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Understanding the factors influencing the acceptance and adoption of Hyperloop systems

A thesis presented in part fulfilment of the requirements of the Degree of Master of Science in Transportation Systems at the Department of Civil, Geo and Environmental Engineering, Technical University of Munich.

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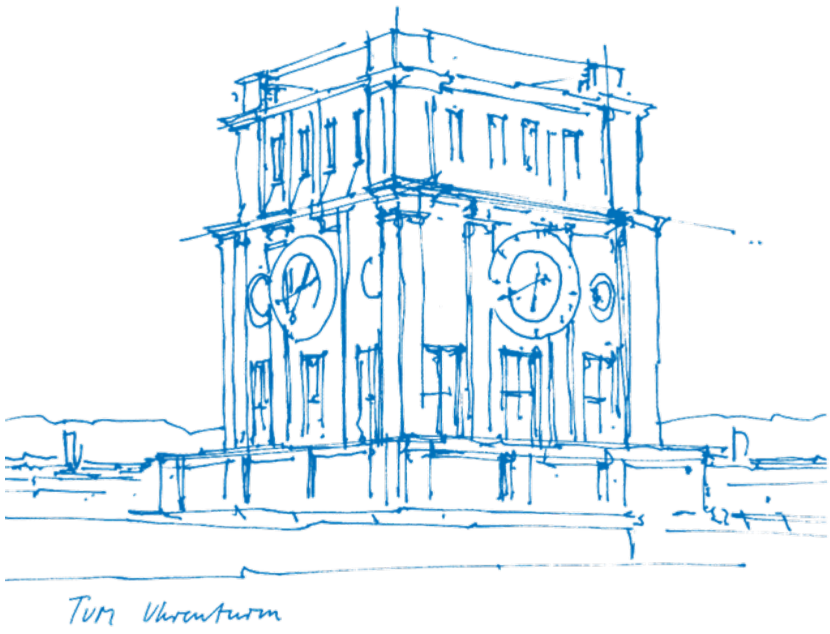

Declaration

I hereby confirm that the presented thesis work has been done independently and using only the sources and resources as are listed. This thesis has not previously been submitted elsewhere for purposes of assessment.

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Abstract

Many consider Hyperloop to be one of the most promising technologies in transportation to date. According to Hyperloop Alpha white paper, Virgin Hyperloop, and Hyperloop Transportation Technologies (HTT), the Hyperloop can travel with a maximum speed ranging between 1000 km/hr and 1200 km/hr, with fewer emissions and noise, compared to other high-speed modes, namely high-speed train, and jets. Since Hyperloop deployments do not exist yet, and as to the best of the authors‘ knowledge, research around its acceptance is limited, it would be of enormous use to understand user perceptions towards it.

This research intends to gain insights into the differentiation of users' preferences between Hyperloop and other high-speed transportation modes like high-speed train, flight in Germany. This research also identified the Hyperloop service attributes and users' socio-demographic characteristics that affect the users' preferences and the system's acceptance.

A stated preference survey including a stated choice experiment was designed and used for the elicitation of the acceptance parameters for this study, including three transportation alternatives: high-speed train, flight, and Hyperloop. The attributes included in the stated choice experiment are travel time (including access time, egress time, and waiting time), travel cost, safety level, and daily frequency of the different modes. The survey also covered a wide range of acceptance-related questions, including reasons, concerns, willingness to use the technology, expectations, users' usual commute and travel patterns, and their socio-demographics.

The obtained data (total 856 responses, and 8560 observations) were evaluated using factor analysis to explore the factors and clusters of users' cognitive attitudes and personality traits. Different discrete choice models (DCM), including the multinomial logit model, nested logit, and ordered logit, were estimated to investigate the mode choice behavior, time adoption, willingness to pay for the different modes, and the critical factors that influence the Hyperloop acceptance and adoption. The findings exposed travel time, travel cost, and safety are the critical factors of mode choice decisions. Moreover, the highly educated respondents have a relatively lower intent to choose Hyperloop and have higher safety concerns. The results suggest that factors such as safety, prior knowledge about Hyperloop, technological concerns were highly influential in Hyperloop adoption.

The summarized results help to understand the overall perceptions concerning the Hyperloop. The findings also provide meaningful insights for researchers and policymakers for future research and roadmaps for early implementation.

Keywords: Hyperloop, Acceptance, Adoption, Stated preference, Discrete choice modeling, Factor analysis.

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1 Introduction

1.1 Hyperloop

Rapid urban development and population growth have exerted tremendous pressures on urban transportation. According to Angel et al. (2011), by 2050, 80% of the world population will inhabit cities. The associated growth and development will pose severe challenges for urban and inter-city transportation. Moreover, the demand for mobility is growing. Therefore, people would choose a mode of transportation which is faster, cheaper, and efficient than current prevalent modes. As a result, new modes of transportation must be introduced to meet potential mobility demands. Hyperloop is a proposed new mode of transportation that moves very fast and consists of capsules which are propelled by electromagnetic force in low-pressure tubes (Alves, 2020; Cooper, 2016; Planing et al., 2020; Walker et al., 2010). According to Hyperloop Alpha white paper, Virgin Hyperloop, and Hyperloop Transportation Technologies (HTT), Hyperloop can travel with a maximum speed ranging between 1000 km/hr and 1200 km/hr, with fewer emissions and noise, compared to other high-speed modes, namely high-speed train, and jets (Goddard, 2016; HyperloopTT, 2020). "Hyperloop is the transport of the future. A prototype that shows where society is heading and guides the improvements we should propose for a sustainable and truly innovative future," explained by Elon Musk and Space X (Musk, 2013; Turian Hyperloop, 2019).

According to Hyperloop Transportation Technologies (HTT), the Hyperloop operates on the same fundamental principle as airplanes but is much safer (NOACA et al., 2019). The Hyperloop is safer than an airplane and makes more economic sense than traditional transportation (Chandran and Fujita, 2017). They also claimed in InnovFest Unbound conference in Singapore, "It works the same way; an airplane goes into high altitudes because it consumes less energy the higher it goes. It can go much faster with less energy and that's the same concept inside the Hyperloop" (Chandran and Fujita, 2017).

Hyperloop will be considered the most advanced technology in the transportation field and will create a massive shift in human inventiveness (Bradley, 2016; HyperloopTT, 2020). Whether now or 30 years in the future, Hyperloop may bring powerful and auspicious opportunities for society and the environment (Antoniou, 2018).

1.2 Background of the study

According to some researchers, Hyperloop is considered as the fifth mode of transportation after planes, trains, cars, and boats, which would be faster, immune to weather, eco-friendly, and resistant to earthquakes (González-González and Nogués, 2017; Musk, 2013).

Hyperloop operates on the same fundamental principle as airplanes, but it is much faster and energy-efficient, environmentally friendly, and aligned with sustainable development goals (SDGs) 7-10, 11 (HyperloopTT, 2020; Planing et al., 2020; Rajendran and Harper, 2020; Taylor et al., 2016); it makes more economic sense than traditional transportation (Chandran and Fujita, 2017; HyperloopTT, 2020). Moreover, some researchers believe that Hyperloop systems will accelerate economic growth (Marshall, 2019; MORPC, 2020; Pączek, 2017) and enhance the connectivity between cities and become a game-changer tool for intercity mobility (Decker, 2017; Schenker, 2019). The recent rapid studies on Hyperloop research funded by the private and public sectors and feasibility studies of commercial routes in different countries have generated enormous expectations in the performance of this transport technology (Bordone, 2018).

Many consider Hyperloop to be one of the most promising technologies in transportation to date (Alves, 2020; Antoniou, 2018). Since Hyperloop deployments do not exist yet, and to the best of the authors' knowledge, research around its acceptance is limited, it would be crucial to understand users' perceptions towards it.

Understanding people's preferences among different current existing modes are important for anticipating future demand. The mode choice behavior analysis yields insight about new modes with respect to existing alternatives. Furthermore, to the best of the author's understanding, there is no existing study to analyze mode choice behavior for Hyperloop technology with a discrete choice modeling approach. Moreover, there should be an appropriate choice model to understand the overall perceptions concerning the Hyperloop, which will provide meaningful insights for researchers and policymakers for future research and roadmaps for early implementation.

1.3 Objectives and research questions

To develop a successful strategy about potential Hyperloop technology as a mode of transport, it is crucial to understand user's perception and adoption along with mode choice behavior. Therefore, the main objective of this study is to understand the factors influencing the acceptance and adoption of Hyperloop systems.

In this study, A stated preference (SP) experimental survey was designed, and data were collected to address the users' acceptance by answering the following main questions that would help in the future systems development and implementation process:

- How can an experiment be adequately designed to collect mode choice data and identify the factors affecting the preferences?
- What factors affect the choice between Hyperloop and competing modes, namely high-speed train and air transportation?
- What factors affect the acceptance and adoption of the Hyperloop systems?

1.4 Expected contributions

The study is expected to contribute potentially to the following areas:

- Expected methodological contributions:
  - Proposing a stated preference experiment with competitive alternatives and qualitative choice attribute to investigate the mode choice decisions.
  - Proposing a methodology including factors extraction and discrete choice modeling for Hyperloop acceptance and adoption.
  - The survey results and model outputs are to be considered input for further development of the Hyperloop choice model, evaluations, and operational setup.
- Expected practical contributions:
  - Providing valuable suggestions on survey design.
  - Discussing the factors affecting the acceptance and adoption of Hyperloop, and relevant recommendations based on thesis findings.
  - The results may help gain insight regarding the potential market.

– The model results may contribute to the policy-making and suitable regulation formulation.

1.5 Thesis framework

The thesis framework is summarized in Figure 1.1.

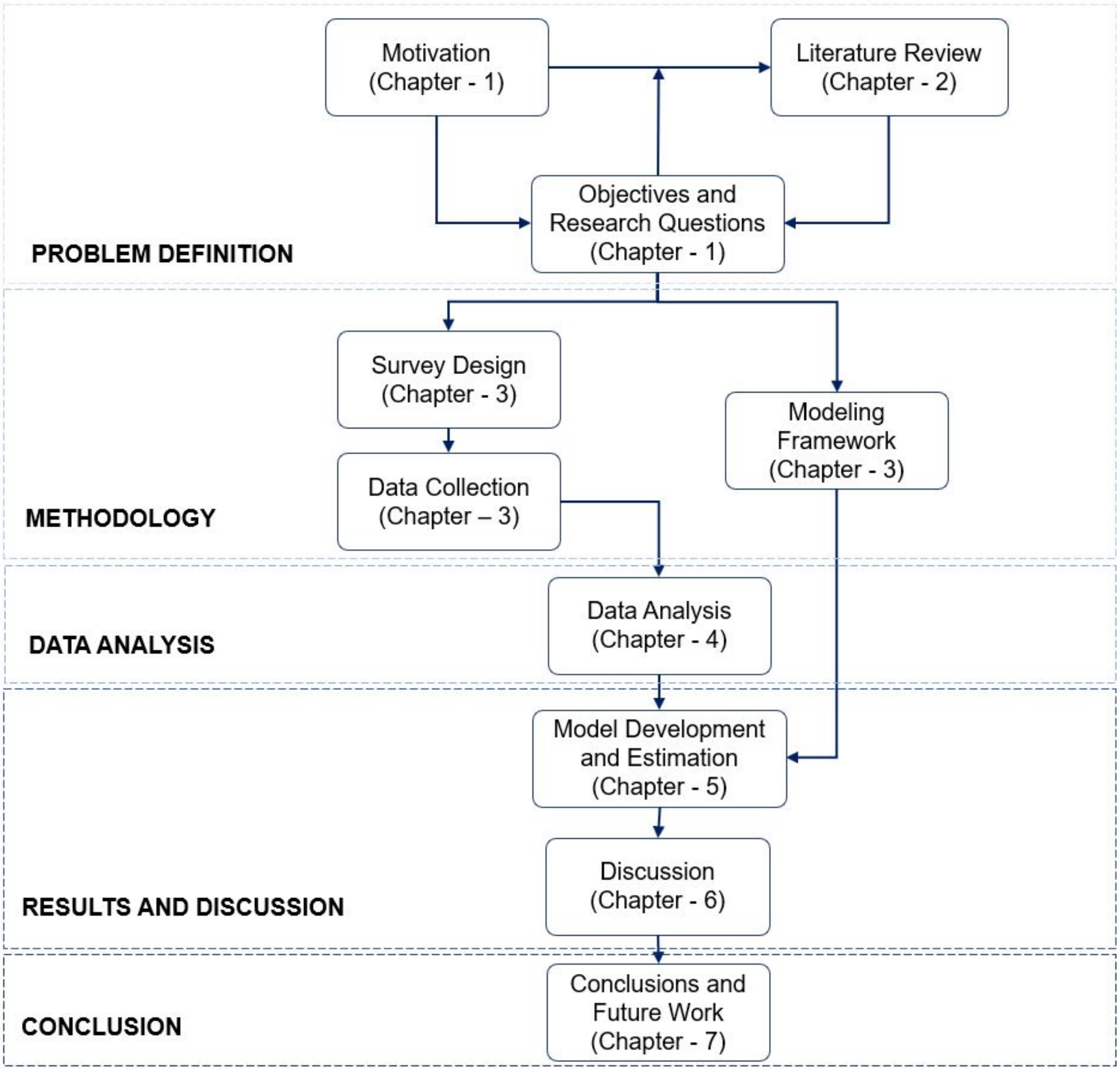

Figure 1.1 Research framework

1.6 Report structure

At first, the objectives, research questions, motivation, and thesis framework are described in the first chapter. In the literature section, the overview of Hyperloop, mode choice factors, stated preference studies, choice modeling overview, acceptance related studies will be presented. After that, the methodology of the study including, experimental design, data collection, data analysis, and modeling, will be presented in the methodology chapter. Then, the data analysis, summary statistics, the model formulation will be presented in the data analysis part. Later, findings of the survey results and models, discussion of model significance, policy implication in terms of demographics and attitude variables will be described. Finally, the limitations of the study and conclusions will be described in the conclusion section.

2 Literature Review

2.1 Review of Hyperloop transportation research

Hyperloop is a proposed new transportation mode with low individual capacity (28-40 people) magnetically levitated pods propelled at high speeds through an external pressure (100 pascals), low friction environment contained within a tube system (Bordone, 2018; Goddard, 2016).

Elon Musk popularized the Hyperloop concept in a White paper, 'Hyperloop Alpha' (Musk, 2013), which proposed building a Hyperloop between San Francisco to Los Angeles as an alternative to the proposed California high-speed rail development (Taylor et al., 2016). The idea was to create a new mode of transportation in which passengers would travel in pods in a system of tubes. Because the tubes maintain low air pressure, the pods would be able to travel by reduced friction or air resistance, reaching speeds of circa 1,200 km/h (Asher, 2020; Berger, 2019). Since then, the concept and the technology have been ambitiously adopted and advanced at pace by several companies worldwide, such as Virgin Hyperloop One and Hyperloop Transport Technologies, to commercialize it by 2021 (Virgin Hyperloop, 2020).

Several studies explored the benefits of Hyperloop systems, including the fastest travel, energy-efficient, environmentally friendly transport mode (Janic, 2018; Janić, 2020). Table 2.1 presents the benefits of the Hyperloop systems according to different literature. According to Hyperloop One, the Hyperloop will connect cities and create massive development in inter-city travel (One, 2017; Schenker, 2019). The Hyperloop systems will undoubtedly improve passenger transport and freight transport (Delas et al., 2019; HHLA, 2020). A geographical cluster was presented by Hyperloop One, which connected two cities that could help reduce travel costs and expand same-day delivery services. In addition, by extending the effective economic boundary of a city, the service users and firms could have better accessibility to manufacturing hubs and save travel time. Figure 2.1 shows the developed effective economic boundary of a city and an agglomeration effect of Hyperloop (One, 2017).

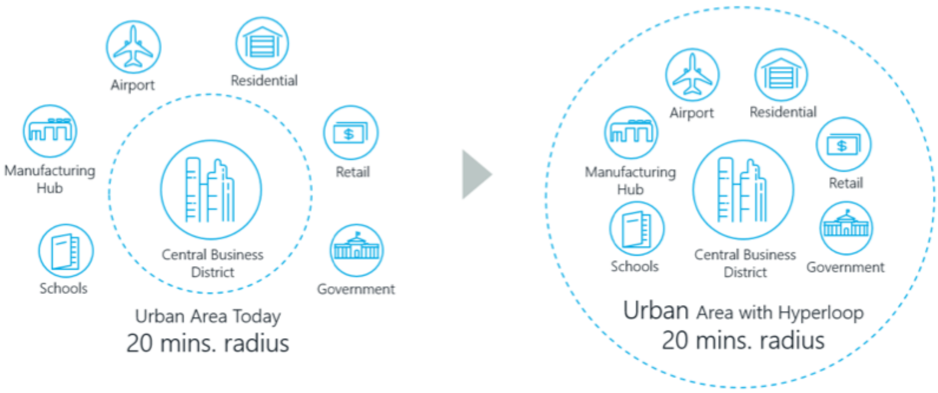

Figure 2.1 Effective economic boundary of a city (One, 2017)

Table 2.1 Benefits of the Hyperloop

Benefits	Sources	Description
Fastest Speed	Arch2O (2020); Covell (2017); MORPC (2020)	-Average operational speed 900 km/h. -Maximum speed would be 1200 km/h. -Fastest mode of transportation under consideration.
Shortest Travel Time	Covell (2017); Marshall (2019); Schenker (2019)	-Hyperloop would support the shortest travel time. -Almost 46% of the total travel time required for the next fastest mode of travel.
Energy Efficient	Antoniou (2018); Covell (2017); MORPC (2020); Shetty (2019)	-Most energy efficient mode of transportation. -Requiring only 45 mega joules of energy per passenger. -More energy efficient than the Maglev train.
Zero CO2 Emissions-operating time	Covell (2017); Hansen (2020); Matteo (2018)	-Cleanest mode of transportation under consideration. -Produces no carbon dioxide emissions.
Self-Sustainable	Covell (2017); González-González and Nogués (2017)	-Sustainably self-powering. -Will take advantage of its solar array design.
Immunity to Weather	Covell (2017); HyperloopTT (2020)	- It is a closed system and immune to the effects of weather.
Resistance to Earthquakes	Alves (2020); Covell (2017); HyperloopTT (2020)	-Only mode of rail transportation that is resistant to earthquakes. -It takes advantage of the pylon and dampening system design to support this feature.

Hyperloop is the competitor of high-speed trains and air transportation. According to Chandran and Fujita (2017) Hyperloop makes more economic sense than traditional transportation. Many researchers believe Hyperloop will be popular than the existing competitive modes (Bradley, 2016). A comparison between Hyperloop and existing transport modes is present in the following Table 2.2.

Feasibility studies are underway for the implementation of Hyperloop in many countries, including the USA, France, India, Saudi Arabia, Russia, Sweden, China, and the UK (Arup et al., 2017; Decker, 2017; Johnson, 2020; NS Business, 2019; Online, 2020; Walker et al., 2010). In November 2020, Virgin Hyperloop became the first to safely transport passengers on a Hyperloop system in Nevada, US (Virgin Hyperloop, 2020). Following Table 2.3 gives an idea about ongoing Hyperloop projects around the world.

2.1.1 Challenges in implementation

Although, in theory, it sounds conspicuous, there are several crucial challenges associated with Hyperloop development and implementation. The biggest challenges of the Hyperloop are technologies and systems implementation costs, safety, reliability, land use, and environmental loss (Voltes-Dorta and Becker, 2018). From an economic standpoint, it was shown

Table 2.2 Hyperloop comparison with alternative modes

	Hyperloop	High-speed train	Flight
Average speed	900-1200km (Taylor et al., 2016).	330- 360km/h (DB, 2020a).	500-550km/h DFS (2018).
Reliability	Protected from rain and snow (HyperloopTT, 2020; Taylor et al., 2016).	Most affected by weather events (Taylor et al., 2016).	Affected by ice and snow events (Taylor et al., 2016).
Comfort	Vomit Comet, Potentially noisy (Taylor et al., 2016).	Comfortable and able to use time productively (Taylor et al., 2016).	Less leg room, less productive time use (Taylor et al., 2016).
Passenger Capacity	28 – 40 medium (Alves, 2020; van Goeverden et al., 2018).	High 500 around (Covell, 2017; van Goeverden et al., 2018).	80 – 220, High and fixed (Rajendran and Harper, 2020).
GHG Emission	Zero (van Goeverden et al., 2018).	Very less (1g/pkm) (van Goeverden et al., 2018).	High (230g/pkm) DFS (2018).
Infrastructure cost	40-50 million euro/km (Pérez, 2018).	8-14 million euro/km DB (2020a).	-
Fuel consumption	Electric (Pérez, 2018).	59 Wh per seat-km (Eckert Fritz et al., 2018).	1.6 – 2.5 kg/km (Young-Brown, 2020).
System Interoperability	Not interoperable, cannot provide local transit (Bordone, 2018).	Used by conventional intercity rail and local commuter rail (Taylor et al., 2016).	Not interoperable, cannot provide local transit (DFS, 2018).

that the Hyperloop project entails a high infrastructure cost, in addition to maintenance and operational costs (Kumar et al., 2020).

The vehicle consists of capsules that are propelled by electromagnetic force in low-pressure tubes. The long vacuum chamber manufacturing requires advanced technical skills, which are costly and risky to maintain (Greco, 2018). High risk to life, limited space in the train, land use rights, and environmental loss (cut down the trees) are some other concerns and challenges that Hyperloop will face (Antoniou, 2018; Bradley, 2016).

2.1.2 Hyperloop in Europe and Germany

Regarding the Hyperloop system in Europe, several Hyperloop promoters are planning testing centers in Europe (Industry Europe, 2020; Veronika, 2019). In Spain, Zeleros is creating the first European Hyperloop center and building a 3 km track for testing (TheSpain, 2020; Zeleros, 2020). Their goal is to have the fastest and most energy-efficient system in the world (Zeleros, 2020). Hardt Hyperloop, supported by the European Institute of Innovation and Technology (EIT), plans a 3-km test track in the Dutch province of Groningen (Arup et al., 2017). In addition, Hyperloop TT is building a full-scale test track in Toulouse, France (HyperloopTT, 2020).

A joint program of the Technical University of Munich and NEXT Prototypes named TUM Hyperloop has been working on Hyperloop development and feasibility in Germany (TUM Hyperloop, 2020). This research program is working on the Hyperloop systems' potential impact considering financial, market, environmental, and safety aspects. Notably, a 24-meter long demonstrator including a full-scale pod is currently in development, and it is going to be built and put into operation in 2021 (TUM Hyperloop, 2020).

