Article

User Preferences towards Hyperloop Systems: Initial Insights from Germany

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Abstract: The rapidly evolving urbanization is generating unprecedented travel demand, notably in intercity travel. With increasing challenges in motorized traffic, innovative and sustainable transport modes are more than ever necessary. The Hyperloop system is an emerging transportation mode with the potential to change long–distance commutes, especially between cities. There is a need for, but also gap in, understanding this potentially emerging transport mode. This study aims at filling this gap by deploying a stated preference study in Germany, in which data was collected for 786 respondents with 5640 scenarios, to investigate the factors impacting users' preferences towards Hyperloop systems. Models were developed to examine factors impacting the immediate Hyperloop adoption (in the first year of its implementation), but also the choice between Hyperloop and other long–distance travel modes, such as airplanes and high-speed trains. Results indicate that mode-related characteristics (travel time, travel cost, safety), individual characteristics (gender, income level, availability of a driving license, access to a car, familiarity with the Hyperloop system), the current satisfaction level with high-speed trains and airplanes, and personality traits (confidence, affinity to technology) are the most significant factors in the choice and early adoption of Hyperloop systems.

Keywords: Hyperloop; user preferences; technology adoption

1. Introduction

According to the United Nations, around 68% of the world's population is expected to live in urban areas by 2050 [1]; other studies expect this percentage to go up to 80% [2]. This ever-growing urbanization, along with people's increased mobility needs, call for innovative solutions to accommodate the expected increase in transportation demand. Among other emerging transport modes, the Hyperloop system, advertised by Elon Musk in his Hyperloop Alpha white paper [3], is a new transport mode consisting of capsules propelled by electromagnetic forces in low-pressure tubes [4–7]. The system is claimed to reach maximum speeds ranging between 1000 km/h and 1200 km/h, while generating less emissions and noise compared to existing high-speed modes, namely high-speed trains and jets [8,9]. Hyperloop is also believed to be much safer than airplanes [10], making it a more reasonable choice than flying from an economical perspective [11].

In theory, Hyperloop is immune to severe weather conditions and is resistant to earthquakes [3,12]. It is also claimed to be energy-efficient, with low emissions, making it a more sustainable mode of transport [6,9,13]. Benefits promised by the Hyperloop system have encouraged researchers to believe it would accelerate economic growth [14–16], become a game-changer in the intercity mobility landscape [17,18], and ultimately bring positive benefits for society and the environment [19]. The prospects of Hyperloop's high technological nature, and the high expectations of having a faster, safer, and more sustainable mode of transport compared to the existing ones, makes it attractive to different stakeholders [20]. However, deployment of the Hyperloop is yet to occur, and to the best

of the authors' knowledge, research on factors impacting its demand and adoption is still limited. This study aims to fill this research gap by developing a stated preference (SP) survey to answer the following research questions:

- What factors impact the early adoption of Hyperloop?
- What factors affect the choice between Hyperloop and competing modes, namely high-speed train and air transportation (airplanes)?

The rest of this article is organized as follows: Section 2 presents an overview of the existing research on Hyperloop and on common factors used in mode choice. Section 3 presents the data and methods used in this study, including the questionnaire design, data collection tools, and the modeling framework for analysis. Sections 4 and 5 show the collected sample, and the different model results. Finally, Section 6 discusses the model findings, including limitations and potential future research, and concludes with the key takeaways from this study.

2. Literature Review

2.1. Hyperloop Overview

The concept of Hyperloop was first popularized by Elon Musk [3] as an alternative to the California high-speed rail development to connect San Francisco and Los Angeles [21]. Since then, international companies have adopted and advanced the idea of pods/capsules traveling with reduced air resistance through low-pressure tubes [22–24]. Several studies have explored the potential benefits of Hyperloop systems, such as, but not limited to, faster travel speed; savings in travel time, energy consumption, and emissions; self-sustainability; and resistance to severe weather conditions and earthquakes. Positive benefits of this mode can be summarized as faster operation speed (up to 1200 km/h) [15,25], lower or no emissions during trips [26–28], and resistance towards adverse weather conditions [4,9,26]; due to these strengths and promising potentials, Hyperloop is believed to be capable of bringing about massive shifts in intercity travel [18,29] for both passenger and freight transportation [30,31]. Regarding business operations for freight transport, Hyperloop could reduce travel costs, expand same-day delivery services, increase accessibility to manufacturing hubs, and extend the effective economic boundaries of a city [29].

Despite Hyperloop's attractiveness, the realization of the systems is hindered by many factors, such as high costs of infrastructure, maintenance and operation, safety aspects, reliability, land-use expropriation, and environmental impacts [32,33]. Moreover, manufacturing long vacuum chambers of a Hyperloop system requires advanced technical skills, which are also costly, hard to find, and risky to maintain [34]. Moreover, space in the train is also a concern in relation to Hyperloop operation [19,35]. Notwithstanding the previous hurdles for Hyperloop implementation, feasibility studies for system implementation are underway globally. Some of the proposed Hyperloop projects are summarized in Table 1.

Table 1. Summary of proposed Hyperloop projects.

Country	Proposed Route	Length	Company	Description/Type	Source(s)
Canada	Toronto–Windsor	370 km	TransPod	Passenger, cargo	[36]
China	Guizhou, China.	-	HyperloopTT	Passenger, 10 km commercial system in Tongren	[36]
India	Bengaluru–Chennai, Mumbai–Chennai	350 km 1340 km	Hyperloop One	Feasibility study	[22,37]
Saudi Arabia	Mecca–Riyadh	870 km	TransPod	Passenger	[36]
Sweden	Stockholm–Helsinki	500 km	Hyperloop One	Commercial passenger	[38,39]
UK	London–Glasgow, Edinburgh–London	820 km 650 km	TransPod Hyperloop One	passenger system Cargo	[36]

Table 1. *Cont.*

Country	Proposed Route	Length	Company	Description/Type	Source(s)
USA	Cleveland–Chicago, San Francisco–Los Angeles	520 km 563 km	HyperloopTT	Northeast Ohio Coordinating Agency Commercial passenger, cargo	[4,9,15]
UAE	Dubai–Abu Dhabi	150 km	HyperloopTT	Passenger system [9,36]	
Germany	Hamburg	-	HyperloopTT	Joint Venture Cargo HTT and Port of Hamburg operator	[31,40,41]
Netherlands	Amsterdam–Frankfurt	450 km	Hardt	Passenger system	[42,43]
Switzerland	Zurich–Geneva	250 km	Swisspod	Passenger and cargo system	[44,45]

