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An explorative analysis for Europe**

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Is Hyperloop helpful in relieving the environmental burden of long-distance travel?

An explorative analysis for Europe

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Overview

Long-distance travelling accounts for a significant and increasing part of the mileage of person travel and the respective environmental impacts (Van Goeverden *et al.*, 2016). Energy consumption and emissions connected with long-distance travelling might be substantially reduced through use of evacuated tubes of low air resistance, such as the recently proposed Hyperloop transport system (HL). This paper explores the extent to which a fully developed HL network system in Europe could reduce energy consumption and GHG emissions of long-distance passenger transport.

Methods and Data

The analysis includes two main stages: a calculation/estimation of the energy consumption and CO₂-emissions of the HL mode; and a forecast of the impact on travel demand. The latter includes both the design of an HL network which defines the service level and the capacity of the HL mode, and the estimation of the (potential) demand; the actually transported demand can be lower than the potential demand because of capacity limitations.

The energy consumption is calculated both for the HL vehicles movement and for the life-cycle of the HL project, assuming a cruising speed of 1200 km/h and an acceleration and deceleration of 1.5 m/s². The energy consumption of HL vehicles is strongly negatively correlated to the distance between stops, because a significant part of the consumption is for acceleration and deceleration. The calculated consumption, expressed in kWh/seat km, is 0.1 for 200 km, 0.036 for 600 km, and 0.025 for 1000 km distance between stops. The additional energy consumption for the life-cycle of the HL project is likely to be significantly higher; we assume roughly 500 kJ/seat km, somewhat more than that for railways. The limited freedom in the routing of HL lines due to the very wide curves may require to build a significant part of the network in tunnels below the earth surface and this could consume a relatively large amount of energy.

The CO₂-emissions related to HL vehicles depend on the source of electricity used. The initial HL proposal involves solar cells on the tube that could produce all required energy for vehicle movement (Musk, 2013). In this case, the CO₂-emissions would be zero. However, this is not possible for tunnelled parts of the network. We assume two variants of the HL system, one with zero emissions and one where a significant part of the network is tunnelled and where the emissions (in gram) are calculated by multiplying the energy consumption in MJ with the factor 70, which is the (rounded) conversion factor for fuel. The same factor is used for the emissions related to the additional energy consumption for the life-cycle.

The defined HL network consists of links between the European cities that have a population of at least 500,000 inhabitants. Lines in the network may cross important physical barriers in the case the barriers currently are crossed by railway lines or roads (like the Alps or the Channel). There are no links to more remote isles like the Canary Isles and no intercontinental links, except for links between Europe and Turkey. The density of the designed network is 0.01 km/km², the average distance between stations is 300 km. We assume that the services do not stop at each station and that the average distance between stops is 600 km.

The impact of the introduction of a HL system on travel demand includes both shifts from other modes to HL and induced demand. We made a forecast of the two impacts for the year 2025. At first, the total long-distance travel demand is estimated for 2025. The estimation is based on the microdata of the Dateline-project, a survey of long-distance travelling of the residents of 16 European countries conducted in 2001/2002, tourist statistics, statistics of Eurostat on long-distance travelling, and published expectations about future trends (e.g. EC, 2013). The analysis is limited to the travel demand of the residents of the Dateline countries that include nearly all Western-European countries but exclude most of those located in Eastern Europe.

The potential shift from alternative modes to the HL is estimated by assuming different shift factors based on travel times, travel costs/fares, and typical modal qualities. The HL mode is assumed to have the most competing travel times for long trip distances and for origins/destinations that have over 500,000 inhabitants. Travelling with HL is likely to be expensive (Van Goeverden *et al*, 2017) making the system relatively unattractive for leisure travellers. With respect to the modal qualities, the HL is assumed to be most competitive to the other public modes (train and airplane). Private modes (e.g. car, bus chartered for group travel) have special qualities like avoiding access/egress trips, availability of the mode at the destination, and a lot of room for luggage (car).

The estimation for induced demand is based on the observation that no correlation seems to exist between speed of the transport system and travel time (Schafer, 1998). In that case, the induced+shifted trip kilometres are equal to the product of the relative reduction in travel time (ratio of the door-to-door travel times by the original travel mode and HL) and the shifted kilometres to HL. We assume that the induced kilometres are two times the shifted kilometres from the relatively slow land modes and 30% of the shifted kilometres from the much faster airplane.

Results

The estimated demand for HL exceeds by far the capacity. The calculated capacity is 180 billion seat km in the whole continent, and 115 billion seat km in the Dateline countries. The forecasted person km by HL is in the order of 500 billion. This means that either the capacity has to be enlarged by building parallel lines for accommodating the potential demand, or the transported demand will be limited to the low capacity. We analysed both variants. In the case the capacity is not enlarged, we assume the fares of HL being raised to the level where capacity and potential demand are balanced. The higher fares will particularly reduce the leisure travel segment, which is by far the largest segment of the long-distance travel market. Additionally, we assume no induced demand in the case the capacity is an important bottleneck and the fares are extremely high.

The estimated reduction of energy consumption of long-distance travelling as the result of HL introduction is 3.1% in the case the capacity is enlarged, and 1.8% if capacity is a serious bottleneck and the fares are raised. The values for the whole life-cycles are smaller: 0.2% and 1.3% respectively. The reductions of the CO₂ emissions are close to those for energy consumption, except when zero emission for HL vehicle movement is assumed; in that case the reductions are about 2 and 0.4 percentage points larger for the variants with and without sufficient capacity. With reference to the smaller travel market of long-distance trips inside the area served by the HL network, the reductions in terms of percentage are about a factor 1.7 larger.

Conclusions

A Hyperloop transport system will likely reduce the energy consumption and emissions of long-distance person transport, but the reduction will be small, just a few percent. Considering the whole life-cycle, the reduction is negligible. The HL is not more energy-efficient than train or bus and competition with these modes will increase the total energy consumption as the consequence of induced demand. The total, favourable impacts are the balance of an increase of energy consumption caused by the competition with train and bus, and a larger decrease caused by the competition with airplane and car. The impacts can likely be increased by designing a HL network that provides only services on routes where currently the airplane is the dominant mode.

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