Table 2.3 Hyperloop projects around the world

Country	Proposed route	Length	Company	Description	Sources
Canada	Toronto– Windsor	370 km	TransPod	-Passenger, -Cargo	Stubbing et al. (2020)
China	Guizhou, China.	-	HyperloopTT	-Passenger -10 km commercial system in Tongren	Stubbing et al. (2020)
France	Paris – Toulouse	700 km	TransPod	-Passenger, -Cargo	Stubbing et al. (2020)
India	Bengaluru–Chennai, Mumbai- Chennai	350 km 1340 km	Hyperloop One	Feasibility Study done	Online (2020); Virgin Hyperloop (2020)
Saudi Arabia	Mecca–Riyadh	870 km	TransPod	-Passenger	Stubbing et al. (2020)
Sweden	Stockholm-Helsinki	500km	Hyperloop One	-Commercial Passenger	KPMG; Sahlgren (2016)
UK	London-Glasgow, Edinburgh–London	820 km, 650 km	TransPod Hyperloop One	Passenger System -Cargo	Stubbing et al. (2020)
USA	Cleveland to Chicago, San Francisco – California	520 km, 563 km	HyperloopTT	-Northeast Ohio Coordinating Agency -Commercial Passenger -Cargo	Alves (2020); HyperloopTT (2020); MORPC (2020)
UAE	Dubai-Abu Dhabi	150 km	HyperloopTT	Passenger System -Construction Target- Q1- 2020	HyperloopTT (2020); Stubbing et al. (2020)
Germany	Hamburg	-	HyperloopTT	Joint Venture Cargo HTT and Port of Hamburg operator	HHLA (2020); IV (2018); Welle (2017)
Netherlands	Amsterdam–Frankfurt	450 km	Hardt	Passenger System - 48 M passengers annually	Business Insider (2019); Wedia (2019)
Switzerland	Zurich-Geneva	250 km	Swisspod	Passenger System -cargo	Swissinfo (2020); Swisspod Technologies (2020)

According to Angela Titzrath, Chairwoman of the Hamburger Hafen und Logistik Gesellschaft (HHLA), reported in November 2018 that Hamburg's port is planning to use Hyperloop for their containers transportation (HHLA, 2020; Mühlbauer, 2018). Currently, shipping containers are being transported by rail and truck, which is a time-consuming process (Port of Hamburg, 2020). The Port of Hamburg has decided to work with Hyperloop Transportation Technology (HyperloopTT, 2020) to bring fast and efficient transportation of containers (Mühlbauer, 2018). The shipping containers will be transported to the mainland from Hamburg Hanseatic city through Hyperloop tube at 1200 km/hr (Marcus, 2016; Mühlbauer, 2018; Port of Hamburg, 2020).

2.2 Review of transportation mode choice research

Since Hyperloop is a novel transport mode, the research is still focusing on the technological and operational viewpoints. Nonetheless, no studies analyzing the potential user perceptions and preference among existing modes and Hyperloop has been found. Therefore, existing studies related to conventional modes were considered to determine significant factors that might influence the likely mode choice decision and the Hyperloop technologies' adoption. This section's discussion is mainly focused on various aspects of mode choice decisions for long-distance and high-speed transport modes.

Mode choice decision defines as an unpredictable interaction that relies on different factors. Mode choice decision was characterized as "the decision process to choose between different transport alternatives, which is determined by a combination of individual socio-demographic factors and spatial characteristics and influenced by socio-psychological factors" (De Witte et al., 2013). In another study, Buehler (2011) analyzed mode choice decision determinants based on Germany and the USA. Existing research focused on two types of mode choice decisions, such as unimodal and multi-modal transportation, related to other modes, like trains and aircraft (Zhao and Li, 2017). These studies (De Witte et al., 2013; Zhao and Li, 2017) identified three types of factors related to the mode choice for long-distance travel: trip attributes, socio-demographics, and spatial indicators. Table 2.4 shows the factors that affect the mode choice decisions.

Long-distance trips define as city trips typically separated from short outings using a distance limit. Even though there is no standard definition, trips are usually characterized as significant distances on the off chance that they are longer than a limit between 50 to 100 Km (Axhausen, 2003). Consequently, long-distance travels are less regular, making explorers less acquainted with accessible transportation options. Faster travel modes are typically liked in terms of long-distance trips (Pérez, 2018).

The trip characteristics, including total travel time and travel distance, are the most important explanatory variables for conventional transport mode choice (Moeckel et al., 2015). Several studies mentioned actual travel time (Cervero, 2002), access time to airports (Pels et al., 2003), access and egress time to/from terminals (Martín et al., 2014) are the critical factors in deciding the spatial intensity of transport modes for various travel purposes. Moeckel et al. (2013) created a thorough depiction of long-distance choice decision considers zeroing in on trip attributes. However, a study (Wen et al., 2012), in Taiwan, showed that travel costs are more related to the mode choice decision than the access time.

Several studies described the users' socio-demographic characteristics as the critical factors for mode choice decisions. Socio-demographics variables such as gender (Stronegger et al., 2010), income (Zhao and Li, 2017), education (Limtanakool et al., 2006), age (Mallett, 1999) are explained as a mode choice factor in different studies. Commins and Nolan (2011); Kim and Ulfarsson (2008) found that males are more likely to use a private car than females because females are aware of high driving risk. A study in Toronto-Montreal Corridor (Bhat, 1997) found that women were more likely to use than men in Canadian inter-city travel. According to Georggi and Pendyala (2001) and Mallett (1999) , men tend to use a car rather than women in long-distance travel. With regards to income, high-income people prefer to drive, whereas low-income prefers buses (Zhao and Li, 2017). Higher educated people tend to take public transport for long-distance travel (Limtanakool et al., 2006). Another study showed the car is a preferred mode for higher educated people in the Netherlands (Dieleman et al., 2002).

Moreover, the mode choice decision also depends on the trip's purposes due to their different space-time fixity and time value (Pan et al., 2009). Generally, business travelers are more fixed within time and place (Pels et al., 2003; Wang, 2015); thus, they used more expensive modes than the other purposes (Algers, 1993). Several studies considered the transit station's location as an important factor for mode choice decisions (Cervero, 2001; Dobruszkes et al., 2014; Krygsman et al., 2004; Martens, 2004). People are more like to take the buses if the railway station is outside the city center (Cervero and Duncan, 2003; Krygsman et al., 2004; Martens, 2004; Zhao and Li, 2017). Finally, another study (de Lapparent et al., 2009) talked about 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.

Table 2.4 Factors that affect the mode choice decision

Mode choice factor	Study types	Studies
Travel time	Long-distance trips, short trips	Bouscasse et al. (2019); Cho (2013); de Bok et al. (2010); Khan et al. (2020); Moeckel et al. (2013,1); Neely (2016); Wang and Ross (2018); Yang and Wang (2019)
Travel cost	Long-distance trips, short trips	Bouscasse et al. (2019); Cho (2013); de Bok et al. (2010); Khan et al. (2020); Moeckel et al. (2013,1); Neely (2016); Wang and Ross (2018); Yang and Wang (2019)
Safety	Long-distance trips, short trips	de Bok et al. (2010); Fu et al. (2019); Twaddle (2011)
Access/egress/ waiting time	Long-distance trips, short trips	de Bok et al. (2010); Moyano et al. (2018a); Neely (2016)
Service frequency/optimal headway	Long-distance trips, short trips	Han et al. (2018); Stubbing et al. (2020); Witchayaphong et al. (2020)
New technology	Short trips	Cho and Yu (2000); Khan et al. (2020); Kim et al. (2020)
Environmentally friendly	Long-distance trips	Neely (2016); Stubbing et al. (2020)
Level of service	Long-distance trips, short trips	Eisenhauer et al. (2015); Stubbing et al. (2020)
Distance to station	Short trips	Li et al. (2015); Yang and Wang (2019)
Efficient modes	Long-distance trips	Stubbing et al. (2020)
Comfort	Long-distance trips	Kant (2008); Neely (2016)
Multitasking/ workability	Long-distance travel, short trips	Fu et al. (2019); Singleton (2017,2)
Travel purpose	Long-distance trips, short trips	Bouscasse et al. (2019); Moeckel et al. (2013,1); Neely (2016)
Demographics	Long-distance trips, short trips	Fu et al. (2019); Kant (2008); Khan et al. (2020); Lavieri and Bhat (2019); Li et al. (2019); Neely (2016); Ni (2019); Steinkuhler (2015)

2.3 Review of choice modeling

2.3.1 Overview of choice modeling

Mode choice modeling is an essential part of transport planning to design new transport modes by exploring users' behavior. Statistical and computational intelligence are two popular methods of choice modeling. To understand the factors influencing the mode choice decision, these methods have been using not only in transportation but also in other fields. The statistical method is known as discrete choice modeling. Nevertheless, the computational method is referred to as the combination of fuzzy logic and AI (Karlaftis and Vlahogianni, 2011).

The traditional choice models (discrete choice model) are based on the theory known as the 'utility maximization.' Based on this theory, the individuals settling on a specific decision from various alternatives will search for the best options to boost the benefits (utility) he gets. These methods are widely used for travel mode choice and route choice modeling (Lee and Waddell, 2010). Based on the number of alternatives, choices, and goals, different models such as multinomial logit, probit, binomial, nested, ordered logit are used.

Ben-Akiva and Lerman (1985) described the four-choice behavior elements for discrete choice modeling.

1. The individuals' characteristics, such as age, gender, education, income, social status, which affect the decision process.
2. A set of prominent alternatives that are used to create a discontinuous choice situation.
3. The attributes of the alternatives that influence utility are another element of discrete choice modeling. The attributes include travel time, travel cost, travel safety, frequency of the trip, etc.
4. Finally, the decision rules or utility theory, such as dominance theory, satisfaction theory, utility maximization. In addition, utility maximization is the most widely used theory for discrete choice modeling.

The utility is defined as the index of a individual's preferences. The utility of a traveling mode is defined as an attraction associated with an individual's trip, and this hypothesis is known as utility maximization. The following equation 2.1 is shown the utility of i alternatives for q individual with the systematic element V_{iq} (Louviere et al., 2010).

$$U_{iq} = V_{iq} + \varepsilon_{iq} \tag{2.1}$$

where, U_{iq} - utility of the ith alternative for the qth individual, V_{iq} - systematically derived element of the ith alternative for the q individuals, ε_{iq} - error component.

Generally, The utility function has two parts: deterministic part and error term (Louviere et al., 2010). The specific components of a utility model are shown in the following equation 2.2.

$$U_{iq} = V(X_{iq}) + V(S_q) + V(X_{iq}, S_q) + ASC_{iq} + \varepsilon_{iq} \tag{2.2}$$

where U_{iq} -utility of the ith alternative for the qth individual, $V(X_{iq})$ -systematically derived element of the ith choice for person q, $V(S_q)$ -the portion of utility-related to characteristics of individual q, $V(X_{iq}, S_q)$ -the part of utility resulted from interactions between the attributes of alternative i and the characteristics of individual q, ε_{iq} -error term.

In a decision process, individuals are always supposed to choose the highest utility, but the decision process is not smooth and involves uncertainty in some particular cases. The utility models with complete information and behavior without considering the preferences of individuals are called deterministic utility models.

The error term is another component of a utility function. To describe the error term in utility function, the error terms are used to deal with the unperceived eccentricity of individuals' preferences (Koppelman and Bhat, 2006).

The primary sources of error in the use of deterministic utility functions are (Louviere et al., 2010):

- Incomplete or incorrect information of individuals about the attributes or alternatives.
- Different or incomplete statements of the observer about attributes relative to the individuals.
- Specific circumstances of the individual's travel decision and situations are unknown or not attractive to observers.

A constant with linear parameter is used to specify the observed part of utility function called an alternative specific constant (ASC) (Bierlaire, 2015). Alternative specific constant (ASC) are habituated to represent inherent and independent preferences of particular attribute values. ASC presents the average effect on the utility of all factors excluded in the model for alternatives. Based on a study (Bierlaire, 2016) only the ASC differences in utility are considerable rater than their absolute values. In general, it is only possible to estimate the ASC differences by normalizing the specification and setting the ASC of one alternative to zero.

2.3.2 Formulation of models

Discrete choice models, namely multinomial logit , nested logit, ordered logit, mixed multinomial logit, and multinomial probit, are established and widely used techniques in mode choice modeling. Therefore, these models are briefly described in the following section. Additionally, the comparison between these models are shown in Table 2.5.

Multinomial logit model

The multinomial logit model has been widely used in choice modeling. The random components of the different alternatives' utilities are independent and identically distributed with a gumbel distribution (McFadden, 1987). The equation 2.3 can express the probability of a traveler to choose a particular mode in logit models,

$$P_{ik} = \frac{e^{V_{ik}}}{\sum_j^{e^{jk}}} \tag{2.3}$$

Where, P_{ik} -probability of trip maker i choosing mode k out of j alternatives, V_{ik} -utility of alternative k for trip maker i.

Multinomial Logit models have been used for mode choices modeling which are useful to understand the choice-making phenomenon and the relative significance of the variables. Different statistical tests such as t-tests for various coefficient values are used to arched this model (Bhat, 1995; Horowitz, 1991). The multinomial models are simple in terms of mathematical form and computation. Nevertheless, this model's main limitation is equity, i.e it signifies all alternatives equally (Koppelman and Bhat, 2006). Another limitation, the deterministic part of the utility function should be error-independent in terms of alternatives. However, this can be solved by distributing the error terms for different assumptions.

Probit models

Probit models have also been very popular and widely used among traditional transportation planning techniques, especially the mode and route choice models (Bunch, 1991; Yai et al., 1997). The model can be described as the probability of making a choice decision using the following equations 2.4 (Louviere et al., 2010):

$$U_i = V(X_i, S) + \varepsilon_i \tag{2.4}$$

For all available alternatives j other than i, the probability of choosing mode P_i

$$P_i = P(U_i > U_j) \tag{2.5}$$

where U_i is the utility of the ith mode, V is the systematic component of the utility function, X is the vector of explanatory variables, S is the vector of coefficients, ε is the random or error component of the utility function, P_i is the probability of choosing the ith mode, and j is the total number of modes in the model.

Different statistical tests such as t-tests for various coefficient values are used to arched the significance of the parameters and the accuracy. The main difference is the general covariance structure as alternative specific error terms that must be assumed during the modeling process compared to other models (Louviere et al., 2010).

Nested logit models

Nested Logit (NL) Models have been utilized in various transportation research sectors, like mode choice decision, parking choice decision (McFadden and Train, 1999). NL models are developed by classifying the modes or choices in different sets (called nests) based upon particular characteristics. The probabilities of choices are estimated using the following equation 2.6:

$$P_l = P(l|m).P_m \tag{2.6}$$

where P_l represents the choice of the user to select mode l, given that the user has selected nest m. Its conditional probability is as follows:

$$P(l|m) = \frac{e^{V_l u_l}}{\sum_{l\varepsilon l_m} e^{V_l u_l}} \tag{2.7}$$

where V_l is the utility for mode l, l is the scale parameter for l, and L_m is the total number of modes in nest m. The marginal probability of choosing nest m is given by,

$$P(m) = \frac{e^{V_m u_m}}{\sum_{m\varepsilon l_m} e^{V_m u_m}} \tag{2.8}$$

where V_m denotes the log-sum of utility values associated with nest m and m represents the scale parameter of the nest.

Even though the Nested model shows it's multidimensionality in transport planning model, it imposes an unnecessary restriction on the model on shared observes attributes with one choice dimension (Lee and Waddell, 2010; Sun et al., 2017). NL models' major limitation is that the number of different structures searching for the best structure increases rapidly as the number of alternatives increases (Sekhar, 2014).

Ordered logit models (OLM)

The ordered logit model is used when a dependent variable has more than two categories and each category's values (McCullagh, 1980). The main objective is to find out how well the responses can be predicted where respondents are asked to rank their choice on a Likert scale (Likert, 1932). The ordered logit model can be defined as the following equation 2.9 (Louviere et al., 2010),

$$y = X\beta + \varepsilon \tag{2.9}$$

where, X is the vector of independent variables, ϵ is the error term, and β is the vector of regression coefficients.

The probability of choosing the first level of the outcome (y = 1) of each of the choice levels can be formulated as:

$$y = \begin{cases} 0 & \text{if } y^* \le \mu_1, \\ 1 & \text{if } \mu_1 < y^* \le \mu_2, \\ 2 & \text{if } \mu_2 < y^* \le \mu_3, \\ \vdots & \\ N & \text{if } \mu_N < y^* \end{cases} \tag{2.10}$$

where the parameters μ_i are the externally imposed endpoints of the observable categories. Then the ordered logit technique will use the observations on y, which are a form of censored data on $y*$, to fit the parameter vector β

Mixed multinomial logit model

According to Hensher and Greene (2003); McFadden and Train (2000); Ratrout and Gazder (2014), mixed multinomial logit models can be defined as multinomial logit model with random coefficients from a cumulative distribution function as equation 2.11 and 2.12.

$$P_c(i|x, \Theta) = \int L_c(i; x, \alpha).G(dx; \Theta) \tag{2.11}$$

$$L_c(i; x, a) = e^{x_i \alpha} / \sum_{j \varepsilon C} e^x j^x \tag{2.12}$$

where,
x = variables included in the utility function;
α = random coefficient of variable; and
Θ = standard deviation of the distribution of .

Mixed logit models are also known as the random coefficient logit models because the random parameter is assumed to be heterogeneous and a normal distribution function (Hensher and Greene, 2003; McFadden and Train, 2000). The mixed logit models are considered a promising and widely accepted approach for discrete choice modeling (Ratrout and Gazder, 2014). Another variation to mixed logit models is the latent class models. These models assume random coefficients to be arising from a discrete distribution rather than a continuous distribution.

Table 2.5 Comparison between different discrete choice models

Model	Studies	Description
MLogit model	Bhat (1997); Ding et al. (2021); Dow and Endersby (2004); Hensher; Horowitz (1991); Humagain and Singleton (2021); McFadden (1987); Wong and Farooq (2021)	-Less computation. -Utility functions are of the same nature as a regression model. -Significance and elasticity can be easily investigated. -Mode-related randomness is not considered. -Difficult to develop with a large number of variables. -Accuracy: high
Nested logit	Bhat (1998); Chen et al. (2020); Qi et al. (2020); Reck et al. (2021); Runa and Singleton (2021)	-Inclusion of exogenous factors. -Multidimensional analysis is possible. -Shared unobserved attributes can be associated with only one of the chosen dimensions. -Independent, but not identically distributed error term. -Accuracy: low
Probit	Dow and Endersby (2004); Keane (1992); Liu et al. (2020); McFadden and Train (1999); Said et al. (2021); Yai et al. (1997); Yuntao Guo et al. (2021)	-Error term which is mode specific and has a general covariance structure. -Utility functions can be simplified. -Significance and elasticity can be investigated through statistical tests. -Extra computations required due to the randomness effect. -Difficult to develop with a large number of variables. -Accuracy: low
Ordered logit	Ben-Akiva and Lerman (1985); Efthymiou et al. (2013); Harrell (2015); Joachim Schleich, Corinne Faure, Marie-Charlotte Guetlein, Gengyang Tu (2019); Liu et al. (2020); Pavlyuk and Gromule; Said et al. (2021); Tyrinopoulos and Antoniou (2008); Washington et al. (2003)	-Extensions of the logistic regression models. -Applied to more than two ordered responses or dependent variables. -Assumptions of the independence of irrelevant alternatives. -Intercepts or cutoff values are estimated between the different ordered outcomes. -Mostly applied in user preference studies. -Accuracy: high
Mixed logit	Ben-Akiva et al. (2002); Cantarella and de Luca (2005); Cohen (1996); de Jong et al. (2003); Hensher and Greene (2003); Horowitz (1991); Jia Guo et al. (2020); Wang et al. (2020)	-Use of random coefficients. -More suitable to capture individual taste heterogeneity. -More flexibility than multinomial and nested logit model. -Accounts for every individual through random components of choice through distribution of coefficients. -More computations than other logit models. -Requires better quality and amount of data. -Accuracy: high

2.3.3 Maximum likelihood estimation

Maximum likelihood (ML) estimation is a general principle to derive point estimators in probabilistic models. Fisher popularized Maximum likelihood estimation at the beginning of the

20th century (Klein and Mélard, 1995). Therefore it has widely been using in different fields. ML estimation's fundamental idea is to select that parameter value as a point estimate of the faithful but unknown parameter value that gave rise to the data, maximizing the data's probability under the model of interest. The probability of each person q choosing the alternatives i in an independent choice decision can be described as the following equation 2.13 (Louviere et al., 2010),

$$L(\beta) = \prod_{q=1}^{Q} \prod_{i} (P_{iq}^{y_{iq}}) \tag{2.13}$$

β is the vector of the model's parameters that is needed to be estimated. The log likelihood function is formulated as:

$$L(\beta) = \sum_{q=1}^{Q} \sum_{i} y_{iq} ln P_{iq} \tag{2.14}$$

According to McFadden and Train (2000), the previous equation is a global concave function for linear parameters utility. The maximum likelihood function can be found when its derivative concerning each of the parameters is zero.:

$$\frac{dL(\beta)}{d\beta} = 0 \tag{2.15}$$

2.3.4 Model outputs and statistical significance

The model outputs are estimated and interpreted as the weight of attributes and alternatives of the utility function. The parameter can be generic or alternative-specific for an attribute in utility function across the choice set (Louviere, 1988; Louviere et al., 2010). Different statistical tests, including hypothesis testing, likelihood ratio test, goodness of fit, are used to determine how well the model fits the data or evaluates the significance of the estimated model's parameters. The maximum likelihood procedure allows testing the statistical significance of the utility parameters, including the calculation of asymptotic standard errors in the model (Louviere et al., 2010). The t-value referred to as the standard error of the mean parameter is expected 1.96 or higher, which denotes that 95% or greater confidence that the mean is statistically significantly different from zero (Louviere et al., 2010). However, several reasons could explain the insignificance of the parameters, such as the involvement of outliers and missing data, the fact that the attribute is not essential, etc.