2.2. Common Factors in Mode Choice

To the best of the authors' knowledge, previous research has not yet investigated the impact of introducing Hyperloop on existing modes of transport and the potential modal shift resulting from this market penetration. Studies on conventional mode choice and emerging modes of transport, especially for long-distance travel, were therefore reviewed to determine significant factors that could influence mode choice decisions, and they were considered and used in the questionnaire design (Section 3). De Witte et al. [46] defined mode choice as the process of choosing between different travel alternatives. It is defined by a mixture of different factors, including individual sociodemographic, sociopsychological factors, and spatial characteristics. Some of the most significant factors for mode choice for long trips are travel time and cost [47–51], safety [52], access time, egress time, waiting time [49,53,54], level of service [36,55], comfort [49,56], travel purpose [47,49,57], and individual sociodemographics [48,49,52,56,58–60]. Previous studies differentiated between short-distance and long-distance trips as trip distance might influence the mentioned factors, although there is no standard definition for long trips. A long-distance trip is typically described as longer than 50–100 km [61]; consequently, long-distance trips are less regular, making travelers less familiar with accessible transportation options. It is to be noted that faster travel options are typically preferred in terms of long-distance trips [62].

Several studies described sociodemographic characteristics as critical for mode choice decisions. Sociodemographic variables such as gender [63], income [64], education [65], and age [66] are considered significant in different studies. For example, a study in the Toronto–Montreal Corridor [67] found that women have different tendencies compared to men in Canadian intercity travel mode choice. According to Georggi and Pendyala [68] and Mallett [66], males tend more than women to use a car in long-distance travel. Regarding income impact, high-income individuals tend to drive more compared to low-income people, who prefer to use buses [64]. When it comes to education level, studies have shown contradictory findings. In one study, people with higher education levels were found to prefer public transport for long-distance travel [65], whereas in another study, they were found to prefer a car [69]. Mode choice also depends on the trip purpose due to the different space–time fixity and time value [70]. Generally, business trips are more fixed within time and place [71,72]; thus, travel tends to use more expensive modes for business trips compared to other trip purposes [73]. Moreover, several studies considered the transit station location as an important factor for mode choice [74–77]. People are more likely to take the bus if the railway station is outside the city center [64,75,76,78]. Finally, de Lapparent et al. [79] studied the imbalance of heterogeneous preferences among European countries. According to this study, spatial heterogeneity in traveler composition and preferences can play an important role in mode choice decisions.

Utility maximization theory assumes that individuals faced with various alternatives will opt for the ones that yield the best benefits (utility) for them. Different computational and statistical techniques have been widely used in many fields, including transportation, to quantify the factors influencing mode choice decisions. The more traditional statistical methods used are known as discrete choice models, which are prevalent in transport mode and route choice modeling [80] and are usually based on the utility maximization theory. Based on the number of alternatives and goals, different models, such as multinomial logit, probit, binomial, nested, and ordered logit, are used [81]. The application of choice models in transportation is extensive; for example, Abouelela et al. [82] used choice models, including binary logit model, hybrid choice model, and an ordered logit model, to quantify the factors impacting the shift from traditional modes to pooled rides, the choice between different pooled ride services, and the frequency of using pooled rides, respectively. Mode choice studies have also been used in understanding emerging modes of transport; Al Haddad et al. [83] used an ordered logit model and multinomial logit models to assess the acceptance and adoption of urban air mobility.

3. Data and Methods

3.1. Questionnaire Design and Data Collection

3.1.1. Questionnaire Design

To understand user preferences for Hyperloop use compared to existing intracity mass transit modes, a stated preference (SP) survey was designed and disseminated in Munich, Germany. The survey consisted of four main parts. The first part investigated the users' general travel behavior, such as the users' main commute mode, modes used for long-distance trips (trips longer than 400 km), and satisfaction level with flights and high-speed trains, but also other questions including ownership of a driver's license or access to a private car. Finally, this part included questions to assess general factors impacting users' mode choice, including different attributes. The second part then investigated respondents' familiarity with Hyperloop systems, including their perceptions and expectations from this mode .

The third part of the survey was the stated preference part, which consisted of 10 blocks with 10 scenarios/block. The number of scenarios was chosen using random design as previously used in Abouelela et al. [84], Walker et al. [85]. The scenarios were built considering one of the heaviest traveled corridors in Germany [86], between Berlin, the capital city of Germany and Munich. Berlin is the capital and largest city of Germany with a population of about 3.6 million individuals [87], and Munich is the third largest city with 1.5 million inhabitants [88]. Around 1.8 million passengers travel between Munich and Berlin by high-speed train, representing 46% of the total number of trips between the two cities, while 1.2 million people use an airplane for the same route, an equivalent of 30% of the total trips [89]. The distance between Munich and Berlin is about 623 km for the high-speed train and 504 km in flights. This frequently traveled corridor was chosen for the experiment design to give the respondents a realistic scenario for the mode choice decision and to reduce the hypothetical bias in the SP survey responses [90]. Table 2 shows the summary of the attributes and levels used in the designed survey, and Figure 1 shows the scenario details and a block example.

Table 2. Scenario levels and attributes.

Alternatives	Attributes	Attribute Levels	Values	Unit	Sources
Hyperloop	Travel time	−30% , 0%, +30%	100/140/180	min	Created for this experiment
	Travel cost	−30% , 0%, +30%	46/69/92	EUR	Created for this experiment
	Safety	Driving safety level, two times safer than driving, four times safer than driving			[84]
	Frequency	5 min, 10 min, 15 min	Every 5/10/15	min	Created for this experiment
High–speed train	Travel time	−30%, 0%, +30%	230/310/390	min	[91,92]
	Travel cost	−30%, 0%, +30%	46/69/96	EUR	[91,92]
	Safety	Driving safety level, two times safer than driving, four times safer than driving			[84]
	Frequency	3, 4, 5 trips/day	every 5/6/8	hour	[91,92]
Airplane	Travel time	−30%, 0%, +30%	180/250/320	min	[92]
	Travel cost	−30%, 0%, +30%	90/140/190	EUR	[92]
	Safety	Driving safety level, two times safer than driving, four times safer than driving			[84]
	Frequency	3, 4, 5 trips/day	every 5/6/8	hour	Created for this experiment

Figure 1. Survey block design example.

