airport d. This is calculated as follows:

$$U_{zod} = \ln(freq_{od}) + \alpha(access\ cost_{zo} + flight\ cost_{od})$$

$$access\ cost_{zo} = av.cost\ (car_{zo}, rental_{zo}, taxi_{zo}, shared_{zo}, courtesy_{zo}, transit_{zo}) + av.time\ (car_{zo}, rental_{zo}, taxi_{zo}, shared_{zo}, courtesy_{zo}, transit_{zo}) \cdot surface\ VTT$$

$$flight\ cost_{od} = avg.fare_{od} + [NST_{od} + \mu_{od} \cdot (\rho_{CT} \cdot CT_{od} + \rho_{TT} \cdot TT_{od})] \cdot airVTT$$

The log-utility of a given travel alternative depends on two principal factors: 1) the log of the weekly frequency of air transport services between the set origin and destination airports ($freq_{od}$), and 2) the generalized travel costs for the passengers, which include both the cost of access from the place of residence or stay to the departure airport ($access\ cost_{zo}$) and the cost of flying ($flight\ cost_{od}$). Despite the well-established heterogeneity in preferences according to travel purpose (e.g. Hess and Polak, 2006; Johnson et al., 2014), we do not have disaggregated bookings data to separate between business and leisure passengers. Hence, all measures explained below refer to all-purpose travel, with an internal weighting of 70% leisure, 30% business when required, as approximated from the latest airline passenger surveys from LAX and SFO airports (LAWA, 2016; SFO, 2015). Table 2 below summarizes the definitions and data sources for all the components of our MNL model.

Table 2. Summary of definitions and data sources for MNL model in baseline scenario (no Hyperloop)

Element	***Definition***	***Value***	***Data Source***
$Freq_{od}$	Weekly air frequencies (direct and indirect) between origin airport *o* and destination airport *d*.		OAG Schedules
α	Sensibility of passenger utility to generalized travel costs: all-purpose travel	Calibrated with data on airline passenger surveys	Lieshout (2012)
$Access\ cost_{od}$	Generalized access cost for passengers	Monetary cost plus time cost.	Modal splits for each airport were obtained from airport passenger surveys. Driving times and distances for private transportation are calculated using ArcGIS.
Car_{zo}	Access time and cost for private car	USD 0.168 per passenger-km	AAA (2015), (TSDC, 2016)
$Rental_{zo}$	Access time and cost for rental car	32% of taxi costs per km	VTPI (2017)
$Taxi_{zo}$	Access time and cost for taxi		Various online sources
$Shared_{zo}$	Access time and cost for carsharing		Various online sources
$Courtesy_{zo}$	Access time for courtesy transport		
$Transit_{zo}$	Access time and cost for public transit		MTC (2016)
surfaceVTT	Value of Travel Time Savings for local surface transport: all-purpose travel	USD 16.42 to reflect a 70/30 per cent split between leisure and business travel, respectively.	DOT (2014)
$Flight\ cost_{od}$	Generalized cost of flight for passenger	Airfares plus flight time costs	
$Avg.\ fare_{od}$	Average airfare in the market from *o* to *d*		DB1B Dataset (DOT, 2015)
NST_{od}	Non-stop travel time from *o* to *d*		OAG Schedules Analyser
CT_{od}, TT_{od}	*CT* = Circuitry time (indirect flight distance over non-stop travel distance); *TT* = Transfer time for connecting itineraries		OAG Connections Analyser
μ_{od}, ρ_{CT}, ρ_{TT}	ρ_{CT} = penalty factor for circuitry time, ρ_{TT} = penalty factor for transfer time. μ_{od} = penalty factor for both CT and TT.	ρ_{CT} = *1.7* and ρ_{TT} = 1.36 to reflect a 70/30 per cent split between leisure and business travel, respectively. $\mu_{od} = 3\text{-}0.075 \cdot NST_{od}$	Lieshout (2012)
airVTT	Value of Travel Time Savings for long-distance air and HSR transport: all-purpose travel	USD 42.31 to reflect a 70/30 per cent split between leisure and business travel, respectively.	DOT (2014)

The value of $freq_{od}$ is calculated by identifying all direct (non-stop) and indirect airline itineraries between airports *o* and *d,* using our data on airline bookings and schedules from OAG. The information on airline bookings comes disaggregated by ticketing airline and flight itinerary (e.g. 278 bookings for United Airlines serving LAX-EWR-BOS). Thus, it reveals not only the split between direct and indirect travel, but also provides detailed information about the airports that served as intermediate hubs in each *od* market. The schedules data is then brought in to find all flights (or flight combinations) delivered by the ticketing airline that could have served those real-world bookings. A simple connections-building algorithm, based on airline partnerships and published minimum connecting times (also sourced from OAG), reveals the fastest available connections for each indirect itinerary. A maximum connecting time of one hour above the fastest connection is set to retain only the competitive travel options (as in Voltes-Dorta et al., 2017). After that, the total number of bookings recorded for a given itinerary is distributed across all identified flight combinations according to seat capacity. This allows us to calculate passenger-weighted average values of the quality of *od* air connectivity later on.

An implicit coefficient of 1 for the logged frequency is imposed by the simplified MNL model, which establishes a linear relationship between flight frequency and travel utility. Past papers on airport choice in the Bay area (Pels et al., 2003; Hess and Polak, 2006) offer estimates ranging from 0.72 to 1.44 for summer data, depending on travel purpose. Appendix A provides a sensitivity analysis employing the values 0.8 and 1.3 for the frequency coefficient.