The likelihood ratio index is often used as a statistical method to test the data fit in discrete choice models. The index is known as p^2 in regression analysis and explained as equation 2.16 where log-likelihood function represented by L. ,

$$\rho^2 = 1 - \frac{L(\beta)}{L(0)} \tag{2.16}$$

The main drawback of this approach is that the rho-squared values increase with the number of independent variables. Additionally, there is no instruction about the perfect rho square for a model. Therefore, the rho squared bar adjusted with degrees of freedom (K) improved this approach. The rho squared bar is explained as,

$$\rho^{-2} = 1 - \frac{L(\hat{\beta}) - K}{L(0)} \tag{2.17}$$

A likelihood ratio test is performed to validate if the exclusion of the insignificant variables from the model containing the extracted factors from factor analysis is significant based on chi-squared distribution (Bierlaire, 2015). The likelihood ratio test can be shown as the following Equation 2.18, which is used to test the hypothesis that restrictions are valid.

$$-2(L(\beta R) - \beta U) \sim X^2_{KU-KR} \tag{2.18}$$

KU and KR are the log-likelihood of the restricted model and the unrestricted model, respectively; KR and KU are the parameters in the restricted and unrestricted models. The likelihood ratio test is valid for two competing models when the other model (2nd model) use linear restrictions of the parameters (Bierlaire, 2016).
Several other estimation methods like AIC (Akaike, 1974) and BIC (Schwarz, 1978), Cox test (Cox, 1961), Davidson and McKinnon J test (Davidson and MacKinnon, 1981) are also used to validate the model depending on the model types and parameters.

2.4 Review of stated choice methods

Stated preference experiments have been widely used in travel demand modeling. The stared preference survey method has been used to understand the future demand and users' perception towards new modes with a choice model. An overview regarding the types of experimental design, data, and methods is provided in this section.

2.4.1 Stated preference and revealed preference

Generally, there have been two techniques for collecting choice data, stated choice experiment and revealed choice experiments (Louviere, 1988).

Stated choice experiments that conduct on to a decision circumstance that doesn't yet exist can be surmised (Hensher et al., 2001). In transportation-related research, this is a useful method because the impact of this approach or measure can be assessed before it is executed. Revealed choice experiments (RP) are acquired by observing users' situation in the current market, portraying the world as it is presently.

Both experiments have benefits and disadvantages from different aspects. The main advantages of the revealed experiments are reliability and data validity. Moreover, the current circumstance regularly doesn't give sufficient fluctuation in the defining factors to acquire a genuinely enormous comprehension of their impact (Hensher et al., 2005). In some cases, this could be solved by designing efficient stated choice experiments (Twaddle, 2011).

Alternately, stated choice experiments are significant on the grounds that the conduct reaction to a decision circumstance that doesn't yet exist can be derived. However, sometimes the stated choice experiments are biased for different statements and market scenarios. Nevertheless, different methods were proposed, such as a combination of SP and RP (Morikawa, 1989), the inclusion of non-alternatives (Chrzan and Orme, 2000), to solve this issue.

2.4.2 Selection of the alternatives, attributes, and attribute levels

The selection of the alternatives, attributes, and attribute levels is crucial to design a stated choice experiment. All alternatives should be viable to satisfy the utility-maximizing rule. According to Hensher et al. (2005), the list of all alternatives must be culled to create a practical choice experiment.

The first and most measurably proper technique for restricting the number of choices introduced to every respondent is to randomly choose various options from the comprehensive arrangement of choices to allot to respondents.The other methodology is to make an abstract determination of the critical other alternatives. This methodology dispenses with every one of the alternatives that are considered irrelevant and not significant.

2.4.3 Experimental design

An experimental design defined in scientific terms involves observing the effect upon on variables; a response variable is given the manipulation of one or more other levels. According to Louviere and Hensher (1983), "a designed experiment is a way of manipulating attributes and their levels to permit rigorous testing of certain hypotheses of interest." Several experimental designs have been using widely, including full factorial, fractional factorial, and random design (Louviere et al., 2010).

Factorial designs are designs in which each attribute's level is combined with every level of other attributes. In this design, all elements can combine to make choice sets. In general, a factorial design is simply the factorial enumeration of all possible combinations of attribute levels (Louviere et al., 2010). Therefore, this complete enumeration is called full factorial and is described in the following equation 2.19.

$$P^i = \prod_{j=1}^{j} \prod_{k=1}^{k} l_{jk} \tag{2.19}$$

where,
P^i = total number of choice situations,
j= alternatives,
k= attributes of alternatives,
l=levels within the attributes.

The full factorial design produces practically unfeasible and extensive combinations. Selection of the most prominent situation from all combinations is common practice to reduce the combination. Nevertheless, it creates biases in the experiment. Therefore, factional design can reduce the number of combinations without being a biased experimental design (Schmid et al., 2016).

According to ASQC (1983), "A factorial experiment in which only an adequately chosen fraction of the treatment combinations required for the complete factorial experiment is selected to be run." A fractional factorial design's fundamental purpose is to economically investigate cause-and-effect relationships of significance in a given experimental setting. Fractional designs are expressed using the notation lkp, where l is the number of levels of each factor investigated, k is the number of factors investigated, and p describes the fraction of the full factorial used. A design with p such generators is a $1/(lp) = l - p$ fraction of the full factorial design (Louviere et al., 2010). Blocking is applied to orthogonally segment the design into smaller designs to limit choice tasks (Hensher et al., 2001).

Random design is another simple approach to design an experiment. The main concept of this method is a random selection of choice task from full factorial design. Several researchers (Louviere et al., 2010; Schmid, 2016; Schmid et al., 2016) claimed this as a well-performed design approach. The random design is widely popular due to being a combination of randomized strategies with orthogonal characteristics. Moreover, the design follows the principle of attribute level balance and orthogonality, which means attribute level is uncorrelated with other attribute levels. However, the orthogonality cannot be maintained while working with preference constraints (Schmid et al., 2016). Therefore, Efficient experimental designs is a more sophisticated approach to overcome the previous problems. The efficient design minimizes the variances of parameter estimates taken from the variance-covariance matrix of a design.

According to Schmid (2016) there are no substantial differences between the different design approaches as they robust and reproduce the apriori values. From a behavioral viewpoint, dominant and weakly dominant alternatives are always should be excluded. To conclude, the design should be efficient by carefully thinking about the research's goals and objectives. Schmid (2016) suggested a block design with an eight choice set would a general efficient design. In addition, a pre-test study is also recommended. Finally, a comparison of all described experimental designs in different relevant studies is shown in the following Table 2.6.

Table 2.6 Different experimental designs in relevant studies

Studies	Data collection	Study type	Choice factor	Modes	Model	Design types
Al Haddad et al. (2020)		Adoption	Travel time, travel cost	Urban air mobility, taxi	MNL, ML, NL, OLM	
Fu et al. (2019)	SP	Mode choice	Travel time, travel cost, safety, multitasking	Autonomous flying taxi, PuT, private var, autonomous taxi	MNL, profiled based MNL, ML, NL	Random
Twaddle (2011)	SP	Mode choice	Travel time, travel cost, access time, parking cost	Bicycle, car, PuT		Random
Yang et al. (2009)	SP , RP	Mode choice	Travel time, travel cost, access time, waiting time, transfer, congestion charge	Car, Carpool, Bus, Heavy mode, Bus, One-way car rental, Shared taxi, Express minibus, Park & ride, One-way car rental with heavy mode.	MNL, NL	Fractional factorial design
Burge et al. (2011)	SP	Mode choice	Travel time, travel cost, service frequency, interchange	Car, rail, air	MNL, NL	Orthogonal fractional
Yang et al. (2014)	SP, RP	Mode choice	In-vehicle time, Cost, Waiting time, Arrival time, Off-vehicle time	Bus, coach, taxi, metro, car	MNL	Random factional
Weis et al. (2021)	SP, RP	Mode choice	In-vehicle time, Access/egress time, Travel costs, transfers, Headway, Capacity, Delay	Car, PuT, bicycle, foot	MNL	Random
Pavlyuk (2011)	-	Mode choice	Travel time, travel cost	Car, coach, and train.	MNL	
Guerra (2019)	SP	Adoption	Cost, fuel price, charging cost	Electric motorbike	MNL, ML	

2.5 Review of technology acceptance studies

The adoption of new technology has been explained by theories exploring the technology or the target group (Bjerkan et al., 2016). Approaches such as Rogers Model of Diffusion of Innovation (Klapp, 2010; Rogers, 2004) explore the technical attributes. Theories such as the Technology Acceptance Model (Davis et al., 1989) and Theory of Planned Behavior (Ajzen,

1985) explore the general public's underlying motivations in adopting technology. These theories emphasize the public perception of these technologies regarding ease of use, increased utility derived, influence of society, and facilitating conditions (Venkatesh and Davis, 2000). There are several factors, including trust, perceived reliability, safety, ethical concerns, perceived usefulness, trip purpose, the value of time, costs, social behavior, vehicle and operation characteristics, cultural differences, socio-demographic impact, previous experience, and Technology awareness, that affect the public perception of new technology (Klapp, 2010; Son et al., 2012; Turner et al., 2010; Venkatesh et al., 2003; Wu et al., 2011). Moreover, These factors played a critical role in acceptance-related studies, specifically in different technology acceptance Models. Several studies related to technology acceptance models and their factors are summarized in the following Table. 2.7.

Table 2.7 Different acceptance related studies for different modes

Studies	Mode	Methods	Factors
Shetty (2019)	Hyperloop	Q methods	Positive knowledge, Research on Hyperloop, Improvements in Current Transport Modes, Implementation of Hyperloop, Skeptical of Hyperloop Development
Al Haddad et al. (2020)	Urban air mobility	Technology acceptance model (TAM)	Socio-demographic, technological awareness, Trust and safety, Perceived usefulness, Social influence, value of time, perceived costs, data concerns.
Chen (2019); Dirsehan and Can (2020); Glerum and Stankovikj (2020); Man et al. (2020); Yuen et al. (2020); Zhang et al. (2019,2)	Autonomous vehicles	Innovation diffusion theory (IDT), Technology acceptance model (TAM)	Reliability, safety, trust, risk perception (perceived safety risk and perceived privacy risk), compatibility, and system quality. perceived ease of use and perceived usefulness, technological awareness, Trust and safety.
Bjerkan et al. (2016); Fett et al. (2018); Müller (2019); Thilina (2019); Tu and Yang (2019)	Electric vehicles	Planned behavior (TPB), Technology acceptance model (TAM) and Innovation diffusion theory (IDT)	Behavioral intention, consumers' environmental awareness, subjective norms, perceived usefulness, wireless charging uses, perceived organisational usefulness, vehicle characteristics

Fred D. Davis developed the Technology Acceptance Model (TAM) in 1989 (Davis et al., 1989). According to this model, the Intention to use new technology depends on perceived usefulness and ease of use. Perceived usefulness can define as the degree to which a person believes that their work performance can be increased using the system. Perceived ease of use refers to how a person has to make a mental or physical effort to use the technology.

Because of increasing criticism towards the technology acceptance model, additional factors, such as social influence, age, and gender, influence behavior intention. TAM2 is an extension of the original technology acceptance model by Venkatesh and Davis (2000), including external social factors that influence the behavioral intention to use new technology. This acceptance model's main advantage is the high level of predictiveness in many contexts while having different aspects.

UTAUT is known as Unified Theory of Acceptance and Use of Technology and also developed and extended by Venkatesh et al. (2012). This model also includes factors relevant to the consumer market that influence the behavioral intention to use new technology.

The technology acceptance and unified theory of acceptance model have been using widely for new technologies by many researchers. Several researchers used it in the transportation field as an acceptance study of electric mobility (Bjerkan et al., 2016; Fett et al., 2018; Müller, 2019; Thilina, 2019; Tu and Yang, 2019), autonomous vehicles (Chen, 2019; Dirsehan and Can, 2020; Glerum and Stankovikj, 2020; Man et al., 2020; Yuen et al., 2020; Zhang et al., 2019,2), urban air mobility (Al Haddad et al., 2020). Therefore, these models could be relevant to be applied to Hyperloop technologies.

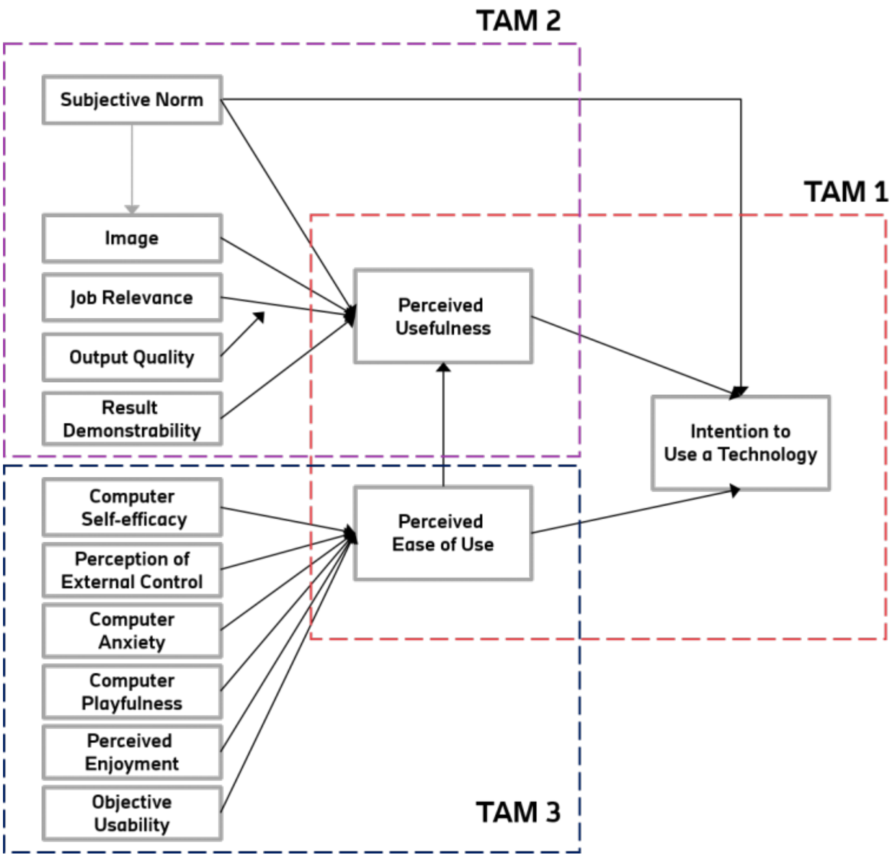

Figure 2.2 TAM 1, 2 3 – Simplyfied omitting moderators, (Davis et al., 1989; Venkatesh and Davis, 2000; Venkatesh et al., 2012)

2.6 Summary and literature gap

Based on the above-described literature about Hyperloop, Choice models, stated preference experimental studies and acceptance related studies, the summary findings and literature gaps are described below.

- There is no existing study about Hyperloop mode choice modeling with a stated preference survey.

- There is no study exists about the stated preference survey and data collection related to the Hyperloop study.
- Different feasibility studies exist about Hyperloop and adoption, but none of them described the behavioral intention based on the technology acceptance model.

The relevant studies and literature were collected from different sources, including newspaper, thesis studies, feasibility studies, journals, and conference proceedings. As Hyperloop is a very new topic and not developed yet, very few studies exist about it. Therefore, the study relied on newspapers, the company's website, and other internet documents, apparently marketing-based. A chord diagram 2.3 is shown below to describe the connection, gap, and number of literature were collected and studied in this thesis.

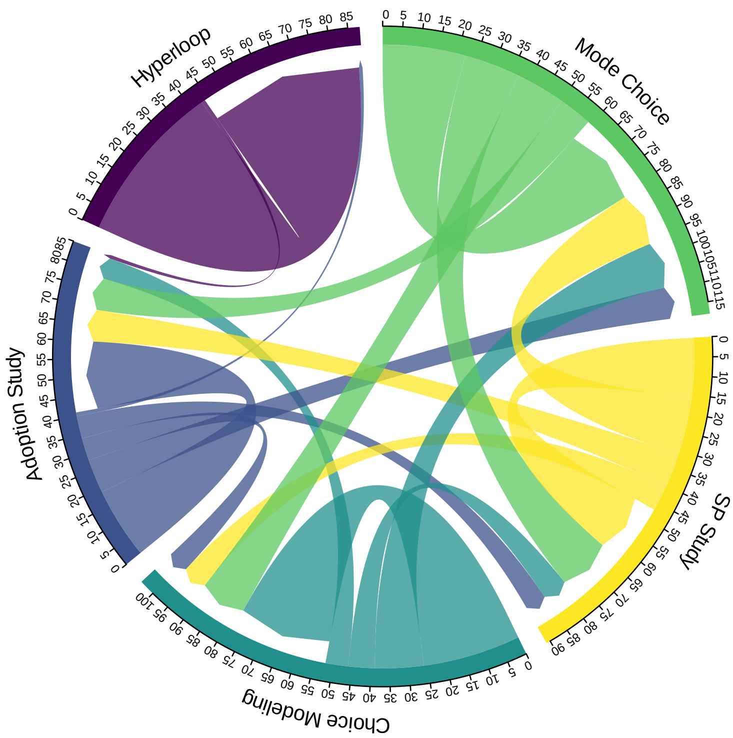

Figure 2.3 A Chord diagram for all literature

3 Methodology

3.1 State preference study

A stated preference (SP) survey including a stated choice experiment is designed and used for this study. The initial data was collected from Germany but mostly from Munich, which is the third-largest city in Germany. This section describes the structure of the SP survey, the stated choice experiment's design, and data collection in detail.

3.1.1 Design of stated choice experiment

The preliminary settings of alternatives, attributes, and attribute levels are selected based on relevant mode choice studies and the circumstance selected route. The objectives were to find out the most relevant and viable alternatives, attribute and levels which could act as a significance mode choice factor for Hyperloop, high-speed train, and flight in SP experimental study. Chrzan and Orme (2000) suggested giving respondents a realistic scenario for making the mode choice decision to reduce hypothetical bias in SP survey. Munich to Berlin/ Berlin to Munich travel patterns were observed to find out the alternatives, attributes, and level for this study with a travel range of 600 km. No specific hypothetical trip purposed was considered for this study. The details of the selection of alternatives, attributes, and levels are described next section.

3.1.2 Route selection

One of the routes that are expected to be popular and busy (Munich - Berlin) (Welle, 2018) was chosen for this study. Berlin is the capital and largest city of Germany with a 3.6 million population (Berlin.de, 2020). Munich is the 3rd largest city with 1.5 million habitats (Statista, 2020). According to Deutsche Bahn, around 1.8 million passengers travel between Munich and Berlin routes by high-speed train (DB, 2020a). Nevertheless, about 1.2 million people use flights on this route (DFS, 2018). The distance between Munich and Berlin is about 623 km for the high-speed train and 504 km for Flight (DB, 2020a). Since these two cities are the largest and populated city with industries, business centers, and historical places, so business travel, traveling, and commuting are the main purpose for using this route. Around 46% passengers travel with train followed by 30% and 24% uses flight and street modes (Cars or buses) in this route (DB, 2020b). The available transport modes for this route are car, bus, high-speed train, and flight. The comparison between different modes in this route is described below.

The access time, egress time, and waiting time were calculated for around 70% population of the city based on the catchment area. The average waiting time was calculated as one hour for the domestic flight (Lufthansa, 2020). Many experts said that the Hyperloop stations would be near to city centers, the access and egress time were considered as like high-speed trains. Additionally, the average ticket prices for high-speed trains and flights are based on the last min and two weeks before the trip.

Table 3.1 Comparison of different modes between Munich and Berlin

Indicator	Hyperloop	High speed train	Flight
Travel time	1 hr 05 min (Pączek, 2017)	3 hr 55 min (DB, 2020b)	1 hr 10 min (Lufthansa, 2020)
Access time	35 min	35 min (Geoapify maps, 2020; Pfertner, 2020)	65 min (Brian's Guide, 2020; Geoapify maps, 2020)
Egress time	40 min (Berlin.de, 2020; Geoapify maps, 2020)	40 min (Berlin.de, 2020; Geoapify maps, 2020)	55 min (Brian's Guide, 2020; Geoapify maps, 2020)
Waiting time	-	-	60 min (Bryant, 2015; Lufthansa, 2020; Munich Airport, 2020)
Travel Cost (Euro)	-	46 - 108 EURO	90 - 180 EURO
Frequency	Minimum headway - 12/hour (van Goeverden et al., 2018)	3-5 trip/day (DB, 2020a)(ICE Sprinter)	3-5 trip/day (Lufthansa, 2020)

3.1.3 Selection of alternatives, attributes, and levels

According to Hensher et al. (2012), all existing alternatives must be universally compiled to fulfill the global utility-maximizing rules. One of the routes that are expected to be popular and busy (Munich - Berlin) (Welle, 2018) was chosen to design the stated choice experiment. Since the number of transportation modes between Munich and Berlin contains many alternatives, it is crucial to select the most viable alternatives. High-speed train and flight were considered as relatively comparable alternatives with Hyperloop (Hansen, 2020).

The distance between Munich and Berlin is around 600 km for different modes. Car, bus, high-speed train (ICE), and flight are the most prominent alternatives for this route. Car and Bus are not as competitive with other modes in terms of speed and travel time. Nevertheless, the high-speed train, flight, and Hyperloop are the three alternatives selected for experimental design. Meanwhile, an additional alternative None was also included.

After selecting the most viable alternatives, it was necessary to determine which attributes should be included to describe each of the alternatives to design an efficient experimental study. The attributes included in the stated choice experiment were total travel time (including access time, egress time, and waiting time), total travel cost, safety level, and daily frequency of the different modes. These attributes were defined based on relevant literature (Cho, 2013; Fu, 2018; Michiel de Bok; Neely, 2016; Twaddle, 2011) for experimental design to specify each of the three alternatives transport modes (Table 3.2). The attribute levels are described as follows:

Mode choice attributes and levels

Attribute 1: Total travel time

The total travel time is one of the most significant attributes for mode choice studies. Current existing mode choice studies (Chen et al., 2015; de Bok et al., 2010; Fu et al., 2019; LaMondia et al., 2015; Moeckel et al., 2015) considered travel time as an attribute describing all the modes in experimental design. The total travel time defines in this study as the door-to-door travel time, including the access, egress, and waiting time at the station or airport.

For Hyperloop, the travel time was calculated based on the operational speed of Hyperloop. According to Pączek (2017) the operating speed was calculated about 600 km/hr. Therefore, the vehicle travel time was calculated around one hour for Munich to Berlin/Berlin to Munich. The details of travel time, including access, egress, and waiting time, were described in Table 3.1 in the previous section.

According to Deutsche Bahn, The ICE Sprinter is the fastest direct connection between Munich and Berlin, and the travel time is about 4 hours. With average access and egress time (presented in Table 3.1) for Munich and Berlin, the total travel time was calculated around 5 hours 10 minutes using the Deutsche Bahn's trip planner (DB, 2020a).

In terms of flight, the reference value of in-vehicle travel time was estimated around 1 hour 10 minutes and about 4 hours 10 min with access, egress, and waiting time at the airport. In addition, the average access and egress time were considered for Munich and Berlin airport.