3.1.2. Data Collection

The designed survey was distributed online and was administrated on the online platform LimeSurvey (limesurvey.org, accessed on 6 October 2022). The data were collected from mid-January to the end of March 2021. The survey targeted users from Germany, specifically Munich, and was available in English and German and distributed among various groups, including local university groups, community groups, student dormitories, professional groups, and related research companies. The survey was further distributed on social networks, mailing lists, and professional media platforms such as Facebook, Linkedin, and XING).

3.2. Modeling Framework

The first modeling technique used was the exploratory factor analysis (EFA), a statistical method used to explain the variability within observed and correlated variables in terms of the lower number of unobserved variables; in other words, it is used as a dimensionality reduction technique [93,94]. In addition, it has been widely used in transportation research to estimate the latent construct of the data or users' attitudes and perceptions [82], which was the case in this research. A scree plot test was performed to define the number of factors, in particular, a polychoric correlation coefficient was used for its appropriateness compared to Pearson's correlation for ordinal categorical variables, using a Likert scale [95]. After applying the scree plot test, the final factors numbers considered the lowest variance per factor to be 10% of the total variance following an approach similar to the one used in Abouelela et al. [82], Tyrinopoulos and Antoniou [96]. Loadings higher than 0.40 were kept, considering the sample size, in accordance with Costello and Osborne [97], Hair et al. [98]; factors with loadings less than 0.4 were removed iteratively. Varimax rotation was applied to obtain a simple orthogonal structure between the different factors.

As the aim of this paper is to investigate the factors impacting the adoption and choice of Hyperloop, and due to the discrete nature of the dependent variables of interest, i.e., immediate adoption of Hyperloop (yes vs. no) and the mode chosen for travel (Hyperloop vs. other modes), discrete choice models were used; in particular, a binary model was used for the former and a multinomial logit model for the latter. Users' attitudes, in terms of personality, traits, and perceptions of new technologies, extracted by the exploratory factor analysis results were incorporated into the modeling process in addition to individual and modal characteristics and attributes.

4. Data Analysis

4.1. Sociodemographic Characteristics

A total of 980 responses were collected; after removing the uncompleted responses, a total of 786 responses were deemed adequate to use. Table 3 shows the sociodemographic characteristics of the collected sample. In terms of gender, age, and education, the sample was skewed towards highly educated young males compared with the city of Munich (Germany 2011 census data). It is to be noticed that the majority of participants were young, 85% were under 34 years old, and 86% of the participants had at least a bachelor's degree compared to 25% of the population. The strong presence of the young respondents was justified by being the target group of interest. In addition, in terms of occupation and household income, there was a strong presence of students, with a lower average income, compared to the city's average, which makes sense (as most respondents were students). Moreover, around half of the sample had a valid driving license and access to a car. As this study focuses on the adoption and use of Hyperloop by young users, only responses for individuals between 18 and 34 years will be analyzed and presented in the following section.

Table 3. Sample sociodemographic characteristics.

	Freq (Pct%)	Munich Census (2011)
Gender		
Female	272 (35%)	48.30%
Male	487 (62%)	51.70%
I prefer not to answer	27 (3.4%)	
Age		
18–24	267 (34.1%)	8.10%
25–34	422 (54%)	18%
35+	86 (12.3%)	73.90%
I prefer not to answer	11 (1.4%)	
Education		
Master or PhD	329 (42%)	2.5% (PhD)
Bachelor	348 (44%)	Bachelor/MS: 22.7%
Other	101 (13%)	
I prefer not to answer	8 (1.0%)	
Occupation		
Working (Full-time)	206 (26%)	Full/part time 87.1%
Working (Part-time)	65 (8.3%)	
Student	454 (58%)	2.90%
Other	49 (6.2%)	
I prefer not to answer	12 (1.5%)	
Household Income		
Up to 1000 €	273 (35%	
1000 to less than 2000 €	140 (18%)	
2000 to less than 3000 €	98 (12%)	Avg: 4220 €/household
3000 €or more	130 (17%)	
I prefer not to answer	145 (18%)	
Driving license		
Yes	452 (57%)	
No	319 (41%)	
I prefer not to answer	15 (2%)	
Access to car		
Yes	374 (48%)	
No	395 (50%)	
I prefer not to answer	17 (2%)	
Total (N) = 786		

4.2. Travel Behavior

The first part of the survey investigated respondents' travel behavior, as it has been found to impact mode choice and use emerging transport modes [82]; also, gender was found to play a significant role in the adoption of disruptive transport technologies, such as in the case of urban air mobility [83]. Therefore, respondents' travel behavior was investigated, with a focus on gender differences. First, the most frequently used modes for urban travel were investigated and compared based on gender, as shown in Figure 2. Results indicate that respondents were frequent public transportation users and less dependent on a private car for daily movement; respondents also showed affinity to new transportation modes, i.e., scooters, despite it being limited to around 3% of users. A Chi-square test was performed to compare differences across gender; results indicated that there were no

differences between the collected sample of males and females for general travel behavior in the urban environment.
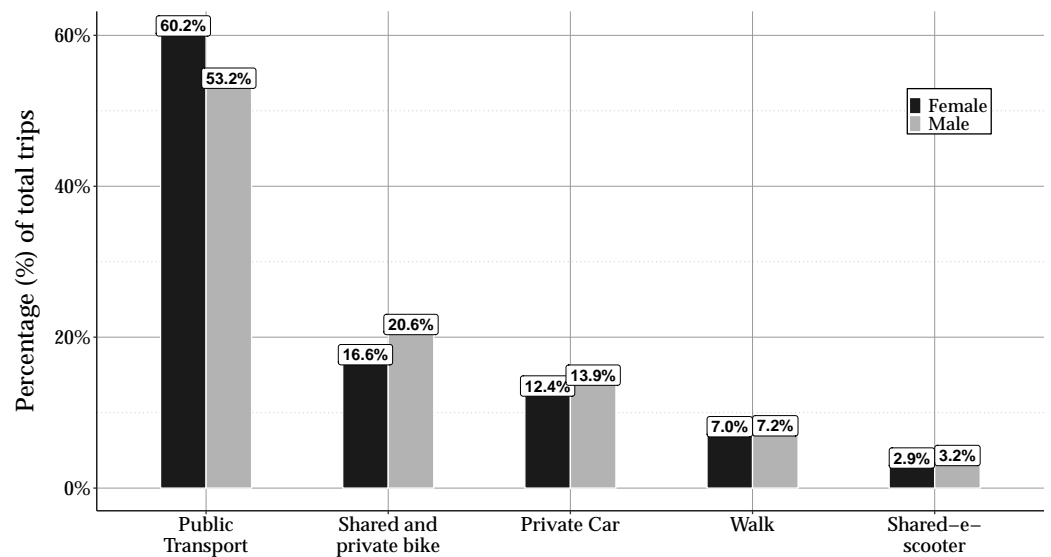
Figure 2. Main mode of transport as a percentage of total trips by gender.