The first component of flying costs is the average airfare in each *od* pair, expressed in USD ($avg.\ fare_{od}$). Data on airfares has been sourced from the well-known DB1B database maintained by the US Department of Transportation (DOT, 2015). Since the fares are itinerary-specific, these are merged with our OAG itineraries so passenger-weighted averages can be calculated. The second component of flying costs is the cost of travel time itself. For each *od* pair, this is calculated by multiplying the average total air travel time (in hours) by the relevant value of time (*airVTT*). For this case study, we use USD 42.31 per person-hour following the guidance of DOT (2014). Average total travel time is disaggregated into three components (Lieshout, 2012): 1) non-stop travel time (NST_{od}): for itineraries without non-stop travel options, a hypothetical direct travel time (in hours) is calculated as a function of great-circle distance between airports *o* and *d* and an average speed based on the most common type of aircraft flying on the relevant distance range. 2) Passenger-weighted average circuitry time (CT_{od}): it refers to the excess flying time (in hours) associated to indirect travel options with respect to *NST*. 3) Passenger-weighted average transfer time (TT_{od}): it refers to the total time spent at intermediate airports to change flights in indirect travel options. Both *CT* and *TT* are calculated from the output of the connections-building algorithm described above. These extra travel times are perceived as more inconvenient for the passengers the shorter the *NST* is. Hence, a generic penalty factor is introduced for both *CT* and *TT* ($\mu_{od} = 3\text{-}0.075 \cdot NST_{od}$), as recommended by de Wit et al. (2009), followed by specific penalty factors for *CT* ($\rho_{CT}=1.7$), and *TT* ($\rho_{TT}=1.36$), based on the reference values from Lieshout (2012). The higher the *CT* and *TT* averages, the worse the quality of airline connectivity in the *od* pair, as the airlines in airport *o* depend more on indirect connections to reach destination *d.* Passengers could potentially trade-off higher access times in exchange of lower air travel times by driving to a more distant airport that has a higher proportion of non-stop frequencies. The chosen values are taken directly from Lieshout (2012) since there is no practical way to calibrate them individually with our available data[2]. A sensitivity analysis with values 10% higher and lower for ρ_{CT} and ρ_{TT} is provided in Appendix A.

In regards to the access costs, the first component is the explicit cost of ground transport between *z* and *o*. This is calculated as a weighted average of the costs of six access mode categories: private car, rental car, taxi/Uber, shared/door-to-door shuttle, courtesy van, and public transit. Each departure airport has its own modal split, indicated in Table 3. This data was obtained from the latest passenger surveys of LAX, SFO, SNA, and BUR that are available online, though for the latter the survey dates to 2008. For OAK and SJC, the data comes from the Metropolitan Transport Commission's (MTC) periodic passenger surveys of airports in the Bay area. The latest version for

[2] In a typical 3-hour NST itinerary, the penalty factors lead to implied values of time of USD 199.6/h and USD 159.7/h for CT and TT, respectively. These values fall comfortably within the implicit ranges used by Lieshout (2012): between USD 108.2/h and USD 283/h, depending on travel motive.

OAK is from 2006 and for SJC from 2002. The remaining airports assume the modal split of their closest comparable point of reference, except the relatively isolated FAT and PSP airports, which are given generic modal splits based on the station categories defined by CHSR (2011).

Table 3. Ground access modes for airports and Hyperloop stations

Access Mode	*SFO*	*OAK*	*SJC*	*HYN*	*SMF*	*FAT*	*LAX*	*SNA*	*BUR*	*HYS*	*SAN*	*LGB*	*ONT*	*PSP*
Private – own car (%)	39	56	67	56	67	87	47	56	66	66	66	66	66	87
Private – rental (%)	12	16	19	16	19	3	17	17	17	17	17	17	17	3
Taxi/Car sharing (%)	29	5	7	5	7	3	24	15	9	9	9	9	9	3
Shared/Shuttle (%)	6	6	3	6	3	3	9	5	3	3	3	3	3	3
Courtesy van (%)	4	2	2	2	2	3	2	6	4	4	4	4	4	3
Public Transit (%)	10	15	2	15	2	1	1	1	1	1	1	1	1	1

Sources: LAWA (2016), SFO (2015), JWA (2015), BUR (2008), MTC (2007), MTC (2003), CHSR (2011), Own Elaboration

Driving times and distances between all zip codes and the relevant airports are calculated with a commercial Geographical Information System (GIS). The costs per km of using an owned car to get to the airport is USD 0.303, including fuel, maintenance, insurance, taxes, and depreciation as estimated by AAA (2015). This is converted to USD 0.168 per passenger-km once we assume an average of 1.81 passengers using data from the 2012 California Household Travel Survey (TSDC, 2016). The same reference is used to obtain passenger-km costs for all other modes (except public transit). Average taxi and Uber fares per km at a city/county level were easily compiled from a variety of online sources. For simplicity, we assume 50% split between traditional taxi and Uber or similar services. For paid door-to-door shuttle services, a sample of routes between the airports and selected destinations was collected and an average price per passenger-km then derived by simple regression analysis, in similar fashion than Pels et al., (2003). Average rental costs per km were calculated as 32% of taxi costs per km, following the benchmarks provided by VTPI (2017). Due to the very low proportion of public transit access to the airports in South California, this travel option is only included for the three airports in the Bay Area (Caltrain and local buses give service to SFO, OAK, and SJC, while the Bay Area Rapid Transit – BART serves the first two). Public transit times and travel costs (in 2000 dollars) between our zip-codes[3] and the departure airports were obtained using the origin-and-destination metropolitan travel forecasts for 2015 developed by MTC (2016). The travel costs were converted to 2015 dollars.

The second component of access costs is the cost of access time. For each *zo* pair, this is calculated by multiplying the weighted average surface access time (in hours) by the relevant value of time (*surfaceVTT*). For this case study, we use USD 16.42 per person-hour following DOT (2014).