The attribute levels for total travel time were pivoted around the reference value by -30%, 0% (reference scenario), and +30%. In order to represent the total travel time and simplify the stated choice experiment questions, the total trip time, the access time, and egress time were summed and presented to the respondents. Additionally, the attribute levels are pivoted using absolute values rather than percentages. Furthermore, the total travel time was considered 100 min, 140 min, and 180 min for Hyperloop; 230 min, 310 min, and 390 min for the high-speed train; 180 min, 250 min, and 320 min for flight in the experimental design.

Attribute 2: Total travel cost

The total travel cost was included in this experimental design. Travel cost is one of the significant mode choice factors that has been used in different mode choice studies. In order to provide a general idea of total travel cost, total travel cost indicates the monetary cost for the trip. The study only considered the ticket cost for the transport modes.

The travel cost was estimated for Hyperloop, high-speed train, and flight based on relevant studies, Deutsche Bahn, and Lufthansa trip planner, briefly described in Section 3.1.3.

Since the Hyperloop deployments do not exist yet, there was no direct study about Hyperloop ticket price. Few recent feasibility studies in the USA estimated Hyperloop ticket cost as two-third of the high-speed train (Covell, 2017; NOACA et al., 2019). Nonetheless, other related studies (van Goeverden et al., 2018) suggested the cost could be high (0.30 Euro per km). Thus, the study considers the travel cost similar to the high-speed train. The total travel cost attribute levels were pivoted around a reference value by - 30%, 0% (reference scenario), and +30%. Besides, the attribute levels are diverted using absolute values rather than percentages. The reference value was estimated using the trip planner provided by the DB and Lufthansa (DB, 2020a; Lufthansa, 2020). The travel cost was estimated 46 €, 69 €, and 92 € for Hyperloop and high-speed train followed by 90 €, 140 €, and 190 € for flight.

Attribute 3: Safety level

Safety level was included for experimental design, which is considered as an important mode choice factor based on relevant studies (Fu et al., 2019). The safety level denotes the likelihood of having an incident. The fatality or crash rate is specified based on fatality per 100 million passengers. Since the car has a relatively higher incident rate, the driving level safety was considered a reference safety level compared to other modes.

Moreover, the safety level of Hyperloop is unknown at the moment, as currently no regulation and official safety requirements is there yet to guarantee safe, reliable, and efficient operations of Hyperloop systems. Different Hyperloop companies are working on safety, and few companies (HyperloopTT, 2020; Virgin Hyperloop, 2020; Zeleros, 2020) claimed that the Hyperloop is safer and reliable related to other competing modes.

The reference safety level was considered driving-level safety as the car to make the attribute levels more understandable. In contrast, all levels of the other modes were represented as relative values. Thus, at least two times safer than driving-level-safety and four times safer than driving-level-safety was considered for this experiment.

Attribute 4: Frequency of the trip per day

Service frequency is another mode choice factor for experiment design. However, the trip frequency was selected because it has been found to have a strong and significant influence on mode choice behavior. Additionally, this is considered an important predictor of long-distance mode use. The service frequency per day indicates the number of trips per day between the origin and destination.

The frequency was estimated 3-5 times per day for high-speed train and flight depending on the travel demand based on the DB and Lufthansa trip planner (described in Table 3.1). Several studies estimated 5 min minimum headway for Hyperloop (Gkoumas and Christou, 2020; MORPC, 2020; van Goeverden et al., 2018). Thus, 5 min, 10 min, and 15 min headway were considered for this experimental design. Moreover, the frequency attribute levels were pivoted around 3 trip/ day , 4 trip/ day, and 5 trip/ day headway for high-speed train and flight.

Table 3.2 Summary of the alternatives, attributes, and attribute levels

Alternatives	**Attributes**	**Attribute levels**	**Sources**
Hyperloop	Travel time	30% less, unchanged, 30% more	Created for this experiment
	Travel cost	30% less, unchanged, 30% more	Created for this experiment
	Safety	Driving safety level, two times higher than driving, four times higher than driving	Created for this experiment
	Frequency	5 min, 10 min, 15 min	Created for this experiment
High-speed train	Travel time	30% less, unchanged, 30% more	Burge et al. (2011); Dubernet and Axhausen (2020)
	Travel cost	30% less, unchanged, 30% more	Burge et al. (2011); Dubernet and Axhausen (2020)
	Safety	Driving safety level, two times higher than driving, four times higher than driving	
	Frequency	3, 4, 5 trip/day	Burge et al. (2011); Dubernet and Axhausen (2020)
Flight	Travel time	30% less, unchanged, 30% more	Burge et al. (2011)
	Travel cost	30% less, unchanged, 30% more	Burge et al. (2011)
	Safety	Driving safety level, two times higher than driving, four times higher than driving	Burge et al. (2011)
	Frequency	3, 4, 5 trip/day	Created for this experiment

3.1.4 Setting of the choice sets

Ten choice sets were created for ten hypothetical scenarios (total 100 scenarios for 10 choice set) using random design. The choice sets were identical in terms of order and contents by applying minimal overlapping principal in experiment design.

There were total 10 scenarios in each questionnaire and 10 unique choices set were created for the questionnaire. Each respondent received one questionnaire including ten unique scenarios. A sample choice set is shown in figure 3.1.

Given the following options for the trip above, which would you choose?

Scenario 1	**Hyperloop**	**High-speed train**	**Flight**
Total travel time	2 hour 20 min	3 hour 50 min	3 hour
Travel cost (EUR)	92	92	90
Safety level (compared to car)	2 x more safety than driving level	Driving level	4 x more safety than driving level
Frequency of trip per day	Every 10 min	Every 5 hour	Every 3 hour

Choose one of the following answers

Hyperloop | High-speed train | Flight | None

Figure 3.1 Sample choice set

3.1.5 Questionnaire design

The survey questionnaire was structured into four parts. In the first part, the respondents were asked the basic questions about their daily transport mode and long-distance trip (>400 km), and few general questions about mode choice preference. There were questions about Hyperloop systems' prior knowledge and respondents' general technological concerns in the second part. Then stated choice scenarios were introduced for different hypothetical scenarios. Ten choice sets were created for each hypothetical scenario (ten scenarios) using a randomized experimental design with a minimal overlap principle. In the last part, there were few questions about respondent's personalities and their demographic questions, including education, income, occupation, etc. The complete questionnaire is shown in Appendix E.

3.1.6 Data collection

The survey was conducted from mid-January to March 2021 on the online platform. As a result, respondents from Munich and other cities in Germany filled up the questionnaire. The survey was conducted online using LimeSurvey (limesurvey.org) and available in English and German and distributed among various groups, including local university groups, community groups, student dormitories, professional groups, related research companies, etc. The survey was further distributed on social networks, mailing lists, and professional media platforms such as Facebook, Linkedin, and XING.

3.2 Modeling framework

This section describes a general description of the modeling framework, including factor analysis, model formulation, and estimations. At first, explanatory factor analysis is described and presented. Then, the general framework of model development is presented in this section.

3.2.1 Exploratory factor analysis

The factor analysis is a statistical method to explain the variability within observed and correlated variables in terms of the lower number of unobserved variables (Wang et al., 2019). This factor looks at their maximum common variability, and the proportion of the overall data set variance. This method is used to reduce the number of less correlated variables in transportation data analysis (Agus Prasetio et al., 2019; Washington et al., 2003).

There are two types of factor analysis: the Exploratory Factor Analysis (EFA) and the Confirmatory Factor Analysis (CFA) (Wang et al., 2019). The explanatory factor analysis observes the relation between different variables in the dataset. The main objective of this explanatory factor analysis was to the reduction of data dimension and identification of latent variables for the model.

The procedure for performing an exploratory factor analysis can be summarized as the following steps.

1. **Adequacy test.** Before performing the factory analysis, "factorability" of the data-set was evaluated. In general, there are two methods to check it (Adequacy test), i.e. Bartlett's test and Kaiser-Meyer-Olkin (KMO) test.
2. **Determine the number of factors.** The most common method to do this task is using the scree plot of the data.
3. **Validity test.** In the simplest way, this can draw the conclusion about the validity of the performed factor analysis by calculating the factor correlations.
4. **Interpretation of factors.** After performing the factor analysis, a pattern matrix was generated for the selected factors. By analyzing loadings for a specific factor, its possible to get a logical understanding of it.

Since factor analysis can only be used among continuous or ordinal variables, so this only applies to attitude questions.

In this study, explanatory factor analysis was applied using SPSS statistical software. KMO and Bartlett's Tests were performed to check the fitted variables for exploratory factor analysis. Principal Component Analysis was applied as the factor extraction method. The number of factors was obtained from the scree plot. In addition, Varimax with Kaiser Normalization orthogonal rotation was used, and all factors were assumed uncorrelated.

While performing EFA using principal axis factoring with promax rotation, Costello and Osborne (2005) suggest that the commonalities above 0.4 are acceptable. However, IDRE (2020); Izquierdo et al. (2014) suggests that the value of communality below 0.2 should be removed. Different studies (Brett Williams et al., 2012; Wang et al., 2019) suggested values above 3.0 are acceptable for principal component analysis. In this study, factor_loadings less than 0.4 were removed to reduce the data's noise, with several trial error processes. According to Costello and Osborne (2005); Izquierdo et al. (2014); Maskey et al. (2018) factors were expected to explain at least 10% of the variables' variance. Finally, factor scores were calculated for variables as the weighted sum of the factor loads.

3.2.2 Model formulation and estimation

Mode choice model

In an aim to identify the mode choice factors for Hyperloop systems, several choice models, including the multinomial logit model, nested logit with the dependent variables, were developed. Four alternative modes, namely Hyperloop, high-speed train, flight, and none, were given as the choice option. The results of the survey parts, factor analysis results were considered as dependent variables.

MNL models

First, the quantitative attributes such as travel time and travel cost were included as linear parameters in the generic model. First, two MNL models including alternative-specific and individual-specific variables were estimated, one with the choice of none excluded. The other, including the choice of none, only statically significant parameters, was included and estimated as alternative-specific parameters in models. The qualitative attributes, including safety and all other socio-demographic variables, were included later. Moreover, only statistically significant parameters were included in the final model. The model was estimated and implemented in Python Biogeme (Bierlaire, 2016). The models were obtained for the probabilities of choosing each alternative as the following equation 3.1,

$$P_{ik} = \frac{e^{V_{ik}}}{\sum_j^{e^{jk}}} \tag{3.1}$$

Where, P_{ik} probability of trip maker i choosing mode k out of j alternatives, V_{ik} utility of alternative k for trip maker i.

With the trial-error process and by checking the model results, the model with a better model fit was selected for further model development. Similarly, the profile-based MNL for highly educated and moderate educated people were developed and estimated with including and excluding the choice of none.

Nested logit model

Nested logit models were also developed with nesting options as the Hyperloop and high-speed train are in the same nest.

Adoption model

To identify the factor affecting the Hyperloop systems' adoption, MNL and ordered logit model (OLM) were developed and estimated based on the factor analysis and attitude-related variables. Therefore, the choices were given options ranging from immediate adoption (Y1) to later adoption (Y2-Y3, Y4-Y5, Y6+), non-adoption (Never), or uncertainty (Unsure). In the case of MNL, the factors and demographics variables were considered as the dependent variables.

The significant variables from MNL were used to developed and estimate the OLM model. Therefore, Y1 and Y2-3; Y2-3 and Y4-5; Y4-5 and Y6; Y6 and YNever; YNever and Y Unsure were considered as the ordered in the model, respectively. As the choice group of Y6 and UNever have fewer data with similarity, another model was developed and estimated by combining these two groups. Additionally, another OLM was developed without the uncertainty (Unsure) adopters.

3.2.3 Built hypotheses

Demographic related

1. Males are more likely than females to be early adopters of Hyperloop systems.
2. Young respondents are more likely to be early adopters.
3. Fully-employed respondents are more likely to be early adopters compared to students, part-time or unemployed.
4. Respondents answering the German survey are more likely to be late adopters or unsure about their intended adoption time than those answering it in English.
5. Higher-income respondents are more likely to be early adopters.
6. Higher educated people are more likely to be late adopters.

Mode choice factor-related

7. Travel time significantly affects the use of Hyperloop systems.
8. Travel cost significantly affects the use of Hyperloop systems.
9. The frequency of service affects the use of Hyperloop services significantly.
10. Safety would be an important factor in to use of Hyperloop.

Attitude-related hypotheses

11. Prior knowledge is very likely to be associated with early adoption.
12. Technological understanding is very likely to be related to early adoption.
13. Psychological well-being could be an important factor for Hyperloop choice and adoption.
14. Higher existing mode transportation satisfaction is more likely related to later or uncertain adoption of Hyperloop systems.

Model-based

15. Involving the choice NONE to the estimation process can improve the MNL model.
16. The model can be improved by adding Demographic characteristics.
17. The model can be improved by adding attitude-related variables and factors.
18. The Hyperloop choice model can be nested according to different nesting options.
19. An ordered logit model can be modeled for Hyperloop adoption.

3.2.4 Acceptance model

In this section, the Technology Acceptance Model (TAM) for Hyperloop is described based on the literature. The model is developed based on the existing TAM and the UTAUT model. The model has four primary factors: perceived usefulness and perceived ease of use, perceived trust, and social influence.

Perceived Usefulness (PU) indicates the extent to which users believe that using a particular technology system will enhance his or her job performance or performance of daily activities. Contrastingly, Perceived Ease to Use (PEU) indicates to which extent users believe using a particular technology system will be accessible by effort. A person's belief towards a novel technology may be influenced by other factors referred to as external variables in the model, such as trust, social influence, behavior, and demographics.

Social behavior or social attitude is defined as the Social Influence (SI) that includes behavioral attitudes towards automation, psychological behavior, social norm, etc. Finally, socio-demographic variables including age, gender, income, and technology concerns are the comprehensive factors in Hyperloop TAM.

The proposed model will be validated based on the survey data and model outcomes. As the survey doesn't have the behavior intention for TAM as Hyperloop is not yet available. Therefore the study uses Hyperloop early adoption as a behavioral intention based on the Hyperloop choice model.

Reliability analysis will be done to validate the model. The reliability evaluates the consistency of results obtained from different test methods like Cronbach's alpha. In addition, the indicator loadings and the average variance will be extracted to assess the convergent validity of a reflective construct. The value of Cronbach's alpha in composite reliability (CR) model range between .70 and .95 are considered a good fit.

4 Data Analysis

4.1 Summary statistics

Two data set were used in this study. The survey for the thesis had generated 254 responses, and the other dataset (602 responses) was from the Chair of Transportation Systems Engineering. After checking the quality of both datasets, the combined dataset was used for analysis and modeling as the combined dataset showed the best results. The combined dataset had 856 responses, with most respondents residing in Germany and mostly in Munich. The survey was conducted online and collected data from all over the world. Besides, the spatial focus was given on Munich and Berlin region for data collection. It has been noticed that younger people seemed more interested in this research topic than older people, considering the fact that older people have less access to the internet (Koppelhuber et al., 2017). Some statistics are not entirely representative, as expected for an internet-based survey (Efthymiou et al., 2013). In the following table 4.1 the summary statistics of the full dataset and the Munich subsample are presented.

The main assumptions of the sample distribution are summarized below.

1. The sample overrepresents younger and higher educated respondents, possibly due to the online survey dissemination.
2. Public transport as a main mode of transport was overrepresented for the Munich subsample.
3. High-speed train as a main for long-distance travel was overrepresented for both samples.
4. Age categories 0-17 and 18-24 were combined together in one category for less than 24 years old. Similarly, 55-64 and 65+ were combined.
5. Occupation categories were reassigned to the full-time, part-time, student, and unemployed.
6. Education categories were reassigned to bachelor or lower (high school, apprenticeship, bachelor), master, and doctorate levels.
7. Income categories were combined to up to 1000 euro, 1000 to 3000, 3000 to 6000 and 6000 and more.

The mode choice statistics show that Hyperloop was chosen in 67%, high-speed train in 25%, flight in 6%, and None in 2% of all observed choices. In addition, the distributions of time adoption also show that around 70% express their interest in adopting the Hyperloop systems in the first three years of its implementation. Contrarily, a lower percentage for late (Y4-Y5, Y6+) and non-adopters (Never) were observed. The distribution of the outcomes is shown in Table 4.2 and Table 4.3 below:

Table 4.1 Summary statistics

		Total sample (N=856) %	**Germany subsample (N = 592)** %	**Germany statistics (2019)** % Destatis (2020)
Gender	Female	34	33.6	50.4
	Male	60.2	62.7	49.4
	Prefer not to answer	2.9	3.3	-
Age	0–17	0.2	0.4	14.7
	18–24	32.5	27.6	6.2
	25–34	51.2	54.5	13.7
	35- 44	7.7	8.1	16.7
	45–54	2.6	3.3	23.6
	55–64	1.6	1.1	6.8
	65+	1.1	1.7	18.9
	Prefer not to answer	1.6	0.8	
Main occupation	Full time employed	28.6	23.4	76.7
	Part-time employed	8.2	12.3	-
	Student	51.7	52	-
	Unemployed	1.6	1.6	5
	Self-employed	3.6	2.4	7.8
	Retired	1.1	1.7	-
	Prefer not to answer	2.1	0.8	-
Education	High School	9.8	11.8	
	Apprenticeship	1.6	0.8	31.9
	Bachelor	40.6	43	17.6
	Master	37.8	38.4	
	Doctorate	3.6	2.3	2.5
	Prefer not to answer	1.2	0.3	
Household income	<500 €	9.6	9.4	3182 € (avg net)
	500–1000 €	23.1	27.4	
	1000–2000 €	17.4	19.5	
	2000–3000 €	11.9	13.5	
	3000–4000 €	5.3	4.6	
	4000–5000 €	4.1	4.5	
	5000–6000 €	3.2	3.4	
	6000–7000 €	1.1	1.6	
	>7000 €	3.1	2.5	
	Prefer not to answer	17.2	13.2	
Main mode-long-distance	Bus	11.5	9.05	
	Car	22	16.6	
	Flight	23.4	23.7	
	High-speed train	40.5	48.3	
	Ridesharing	0.6	0.9	
	Other	1.6	0.6	

Table 4.2 Distribution of survey outcomes for adoption (%)

	Frequency (%) (Observation= 856)
During 1st year of operation	33.6
During 2nd or 3rd year of operation	38.9
During 4th or 5th of operation	6.0
Starting the 6th year of operation	2.8
Never	1.5
Unsure	16.2

Table 4.3 Survey choice analysis

	Frequency (%) (Observation= 8560)
Hyperloop Systems	67.2
High-speed train	25.3
Flight	5.5
None	1.7

4.2 Further Insights of the survey results

This section discusses further insights about the survey results, including current travel patterns, satisfaction for current existing modes, mode choice factors, choice decisions influenced by respondents' demographic characteristics, adoption influenced by demographics.

4.2.1 Current travel pattern

The main mode of transport for long-distance travel

The main mode of transport was public transport for 57% of respondents, followed by car and bicycle was chosen for 15%, 18% respondents. In addition, car-sharing, ride-hailing, scooter, and walk were the main mode of transport for around 10% of the respondents (Figure 4.1).

In terms of long-distance travel (> 400 km)., the majority of the respondents stated high-speed train (40%) as the main mode of transportation. Besides, about 24% and 21% of respondents stated that they use flights and cars as a mode of transport, respectively. The following Figure 4.2 shows the main mode of transport for long-distance travel for respondents.

Level of satisfaction for current modes

Respondents were asked about their satisfaction level for current long-distance travel modes as high-speed train and Flights. Their satisfaction level is almost the same for both transport modes. Interestingly, the flight users are slightly more satisfied than the high-speed train users.

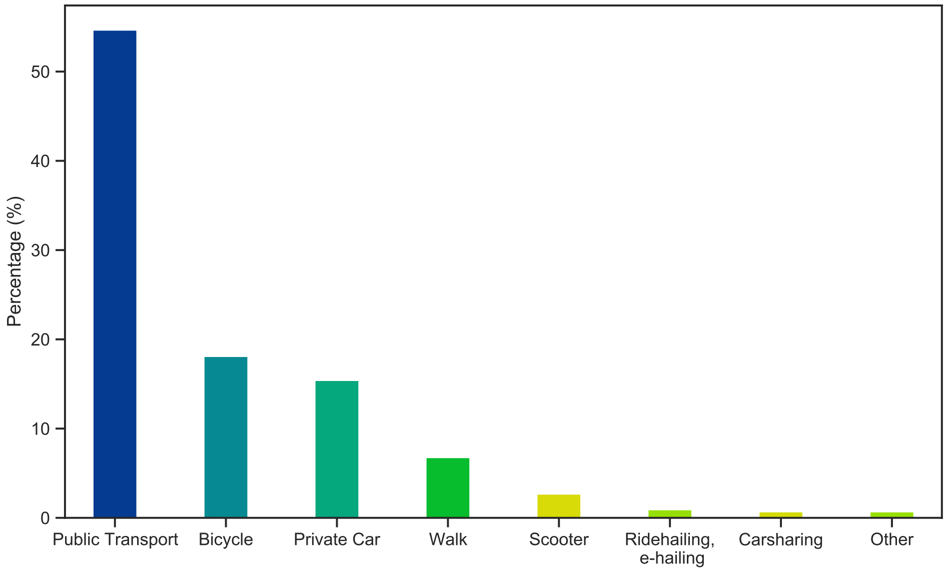

Figure 4.1 Main mode of transportation (N= 856)

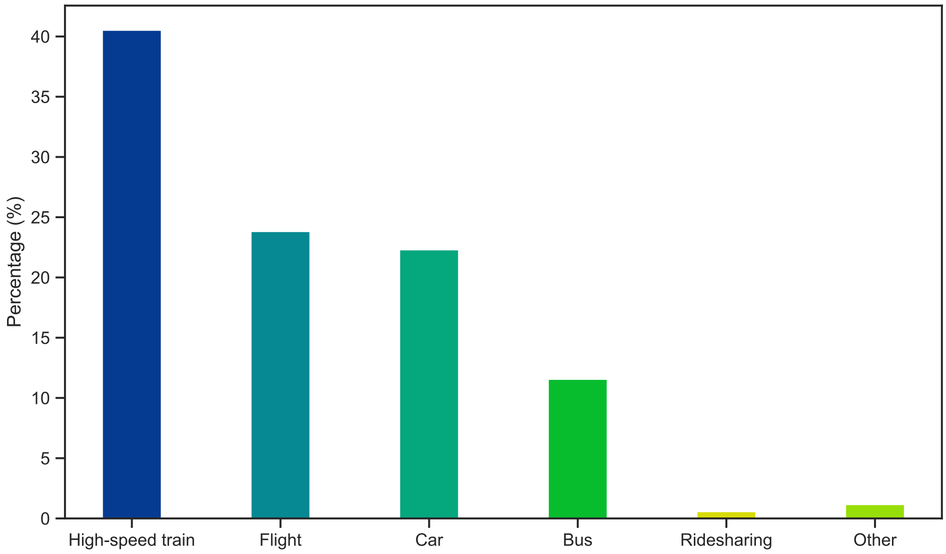

Figure 4.2 Main mode of transportation for long-distance travel (N= 856)

Mode choice factors

The Figure 4.3 shows the influence factors for the mode choice decision. Respondents were asked about the importance of these mode choice factors on a scale of 1 to 6. The figure presents the mean values for time, cost, safety, comfort, and environmental effect on mode choice decision. However, Travel cost, travel time, and travel safety are the more concerning issue for a mode choice decision. Nonetheless, the environmental effect has the lowest impact on a choice decision. Interestingly, for females, respondents stated the travel time and travel safety are most influential factors than males.