The second item related to respondents' travel behavior investigated the main modes used for long-distance trips, i.e., trips longer than 400 km. The top three chosen modes were high-speed train (HST), airplane, and car, representing 43%, 24%, and 21% of respondents, respectively. These results reflected the popularity of HST among respondents, as it captured about double the share of other modes. For this travel behavior item, gender was also not found to be significant for the choice made; a descriptive visualization of the results is shown in Figure 3.
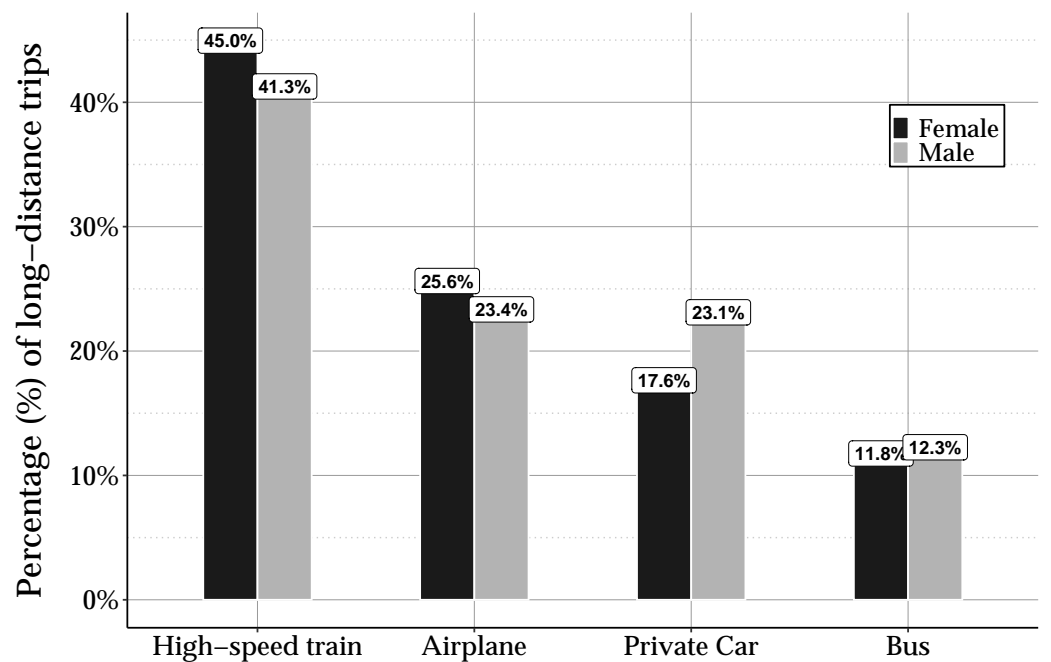
Figure 3. Respondents' main mode of transport for long-distance trips (≥400 km) by gender.

Users also had to specify their use frequency for bus, car, airplane, HST, and ride–sharing services such as (BlablaCar). The frequency of use was specified on a four-point Lik-

ert scale, ranging from: (i) never or almost never; (ii) less than once a month; (iii) 1–3 times per month; (iv) and finally 1–3 times per week. The analysis of the frequency of use showed that respondents mainly traveled long distances less than once a month, and the distribution of the different modes used per gender showed no significant differences across gender.

Respondents' satisfaction level for both HST and airplanes (flights) was visualized and is depicted in Figure 4. On average, the satisfaction level was slightly higher for females compared to males, but the differences were not statistically significant for both modes, and the satisfaction with airplanes (flight) use was slightly higher than that of HST: 63% and 46%, respectively.
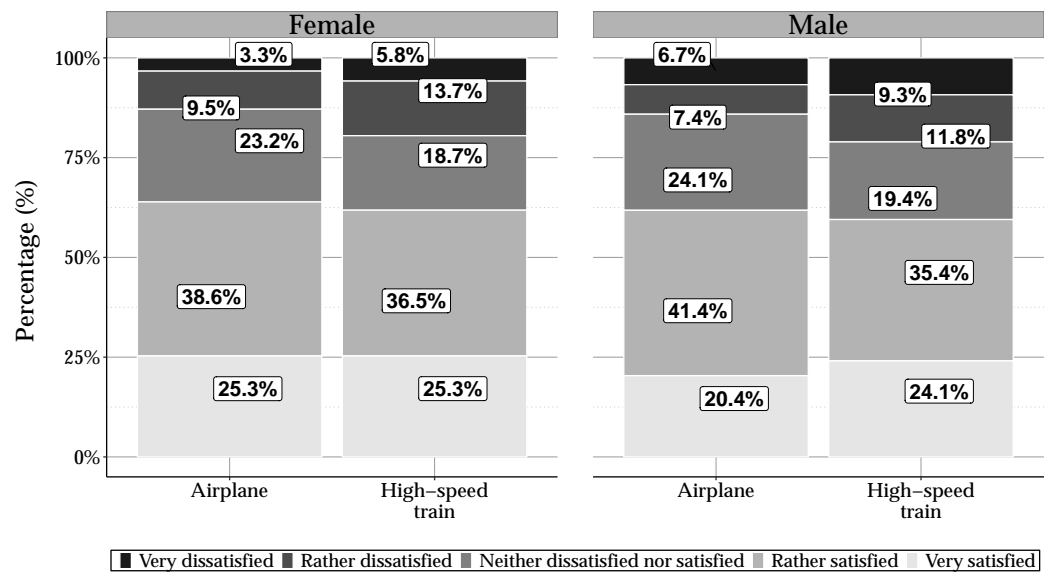
Figure 4. Respondents' current level satisfaction with airplanes (flights) and high-speed trains by gender.

Respondents also evaluated five aspects of mode choice that were most present in previous mode choice literature as indicated in Section 2; these were namely: comfort, environmental impact, travel time, and travel cost. This assessment included a ranking of the most critical factor in mode choice decision. Respondents' ranked their options based on a five-point Likert scale, ranging from "very important" to "not important at all". Results for this assessment are presented in Figure 5 and showed that cost, time, and safety were the most decisive factors in mode choice, capturing 91%, 89%, and 82% of the users, respectively. Similar to the previous question, the assessment of the responses to this question by gender showed no significant differences between female and male respondents.