Finally, the coefficient *alpha* (α) represents the sensitivity of passenger utility to generalized travel costs. Given all the other parameters of the model, *alpha* was calibrated with the objective to minimize the average absolute deviation between the actual and predicted geographic distribution of departing passengers by county of origin for LAX and SFO airports. A value of $\alpha=-0.0265$ was obtained[4]. Table 4 shows the actual and predicted geographic distribution for the base model assumptions (without Hyperloop). The actual distribution that serves as benchmark comes from the respective passenger survey reports.

Table 4. Actual and predicted distribution of originating passengers at LAX and SFO airports

SFO			*LAX*		
Counties of Origin	*Actual*	*Predicted*	*Counties of Origin*	*Actual*	*Predicted*

[3] We linked each of our zip-code areas to the closest MTC travel analysis zone (TAZ) using GIS.

[4] Taking the value $\alpha = -0.02$ as reference (Lieshout, 2012), an exhaustive search was done in the interval (-0.01, -0.03). The lower the value, the higher the penalty to counties located farther away from the airport. The average absolute deviation per airport around the optimal solution $\alpha = -0.0265$ ranges between 10-11% but is always higher as we move away from it.

San Francisco	46%	46%	*Los Angeles*	71%	68%
San Mateo	14%	19%	*Orange County*	14%	18%
Santa Clara	11%	10%	*San Bernardino*	4%	4%
Alameda	10%	10%	*Ventura*	4%	2%
Contra Costa	5%	4%	*Riverside*	3%	4%
Marin	4%	2%	*San Diego*	2%	3%
Sonoma	3%	2%	*Santa Barbara*	2%	1%
Napa	2%	1%	*Kern*	<1%	<1%
Solano	1%	1%	*Tulare*	<1%	<1%

Sources: LAWA (2016), SFO (2015), Own elaboration.

After calculating U_{zod}, we can distribute the number of bookings per *od* pair across all zip-codes as follows:

$$P_{zod\ (baseline)} = bookings_{od} \frac{exp(U_{zod}) \cdot potential_z}{\sum_z exp(U_{zod}) \cdot potential_z},$$

$$potential_z = (\%resident_z \frac{airfare\ expenditure_z}{\max(airfare\ expenditure_z)} + \%visitor_z \frac{visitor\ sales_z}{\max(visitor\ sales_z)}),$$

where $P_{zod\ (baseline)}$ denotes the number of *od* passengers estimated to have started their journey in zip-code z. This value is proportional to the product of travel utility $exp(U_{zod})$ and the travel potential of z ($potential_z$) against all other zip-codes in airport o's catchment area. The potential of zip-code z to generate resident and visitor air travel is calculated as the weighted average of the normalized[5] airfare expenditures by residents and the normalized visitor sales revenue (data provided at a zip code level by Esri and extracted with ArcGIS online, in combination with the county-level data reported in Visit California, 2015). $\%resident$ and $\%visitor$ refer to the split of potential passengers by travel purpose originating from each zip code. These weights take the value of the closest airport for which travel purpose data is available.

Aggregating P_{zod} by origin airport results in the total passengers that travel between z and d (P_{zd}). This becomes an important reference measurement for the next stage, as passengers in each *zd* market re-evaluate their choice of departure airport *o* after the introduction of the Hyperloop.

$$P_{zd} = \sum_o P_{zod}$$

2.3 Hyperloop scenario

The scenario with the Hyperloop employs the same MNL model, with the addition of new travel alternatives generated by the Hyperloop service[6]. In addition, a number of sub-scenarios are run for a sensitivity analysis of the impact of two Hyperloop level-of-service attributes: fares and station processing times (See Table 5). The new Hyperloop itineraries always involve residents/visitors in Northern California departing from a South California airport and vice-versa. These new travel alternatives, have different access costs, which are now split in three stages: 1) travel from z to the nearest Hyperloop station, 2) Hyperloop transfer, and 3) transfer from the arriving Hyperloop station to departure airport o. Stage 1 employs the modal splits from Table 3 to access the Hyperloop stations, which are taken from the nearby OAK and BUR airports, and also

[5] Values are normalized by dividing by the largest value across all zip codes in the sample.

[6] One could argue that travel alternatives should be grouped into "local" vs "Hyperloop" ones. Indeed, the pattern of substitution between any local departure and a Hyperloop-assisted one is likely to depend on other local alternatives available. This violates the assumption of independence of irrelevant alternatives (IIA) that is implicit in the MNL model. Clearly a Nested Logit (NL) specification would be more suitable. However, the NL option requires us to model the utilities at a branch level, leading to different parameters for the Hyperloop travel alternatives for which no published references or data are yet available for calibration purposes. This leads to the MNL simplification and explains why the present contribution remains largely exploratory in nature.

employs *surfaceVTT* for the time valuation. Stage 2 assumes the announced 35-minute travel time between Oakland and the San Fernando Valley, valued at *airVTT* levels (which are also applicable to high-speed rail travel), plus either 15-min or 30-min station processing times (this includes both access and egress), valued at USD 26.29 per person-hour (DOT, 2014). In regards to the Hyperloop fare, the original Hyperloop proposal indicated a one-way ticket price of USD 20 (SpaceX, 2013) to recover capital costs. Since there is no practical way to provide an accurate estimate of operating costs per passenger for the Hyperloop, we assume USD 30 calculated from the California HSR Annual Ridership and Operating Cost documentation (CHSR, 2011). This provides a more conservative ticket price of USD 50 for the Hyperloop. Two additional sub-scenarios with USD 30 and USD 70 are also run for a sensitivity analysis. Stage 3 assumes the modal split characteristic for the departure airport but removing the two car-driving options, thus relying primarily on taxi/carsharing, prearranged shuttles, and public transit. In order to penalize the Hyperloop access alternative for the lack of seamlessness in the transfer from the station to the departing airport (a key feature of good air-rail intermodality; Goetz and Vowles, 2010), the access time in Stage 3 is valued at *airVTT* levels with the same penalty factor as airline transfer times. This effectively makes the Stage 3 transfer an additional leg in the passenger's flight itinerary.