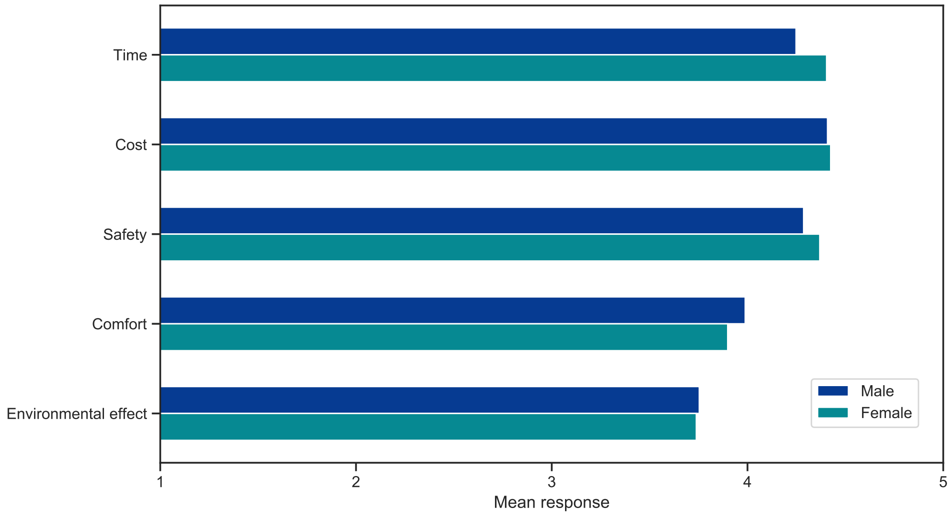

Figure 4.3 Mode choice factors (N= 856)

Knowledge level regarding Hyperloop

Respondents were asked whether they had prior knowledge about Hyperloop systems. The majority of respondents (70%) stated that they had heard about Hyperloop technology before the study, out of which 9% claimed to have a deeper understanding of Hyperloop systems, whereas 30% people had no prior knowledge about Hyperloop systems (Figure 4.4). Men had significantly more knowledge about Hyperloop than women, and overall, male participants had a more favorable opinion than female participants regarding the technology. Notably, respondents who reported a high level of prior knowledge about the Hyperloop had more negative associations with the technology than those who had only limited knowledge about Hyperloop prior to the study.

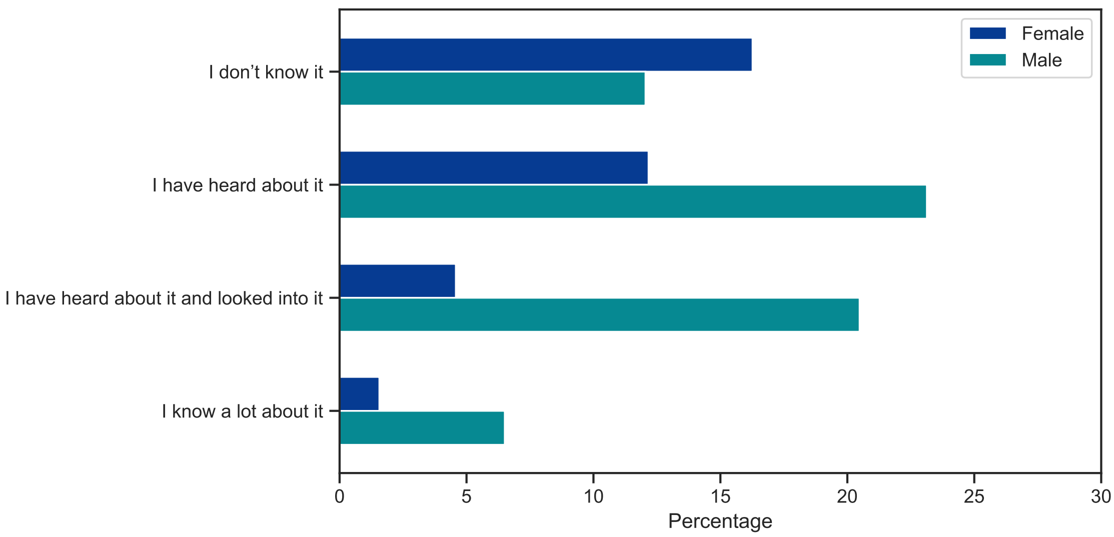

Figure 4.4 Understanding about Hyperloop systems prior to the study (N= 856)

4.2.2 Stated choice analysis

Each of the 856 respondents completed ten scenario tasks. Therefore, 8560 choices were observed based on the combined dataset. Hyperloop was chosen in 67%, high-speed train in 25%, flight in 6%, and None in 2% of all observed choices. The socio-demographic characteristic of the respondents influenced the mode choice decision. Therefore, the impacts of age, gender, education, and income on mode choice decisions are shown in the following figures.

Mode choice by gender

The analysis of the mode choices by gender shows that there are no significant differences between males and females respondents. Figure 4.5 shows that males have a slightly higher tendency to choose Hyperloop.

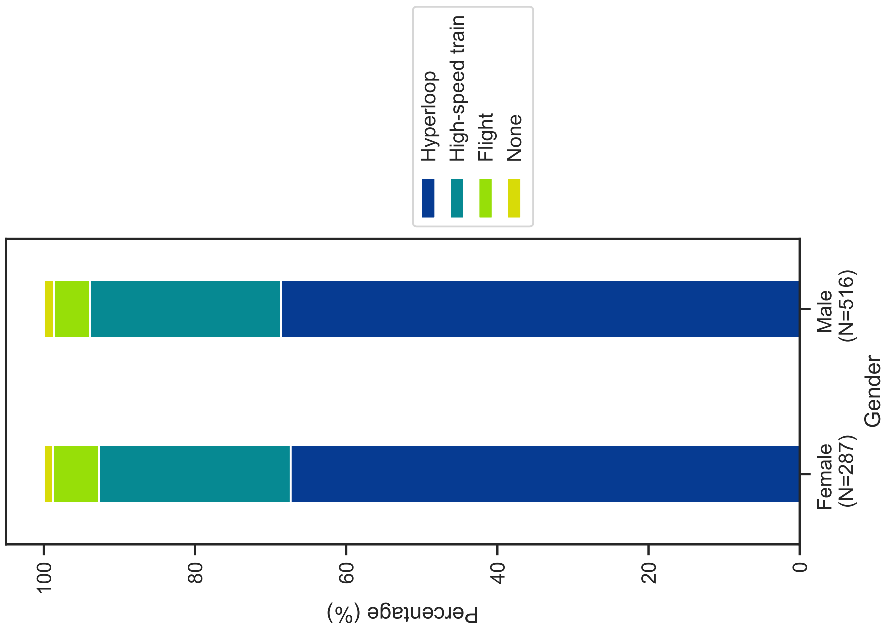

Figure 4.5 Mode choice decision of different gender (N= 856)

Mode choice by age

The analysis of the mode choices by age shows that young people tend to choose Hyperloop, satisfying Hypothesis 2. The medium ages people (45+) have a lesser tendency to choose Hyperloop, but they preferred flights more than other age groups. Figure 4.6 shows the choice decision influence by age groups.

Mode choice by occupation

Figure 4.7 shows the choice decision influence by occupation. Full-time employees and students have a higher inclination to choose Hyperloop than other occupation groups. This finding has satisfied hypothesis 3. In addition, unemployed people have less interest in Hyperloop.

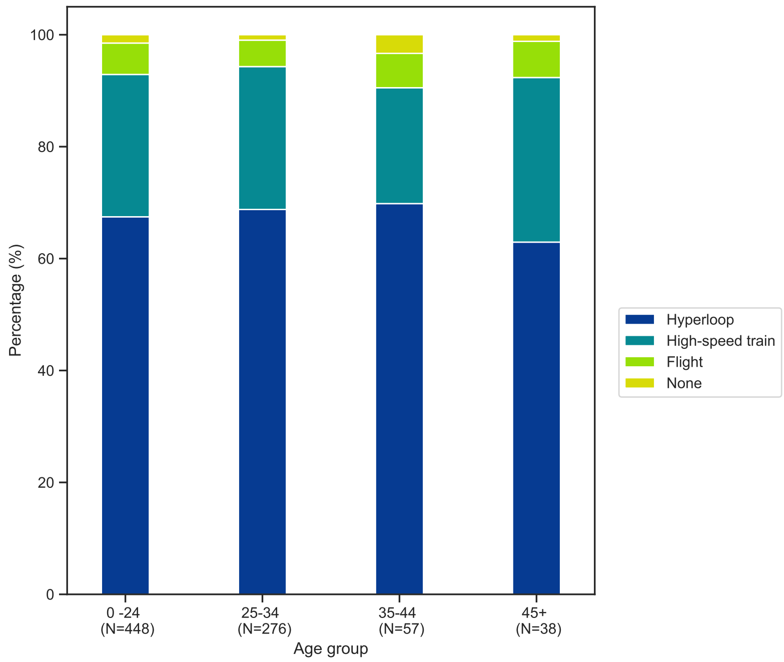

Figure 4.6 Mode choice decision of different age groups (N= 856)

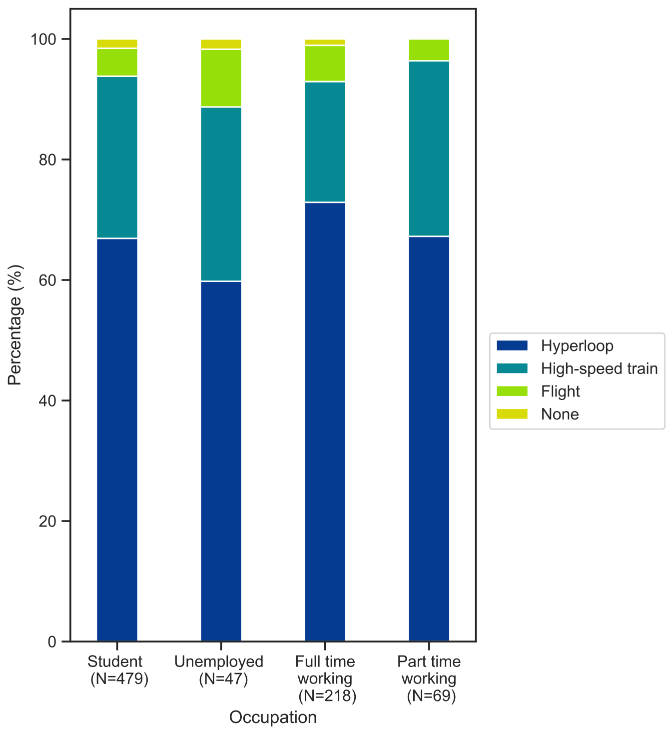

Figure 4.7 Mode choice decision of different occupation groups (N= 856)

Mode choice by education

Figure 4.8 shows that education influenced the mode choice decision. Highly educated people like doctorate respondents choose Hyperloop less. But there is no significant difference between other groups.

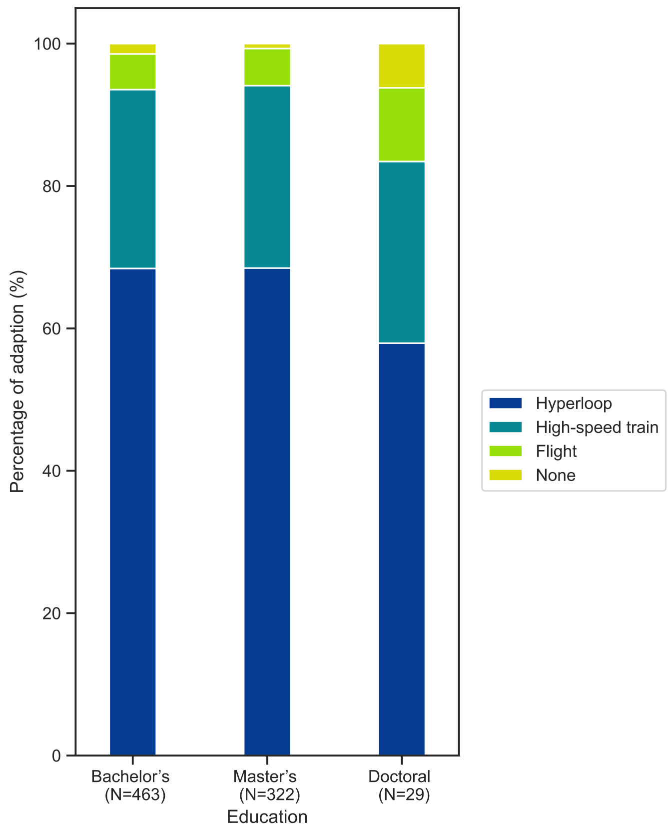

Figure 4.8 Mode choice decision of different education groups (N= 856)

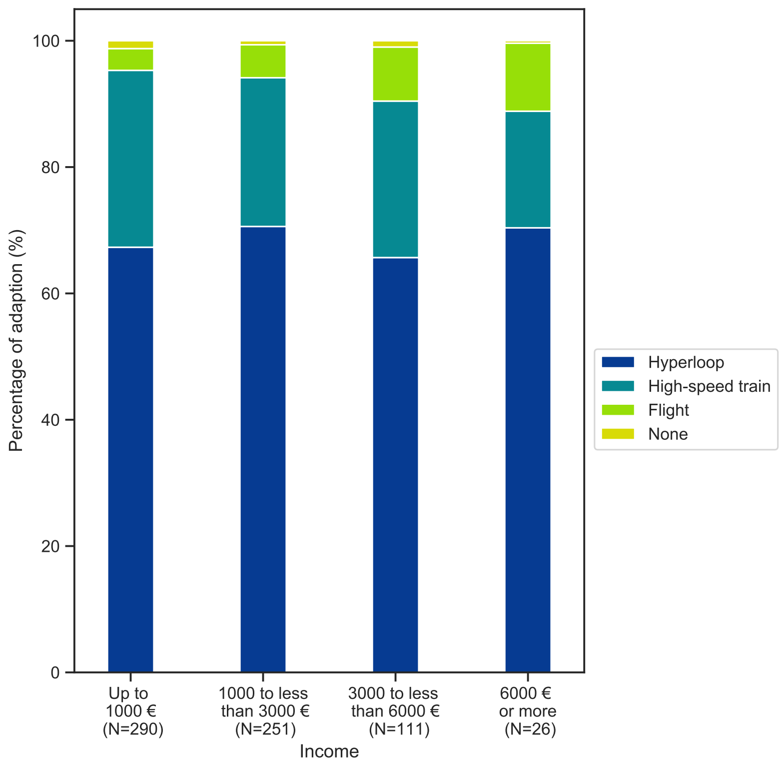

Figure 4.9 Mode choice decision of different income groups (N= 856)

Mode choice by income

The analysis of the mode choices by income shows no significant differences between different income groups. Figure 4.9 shows that moderate and very high-income groups tend to choose Hyperloop over other income groups.

4.2.3 Profile-based demographic characteristics

The highly educated (Masters and Ph.D.) profile is represented mainly by mid-aged employed people with high income, as shown in Table 4.4. The medium-level educated people (up to bachelor level) profile is represented by the younger-aged student and relatively low income, as shown in Table 4.5.

Table 4.4 Share of high educated respondents characterized by age, education level, and employment status

age group	occupation	income	Percentage (N=372)
0 - 24	Working (Full-time)	1000 - 3000	3.2
25 - 34	Student	Up to 1000	9.3
		1000- 3000	10.1
	Working (Part-time)	Up to 1000	4.8
		1000- 3000	4.6
	Working (Full-time)	3000 - 6000	5.6
		1000 - 3000	11.1
45 - 54	Working (Full-time)	1000 - 3000	5.4
		3000 - 6000	7.3

Table 4.5 Share of medium level educated respondents characterised by age, education level, and employment status

age group	occupation	income	Percentage (N=484)
0 - 24	Working (Full-time)	1000 - 3000	7.6
		Up to 1000	17.8
25 - 34	Working (Full-time)	3000 - 6000	5.5
	Student	1000 - 3000	7.8
		Up to 1000	21.4
		3000 - 6000	6.2
45 - 54	Working (Full-time)	3000 - 6000	7.4

4.2.4 Adoption and attitudes of different demographics

The socio-demographic characteristic of the respondents influenced the Hyperloop time adoption. Therefore, the impacts of age, gender, education, and income on mode choice decisions are shown in the following figures.

Adoption by gender

Figure 4.10 shows the analysis of the adoption choices by gender. The males have a higher tendency to early adoption than females, which is satisfied hypothesis 1. In addition, a higher number of respondents were unsure about their adoption time.

Adoption by age

Figure 4.11 shows that younger people (0-35 years old) tend to be the early adopters (Y1 and Y2-3) for Hyperloop systems and a lower for late adoption. However, the mid-age group (35 - 54) have a higher tendency to be late adopter and lower for early adoption.

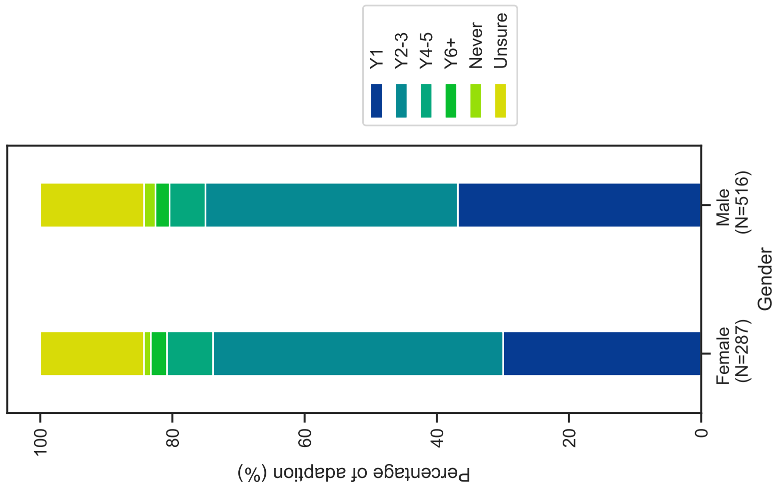

Figure 4.10 Hyperloop adoption by gender (N= 856)

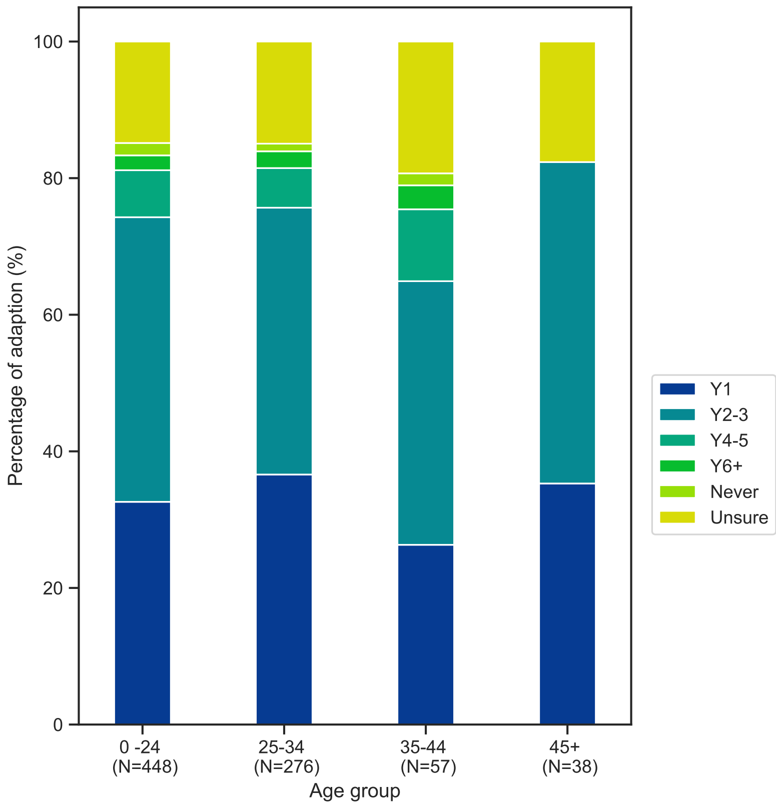

Figure 4.11 Hyperloop adoption by age groups (N= 856)

Adoption by occupation

The analysis of the adoption choices by occupation shows that full-time employees and unemployed people tend to be late adopters than part-time employees (4.12).

Adoption by income

The Figure 4.13 shows the adoption time for different income groups. Highly income groups and very lower income groups have a tendency to be the early adopter (Y1 and Y 2-3) for Hyperloop systems. However, the higher income levels share higher percentages of early adoption (Y1 and Y 2-3) than lower income levels.

Adoption by survey language

Figure 4.14 shows an interesting analysis of the adoption choices by survey languages. The survey was circulated in two languages: German and English. The respondents answering in English have a higher tendency to be an early adopters and uncertain about their adoption time. On the other hand, respondents answering in the German language have a higher tendency to be mid-time adopters (Y2 -Y3).