Finally, respondents ranked their previous knowledge of Hyperloop systems on a four-point Likert scale, ranging from: "I know a lot about it" to "I do not know it"; results are presented in Figure 6. While almost a third of respondents (29%) had not previously heard about the system, only 9% claimed to have good knowledge of it. When comparing responses by gender, significant differences were observed, with a high confidence level. The majority of male users knew a lot about Hyperloop, or at least had looked into it (78% and 82%, respectively), compared to female respondents (22% and 18%, respectively). Therefore, gender is expected to play a significant role in Hyperloop use and adoption.
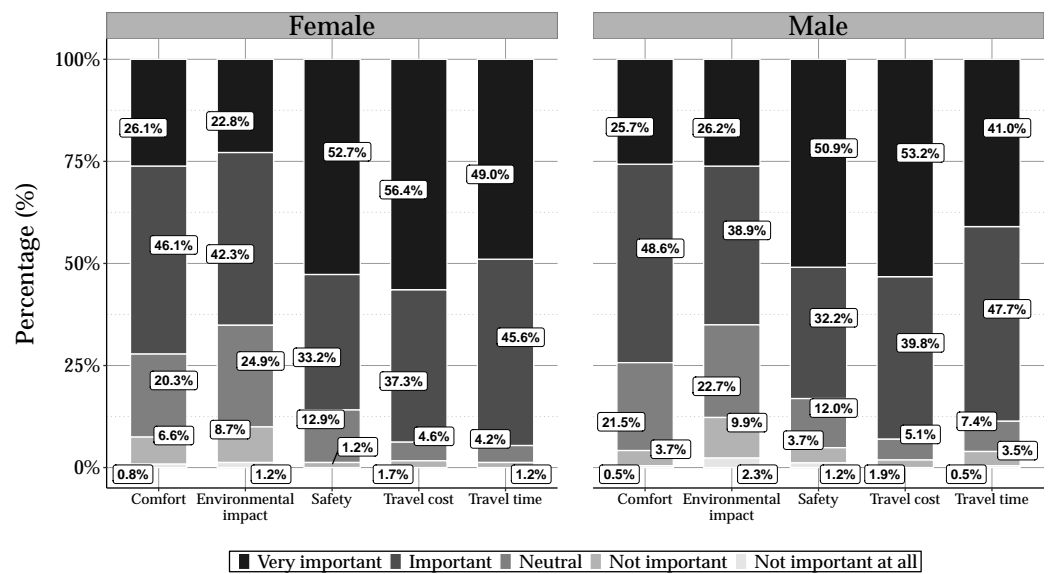
Figure 5. Respondents' evaluation of mode choice attributes by gender.
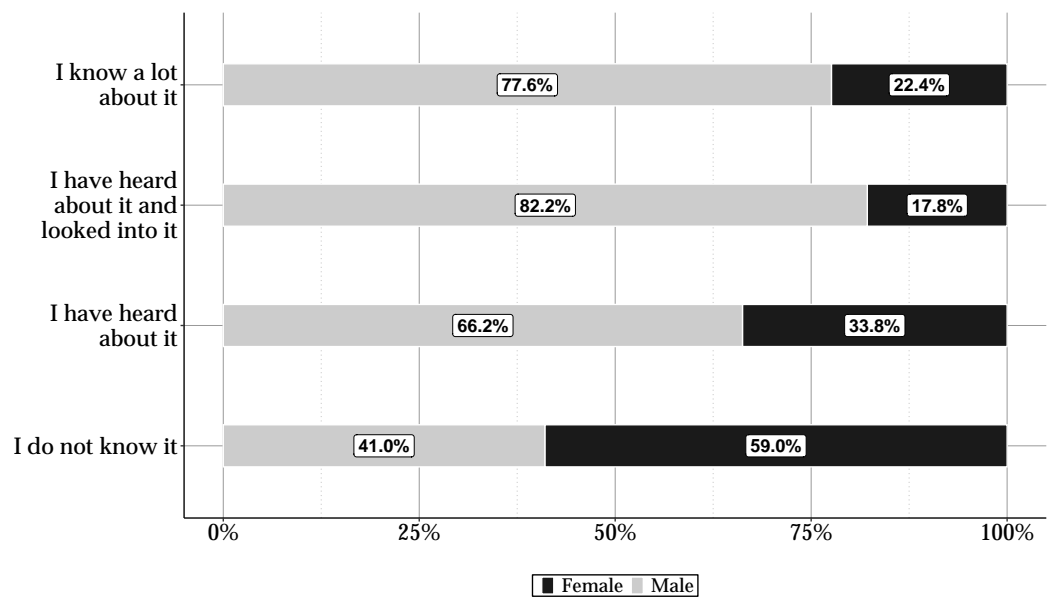
Figure 6. Respondents' familiarity with Hyperloop by gender.

5. Modeling Results

5.1. Exploratory Factor Analysis

Exploratory factor analysis (EFA) was performed on two different sets of questions. In the first set, respondents were asked to respond to five statements on their concerns towards new technologies, with answers on a five–point Likert scale, ranging from "strongly agree" to "strongly disagree". The main reason for using EFA was to reveal latent constructs behind different statements. Procedures for EFA estimation mentioned in Section 3.2 were followed, namely the use of varimax rotation and the cut-off value of 0.4 for factor loadings. Results for the performed factor analyses are presented in Table 4.

The estimated two factors for the first set of statements on technological questions were interpreted as technological affinity (Factor 1) and technological concerns (Factor 2). In the second set of questions used for the EFA, respondents rated their agreement with four statements regarding their personality, with answer options also following a five-point Likert scale as described above. Two factors were estimated with the proportion of

variance more than 0.10 and factor loadings more than 0.40, following guidelines mentioned in Section 3.2. The extracted factors were interpreted as confident personality and non-confident personality.

Table 4. EFA results for technology and personality-related statements.