One can also expect a reaction from the incumbent airlines to the introduction of the Hyperloop. Airlines could reduce frequencies and/or increase fares to compensate for reduced load factors due to leakage of demand to Hyperloop, or they could attempt to retain market share by lowering fares. In a comprehensive review of studies about air-HSR competition, Albalate et al. (2015) notes that reductions in either airline fares or frequencies are common after the introduction of HSR routes that compete directly with air corridors[7]. In order to incorporate these effects into our simplified MNL structure, we refer to the Ridership and Revenue forecast model developed for the California HSR 2012 Business Plan (Cambridge Systematics, 2012). Due to the lack of an HSR scenario in California, the authors base their analysis on the competitive responses to the entry of Virgin America in the SFO-LAX market in 2007 and the SFO-SAN market in 2008. We use two of their competitive response sub-scenarios: a) no fare changes, and b) a 9% reduction in fares (derived from the above case studies). It is unclear, though, whether the generalized reduction in fares will have a positive or negative impact on demand for the Hyperloop-facilitated air routes, since these become cheaper as well. No scenario with changing frequencies was developed because our model does not contemplate leakage of demand from air to Hyperloop in long-distance markets (the leakage is between airports). This can only be implemented in the context of a wider-scope study that considers short-distance markets as well, which has a much larger complexity and it is left for future research. In total, eight Hyperloop sub-scenarios are run (see Table 5).

Table 5. Sub-scenarios for the Hyperloop case

Sub-scenario no.	***1***	***2***	***3***	***4***	***5***	***6***	***7***	***8***
Airfare competitive response	No change	No change	No change	No change	9% reduction	9% reduction	9% reduction	9% reduction
Hyperloop one-way fares (USD)	30	50	50	70	30	50	50	70
Station transfer (min)	15	15	30	30	15	15	30	30

2.4 Measuring change in airport competition

Once the new travel utilities are determined, the passenger demand between zip-codes and destination airports established in the baseline scenario (P_{zd}) is re-distributed across departure airports. New travel routes involving a Hyperloop transfer are denoted with the subscript $+h$, and

[7] While most published empirical evidence on these strategic interactions comes from European and Asian case studies, Behrens and Pels (2012) adapted their European results to the California HSR case.

their market shares are determined in the usual fashion: a ratio of their travel utility $exp(U_{zod+h})$ to total utility of all travel alternatives in the market, with and without Hyperloop: $\sum_o exp(U_{zod\pm h})$, i.e.

$$P_{zod+h} = P_{zd} \frac{exp(U_{zod+h})}{\sum_o exp(U_{zod\pm h})},$$

where P_{zod+h} denotes the number of *od* passengers estimated to have started their journey in zip-code *z,* and involving a Hyperloop transfer.

Pre-existing routes, which can either keep their baseline traffic or leak passengers to airport-Hyperloop alternatives, are denoted with the subscript $-h$. Their level of traffic in this new scenario (P_{zod-h}) is calculated by diminishing the baseline forecast in the same proportion captured by Hyperloop routes:

$$P_{zod-h} = P_{zod\ (baseline)} \left[1 - \frac{\sum_o exp(U_{zod+h})}{\sum_o exp(U_{zod\pm h})}\right]$$

Aggregating $P_{zod\ (baseline)}$ by destination delivers the total passengers that travel between *z* and *o* in the baseline scenario: $P_{zo\ (baseline)}$. Aggregating P_{zod+h} and P_{zod-h} by destination delivers the total passengers that travel between *z* and *o* in the Hyperloop scenario: $P_{zo\pm h}$. From that, calculating the market share of airport *o* for residents or visitors in *z* (S_{zo} and $S_{zo\pm h}$) is straightforward.

$$P_{zo} = \sum_d P_{zod}\ ; \quad S_{zo} = \frac{P_{zo}}{\sum_o P_{zo}}$$

$$P_{zo\pm h} = \sum_d P_{zod\pm h}\ ; \quad S_{zo\pm h} = \frac{P_{zo\pm h}}{\sum_o P_{zo\pm h}}$$

This step allows us to measure the degree of concentration in airport market shares at a zip-code level (as a proxy for competition) using the well-known Hirschmann-Herfindahl Index. Both before and after estimates are provided (HHI_z *and* $HHI_{z\pm h}$):

$$HHI_z = \sum_o (S_{zo})^2$$

$$HHI_{z\pm h} = \sum_o (S_{zo\pm h})^2$$

3. RESULTS AND DISCUSSION

The potential short-term impact of a hypothetical California Hyperloop service on airport competition is shown in Figure 3, which indicates the percentage change in HHI index ($Delta\_HHI_z$) between the baseline and two Hyperloop scenarios (Scenario 5, with low airfares and the best level-of-service attributes for the Hyperloop, and scenario 4 with the opposite characteristics) for the zip-codes in the Bay Area and Los Angeles. Overall, the average HHI per zip code is predicted to decrease in all cases. However, different geographical patterns can be observed depending on the region analyzed. In the Bay area, the greatest increase in competition (between 22% and 29% decrease in HHI) would be observed in the North Bay, covering most of Marin County, but also parts of Sonoma, Napa, Solano, and Contra Costa. A significant increase in competition is also predicted for the zip-codes around SFO, OAK, SJC airports, and the Hyperloop North station. This covers the entire San Francisco County, a large part of San Mateo, and Alameda. Most of these very densely populated areas are served by BART, which allows for good accessibility to the Hyperloop North Station and hence, it brings SFO a new wave of competition from the airports at the other end of the Hyperloop line.