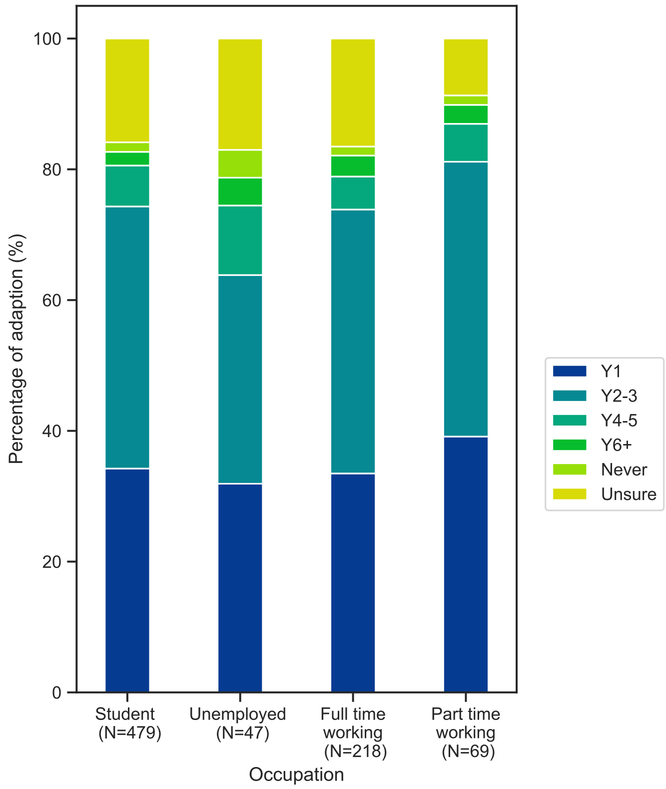

Figure 4.12 Hyperloop adoption by occupation (N= 856)

4.2.5 Attitudes towards automation, safety, and data concerns

Different demographics have different attitudes towards technological concerns, automated systems, and data concerns. Figure A.16 demonstrates a generally positive attitude regarding technological concerns. Moreover, the overall level of trust regarding automated systems is rather low. In addition, females have more fear than males in terms of using automated systems. The figure also shows respondents are highly interested in new technologies and concern about data security. Females respondents have less interest than males but have more privacy and data concerns and new technologies' trust issues.

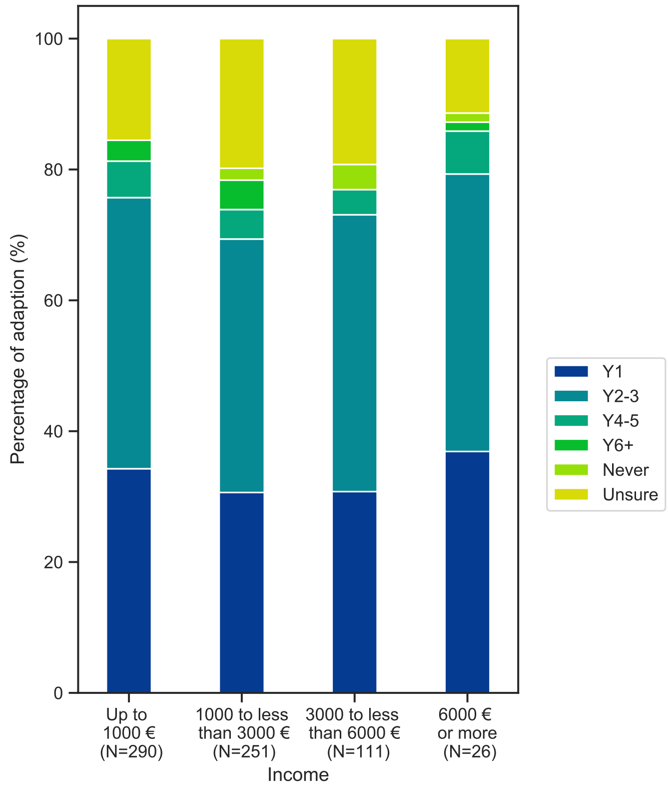

Figure 4.13 Hyperloop adoption by income groups (N= 856)

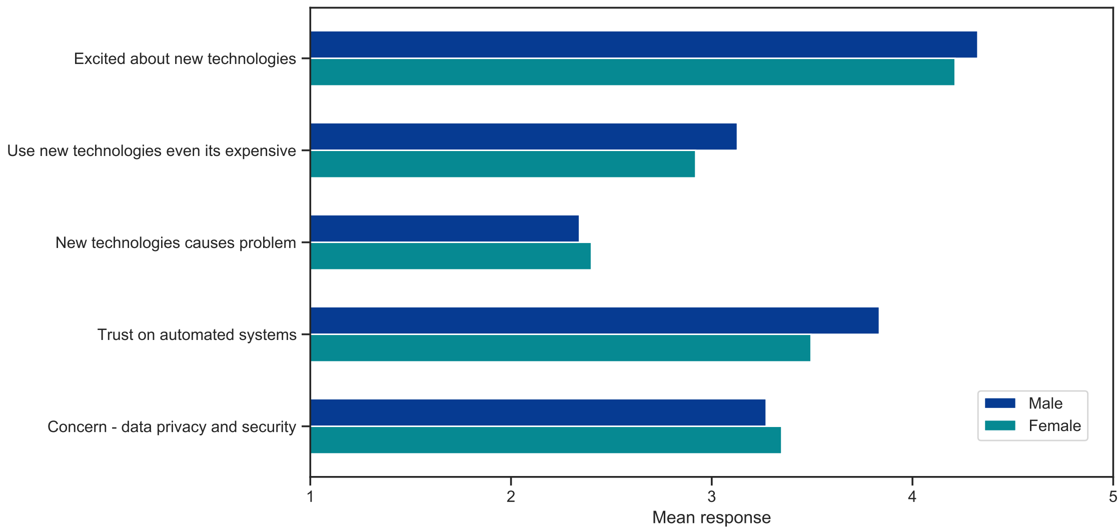

Figure 4.15 Attitudes towards trust and data concerns (N= 856)

4.2.6 Personalities/ Psychological well-being

Respondents were asked a few questions related to their psychological well-being. The Figure 4.16 demonstrates the mean value of respondents' physiological well-being. Individual scores were combined into a composite score to obtain psychological well-being scores based on guidelines (Garrett J. Kafka and Albert Kozma, 2002; Seifert, 2017). The high score people possess a positive attitude toward the self; acknowledges and accepts multiple aspects of self, including sound and bad qualities; feels optimistic about past life, self-determining and inde-

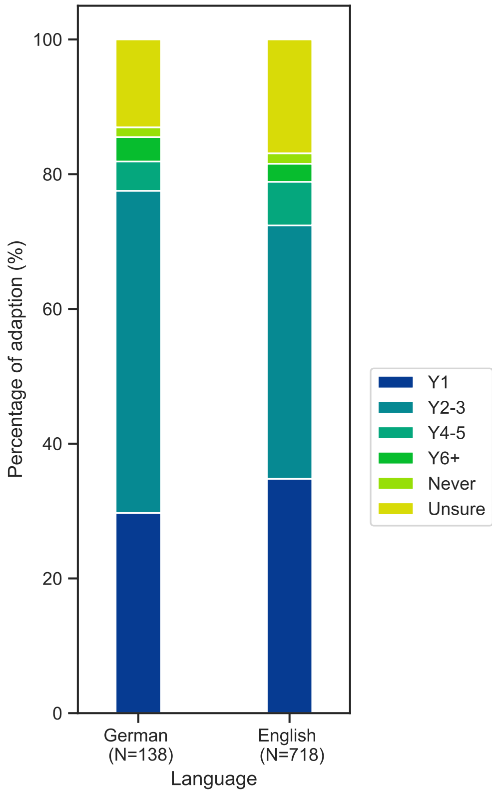

Figure 4.14 Hyperloop adoption by survey language (N= 856)

pendent; able to resist social pressures to think and act in specific ways; regulates behavior from within; evaluates self by personal standards. Nonetheless, low scorer feels dissatisfied with self; is disappointed with what has occurred in a past life; is troubled about certain personal qualities; wishes to be different than what he or she is, relies on judgments of others to make crucial decisions; conforms to social pressures to think and act in specific ways.

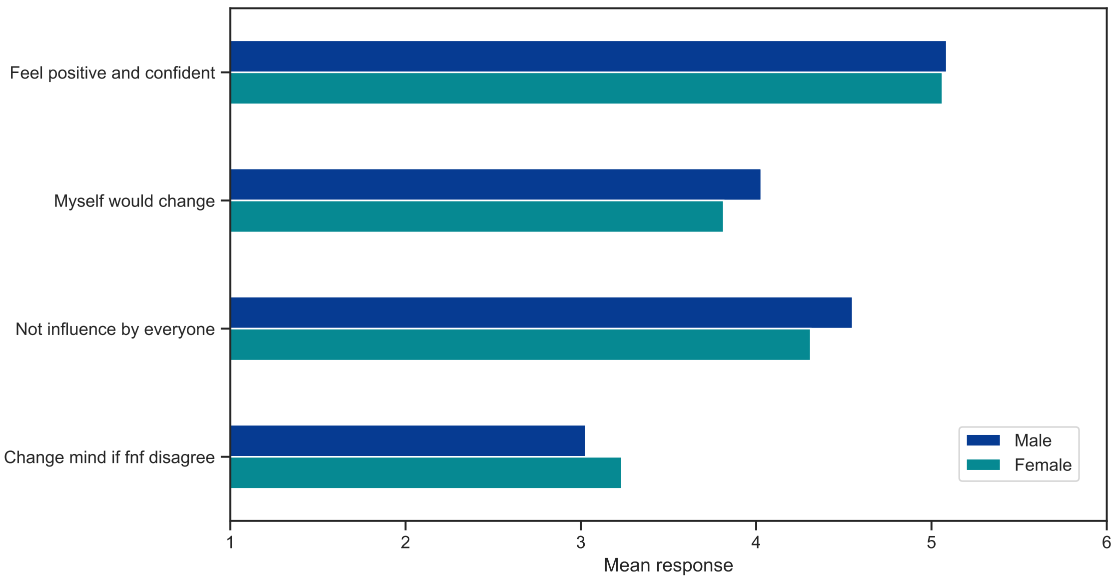

Figure 4.16 Psychological well-being of respondents (Mean value, scale - 1 to 6) (N= 856)

4.2.7 Hyperloop project in Germany

Respondents were asked whether they believed that Hyperloop would be successful in Germany. Interestingly, the majority of respondents (61%) believed that Hyperloop would be successful in Germany (Figure 4.17). Nonetheless, around 19% of people disagree with these statements. In the later section, a qualitative analysis of feedback, comments from respondents related to Hyperloop systems efficiency, success in Germany, the feasibility of the project, etc., were described.

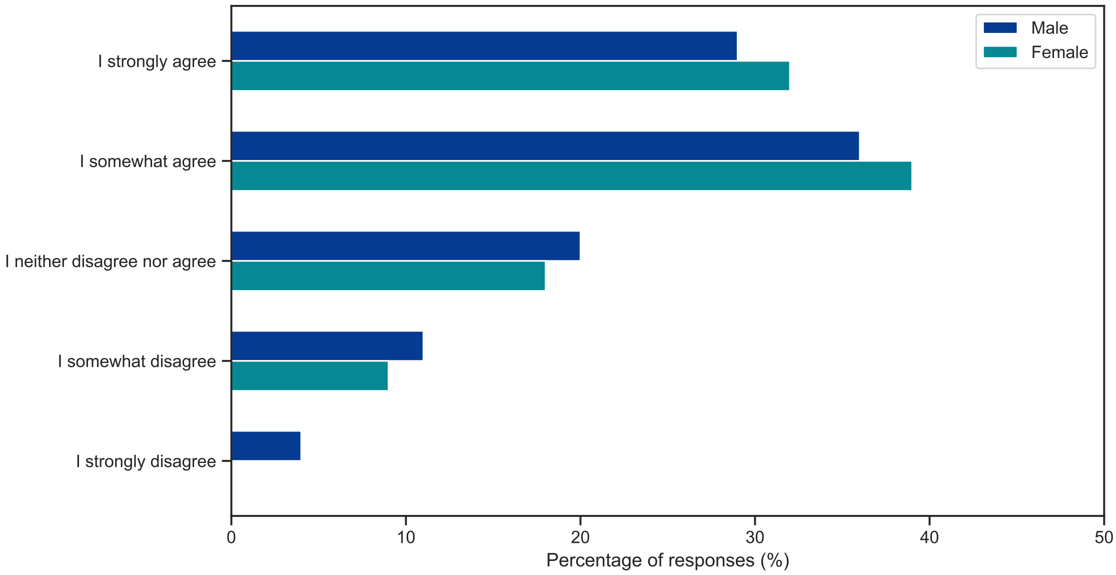

Figure 4.17 The success of the Hyperloop system in Germany (N= 856)

4.3 Qualitative analysis

A qualitative analysis of the survey is described in this subsection, based on the respondent's comments. Around 23% of respondents commented and left feedback about the survey design, study, and the different aspects of Hyperloop technologies such as environmental impact, travel cost, Hyperloop safety, the feasibility of the Hyperloop in Germany. The key findings from these comments are summarized below.

- Environmental effect is one of the major factors stated in survey comments. Respondents were concerned about land use and ecological impact during the construction phase. For example, one statement is presented as follows: "Basically, I am open to new technologies, would be great if they would also prove to be environmentally friendly."
- Safety was cited as a vital issue for Hyperloop. Few experts claimed it as not safe like other modes as train, flights. They are also concerned about the thermal expansion in the vacuum tubes.
- Few Hyperloop experts cited that most of Europe has excellent high-speed rail infrastructure. Rail is well known with reliable and safe proven technology. Considering there are no current official safety requirements (such as CS-25 for aviation or similar requirements for the automobile or rail industries), it is currently impossible to say if Hyperloop will be safer and more reliable. And without these figures, it is impossible to say what the cost will be. In their opinion, the Hyperloop companies will aim to have better safety and security compared to current standards. Therefore, this will ultimately drive the cost of Hyperloop up.

- The total travel time is assessed as a significant parameter to chose Hyperloop systems. People are concerned about their travel time savings.
- Many people stated that they fear Germany has too much resistance to build such a tube. They have had similar experiences with the Transrapid in Germany and especially in the Munich region.

5 Results

5.1 Exploratory factor analysis (EFA)

This section presents the results of the Exploratory Factor Analysis of the variables, as explained in the Methodology Chapter.

5.1.1 Exploratory factor analysis

The explanatory factor analysis of this part initially included 21 variables. After several trail-error processes and noise removal, the result was revealed with four factors. The factors and variables are shown in the following table 5.1.

Table 5.1 Factor analysis

Loadings	**Factor 1**	**Factor 2**	**Factor 3**	**Factor 4**
Use new technology even its expensive	0.76			
Trust automated systems	0.846			
Excited about new technologies	0.793			
How important for a mode choice decision - Safety		0.863		
How important for a mode choice decision - Comfort		0.741		
How important for a mode choice decision - Env. impact		0.657		
Not influenced by others decision			0.838	
Feel confident and positive about self			0.748	
How important for a mode choice decision - Cost				0.821
How important for a mode choice decision - Travel time				0.692
Interpretation	**Affinity to new technologies**	**External choice factors**	**Psychological Well-Being**	**Primary choice factors**
SS loadings	1.73	1.68	1.33	1.3
Proportion Var	17.3	16.83	13.34	13.04
Cumulative Var	17.3	34.13	47.48	60.51

The exploratory factor analysis on this part initially included 21 variables. After several trial-error processes, the results revealed four factors, presented in Table 5.1. The variables that added noise were removed. The obtained factors shared a 60% cumulative variance and were able to cluster 10 variables into the following: affinity to new technologies, external choice factor, psychological well-being and primary choice factor.

External choice factor contain three mode choice influential variables: travel safety, comfort, and environmental concerns.

The Affinity to new technologies cluster has three variables related to technological concerns and perception. Respondents' trust in the automated systems, excitement about new technologies, and uses of expensive new technologies were included in this cluster.

The psychological well-being cluster defines as the respondents' personality and self-acceptance about positive things. This cluster encloses variables related to respondents' confidence, not influenced by other decisions.

Primary choice factor attribute clusters presented two variables: how important the travel time and travel cost in a mode choice decision.

To conclude, the obtained factors minimize variable dimensionality while offering useful perspectives on latent variables, whereas giving importance to affinity to modern technology, choice factors and psychological well-being.

5.2 Model Development

This section explains the model development process, corresponding to the model formulation and estimation process described in the methodology section. The estimated coefficients of different models, specifications, and model comparisons are explained in this section.

5.2.1 Mode choice model

Generic MNL

The MNL models were firstly estimated with and without NONE alternatives, including the ASCs and the attributes of travel time and travel cost. All coefficients, including ASC, travel time, travel cost, were significant with more than 95% confidence level. The specification of utility functions per mode, including the NONE parameter, is presented in the following equation. The estimated coefficients are listed in the following Table 5.2.

$$V_{HP} = \beta_T THP * TT_{HP} + \beta_C OSTHP * COST_{HP} \tag{5.1}$$

$$V_{HST} = \beta_T THST * TT_{HST} + \beta_C OSTHST * COST_{HST} \tag{5.2}$$

$$V_{FL} = \beta_T TFL * TT_{FL} + \beta_C OSTFL * COST_{FL} \tag{5.3}$$

$$V_{NONE} = \beta_T TNONE * TT_{NONE} \tag{5.4}$$

Table 5.2 Estimated coefficients and model information for generic MNL model

	Excluding NONE alternative						Including NONE alternative							
	Hyperloop		**High-speed train**		**Flight**		**Hyperloop**		**High-speed train**		**Flight**		**NONE**	
Coefficient	**Value**	**Rob. t-test**	**Value**	**Rob. t-test**	**Value**	**Rob. t-test**	**Value**	**Rob. t-test**	**Value**	**Rob. t-test**	**Value**	**Rob. t-test**	**Value**	**Rob. t-test**
ASC			**-1.21**	-5	**-5.21**	-14.5			**-1.09**	-4.56	**-5.04**	-14.2	**-8.69**	-34.4
Total travel time	-0.08	-10.8	-0.08	-19.9	-0.06	-6.88	-0.08	-10.6	-0.08	-20	-0.06	-6.89		
Total travel cost	-0.43	-20.6	-0.35	-19.5	0.07	-4.32	-0.42	-20.4	-0.35	-19.4	-0.06	-4.35		
Sample size	**8164**						**8280**							
Nr of estimated parameters	**8**						**9**							
Initial log-likelihood	-8969.07						-11478.52							
Final log-likelihood	-5662.16						-6274.45							
Adjusted rho square	**0.36**						**0.45**							
Rho-square-bar	**0.36**						**0.45**							

MNL with all attribute

After estimating the generic model, the socio-demographic attributes were added in the utility function and evaluated the model. The utility functions for different modes are presented in the appendix A.4. After evaluating and comparing both model's log-likelihood, the model with socio-demographic attributes performed better. The presented ASC and other variables are statistically significant. Moreover, the model including none alternatives also performed better than the model with excluded none alternatives. The adjusted rho square for none included model is 0.45, which is higher than none excluded model's adjusted rho square 0.36. Furthermore, these results satisfied hypothesis 15. The estimated utilities of these models with the robust t-test are shown in following Table 5.3 and Table 5.4. Only parameters that are significant at a 95% and more than 90% level are included in the model. Moreover, the model estimation results presented in Table 5.3 and Table 5.4 indicate that the incorporation of demographics attributes has improved the model and delighted Hypothesis 16 as well.

Model with latent variables

Additionally, the significant factors from factor analysis were also added to estimated another model. The Table C.1 presents the estimated model. Significant factors like affinity to new technologies, primary choice factor, psychological well-being were added in the model. However, only the psychological well-being factor was significant for the models and presented in the Table C.1.

Profiled based MNL

Highly educated

Highly educated Profile-based MNL for highly educated and moderately educated were developed and estimated. The high educated (Masters and PhD) respondents are about 45% of the total respondents. On the other hand, other educational groups, including high school diplomas, appreciation, and bachelor's, are combined. Therefore it was decided to developed two models based on these two educational groups. The estimated utilities of the highly educated profiled-based model, excluding none alternatives, are presented in the Table C.4. Since the share of none alternatives in the highly educated group is less, the model with none alternatives was found insignificant. Comparing these two models, the highly educated-based MNL model excluding the none (with adjusted rho square 0.38) was found to a relatively acceptable result. The specification of the utility functions is described in Appendix A.4. Only those parameters that are significant at a 95% level and more than 90% level are presented in the model estimation results.

Medium educated

The estimated utilities of the medium educated based model, excluding none alternatives, are presented with only those parameters that are significant at a 95% level and more than 90% level in the following Table 5.6. The medium-educated MNL model excluding the none (with adjusted rho square 0.38) was relatively acceptable. The specification of the utility functions is described in Appendix A.4.