Technological Concern Statement	Factor 1	Factor 2
Excited by the possibilities offered by new technologies	0.76	
I use new technology products even when expensive	0.50	
I trust high-speed automated systems	0.64	
Hyperloop will be successful in Germany	0.52	
New technologies causes more problems than they solve		0.55
I have concerns regarding personal privacy and data security for my trips		0.44
Sum of square of loadings	1.41	0.56
Proportion variance	0.23	0.10
Cumulative variance	0.23	0.33
Factor interpretation	Technological affinity	Technological concerns
Personality Statement	**Factor 1**	**Factor 2**
My decisions are not usually influenced by what everyone else is doing	0.75	
Generally, I feel confident and positive about myself	0.40	
Given the opportunity, there are many things about myself that I would change		0.60
I often change my mind about decisions if my friends or family disagree		0.40
Sum of square of loadings	0.74	0.54
Proportion variance	0.18	0.13
Cumulative variance	0.18	0.31
Factor interpretation	Confident personality	Non–confident personality

5.2. Hyperloop Adoption Model

Users also specified their expected use of Hyperloop, with answer options ranging from the first year of operation, to the second or third year of operation, to the fourth or fifth year, starting in the sixth year, never, and unsure. Around 75% of respondents stated a use within the first two years, 14% were unsure, and less than 1% stated that they would never use the service. The year of the adoption reported by the users was initially set as an ordered dependent variable due to its ordinal nature to model the factors impacting the year of Hyperloop adoption. However, the distribution was unbalanced between the different choice categories, which created a separation effect while developing the model [99]. In addition, due to the limited number of unsure respondents and respondents who would never use the system, we excluded both categories from the developed models and aggregated the rest of respondents between respondents who would adopt the service in the first year and those who would adopt it starting from the second year. Table 5 shows the estimation results of the binary logit model, where the adoption year was the dependent variable set to zero when respondents chose to adopt the service in the first year of implementation and one otherwise. Only two variables proved to be statistically significant at a 95% confidence level, namely gender and confident personality (the latter being a newly generated factor based on the EFA results presented in Table 4). These results indicate that males are more likely than females to immediately adopt Hyperloop and that confident users are more likely to adopt the service early on; these findings are at least partially compatible with those presented by Al Haddad et al. [83] in their assessment of acceptance and adoption of urban air mobility, which is also an emerging mode of transport.

Table 5. Hyperloop immediate adoption model results (binary logit model).

	β	**Robust SE**	**Robust *t*-Test**	***p*-Value**
Intercept	−0.53	0.16	−3.26	0.00
Gender (Males)	0.34	0.20	1.71	0.04
Confident personality	0.19	0.10	1.94	0.03

LL(0) = −327.86
LL(final) = −318.37
ρ^2 = 0.03
AIC = 642.74, BIC = 655.21

5.3. Multinomial Logit Model

To extract the factors impacting the choice of Hyperloop among other competing modes, in this case, HST and airplanes, a multinomial logit model (MNL) was developed; the model results are presented in Table 6, including the "none" option, which was kept as it has been previously shown to improve the model fit [52].

Table 6. Multinomial logit model results (Hyperloop vs. other modes).

	Hyperloop			**High-Speed Train**			**Airplane**			**None**		
	β	SE	*t*-Test	β	SE	*t*-Test	β	SE	*t*-Test	β	SE	*t*-Test
Mode characteristics												
ASC				−0.80	0.34	−2.35	−5.48	0.58	−9.44	−9.54	0.77	−12.35
Travel time	−0.01	0.00	−9.13	−0.01	0.00	−13.24	−0.01	0.00	−4.77			
Travel cost	−0.05	0.00	−15.44	−0.04	0.00	−13.01	−0.01	0.00	−4.86			
Safety (ref. = driving level safety)												
Safety >= 2* driving safety level	0.40	0.07	5.62	0.55	0.08	6.55						
Safety >= 4* driving safety level	0.53	0.09	6.19	0.61	0.09	7.06	0.81	0.13	6.30			
Individual characteristics												
Income level (ref. EUR <=1000)												
Income level: between EUR 1000 and 2000	0.36	0.09	4.16				0.84	0.18	4.56			
Income level: between EUR 2000 and 3000	1.66	0.76	2.18	1.53	0.77	2.01	1.95	0.79	2.48			
Income level: EUR >= 3000	0.34	0.11	3.13				1.59	0.19	8.29			
Access to car (ref. = no access)	2.09	0.46	4.57	1.79	0.46	3.92	2.21	0.49	4.52			
Familiarity with Hyperloop (ref. = I know a lot about it)												
I do not know it	−0.15	0.08	−1.96									
I have heard about it												
I have heard about it and looked into it	−0.82	0.31	−2.61	−0.55	0.31	−1.75	−1.19	0.35	−3.43			
Satisfaction with other modes												
Satisfaction with HST (ref. = not satisfied)												
Neutral	−0.75	0.54	−1.41	−0.78	0.54	−1.46	−0.84	0.57	−1.47			
Satisfied	−1.18	0.48	−2.45	−0.77	0.48	−1.62	−1.36	0.51	−2.70			
Satisfaction with airplanes (ref. = not satisfied)												
Neutral	0.43	0.11	3.76									
Satisfied	1.15	0.35	3.27	0.75	0.34	2.20	1.50	0.37	4.08			
Personal attitudes												
Technological affinity	0.53	0.13	4.07	0.20	0.13	1.48	0.28	0.15	1.93			
Technological concern							0.47	0.08	5.94			
Confident personality				−0.18	0.07	−2.76						
Non−confident personality	0.12	0.04	3.25				0.20	0.08	2.68			

LL(0) = −4522.7, LL(final) = −3815.3
ρ^2 = 0.51, $\rho^2_{adjusted}$ = 0.50
AIC = 7728.7 , BIC = 80539

The mode-related attributes were all found to be significant, and the estimated coefficients showed that an increase in travel time and travel cost (negative estimated coefficients) reduce the likelihood of choosing the modes (for all modes), which is intuitive and common in mode choice modeling [52,84]. Safety was also highly significant; the higher the safety level (compared to driving safety level), the more likely the choice of the option. This factor was found to be significant for all modes and all levels (two or four times safer than driving), except for the airplane mode, in which safety level was only significant for the highest safety level (four times safer than driving); the latter is believed to be due to

respondents' general higher safety perceptions of airplanes compared to other modes. In addition, respondents' higher satisfaction with flights compared to HST could be a reason behind the highest safety perception of flights; refer to Figure 4.

Among respondents' individual characteristics, or sociodemographics, only household income, availability of a driving license, and access to a car, were found to be significant sociodemographics impacting the mode choice experiment. After setting the income level less than EUR 1000 as a reference level, all income levels were found to be significant for the examined modes except for HST, where only one level (between EUR 2000 and 3000) was found to be significant. The estimated income coefficients showed that high-income households (between EUR 2000 and 3000) are more likely to use each of the three tested modes compared to other income categories. In addition, the availability of a driving license reduces the likelihood of using different modes, including Hyperloop; however, access to a car increases the possibility of using flight, followed by Hyperloop.