While the increase in competition is also seen in South California, is has a noticeably smaller magnitude. Indeed, the geographic location of the Hyperloop South Station in the San Fernando Valley results in a completely different picture. Most residents and visitors to the South of Los Angeles have easier accessibility to LAX than to the Hyperloop, thus allowing LAX to retain a higher amount of "captive" passengers in a way that SFO cannot. This is how the light shaded areas in Figure 3 can be interpreted (decrease in HHI always lower than 10%). The closer the zip-code is to the San Fernando Valley, the higher the competitive pressure (note the impact on BUR airport), with the passengers originating from the North of Los Angeles County experiencing the highest increase in airport choice with the introduction of the Hyperloop.

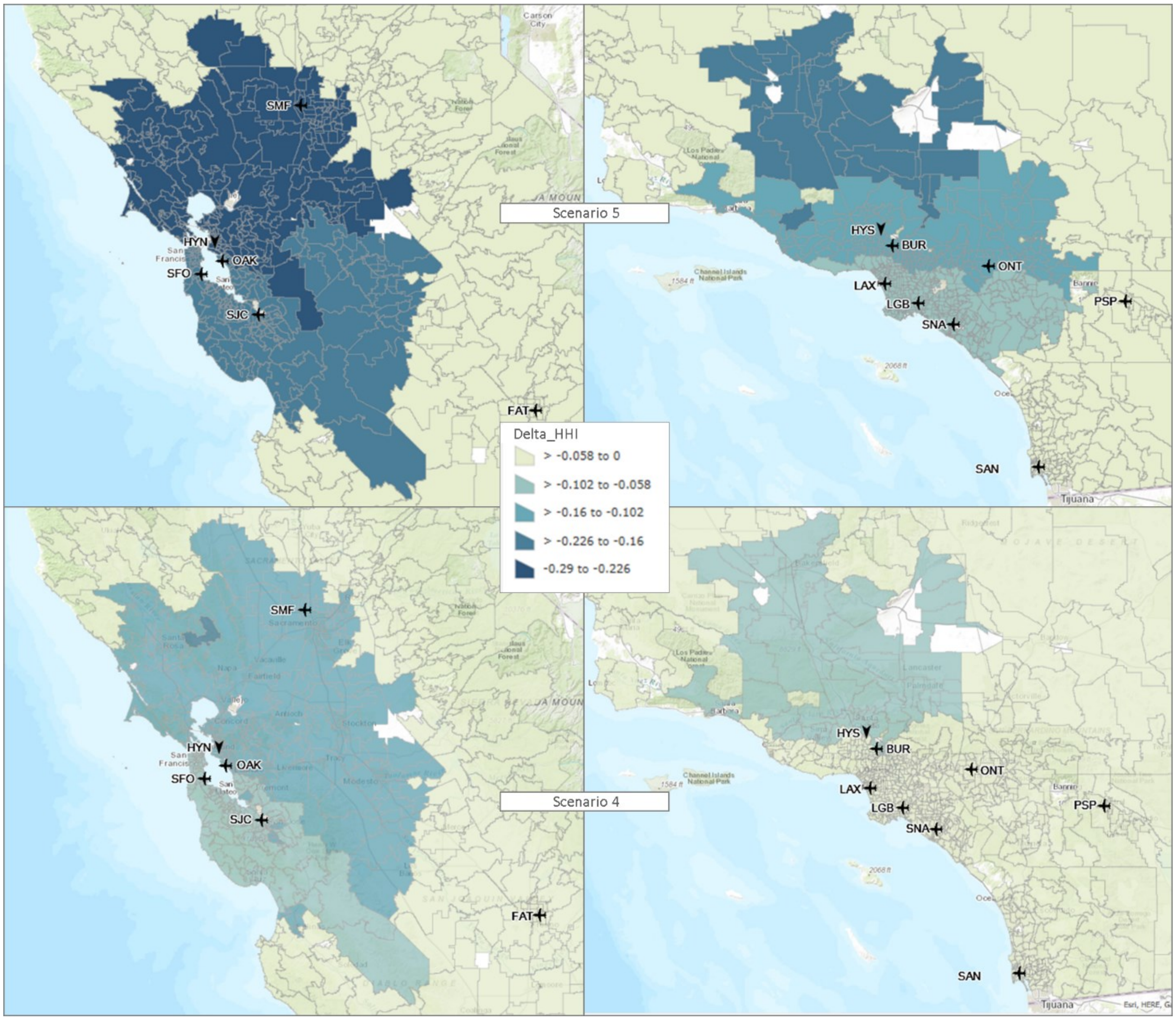

Figure 3. Changes in HHI index in selected scenarios
Source: Own elaboration.

One implication of the above results is that the California airport network could experience a drastic move towards a single airport system due to the time-space compression facilitated by the Hyperloop service. In that context, the scope of geographic competition will be vastly expanded from its current boundaries to have North and South airports competing directly with one another for passengers originating in either region. In this context, are there any airports that would be particularly threatened by the increased competition?

Table 6. Predicted weekly passenger traffic at sample airports in both baseline and Hyperloop scenarios (June 2015)