Table 5.3 Estimated coefficients and model information for MNL model with all attributes

	Hyperloop			High-speed train			Flight		
Coefficient	**Value**	**Rob. Std err**	**Rob. t-test**	**Value**	**Rob. Std err**	**Rob. t-test**	**Value**	**Rob. Std err**	**Rob. t-test**
ASC				-1.07	0.274	-3.89	-4.19	0.379	-11.1
Travel cost	-0.412	0.0229	-18	-0.361	0.0197	-18.3	-0.0737	0.014	-5.26
Total travel time	-0.0931	0.00856	-10.9	-0.0875	0.00459	-19.1	-0.0804	0.0107	-7.49
Safety (reference = driving level safety)									
At least two times safer than driving	4.12	0.637	6.47	5.43	0.728	7.46			
At least four times safer than driving	5.57	0.662	8.41	5.78	0.716	8.07	7.63	1.06	7.23
Frequency of the trip (reference =base)									
Level 2 (4 trip/ day)				-1.35	0.717	-1.89			
Level 3 (5 trip/ day)				1.31	0.714	1.84			
Age (reference = 18-24)									
25-34	0.897	0.461	1.94	0.954	0.518	1.84	-1.85	0.763	-2.43
35-44									
45-54	-5.9	1.77	-3.34						
55+				3.79	1.95	1.94			
Educational level (reference = <= Bachelor)									
Masters				1.23	0.616	2			
PhD	-6.13	1.53	-4						
Employment (reference = Student)									
Full time working				-2.97	0.671	-4.43	6.94	1.86	3.73
Unemployeement	-3.07	1.26	-2.44	-3.87	1.43	-2.7			
Monthly household income (reference = <1000€)									
1000€ - 3000€									
3000€ - 6000€	-2.65	0.599	-4.43	-1.41	0.676	-2.08	4.06	0.896	4.53
>6000€				-5.42	2.1	-2.58			
Driving licence (reference = No)									
Yes	2.28	0.457	4.99	0.937	0.516	1.82	-3.22	0.761	-4.23
Current long distance mode (reference = car)									
High-speed train				3.49	0.584	5.98			
Flight				-6.23	1.17	-5.32			
Sample size				**7907**					
Nr of estimated parameters				**35**					
Initial log-likelihood				**-8686.727**					
Final log-likelihood				**-5284.423**					
Adjusted rho square				**0.392**					
Rho-square-bar				**0.388**					

Table 5.4 Estimated coefficients and model information for MNL model with all attributes including NONE

	Hyperloop			High-speed train			Flight			NONE		
Coefficient	**Value**	**Rob. Std err**	**Rob. t-test**	**Value**	**Rob. Std err**	**Rob. t-test**	**Value**	**Rob. Std err**	**Rob. t-test**	**Value**	**Rob. Std err**	**Rob. t-test**
ASC				-0.965	0.271	-3.56	-4.01	0.372	-10.8	-7.89	0.308	-25.6
Travel cost	-0.4	0.0223	-17.9	-0.356	0.0194	-18.3	-0.0738	0.0139	-5.29			
Total travel time	-0.0896	0.00835	-10.7	-0.0871	0.00455	-19.1	-0.0798	0.0107	-7.47			
Safety (reference = driving level safety)												
At least two times safer than driving	4.15	0.624	6.65	5.53	0.726	7.61						
At least four times safer than driving	5.55	0.647	8.58	5.71	0.713	8	7.56	1.05	7.2			
Frequency of the trip (reference =base)												
Level 2 (4 trip/ day)				-1.41	0.712	-1.98						
Level 3 (5 trip/ day)				1.22	0.711	1.72						
Age (reference = 18-24)												
25-34	2.9	1.03	2.81	2.89	1.11	2.6						
35-44												
45-54	-5.85	1.71	-3.42									
55+				3.64	1.9	1.91						
Educational level (reference = <= Bachelor)												
Masters				1.33	0.613	2.17				-7.95	2.6	-3.05
PhD	-7.92	1.44	-5.51									
Employment (reference = Student)												
Full time working				-2.8	0.635	-4.41				-8.3	2.27	-3.66
Unemployeement												
Monthly household income (reference = <1000€)												
1000€ - 3000€												
3000€ - 6000€							5.84	1.33	4.39			
>6000€				-6.17	2.09	-2.95						
Car access (reference = No)												
Yes												
Driving licence (reference = No)												
Yes	1.21	0.604	2				-4.12	1.2	-3.44	4.64	2.16	2.14
Current long distance mode (reference = car)												
High-speed train										3.4	0.576	5.9
Flight										-6.41	1.17	-5.5
Sample size				**8015**								
Nr of estimated parameters				**32**								
Initial log-likelihood				**-11111.15**								
Final log-likelihood				**-5840.492**								
Adjusted rho square				**0.474**								
Rho-square-bar				**0.471**								

Table 5.5 Estimated coefficients and model information for highly educated people

	Hyperloop			High-speed train			Flight		
Coefficient	**Value**	**Rob. Std err**	**Rob. t-test**	**Value**	**Rob. Std err**	**Rob. t-test**	**Value**	**Rob. Std err**	**Rob. t-test**
ASC				1.13	0.5	2.26	-1.5	0.532	-2.82
Travel cost	-0.403	0.0342	-11.8	-0.307	0.0291	-10.5	-0.0762	0.0205	-3.71
Total travel time	-0.105	0.0129	-8.14	-0.0874	0.00708	-12.3	-0.067	0.0157	-4.27
Safety (reference = driving level safety)									
At least two times safer than driving	1.86	0.589	3.16	2.79	0.622	4.48			
At least four times safer than driving	2.32	0.616	3.77	1.93	0.614	3.14	5.05	1.55	3.26
Frequency of the trip (reference =base)									
Level 2 (4 trip/ day)									
Level 3 (5 trip/ day)				1.99	0.978	2.04			
Age (reference = 18-24)									
25-34	18	2.96	6.08						
35-44	15.3	3.12	4.89						
45-54				-11.8	3.77	-3.13			
55+									
Monthly household income (reference = <1000€)									
1000€ - 3000€									
3000€ - 6000€							5.85	2.32	2.52
>6000€							18	3.26	5.53
Car access (reference = No)									
Yes							-4.11	1.67	-2.46
Driving licence (reference = No)									
Yes	5.21	0.808	6.45						
Sample size				**3349**					
Nr of estimated parameters				**27**					
Initial log-likelihood				**-3679.253**					
Final log-likelihood				**-2271.145**					
Adjusted rho square				**0.383**					
Rho-square-bar				**0.375**					

Table 5.6 Estimated coefficients and model information for medium educated people

	Hyperloop			High-speed train			Flight		
Coefficient	**Value**	**Rob. Std err**	**Rob. t-test**	**Value**	**Rob. Std err**	**Rob. t-test**	**Value**	**Rob. Std err**	**Rob. t-test**
ASC				-0.443	0.38	-1.16	-3.71	0.56	-6.62
Travel cost	-0.429	0.0304	-14.1	-0.401	0.027	-14.9	-0.0706	0.0197	-3.58
Total travel time	-0.0771	0.0115	-6.73	-0.0885	0.00599	-14.8	-0.051	0.0152	-5.97
Safety (reference = driving level safety)									
At least two times safer than driving	4.2	0.84	5	4.45	0.901	4.93			
At least four times safer than driving	6.06	0.868	6.98	5.14	0.953	5.39	10.1	1.52	6.68
Employment (reference = Student)									
Full time working							3.16	1.68	1.88
Unemployeement	-6.94	1.79	-3.87	-3.22	2.13	-1.51	10.2	2.59	3.92
Monthly household income (reference = <1000€)									
1000€ - 3000€									
3000€ - 6000€							-6.07	2.15	-2.82
>6000€	-2.46	1.32	-1.86				5.65	2.42	2.33
Car access (reference = No)									
Yes				-3.65	0.874	-4.17			
Driving licence (reference = No)									
Yes	0.981	0.605	1.62	2.5	0.742	3.37	-3.9	1.01	-3.86
Current long distance mode (reference = car)									
High-speed train									
Flight									
Sample size				**4489**					
Nr of estimated parameters				**27**					
Initial log-likelihood				**-4931.671**					
Final log-likelihood				**-2932.327**					
Adjusted rho square				**0.405**					
Rho-square-bar				**0.4**					

Nested model

A nested model was also developed and estimated for mode choice decisions. Since the high-speed train and Hyperloop mode have similarities, they are considered in the same nest. All demographic attributes and factors are also added to this model. The estimated utilities of the nested model are presented in the Table C.3.

Likelihood ratio test

A likelihood ratio test was done to validate the final model if the exclusion of the insignificant variables from the model gives the better fit and significant variables. The likelihood ratio test can be shown as Equation 5.5, which is used to test the hypothesis that restrictions are valid.

$$-2(L(\beta R) - L(\beta U)) \sim X^2_{KU-KR} \tag{5.5}$$

where $L(BR)$ and $L(BU)$ are the log likelihood of the restricted model and the unrestricted model, respectively; KR and KU are the number of parameters in the restricted model and the unrestricted model.

In our model, $L(BR)$ = 5284.4, $L(BU)$ = 5270.1, KR = 35, KU = 52. So, 2$(L(BR)$ $L(BU)$ = 28.5. Since the degree of freedom is 17, so, 52-35 = 17 = 27.59.
so the hypothesis cannot be rejected for the confidence level at 95%. It means that the restricted model (i.e. MNL with all attribute) cannot be rejected. As a result, the final model outperforms the model with all attributes.

5.2.2 Interpretation of estimated model coefficients

Based on the MNL, NL including none alternatives, these models gives the following insights in terms of service attributes and demographic attributes.

Transportation service attributes

All service attribute coefficients are significant in these models. Therefore, according to ASC from above mentioned three MNL models, Hyperloop is the most preferred mode among all alternatives. The significant negative ASC coefficients indicate that the existing High-speed train and flight users preferred Hyperloop over these existing modes. Nevertheless, the flight users had a higher tendency to choose Hyperloop in comparison to high-speed trains. The travel times and travel costs showed an expected negative sign, and all coefficients were statistically significant. Regarding the negative coefficients of travel cost and travel time, it can conclude that when travel time or travel cost increases, the users' utility decreases. With regards to Hyperloop safety, the coefficient of two times safer than driving safety level is significant and has the expected positive signs concerning the reference level, which represents that safety is a crucial factor to choice Hyperloop and expected to be safer. The estimated coefficients for safety level parameters were significant for all the alternatives. Moreover, the four times safer than the driving safety level has more utility, indicating the users' utility increases with the higher safety level. In terms of the frequency, the coefficient parameters were significant for high-speed train. This parameter indicates that with higher service frequency, the user's utility increases.

Demographic attributes

Regarding the connection among employment status and the inclination to utilize the high-speed mode, a considerable outcome is described for full-time working people, who are moderately less inclined to pick Hyperloop as preferred. Unemployed people are less likely to choose Hyperloop. Concerning education level, the coefficient parameters are significant and indicates highly educated people like PhD are less interested in Hyperloop. With regards to income, there was a high tendency to choose the high-speed train for low-income people. Mid-income level people are more tend to preferred Hyperloop comparing to other modes. Interestingly, the higher-income people (3000-6000 and 6000+) are chosen flight over other Hyperloop and high-speed trains. In terms of the age group and the propensity to use the high-speed mode, a significant relation was found for young people. Young people and mid-age people (24- 34 and 35 - 44) are more likely to chose Hyperloop than other age groups. The older people have less tendency to interest in Hyperloop, possibly due to their lower interest in new technologies. Concerning driving license and access to a car, the respondents had a higher tendency to chose the Hyperloop over other flights and high-speed train those have a driving license and access to a car.

Latent variables

One latent variable named psychological well-being was found significant for the model. The higher score of psychological well-being indicates a positive attitude toward self-determining and independence about their choice and decision (described in the previous section). The model coefficient suggests that the people with a positive attitude tend to choose Hyperloop over other modes, namely high-speed train and flight. Nevertheless, the flight was chosen less compared to other modes.

Highly educated profile

The highly educated profile was considered with the group of MSc and Ph.D. people. In terms of this highly educated profiled-based model, few exciting and significant results were obtained. According to the model, the ASC indicates that highly educated people are less interested in Hyperloop. Overall, this group had a higher tendency to choose the high-speed train over Hyperloop. It might seem because of their more elevated understanding of the Hyperloop system and safety concerns. Among highly educated, the higher income (6k +) people preferred more flight than others. Moreover, according to the coefficient of the safety level, the highly educated people are more concerned about the safety of the Hyperloop. Among this group, in terms of the impact of age group, the young people are more likely to use Hyperloop than other age groups. The significant ASCs suggest that high-speed train is likely to be more attractive than Hyperloop, followed by flight for the highly educated profile. The estimated coefficients on travel times and travel costs are statistically significant and showed an expected negative sign. Regarding the utility of safety levels, only the coefficient of two times and four times safer than driving safety is substantial and has the expected positive sign for all alternatives.

Medium educated profile

Based on the model's estimated coefficient, the medium educated people are more likely to choose the Hyperloop followed by high-speed train and flights. The safety level for Hyperloop and high-speed train is also a critical concerning issue for medium-level educated people as well. In addition, the interaction income attribute and the choice attribute are found significant, and among these medium-level educated people, the low-income people are more interested in Hyperloop. Nevertheless, the higher-income people tend to used flight over Hyperloop and high-speed train.

The significant ASCs suggest that Hyperloop is likely to be more attractive than high-speed train and flight. The estimated coefficients on travel times and travel costs are statistically significant and show an expected negative sign. Regarding the utility of safety levels, only the coefficient of two times and four times safer than driving safety is substantial and has the expected positive sign for all alternatives.

Both highly educated profiled and medium educated profile models are statistically significant. The estimated coefficients like travel time, travel cost safety, and demographic variables are significant. The value of time is higher in the highly educated profiled-based model than the medium educated, which was expected.

Nested model

In the nested logit model, the Hyperloop and high-speed train were considered as in the same nest. All service attribute coefficients are significant in these models. Therefore, according to ASC from the models, the nested mode is preferred over the other. Since the MU is higher, the nested model is fitted. The travel times and travel costs showed an expected negative sign, and all coefficients were statistically significant. Regarding the negative coefficients of travel cost and travel time, the users' utility decreases when travel time or travel cost increases. Regarding safety, the coefficient of 4 times safer than driving safety level is significant. It has the expected positive signs concerning the reference level, representing that safety is a crucial factor in a mode choice decision. In-terms of demography, the higher-income people (3000-6000 and 6000+) have more interest in flight over Hyperloop and high-speed trains.

5.2.3 Adoption model

MNL 1

Initially, the MNL model was developed and estimated, including all six categories Y1, Y2-Y3, Y4-Y5, Y6, Never, and Unsure as dependable variables. The estimated utilities of MNL models are shown with the robust t-test and p-value in Table C.4. Only parameters that are significant at a 95% level are considered for the model except for few exceptional cases.

MNL 2

After adding meaningful and significant attributes and after several iterations, Model 2 was developed and estimated. In this model, The late adoption (Y6) and YNever combined into one group. The tables explained the model estimation with the significant parameters at a 95% level or 90% level.

Table 5.7 Estimated coefficients and model information for adoption MNL 2

Coefficient	Value	Rob. t-test	Rob. p-value
ASC Y4-5	-2.43	-19.6	0
ASC Y6+ or Never	-3.05	-26.4	0
ASC YUnsure	-1.01	-10.4	0
Y1 Age group 24- 34	1.86	3.88	0.001
Y1 Main mode as PuT	-2.94	-8.08	0.001
Y1 Occupation Unemployed	-4.59	-2.43	0.015
Y1 Occupation Working	1.63	3.22	0.001
Y2-3 Survey Language German	-3.14	-5.36	0.001
Y2-3 Education MSc	3.57	6.49	0.001
Y2-3 Females	3.02	6.21	0.001
Y2-3 Frequently Long-distance travel	-0.982	-3.89	0.001
Y2-3 Main mode as PuT	-2.09	-6	0.001
Y4-5 Age group 35 -44	7.32	5.36	0.001
Y4-5 Education MSc	6.56	6.76	0.001
Y4-5 Females	4.24	4.44	0.001
Y4-5 Income group 6000+	-3.42	-2.58	0.001
Y4-5 Main mode as PuT	-2.38	-5.06	0.001
Y6+ Education PhD	13.8	6.91	0.001
Y6+ Income group 6000+	3.41	2.08	0.037
YUnsure Age group 45-54	7.12	4.45	0.001
YUnsure Education MSc	2.83	4.17	0.001
YUnsure Frequently Long-distance travel	-0.727	-2.08	0.037
YUnsure Income group 6000+	2.69	3.19	0.001
YUnsure Main mode as PuT	-2.75	-7.03	0.001
Sample size		**8015**	
Number of estimated parameters		**25**	
Initial log-likelihood		**-14460.95**	
Final log-likelihood		**-10675.7**5	
Adjusted rho square		**0.263**	
Rho-square-bar		**0.261**	

Log-likelihood ratio test was performed for two models. Therefore, the improved model (MNL- 2) performed better than the restricted model. Most estimates of Model were significant to the 95% level of confidence. The generalized insights of the model are summarized below:

There is a significantly positive alternative-specific constant for respondents stating a very early adopter and a negative alternative-specific constant for non-adopters. Gender plays a crucial role in Hyperloop's early adoption, and males tend to adopt Hyperloop early than females. Moreover, education and age group also have an impact on adoption. The highly educated like Ph.D. has positive impact on adoption in the six years of implementation. Full-time employment significantly and positively contributes to adoption in the first three years. There is a positive and significant impact of survey language on adoption time in the 2-3 years of implementation. Additionally, The main mode as public transport has a positive impact on late adoption.

Ordered logit models (OLMs)

In this part, an initial OLM was developed and estimated with dependable variables. The following table presents the OLM model with estimated values. The estimated utilities of ordered models are shown with the robust t-test and p-value. Only parameters that are significant at a 95 % level are considered for the model except for few exceptional cases. Three ordered logit models were developed in three different cases.

- In 1st case, the first model was estimated with all six categories Y1, Y2-Y3, Y4-Y5, Y6, Never, and unsure. Nevertheless, the cluster was considered as follows: Y1 and Y2-Y3; Y2-Y3 and Y4-Y5; Y4-Y5 and Y6; Y6 and Never, Never and unsure.
- In 2nd case, the Y6 and Never were combined in a single group whereas the Never category has less than 5% share of the data and have similarity with Y6 category as well.
- In the third case, the Y6 and YNever were combined in a single group and excluded the uncertain adopters

The initial OLM Model and improved OLM estimation are presented in Table 5.8, Table C.4 and Table 5.9 respectively. Findings are discussed below concerning their significance.

Table 5.8 Estimated coefficients and model information for adoption OLM - 1

Coefficient	**Value**	**Rob. t-test**
Data privacy and security	0.519	2.99
Familiar with Hyperloop	-2.02	-9.1
Frequent long distance travel	-0.799	-3.32
Hyperloop safety	0.784	7.91
Long distance mode- HST	-0.662	-3.41
Main mode PuT	0.499	3.21
Safety consideration during mode choice	0.928	3.38
Technology concern	-3.74	-15.4
Y1|Y23	-1.78	-18
Y23|Y45	0.03	63.7
Y45|Y6+	0.383	22.7
Y6+|Ynever	0.562	14.7
YNever|YUnsure	0.675	11.2
Sample size		**8015**
Number of estimated parameters		**14**
Initial log-likelihood		**-17127.5**
Final log-likelihood		**-10653.88**
Adjusted rho square		**0.378**
Rho-square-bar		**0.377**
Akaike Information Criterion		**21341.77**
Bayesian Information Criterion		**21460.58**

There is a significantly negative alternative-specific constant for respondents stating a very early adopter (Y1 and Y 2-3) and a positive alternative-specific constant for late and non-adopters. The age groups, education, travel cost, and time consideration are eliminated due to their high insignificance.

Moreover, the prior knowledge about Hyperloop technology has a positive influence on early adoption time. The frequent long-distance travel and long-distance transport mode as high-speed train coefficients are significant, which positively impacts Hyperloop's early adoption. The coefficient indicates that those who make frequent long-distance travel and use the high-speed train in long-distance travel will adopt Hyperloop early (Y1 and Y 2-3). The affinity to new technology or interest in new technologies is the influential positive factor for the early adoption of Hyperloop systems. Nevertheless, Data privacy and security and safety considerations during the mode choice are important factors that's influence late and non-adoption.

Table 5.9 Estimated coefficients and model information for adoption OLM - 3

Coefficient	Value	Rob. t-test
Familiar with Hyperloop	-2.02	-8.97
Frequent long-distance travel	-0.671	-2.8
Hyperloop safety	0.952	10.1
Long-distance mode- HST	-0.662	-3.36
Main mode PuT	0.566	3.59
Safety consideration during the mode choice	1.14	4.21
Technology concerns	-3.94	-15.4
Y1|Y23	-1.95	-20.8
Y23|Y45	-0.152	63.7
Y45|Y6+	0.26	22.7
Sample size		**6732**
Number of estimated parameters		**12**
Initial log-likelihood		**-14360.39**
Final log-likelihood		**-10463.05**
Adjusted rho square		**0.261**
Rho-square-bar		**0.261**
Akaike Information Criterion		**20996.09**
Bayesian Information Criterion		**21015.93**

Finally, Hyperloop safety is another crucial concerning issue for Hyperloop adoption. People who are concern about Hyperloop safety would adopt Hyperloop later.

Both models were compared in terms of adjusted rho square, BIC and AIC. Compared to Case 1, Case 3 presents similar values for the relevant parameters, with close estimates in terms of value and significance. The significance and higher rho square, BIC, and AIC indicate that the case 1 model has a better performance than case 2 or case 3.

6 Discussion

6.1 Discussion of main results

The main findings of this study regarding the survey statistics and the model findings obtained from the different analysis methods are described in the following section.

6.1.1 Survey findings

The main findings of the survey are summarized below.

- The majority of the respondents preferred high-speed train (40%) as their main mode of transportation for long-distance trips.
- The flight users are more satisfied than the high-speed train users with their current level of services.
- Travel cost, travel time, and travel safety are the more concerning issue for a mode choice decision. Nonetheless, the environmental effect has the lowest impact on a choice decision.
- The majority of respondents (70%) had prior knowledge about Hyperloop technology before the study, and 9% had a deeper understanding of Hyperloop systems. In addition, Men had significantly more knowledge and interest in Hyperloop than women.
- Hyperloop was chosen in 62%, high-speed train in 25%, flight in 6%, and None in 2% of all observed choices.
- Males have a slightly higher tendency to choose Hyperloop than females.
- Young people tend to choose Hyperloop than other age groups. The medium ages people (45+) have a lesser tendency to choose Hyperloop, but they preferred flights.
- Full-time employees and students have a higher inclination to choose Hyperloop than other occupation groups. Oppositely, unemployed people have less interest in Hyperloop systems.
- Highly educated people like doctorate respondents choose Hyperloop less than other groups.
- Around 70% express their interest in adopting the Hyperloop systems in the first three years of its implementation.
- Males have a higher tendency to early adoption than females. In addition, a higher number of respondents were unsure about their adoption time.
- Younger people (0-35 years old) tend to be the early adopters (Y1 and Y2-3) for Hyperloop systems and a lower for late adoption.
- The full-time employee people tend to be late adopters than other occupation groups.
- The respondents answering in English have a higher tendency to be an early adopters and uncertain about their adoption time.
- The overall level of trust regarding automated systems is rather low. Besides, females have more fear than males in terms of using automated systems.
- Females have less interest in new technologies than males but have more privacy and data concerns and new technologies' trust issues.

6.1.2 Model findings

The factor analysis helped to find out the important latent variables for both choice and adoption models. Psychological well-being, affinity to new technology, primary choice factor, external choice factor were the significant latent variables and attitudes clusters.

Mode choice factors

Based on the fitted models, Travel time and travel cost, and safety are the most influential factor. The travel time played a higher role comparing to travel cost. According to the models, Hyperloop is the most preferred mode among all alternatives. The significant coefficients suggested that the existing high-speed train and flight users preferred Hyperloop over these existing modes. The travel times and travel costs showed an expected negative sign, and all coefficients were statistically significant. Regarding Hyperloop, travel time is the most significant component than the cost to choose this mode of transport.

Hyperloop safety is another significant concerning issue. Based on the coefficient, safety is a crucial factor in choosing Hyperloop and expected to be safer; there is a higher expectation for safety. At this point, the two times safer than driving and four times safety than driving are significant and played an important role in the choice decision. Although the trip frequency is an important factor, the frequency has found insignificant in the most cases and less influence on this mode choice decision.

Full-time working people are moderately less inclined to pick Hyperloop as their preferred mode. Among highly educated, the higher income (6000+) people preferred more flight than others. Moreover, according to the safety level coefficient, highly educated people are more concerned about the safety of the Hyperloop systems.

With regards to income, the lower-income level (up to 1000) people are not highly interested in Hyperloop. Interestingly, the higher-income people (4000-6000 and 6000+) chosen flight over Hyperloop and high-speed trains. The older people have less tendency to interest in Hyperloop, possibly due to their lower interest in new technologies. Based on the coefficient, the people with a positive attitude tend to choose Hyperloop over other modes, namely high-speed train and flight.