Familiarity with Hyperloop coefficients showed that the more the respondents were knowledgeable with the Hyperloop concept, the more likely they were to use it (or state that they would use it). Satisfaction levels with HST and airplanes were aggregated to three levels, namely "not satisfied", "neutral", and "satisfied". The "not satisfied" level was set as a reference level. The coefficient estimated showed that the higher the satisfaction with airplanes, the more likely to use them (airplanes or flights) compared to Hyperloop.

The extracted factors from the EFA were also used to estimate the impact of personal attitudes on the respondents' choices. Affinity towards technology was found to most significantly impact all modes, with a higher magnitude for Hyperloop systems, indicating that the higher affinity would result in a higher likelihood of choosing Hyperloop. On the other hand, technological concerns would reduce this likelihood, and people would be more likely to use airplanes instead. Personality traits factors showed that a confident personality would result in a lower likelihood of using HST compared to Hyperloop and flights. On the other hand, a non-confident personality would result in a higher likelihood of using airplanes compared to Hyperloop.

An important application of MNL models in SP studies is to calculate the value of time (VOT) for the different, mostly for policy making, such as, but not limited to, ticket pricing [100]. VOT can be simply explained as the amount of money travelers value a unit of their time for or the willingness to pay to use a certain mode [101]. Small [102] presented VOT as an indirect utility function with time and value, as presented in Equation (1).

$$VOT = -\frac{dT}{dC} = \frac{\frac{\partial V}{\partial T}}{\frac{\partial V}{\partial C}} \cdot 60 = €/\min \tag{1}$$

where *V* = systematically derived element, *C* = travel costs, and *T* = travel times.

Based on the estimated MNL coefficients (see Table 6), the estimated VOTs for the three modes are; VOT(Hyperloop) = EUR 11.7 h, VOT(HST) = EUR 14.3 h, and VOT(airplane) = EUR 41.7 h. The calculated VOT shows that Hyperloop is the mode with the lowest VOT, compared to HST and airplanes. This calculation did not consider trip purpose, which is a limitation for this study. Wardman et al. [103] estimated VOT for HST commuter trips as EUR 10.5 h for trips shorter than 250 km, EUR 9.55 h for longer trips and business trips shorter than 250 km, EUR 45.6 h for flights, and EUR 30 h for HST. VOT for business trips longer than 250 km was EUR 39.8 h for HST, and EUR 71.1 h for flights. Other trip purposes shorter than 250km were found to have a VOT of EUR 9.8 /h for HST, and EUR 16.5 h for flights, and other trips longer than 250 km were found to have a VOT of EUR 8.22 h for HST, and EUR 18.8 h for flights. The estimated VOT for the HST was higher than the previously estimated German VOTs, except for the business trips; on the other hand, the estimated airplane VOT was higher than that of previous studies in Germany, but lower than the estimates for business trips. This study study calculated VOT based on the total travel time, including the in-vehicle travel time, access/egress time, and waiting time at

the station. In practice, passengers may value these times differently. [54] suggested that in-vehicle time has a higher value than others. These could be limitations of this study, in particular in calculating the value of time.

6. Discussion, and Conclusions

6.1. Survey and Model Findings

The main findings of the data analysis of the survey's results can be summarized as follows; more than half of the users are avid public transport users, and 82% of respondents commonly use sustainable modes for intercity transport, such as public transport, cycling, or walking: 55%, 19%, 7%, respectively. This travel behavior can be associated to many factors, such as the young age of respondents, the limited travel options they possibly have, and their environmental concerns, also reflected in their answers, where around 60% of them mention environmental impacts as an important reason to choose their travel mode (see Figure 5). In addition, for long-distance trips (higher than 400 km), the majority of respondents preferred HST, with around 43% choosing it as their primary mode of transportation for such trips; however, respondents had a higher tendency to be more satisfied with the current level of services of airplanes compared to HST. This could be due to their generally lower income levels, which results in their lower use of flights, and therefore false perception of its quality; however, more investigation is needed to verify this observation.

The majority of respondents (70%) had prior knowledge about Hyperloop technology, with only 9% of them having a profound understanding of this mode. Additionally, men tended to have significantly more knowledge and interest in Hyperloop compared to women. The importance of familiarity or knowledge about the new technologies was also found to play a significant role in further emerging transport modes, such as UAM, as indicated in Al Haddad et al. [83]. The analysis of the choice experiment results showed that Hyperloop was chosen on average around 68%, high-speed train around 26%, and airplanes (flights) around 5%, and none of the three options in less than 1% of the observed choice scenarios, with no significant difference between gender choices. The choice options were also compared to the current primary mode of long-distance travel, with no significant difference observed (see this comparison in Figure 7).

The choice experiment examined four major attributes of the used mode, namely travel cost, travel time, frequency of the service, and safety. Only frequency was not found to be a significant factor for all the tested modes, and safety was the factor with the highest coefficient in comparison to the rest of the service attributes, highlighting its importance for the adoption of new technologies, which was also observed in other emerging mobility studies [83]. Yet, despite frequency not being found as a significant factor, it is possible that respondents did not understand this attribute well, due to the used units, which could be improved in future studies.Individual characteristics also played a significant role in the mode choice. People with higher income levels were found to be more likely to choose flights and Hyperloop. Car access was found to be the individual factor with the highest magnitude. Furthermore, familiarity with Hyperloop and satisfaction with HST and flights played a significant role in mode choice, showing the potential for Hyperloop to attract people from other modes, specifically HST. Finally, personal attitudes showed that affinity to technology indicated a higher likelihood for the choice of Hyperloop, reference (see Table 6).