Airport \ scenario	*Baseline*	*Hyperloop*								*Max Change (%)*	*Min Change (%)*
		1	*2*	*3*	*4*	*5*	*6*	*7*	*8*		
San Francisco (SFO)	224,326	198,962	202,621	210,142	214,022	200,234	203,715	210,846	214,522	-10.7%	-4.6%
Oakland (OAK)	64,044	77,527	75,449	71,377	69,329	75,335	73,596	70,236	68,551	17.6%	8.3%
San Jose (SJC)	58,556	52,816	53,520	54,985	55,772	52,948	53,640	55,077	55,848	-9.6%	-4.8%
Sacramento (SMF)	53,583	45,787	46,665	48,552	49,610	45,947	46,813	48,672	49,715	-14.3%	-7.4%
Fresno (FAT)	8,695	8,231	8,282	8,392	8,454	8,243	8,293	8,401	8,462	-5.2%	-2.8%
Total Bay Area	346,926	329,304	331,590	336,503	339,123	328,517	330,951	336,159	338,921	-5.3%	-2.2%
Total North	409,204	383,323	386,536	393,447	397,187	382,707	386,056	393,232	397,098	-6.5%	-2.9%
Los Angeles (LAX)	328,333	350,724	348,376	343,139	340,141	351,615	349,095	343,509	340,334	7.1%	3.6%
San Diego (SAN)	131,316	129,550	129,832	130,371	130,633	129,685	129,947	130,443	130,684	-1.2%	-0.5%
Santa Ana (SNA)	59,379	56,573	56,989	57,797	58,206	56,830	57,207	57,935	58,304	-4.3%	-2.0%
Ontario (ONT)	21,868	20,792	20,931	21,207	21,354	20,839	20,972	21,237	21,379	-4.7%	-2.3%
Burbank (BUR)	19,757	28,158	26,490	23,318	21,871	27,545	25,977	23,024	21,688	39.4%	10.7%
Long Beach (LGB)	16,211	17,255	17,177	16,965	16,808	17,136	17,062	16,857	16,709	5.7%	3.7%
Palm Springs (PSP)	5,274	4,967	5,011	5,098	5,141	4,985	5,026	5,107	5,147	-5.5%	-2.5%
Total Los Angeles metro	445,548	473,502	469,962	462,426	458,381	473,965	470,313	462,561	458,413	6.4%	2.9%
Total South	582,138	608,019	604,806	597,895	594,155	608,635	605,286	598,110	594,244	4.6%	2.1%

Note: Maximum change is calculated as the difference between baseline and scenario 5, Minimum change against scenario 4.

Table 6 shows the predicted weekly passenger traffic at our sample airports in both the baseline and Hyperloop scenarios. Out of the eight alternatives, Scenario 5 is to be the most optimistic one (cheapest Hyperloop service, fastest station processing, and unchanged airline fares). Scenario 4, which represents the other end of the spectrum, is clearly the most pessimistic one. Regardless of the scenario, however, it is clear that a travel time of 35 minutes from Downtown Oakland to the San Fernando Valley can make airports like Burbank, Long Beach, or Los Angeles very attractive choices for residents in the Bay Area. Conversely, residents in Southern California would benefit from improved accessibility to Oakland Airport. Directional traffic flows are imbalanced, though. Airports in North California are predicted to lose more weekly passengers than those gained from competitors in South California. This conclusion is robust to changes in the model coefficients (See Appendix A for a sensitivity analysis). Depending on the scenario, the leakage effect represents a reduction in traffic between 2.9% and 6.5% (2.2% and 5.3% for the Bay Area airport system). In the North, SFO airport is the one most negatively affected since it serves the largest amount of frequencies and destinations in direct competition with the South airports and LAX. In addition, it being located at a relatively distant location from the Hyperloop North Station reduces the potential to capture Southern residents or visitors. This justifies the positive prospects for OAK, which is predicted to achieve an increase in traffic due to the easy access to the new transport mode. The southern counterpart is BUR, which, despite the evident connectivity gap against OAK (shown in table 1), is also able to capture more passengers from the North than those that leak away. In the end, however, it is LAX, with its dominance in destinations and frequencies, the airport that benefits the most (in terms of passenger traffic) from the introduction of the Hyperloop, with a predicted increase in long-distance domestic passenger traffic between 3.6% and 7.1%. This agrees with our working hypothesis for the paper, that the airport with the largest level of service would benefit the most from collaborating with the Hyperloop, as previously documented for HSR in European case studies (Terpstra and Lijesen, 2014). In spite of that, a few secondary airports in the South, like SNA and ONT, which do not have the same amount of connectivity than the secondary airports in the North, are predicted to experience a net reduction in traffic. This suggests that the introduction of the Hyperloop could lead to a shift in airport roles within the Californian airport system, with substantial changes in how these airports rank against one another in terms of passenger traffic. While the Bay area would move towards a more balanced distribution of traffic across its airports, passenger traffic in the South would become more concentrated in LAX.

Figure 4 shows the predicted catchment areas for the Hyperloop North and Hyperloop South Stations, which effectively show how the South Airports would penetrate the North region and vice versa. The new transport mode is predicted to serve between 30 and 75 thousand and weekly airline passengers that depart from an airport in a local area different from the one in which they reside. This represents between 3% and 7.5% of the total passenger traffic in long-distance domestic markets. The optimistic market shares of Hyperloop-facilitated air routes vary between 8% and 22% in the North region (between 4% and 12% in the pessimistic one), while the same market shares in the South vary from 1% to 12%. An interesting effect of the introduction of the Hyperloop, as planned without intermediate stations between Oakland and the San Fernando Valley, is the creation of discontinuous catchment areas for Californian airports. This is bound to have a disrupting effect on how airport and airline advertising would be carried out, with marketing campaigns now extending beyond the local region to reach passengers on the other side of the Hyperloop line.

