HSLU Lucerne University of Applied Sciences and Arts

Technik & Architektur
BSc. Business Engineering | Innovation
Bachelor-Thesis

Modeling the operating costs of an Hyperloop connection from Zurich to Paris

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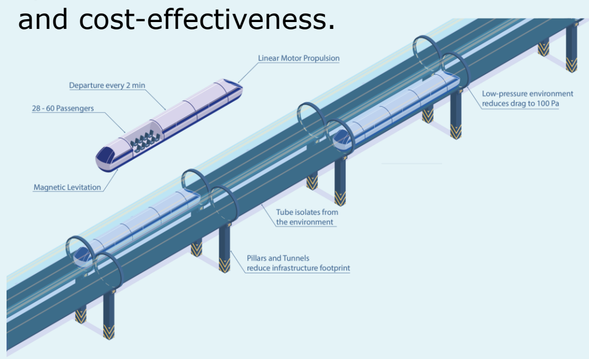
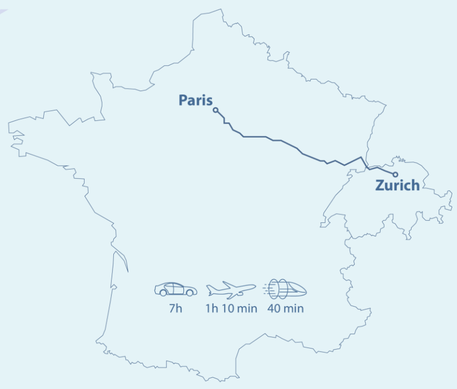
1. Introduction & Objectives

Introduction
Logistics plays a vital role in today's world, with a booming consumer goods market and a significant number of people relying on public transportation for daily commuting. However, modern transportation routes face challenges in terms of sustainability and efficiency. The Hyperloop approach, a revolutionary technology, offers a solution by utilizing a tube system and magnetic fields to transport capsules at high speeds, with benefits such as environmental friendliness, safety, comfort, and cost-effectiveness.





Objectives
This research project aims to model the operating costs of a potential Hyperloop connection between Zurich and Paris. The objectives include developing a scenario, creating a cost model, parameterizing it within the scenario, conducting simulations, and analyzing the results. By understanding the underlying cost structure, this study seeks to evaluate the cost advantages of Hyperloop compared to conventional transportation methods and to identify future research needs.

2. Methodology & Materials

Methodology
This study utilizes desk research to establish a scenario for the Hyperloop system. The primary objective is to define the specific characteristics of the Hyperloop along the route. A high-level cost model is developed through qualitative desktop research and a literature review is conducted to link the cost model to the Hyperloop concept in detail. The cost model is then parameterized, resulting in a comprehensive model that represents the baseline costs of the Hyperloop connection. Subsequently, a sensitivity analysis and a Monte Carlo simulation are performed to examine the model. The sensitivity analysis identifies key variables that significantly impact costs, while the Monte Carlo simulation quantifies the expected costs and provides error bounds for the estimation. The final chapter focuses on the analysis and interpretation of the research results, addressing the expected operating costs, the level of certainty in cost predictions based on the available information, and the parameters with the greatest influence on operational costs.

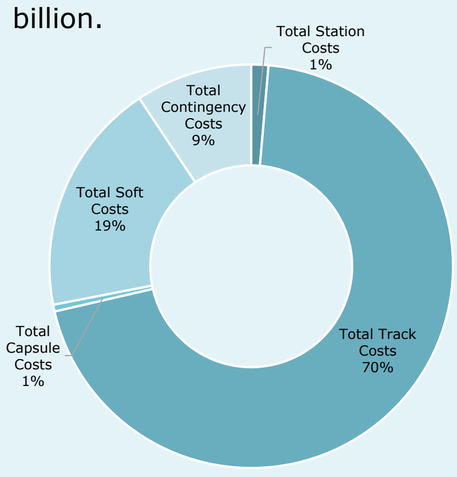
Materials
The Hyperloop concept, popularized by Elon Musk's Hyperloop Alpha white paper, has gained traction as a futuristic transportation system. Companies like Hyperloop One, Hardt Hyperloop, and others are actively developing and commercializing the technology. The Hyperloop involves high-speed capsules traveling through low-pressure tubes, propelled by linear electric motors. Initiatives like the European Hyperloop Center and advancements in energy efficiency and lane-switching capabilities showcase the ongoing efforts to make Hyperloop a reality.
One of the most important pieces of literature is therefore the White Paper itself, in addition to the numerous feasibility studies and concepts that have emerged since then.

3. Results

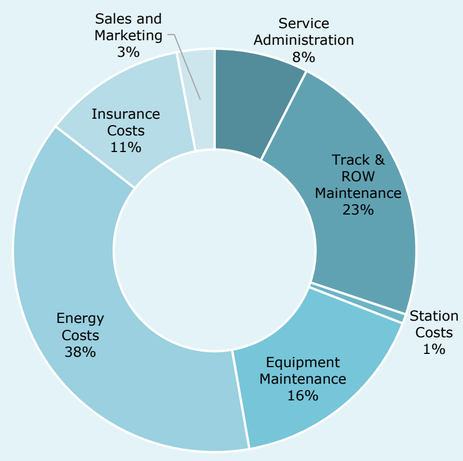
Results
In the baseline simulation, the total capital cost is determined to be $38.8 billion, with the track accounting for 70% of the cost, primarily attributed to tubes, tunnels, pillars, and other components. The operating costs in the baseline simulation amount to around $530 million per year, with energy costs representing the largest portion.

The sensitivity analysis examines the impact of individual parameters on total costs. Changes in factors such as tunnel proportions, land acquisition expenses, tube diameter, and distance affect the overall costs. Notably, the number of passengers per capsule and the travelled kilometer has a significant influence on operating costs. In terms of capital costs, the most significant factor is the tunnel to pillar ratio with higher costs connected to a larger tunnel share.

Additionally, the Monte Carlo simulation reveals a probability distribution for capital and operating costs, with the median capital cost estimated at approximately $62 billion and a 95% probability interval between $48 and $78 billion. The median operating cost is at around $1.13 billion the corresponding 95% probability interval between $800 million and $1.47 billion.



Total Capital Costs of $38.8 billion



Annual Operating Costs of $530.7 million

4. Discussion & Conclusions

Discussion
These findings highlight the need for further research, given the general uncertainty surrounding Hyperloop costs. As the technology evolves and more precise cost models emerge, accurate estimations can be provided. Collaboration among research groups and the establishment of standards and regulators are vital for ensuring compatibility and cooperation in the development of Hyperloop systems.
Route planning plays a significant role in reducing capital costs, particularly by addressing tunnel expenses through innovative solutions like low-cost tunnel-boring machines or by simply avoiding tunnels. Demand forecasting research is crucial for predicting operating costs accurately and facilitating infrastructure planning. Especially since the operating costs depend variably on the number of passengers and the kilometers driven.

Literature

- AECOM. (2020). *Preliminary Feasibility of Hyperloop Technology*.
- EuroTube. (2023). *Potential Analysis for Vacuum Transport Technologies in the Public Transport Infrastructure of Switzerland*.
- Musk, E. (2013). *Hyperloop Alpha*. https://www.tesla.com/sites/default/files/blog_images/hyperloop-alpha.pdf

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