Modeling the early adoption of Hyperloop (using the first year of its implementation as opposed to later on) showed similar results, with only two significant estimated factors: gender coefficient, where males were more likely to be early adopters compared to females, and confident personality, which was also directly associated with early adoption. This gender gap could therefore be a relevant point to be addressed by stakeholders for successful market penetration.
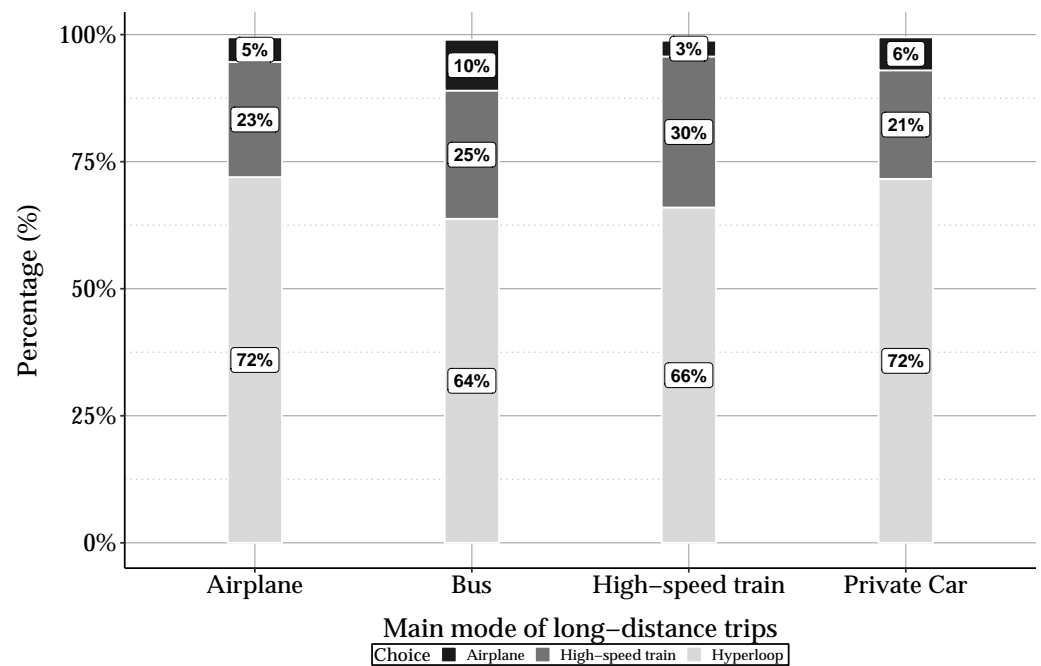
Figure 7. Relationship between the mode for long-distance trips and mode chosen in the experiment excluding the "None" option.

6.2. Policy Implications

The model results indicated that travel time, cost, and safety are crucial factors in mode choice decisions. Therefore, the Hyperloop advantage in travel time should be leveraged and well-marketed, especially for time-sensitive passengers (e.g., people on business trips) who value time more than costs [72] for a successful adoption. Safety factors were also proven to be highly influential. As many experts are still concerned about the safety of the Hyperloop system, this factor should therefore be at the forefront of Hyperloop research and product development.

Models showed that users who have a high affinity towards technology would be more likely to use Hyperloop. Additionally, although gender did not have a significant impact on the mode choice modeling, it was crucial for the early adoption of Hyperloop. The gender impact on the early adoption should be considered in developing policy and marketing strategies of Hyperloop.

Most respondents in this study normally used high-speed trains (43%) as their primary transport mode for long-distance trips. This group of people would likely have a higher tendency to use and adopt Hyperloop, possibly due to their already low satisfaction with HST compared to flights. The same was also observed for public transport users.

For a successful penetration and adoption of Hyperloop systems, this study proved that mode choice decision is highly influenced by service attributes, sociodemographics, and individual attitudes, which should be considered in system planning and policy making. Currently, there are no regulations and official safety requirements for Hyperloop. Therefore, certifications could be a way of gaining users' trust in terms of safety. Environmental and economic gains from Hyperloop should also be highlighted and compared with current modes. Cost is also crucial for mode choice; therefore, an affordable system would ensure a higher level of inclusiveness. Finally, an integration of Hyperloop within the existing modes would be crucial for an efficient and seamless operation.

The obtained results on significant factors are consistent with prior expectations and previous mode choice literature, where travel time, cost, and safety are often found to be major factors considered for decision making in mode choice. However, owing to the lack of literature in Hyperloop mode choice, this study confirms these findings, but also goes

further into estimating a value of time for Hyperloop, as described in Section 5.3. These findings parallel those obtained in Al Haddad et al. [83], in which urban air mobility was assessed as an emerging mode of transport. Understandably, disruptive transport technologies, despite their differences, share commonalities in terms of societal perceptions towards them. In other words, research in Hyperloop could learn from other disruptive modes of transport and look at the lessons learned there, which could possibly be transferable, mostly in terms of policy implications for emerging modes of transport.

6.3. Limitations and Future Work Recommendations

This study of course has its own limitations. The SP survey was developed based on a random experimental design, which may have introduced biased statements and choice scenarios. The online distribution of the questionnaire may have resulted in sampling bias and under-representation of some groups; however, the targeted group of young users was well represented in this research. Still, it would be interesting to look at different age groups, including the working class (employees), as they might be users of interest, commuting for instance longer distances to and from work. In this case, different results could be found, and the current study results and value of time would not be directly applicable; insights from this study concern the targeted age group (younger users), and any extrapolation would need to carefully weigh the results based on the new targeted user group. Moreover, as Hyperloop is still developing, travel times and cost data are limited and purely theoretical. This study incorporated cost values from outside Europe, particularly North America. Translating these values into the European/German context may not be as direct as this study assumed. Due to the lack of safety regulations for Hyperloop, this study compared the Hyperloop, high-speed train, and airplane safety levels to driving safety, which may have caused some confusion for the respondents. Future work could improve these limitations as more research and data on Hyperloop attributes becomes available.

6.4. Conclusions

This study explored users' preferences of Hyperloop, through mode choice and adoption upon a hypothetical Hyperloop implementation, using a stated preference survey targeting young users in Munich, Germany. A factor analysis identified personality traits, such as confidence, non-confidence, and technology affinity or concerns, as significant latent variables and attitude clusters. Discrete choice models were developed to emulate transport mode choice for long-distance trips and revealed that despite HST being the currently most prevalent mode for long-distance trips, people would prefer Hyperloop, should it be implemented. Travel cost, travel time, and travel safety were the more influential factors in the mode choice decision.

Sociodemographic attributes, including gender, income, and access to a car, would have various impacts on Hyperloop use and early adoption, as previously discussed. Moreover, prior knowledge of Hyperloop systems and current satisfaction levels with HST and flight services would also be influential. Interestingly, the primary mode for long-distance travel, personal attitude regarding new technologies, and personal confidence are driving factors for late Hyperloop adoption. The presented findings would be the first to address the research gap on Hyperloop mode choice and adoption, contributing to future studies on societal perceptions of this emerging mode and acting as a stepping stone in this unexplored field of study.

Abbreviations

The following abbreviations are used in this manuscript:

AIC	Akaike's Information Criteria
ASC	Alternative–specific constant
BIC	Bayesian Information Criteria
HST	High–speed train
MNL	Multinomial logit model
Ref.	Reference
SE	Standard error
SP	Stated preference
UAM	Urban air mobility
VOT	Value of time

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