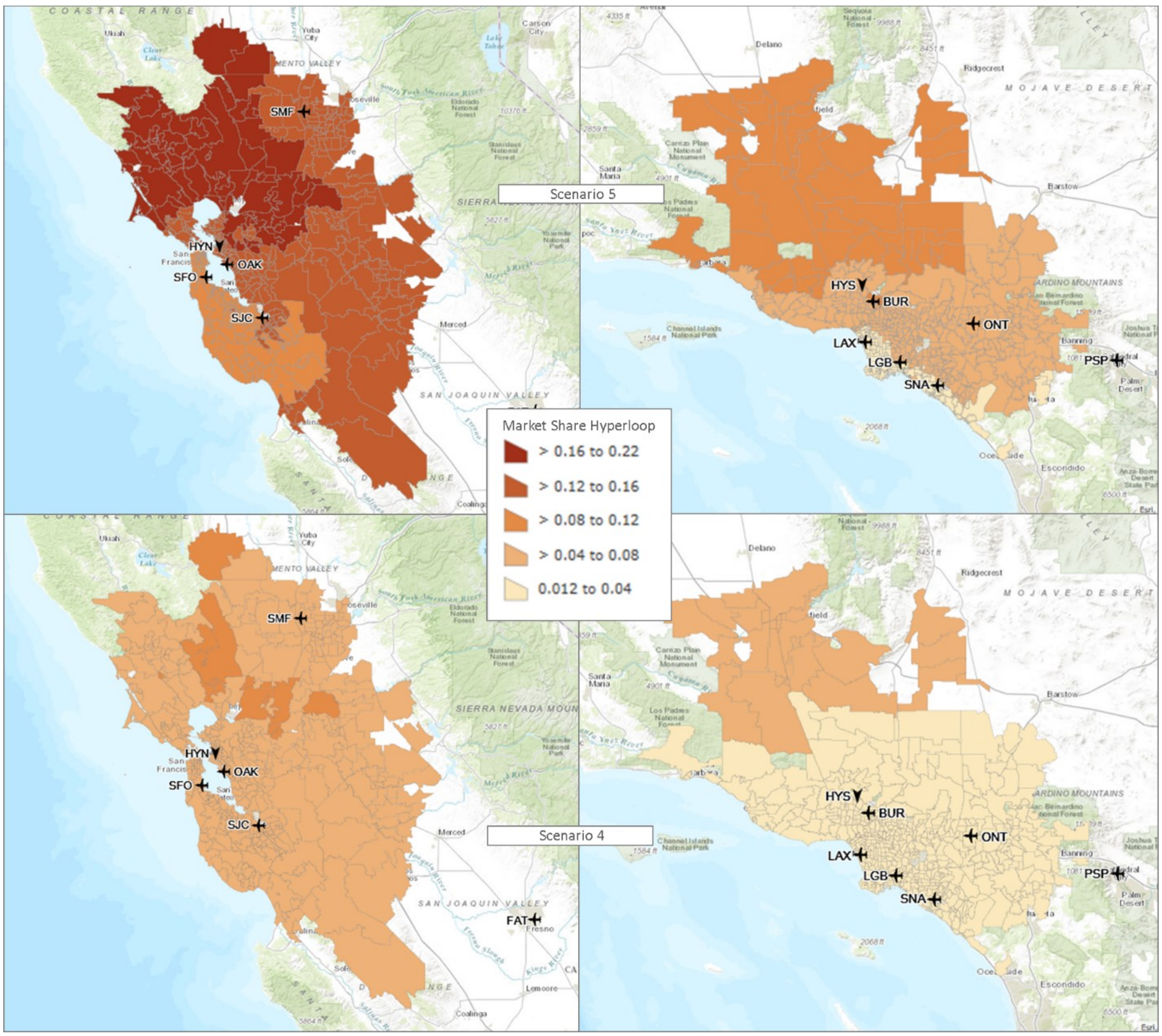

Figure 4. Catchment areas of Hyperloop Stations in selected scenarios
Source: Own elaboration.

Table 7 delivers additional insights on the reasons behind the passenger leakage. It shows the top 10 largest North-to-South leaking markets for SFO airport, and provides a comparative analysis of airfares, the quality of air connectivity, and average access cost differentials between SFO and the equivalent airline itinerary via LAX-Hyperloop. We can see that the gap between the two primary airports is mostly on air transport fares and frequencies, which offsets the increase in access costs from the Hyperloop transfer. It is also worth noting that average circuitry and transfer times are not consistently worse in SFO, despite the lower amount of direct frequencies available. The fact that the massive leakage is largely explained by the higher airfares at SFO suggests that the effects measured by this paper can only be sustained in the short-term. Any geographic price fences that support fare discrimination by airlines serving Californian airports will be broken by the new high-speed travel alternative, thus possibly leading to further harmonization of prices in the medium term, which can also have implications in terms of airlines rationalizing services.

Table 7. Top 10 largest North-to-South leaking passenger markets: LAX vs. SFO airports.

Destination Market	*Airport*	*Via*	*non-stop weekly frequencies*	*Avg fare (USD)*	*non-stop travel time (min)*	*Avg circuitry time(min)*	*Avg transfer time(min)*	*Avg access costs differential (USD)*		*Hyperloop transfers*	
								(min)	*(max)*	*(min)*	*(max)*
Orlando (MCO)	LAX	Hyperloop	568	322	277	20	17	77.4	154.0	1,191	3,041
	SFO		467	348	304	42	31				
Washington (IAD)	LAX	Hyperloop	419	405	290	7	6	77.1	153.7	598	1,935
	SFO		423	490	303	7	6				
Denver (DEN)	LAX	Hyperloop	488	194	139	4	3	76.0	152.6	517	1,812
	SFO		381	271	149	6	5				
Tampa (TPA)	LAX	Hyperloop	363	301	265	34	28	73.4	150.0	1,294	1,800
	SFO		308	321	325	53	76				
San Antonio (SAT)	LAX	Hyperloop	316	228	166	9	8	74.2	150.8	1,632	1,716
	SFO		231	287	202	46	46				
Boston (BOS)	LAX	Hyperloop	791	354	323	12	11	77.5	154.1	319	1,330
	SFO		620	414	333	11	10				
Detroit (DTW)	LAX	Hyperloop	454	323	268	18	18	77.0	153.6	478	1,289
	SFO		317	393	271	23	23				
Austin (AUS)	LAX	Hyperloop	358	222	172	9	8	76.2	152.7	346	1,187
	SFO		270	285	205	10	12				
Indianapolis (IND)	LAX	Hyperloop	344	290	246	23	21	75.9	152.4	502	1,180
	SFO		285	312	256	41	40				
Washington (DCA)	LAX	Hyperloop	569	323	291	27	24	76.2	152.8	362	1,090
	SFO		435	391	300	32	28				

4. SUMMARY AND CONCLUSIONS

In a context of debate about the economic viability of new transport modes and their impact on existing modes, this paper investigates how a hypothetical Hyperloop service connecting San Francisco and Los Angeles' metropolitan areas could affect the level of competition between California's major airports in long-distance domestic markets. To that end, we adapt an established method to determine airport catchment areas based on weekly flight frequencies, access times, and generalized travel costs as the main drivers or passenger choice. The methodology combines publicly available data on airline bookings for June 2015 (obtained from the US Department of Transportation), OAG flight schedules, and additional information on local population and transport accessibility that was compiled using Geographical Information Systems and airport-specific passenger surveys.

Our results clearly predict a substantial short-term increase in airport competition for travellers originating in most municipalities in California and travelling to other US states. A travel time of 35 minutes from Downtown Oakland to the San Fernando Valley can make airports like Burbank, Long Beach, or Los Angeles very attractive choices for residents in the San Francisco Bay Area. Conversely, residents in Southern California would benefit from improved accessibility to Oakland Airport. As a result, the average HHI in the selected markets, measured at a zip-code level, is predicted to decrease as the California airport network will move towards a single airport system due to the time-space compression facilitated by the Hyperloop service. The new transport mode is predicted to serve between 30 and 75 thousand weekly airline passengers that plan to depart from an airport in an area different from the one in which they reside. This represents between 3% and 7.5% of the total passenger traffic in long-distance domestic markets. Directional traffic flows are imbalanced, however, creating a significant leakage of airport traffic from North to South California, explained by the gap in air transport fares and frequencies that offsets the increase in access costs from the Hyperloop transfer. In terms of absolute passenger numbers, Los Angeles Airport is predicted to benefit the most from the Hyperloop in the markets from California to the rest of the US, while San Francisco Airport would be the one most negatively affected.

Due to the degree of interest shown by academics and several local authorities in regards to the development of Hyperloop services in different markets all over the world, the substantial effects on airport competition in long-distance air transport markets should be taken into consideration in the respective economic impact assessments, particularly if the route connects major cities with separate airport systems. From the perspective of airport management, investing in better surface accessibility, as well as improving direct connectivity to domestic destinations, thus reducing passenger travel costs, can be two ways to offset the increased competition and prevent passenger leakage. From the perspective of airline pricing, once the geographic price fence is compromised by the high-speed travel alternative, one can expect a short-term adjustment towards less geographic price discrimination. Indeed, the increase in passenger choice created by the Hyperloop can be expected to put an overall downward pressure on airfares, an effect considered by our model, but we submit that the ultimate impact is difficult to predict due to possible consolidation of frequencies by airlines within a single, state-wide catchment area. On top of that, there are the unaccounted economic impacts related to the improved air connectivity to other US regions linked to the increase in the supply of air services accessible to most Californian municipalities, the quantification of which is left for future research.

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Appendix A. Sensitivity analysis MNL model

Table A1. Scenarios for sensitivity analysis

Sub-scenario no.	*1*	*1a*	*1b*	*1c*	*1d*
Airfare competitive response	No change	No change	No change	No change	No change
Hyperloop one-way fares (USD)	30	30	30	30	30
Station transfer (min)	15	15	15	15	15
Frequency coefficient	1	0.8	1	1.3	1.3
Change to Lieshout (2012) CT and TT penalty factors	0%	-10%	-10%	0%	+10%

Table A2. Predicted weekly passenger traffic at sample airports in several Hyperloop scenarios (June 2015)

Airport \ scenario		*Hyperloop*					*Max increase from scenario 1 (%)*	*Max decrease from scenario 1 (%)*
	baseline	*1*	*1a*	*1b*	*1c*	*1d*		
San Francisco (SFO)	224,326	198.962	200.265	201.033	198.516	197.806	1.04%	-0.58%
Oakland (OAK)	64,044	77,527	81,459	77,625	73,172	73,029	5.07%	-5.80%
San Jose (SJC)	58,556	52,816	53,376	53,292	52,486	52,226	1.06%	-1.12%
Sacramento (SMF)	53,583	45,787	46,290	46,345	45,528	45,261	1.22%	-1.15%
Fresno (FAT)	8,695	8,231	8,253	8,259	8,224	8,211	0.34%	-0.25%
Total Bay Area	346,926	329,304	335,100	331,950	324,174	323,061	1.76%	-1.90%
Total North	409,204	383,323	389,643	386,555	377,926	376,533	1.65%	-1.77%
Los Angeles (LAX)	328,333	350,724	344,018	348,344	357,652	358,516	2.22%	-1.91%
San Diego (SAN)	131,316	129,550	129,332	129,615	129,821	129,808	0.21%	-0.17%
Santa Ana (SNA)	59,379	56,573	56,235	56,684	57,037	56,984	0.82%	-0.60%
Ontario (ONT)	21,868	20,792	20,746	20,845	20,905	20,872	0.54%	-0.22%
Burbank (BUR)	19,757	28,158	29,019	27,317	26,110	26,620	3.06%	-7.27%
Long Beach (LGB)	16,211	17,255	17,403	17,003	16,890	17,013	0.86%	-2.11%
Palm Springs (PSP)	5,274	4,967	4,945	4,979	5,001	4,997	0.68%	-0.44%
Total Los Angeles metro	445,548	473,502	467,421	470,193	478,595	480,003	1.37%	-1.28%
Total South	582,138	608,019	601,699	604,787	613,416	614,809	1.12%	-1.04%

The numbers above show that, as the flight-time penalty factors and the frequency coefficient increase, the market share of Hyperloop routes also increases (note how the predictions for sub-scenarios 1c and 1d are the furthest away from the baseline). The maximum deviation from the values of scenario 1 due to changes in the MNL model parameters is 7.27% for Burbank Airport. However, these deviations do not affect the main implication of our results: that a leakage of demand should be observed from North to South Californian airports in long-distance domestic markets.