Adoption factors

The social demographic attributes, including gender, education, income, have an important role in Hyperloop's early adoption. Additionally, The main mode of public transport has a positive impact on late adoption. Another important factor is the Hyperloop prior knowledge. the coefficient indicates that people who are familiar with Hyperloop would adopt early. Data security and privacy is also an important factor that influences the Hyperloop adoption. According to the model coefficients, data privacy concerns positively influence the Hyperloop late or non-adoption. Moreover, the frequent long-distance travel coefficients indicate that the frequent long-distance traveler will adopt Hyperloop early. The affinity to new technology is also a positive factor for the early adoption (Y1 and Y2-3) of Hyperloop systems. Nevertheless, safety is the most important and crucial factor for Hyperloop adoption. People who consider safety an important factor during a mode choice decision and the overall Hyperloop safety level negatively influence early adoption, specifying that people will adopt Hyperloop later or uncertain.

Calculation of VOT

In mode choice modeling, it is possible to calculate the hidden value of time (VOT), i.e., how much the traveler values a unit of their time. VOT presents through an indirect utility function with time and value (Small, 2012) as the following equation 6.1,

$$VOT = -\frac{dT}{dC} = \frac{\frac{\partial V}{\partial T}}{\frac{\partial V}{\partial C}} \tag{6.1}$$

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

VOT is an essential factor in the choice behavior model that explores the respondents' willingness to pay for the preferred mode. The following Table 6.2 presents the value of time (VOT), based on the model's significant values.

Table 6.1 Value of time (VOT) for Hyperloop, high-speed train, and flight

Coefficient	**Value (EURO/hr)**
Hyperloop	14
High-speed train	16
Flight	66

The estimated coefficient of VOT for Hyperloop and flights are almost the same due to their similar ticket price. Overall the VOT for the high-speed trains is relatively less than the average German VOT and other relative studies. The calculated VOT is compared in the following Table 6.2. In the case of Hyperloop, the value of travel time is less, possibly due to the lower ticket cost. The VOT of flight is 66 Euro/hr, which almost similar to the average German VOT for Air transport (Wardman et al., 2016).

Table 6.2 German meta-analysis of VOT (Wardman et al., 2016)

	Commute trip (Euros per hour)		**Business trip (Euros per hour)**		**Others trip (Euros per hour)**	
	<250km	**>250km**	**<250km**	**>250km**	**<250km**	**>250km**
Train	10.50	9.55	30.01	39.83	9.84	8.22
Flight	-	-	45.57	71.14	16.48	18.75

However, the VOT was calculated based on the total travel time that included the in-vehicle travel time, access time or egress, and waiting time at the station. Practically, the value of time is not the same for these three types of time. According to Moyano et al. (2018b), in-vehicle travel time has a higher value than the others. In this study, higher access and egress time was considered for Hyperloop and high-speed train compared to in-vehicle travel time. Furthermore, as there is no relevant study is available to evaluate the Hyperloop's VOT, in general, people with a higher VOT have a higher willingness to pay for travel time savings.

6.2 Hypotheses results

Based on the above discussion and model finding the following Table 6.3 shows the summarized hypothesis results. In addition, the results are also presented as below.

Table 6.3 Summary of hypotheses results

Hypothesis	Validated	Rejected	Neither validated nor rejected
Hypothesis - 1	✓		
Hypothesis - 2	✓		
Hypothesis - 3	✓		
Hypothesis - 4		X	
Hypothesis - 5		X	
Hypothesis - 6	✓		
Hypothesis - 7	✓		
Hypothesis - 8	✓		
Hypothesis - 9			X
Hypothesis - 10	✓		
Hypothesis - 11	✓		
Hypothesis - 12	✓		
Hypothesis - 13	✓		
Hypothesis - 14			X
Hypothesis - 15	✓		
Hypothesis - 16	✓		
Hypothesis - 17	✓		
Hypothesis - 18	✓		
Hypothesis - 19	✓		

Hypothesis 1: There is no significant difference between Males and females for mode choice decisions. Furthermore, Males are likely to be the early adopters of Hyperloop systems. Therefore, the hypothesis is accepted.

Hypothesis 2: According to model estimation, the young age group preferred Hyperloop more. Additionally, young respondents are more likely to be early adopters. Therefore, the hypothesis is accepted.

Hypothesis 3: The data result shows employment has a positive impact on early adoption, whereas unemployment has a negative impact. Moreover, unemployed people choose Hyperloop less. Therefore this hypothesis is validated.

Hypothesis 4: There are no significant results obtained about this hypothesis. However, respondents answering the English has a negative impact on the early adoption (Y2 -3). Therefore, this hypothesis is rejected.

Hypothesis 5: Based on the choice model, the higher income group chooses Hyperloop less. They preferred flight more than Hyperloop. On the other hand, the adoption model shows higher-income respondents are more likely to be late adopters or non-adopter (Y6+ and Yunsure). So, this hypothesis is also rejected.

Hypothesis 6: According to both choice and adoption model, higher educated people (masters and PhD) choose Hyperloop less and tend to adopt later (Y6+) compared to medium educated people. Therefore, this hypothesis is validated.

Hypothesis 7: The results show the travel time is a significant factor for choosing Hyperloop systems. This hypothesis is therefore validated.

Hypothesis 8: Based on the mode choice model, travel cost is another important factor for mode choice decisions. Contrastingly, the travel cost does not significantly affect to choice of Hyperloop systems. This hypothesis is, therefore, partially validated.

Hypothesis 9: According to the model results, there is no significant impact of frequency on Hyperloop choice decision. Moreover, the findings are not conclusive, and this hypothesis can neither be accepted nor rejected.

Hypothesis 10. The data analysis and model results show safety is the significant factor in the choice of Hyperloop. Moreover, a higher safety level has a positive impact on choice decisions. Therefore the hypothesis is validated.

Hypothesis 11: The results show that prior knowledge is very likely to be associated with adoption time. Those who have a understanding of Hyperloop systems are likely to be the early adopter. Therefore, the hypothesis is accepted.

Hypothesis 12: Technological understanding is a significant parameter in the adoption model for early adoption. Therefore the hypothesis is accepted.

Hypothesis 13: Psychological well-being was found as an important factor for Hyperloop choice and adoption. Therefore, this hypothesis is accepted.

Hypothesis 14: Higher existing mode transportation satisfaction is related to mode choice decisions. People with higher satisfaction of high-speed train choose Hyperloop less. But no significant findings were found from the adoption model. Therefore, the findings are not conclusive, and this hypothesis can neither be accepted nor rejected.

Hypothesis 15: The MNL model was improved with NONE alternatives. The model with NONE alternatives is highly significant than the model without NONE alternatives. Therefore the hypothesis is validated.

Hypothesis 16: According to model fits, the MNL model was improved significantly by adding demographic characteristics to the model. So, the hypothesis is accepted.

Hypothesis 17: The MNL model was also improved significantly by adding attitude-related variables (factors) to the model. The hypothesis is therefore validated.

Hypothesis 18: One nested model was developed, where Hyperloop and high-speed train were considered in the same nest. Therefore this hypothesis is validated.

Hypothesis 19: Two OLM models were developed for Hyperloop adoption, where late adopters were merged with non-adopters. Both models resulted in significant parameters. The hypothesis is therefore validated.

6.3 Acceptance model

In this section, the technology acceptance model is described and validated based on the relevant factors.

The critical and significant factors were identified based on explanatory factor analysis, mode choice models, and adoption models. Based on these factors and the proposed TAM model was constructed and presented in the methodology chapter. As described in the methodology, the model has four primary factors: perceived usefulness and perceived ease of use, perceived trust, and social influence are described in the following Table 6.4. Additionally, the variables questions are described in Table B.2.

Table 6.4 Variables of proposed technology model

Construct	Variables type	Variables
Perceived Usefulness (PU)	Independent variable	Safety, value of time (Panagiotopoulos and Dimitrakopoulos, 2018)
Perceived Ease to Use (PEU)	Independent variable	Technological concerns, cost (Panagiotopoulos and Dimitrakopoulos, 2018; Yuen et al., 2020)
Perceived Trust (PT)	Independent variable	Trust on automated systems, data security, and privacy concerns (Panagiotopoulos and Dimitrakopoulos, 2018)
Social and personal behavior (SI)	Independent variable	Personal behavior
Behavioral Intention to Use (BIU)	Dependent variable	Mode choice, Hyperloop adoption

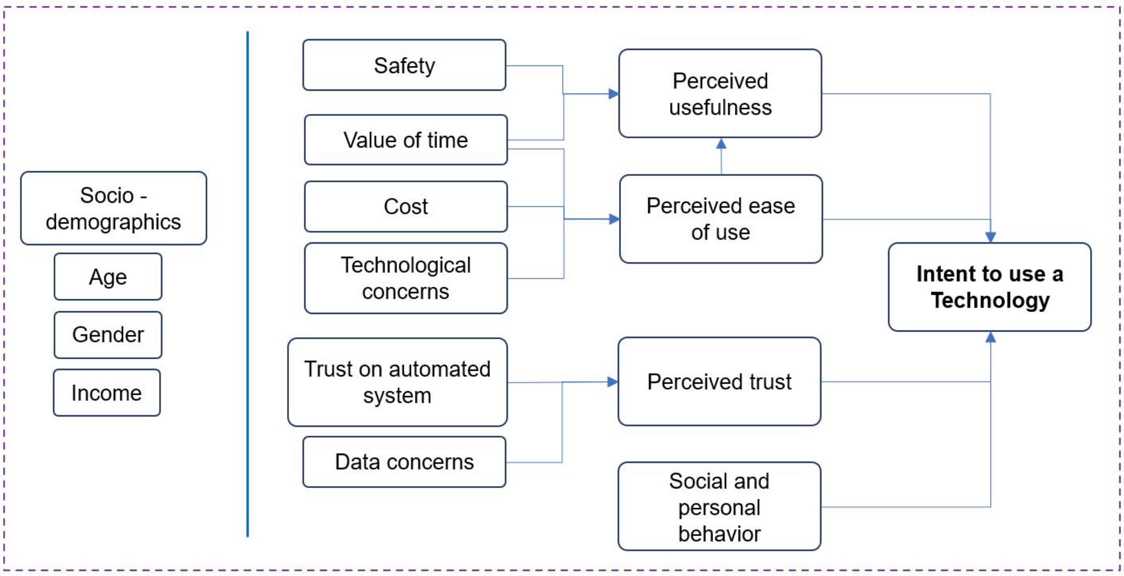

Figure 6.1 Proposed technology acceptance model for Hyperloop

Perceived usefulness is defined as users' expectation and perception of a particular technology that helps in daily activities. A person's belief towards a novel technology may be influenced by other factors referred to as external variables in the model, such as trust, social influence, behavior, and demographics.

Behavioral intention to use is the dependable variable, whereas other variables are independent variables. Social behavior or social attitude is defined as the social influence that includes behavioral attitudes towards technology, psychological behavior, social norm, etc. Finally, socio-demographic variables including age, gender, income are the comprehensive factors in Hyperloop TAM.

The reliability analysis was done with cronbach's alpha to analyze the degree of consistency. The cronbach's alpha coefficient was calculated for all variables. A value greater than 0.7 is better, but the cronbach's alpha coefficient was found to be 0.68 for this study and acceptable (Hair, 1995; Panagiotopoulos and Dimitrakopoulos, 2018). The Table 6.5 presents the pearson inter-correlations for the main variables that suggest all variables are related to each other except the PU-BIU. Two multiple regression was estimated for all variables to find out the variable's influence on Behavioral Intention.

Table 6.5 Pearson product moment inter-correlations of the main variables

	Mean	Std. dev	PU	PEU	PT	SI	BIU
Perceived Usefulness (PU)	4.3	0.61	1.00**				
Perceived Ease of Use (PEU)	3.87	0.64	0.456**	1.00**			
Perceived Trust (PT)	3.49	0.81	0.259**	0.365**	1		
Social Influence (SI)	4.76	0.97	0.224**	0.223**	0.217**	1	
Behavioral Intention to Use (BIU)	2.53	1.73	-0.011*	0.155**	0.122**	0.217*	1

** $p < 0.01$; * $p < 0.1$

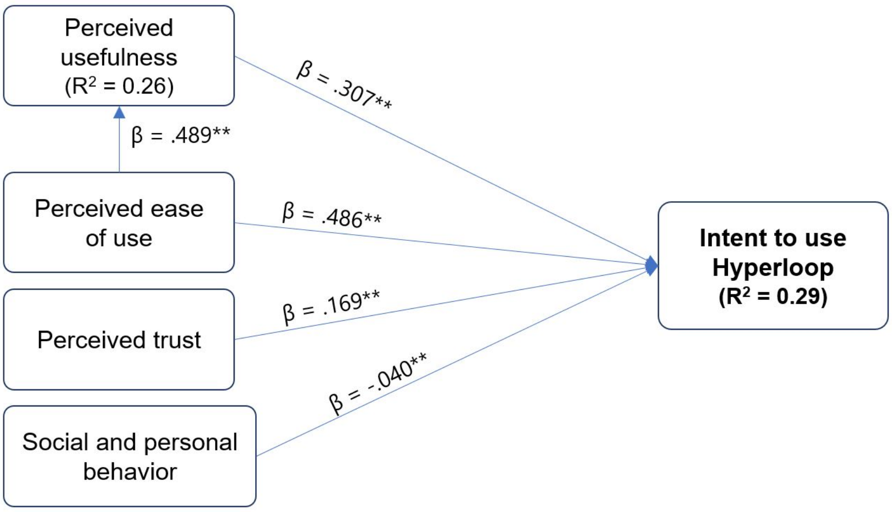

Figure 6.2 Results of relationships in acceptance model

The analysis represents that major constructs namely, perceived usefulness (PU), perceived ease to use (PEU) and perceived trust (PT) has a positive effect on the Behavioral intention to use (BIU) Hyperloop except social and personal behavior (SI), (PU, $= 0.307$, $p < 0.01$; PEU, $= 0.486$; PT, $p < 0.01$; $= 0.169$, $p < 0.01$; $= -0.040$, $p < 0.01$). The Figure 6.2 shows the results of relationships between constructs in acceptance model. Therefore, the model indicates that the four constructs, perceived usefulness, perceived ease to use, perceived trust, and social and personal behavior, influence the intention to use Hyperloop. Additionally, the results also indicate that perceived ease to use has the largest impact on Intention to Use Hyperloop, followed by perceived usefulness, perceived trust, social and personal behavior. Moreover, PU, PEU, PT, and SI are managed to explain the 29% of BIU variance, whereas PEU accounted for around 26%.

6.4 Policy implications

This section concludes and discusses the findings on mode choice behavior and acceptance mode choice attributes regarding mode choice attributes, users demographics, and attitudes. Suggested recommendations and their implications on a policy level are discussed in the following section.

The significant estimation results indicate that travel time is the most influential factor to choose Hyperloop. Hyperloop is mainly for long-distance travel (500 – 1500 km) (Taylor et al., 2016), and long-distance trips are generally business and leisure trips. Furthermore, in a business trip, the travel time is more important than travel cost people are likely to spend more on business trips (Pels et al., 2003).

Safety is another important factor for choosing a mode. The significant result shows that highly educated people are less likely to chose Hyperloop over other modes. One possible reason could be the higher understanding of Hyperloop systems. Currently, there are no safety regulations about Hyperloop. Based on qualitative analysis, few experts of Hyperloop systems are concerned about Hyperloop safety, like the thermal expansion of tubes due to high-speed and magnetic field. Moreover, the model estimation also indicates that users are desire more safety. Additionally, the adoption models also showed that Hyperloop safety is a important influential factor for late adoption.

The age group has a significant impact on mode choice decisions. Young people (age between 25 to 34) are more likely to use Hyperloop. In addition, there is a strong relationship between the young age group and technology concerns. Young people tend to use new technologies, and that could be the possible reason to choose Hyperloop. Contrarily, the older people had less tendency to interest in Hyperloop, possibly due to their lower interest in new technologies.

Nevertheless, the income groups have a significant impact on the choice decisions. Mainly the individuals belonging to the high-income group are likely to have a relatively lower propensity to use Hyperloop. High-income groups have a strong relationship with Highly educated people. The high-income group (3000 -6000 and 6000+) preferred flight possibly due to safety concerns. Furthermore, unemployed people are less like to choose Hyperloop, which is moreover expected. Moreover, it is interesting that even though in the choice scenarios, gender seemed not to have a significant impact, but in terms of adoption, it is clear that there's a considerable difference for early adoption (Y1) between females and males. The majority of the people use the high-speed train (40%) as their primary transport mode for long-distance trips. This group of people is likely to have a lower propensity to use and adopt Hyperloop systems, possibly due to their higher satisfaction level on the high-speed train. Besides, public transport users are also less intend to use and adopt Hyperloop than other groups.

Based on the model and survey findings, the different demographics have different preferences and choices. To ensure a higher adoption rate and social acceptance few recommendation and their implication on a policy level are discussed below:

- Mode choice decision is highly influenced by service attributes, socio-demographics, and users' attitudes, which should be taken into account during policy implication.
- Currently, there is no regulation and official safety requirements for Hyperloop. Therefore, reliability has to be verified through certifications to ensure users' trust in terms of service's performance.
- To ensure more transparent stakeholder involvement, higher awareness and accurate service attributes and business model are necessary.
- The environmental and economic impacts should be highlighted comparing to existing competitive transportation modes.
- To encourage different demographics, different attractive benefits should be provided.
- The reputation of the service provider is also an important issue related to trust.
- The cost could be an important issue, and it should be the similar range of existing competitive modes.
- Environmental impacts and implications should be taken into account.
- Privacy and data security, data sharing is an important issue to gain reliability. The service provider should have transparent regulation and policy about this.
- Coordination with existing transport modes is necessary to ensure integrated and efficient transport services.

7 Conclusion

7.1 Conclusion

This thesis present Hyperloop mode choice and adoption models for exploring the users' preference in a hypothetical scenario. The findings of this thesis suggest strong indications about the main objective of identifying the factors affecting the mode choice decision and adoption of Hyperloop technologies. A stated preference survey was conducted from mid-January 2021 to March 2021, and 254 valid responses were collected in working towards the objectives. The survey data (total 856) analysis identified important socio-demographic groups and their attitudes in mode choice and adoption. The factor analysis explored important latent variables and clusters. Psychological well-being, primary and external choice factor, affinity to new technology were the significant latent variables and attitudes clusters. Several discrete choice models, including the MNL model with two profile-based, a nested model, an ordered logit model for adoption, were developed and estimated to interpret the statistical results. The majority of the respondents are currently using the high-speed train as their main mode of transportation for long-distance trips. The survey and model results indicate that the overall People preferred Hyperloop over other existing modes. Travel cost, travel time, and travel safety are the more concerning issue for this Hyperloop choice decision.

The social demographic attributes, including gender, education have an important role in Hyperloop's use and early adoption. The respondents had some prior knowledge about Hyperloop technology before the study and interestingly affected the mode choice decision and adoption time. Young people tended to choose Hyperloop than other age groups. Highly educated people like doctorate respondents choose Hyperloop less than other groups due to their more profound understanding of technologies. About 70% express their interest in adopting the Hyperloop systems in the first three years of its implementation. The current satisfaction level of high-speed train is also an influential factor for Hyperloop adoption. Additionally, The main mode for long-distance travel, data security, and safety concerns have an impact on late adoption as well.

Finally, a technology model was developed and validated for choice and adoption of Hyperloop using the four primary factors: perceived usefulness and perceived ease of use, perceived trust, and social influence. The results shows that perceived usefulness, perceived ease to use and perceived trust have a positive impact on the behavioral intention to use Hyperloop. The research can be further developed by improving the experimental design and modeling framework. However, there were some limitations associated with this study, including experimental design, biased choice scenarios, online dissemination, actual travel cost and total travel time, safety regulation for Hyperloop safety. Lastly, The summarized results and findings help to understand the overall perceptions and insight concerning the Hyperloop for future research and early implementation.

7.2 Limitations

The section describes the limitation of this study concerning stated preference (SP) survey, travel cost of Hyperloop, Survey dissemination, and sample bias. The limitations are summarised in the following.

- Since this is a stated preference (SP) survey and hypothetical scenarios were created based on random experimental design, some statements and choice scenarios might be biased. The online dissemination of the survey is a limitation of the sampling approach, might influence the results, and lower the population's representativeness. The experimental design and sample can be improved by conducting offline surveys—especially, who do not have access to the internet or are not familiar with using it.
- Since the Hyperloop is still in a developmental stage, limitations concerning information availability were encountered. Very few studies exist about Hyperloop systems in terms of actual travel cost and total travel time. Hence, this study had to incorporate cost values based on studies from outside of Europe, especially North America. However, in reality, translating these costs into the European context may not be as direct as this study assumed it to be. Moreover. the study relied on newspapers and the company's website, and other internet documents, apparently marketing-based.
- Currently, there is no safety regulation for Hyperloop safety. Thus, this study compared the Hyperloop, high-speed train, and flight with driving level safety. Sometimes that created the scenario confused to respondents.

7.3 Further development

This study was constrained with many limitations, as previously outlined. Therefore, suggestions for future work to improve this study include:

- Experimental design optimization and offline dissemination of survey to overcome the sample biases.
- Estimation of travel costs in terms of Germany for higher relevancy and accuracy.
- The scope of the choice experiment could be expanded by introducing different trip purposes.
- A hybrid latent model for both mode choice analysis and Hyperloop Adoption.
- Validation of technology acceptance model through confirmatory factor analysis (CFA).
- More sophisticated validation method of technology acceptance model (TAM).

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A Results of thesis dataset

A.1 Summary statistics of the thesis dataset (N=254)

Table A.1 Summary statistics of the thesis dataset (N=254)

		Total sample (N=254) %	**Germany subsample (N = 181)** %	**Germany statistics (2019)** % Destatis (2020)
Gender	Female	26.7	31.2	50.4
	Male	64.2	63.5	49.4
	Prefer not to answer	2.1	3.3	-
Age	0–17	0.9	1.1	14.7
	18–24	35.2	26.8	6.2
	25–34	46.2	52.3	13.7
	35- 44	7.1	8.1	16.7
	45–54	2.2	3.3	23.6
	55–64	2.2	3.3	6.8
	65+	1.1	1.7	18.9
	Prefer not to answer	3.3	2.8	
Main occupation	Full time employed	25.6	22.4	76.7
	Part-time employed	8.1	11.3	-
	Student	50.1	55.5	-
	Unemployed	7.6	6.6	5
	Self-employed	1.1	1.1	7.8
	Retired		1.7	-
	Prefer not to answer	3.3	2.8	-
Education	High School	6.8	11.8	
	Apprenticeship	2.6	0.8	31.9
	Bachelor	41.6	39.4	17.6
	Master	33.8	39.45	
	Doctorate	3.9	4.2	2.5
	Prefer not to answer	1.2	1.4	
Household income	<500 €	10.1	6.4	average net-3182 €
	500–1000 €	21.2	22.4	
	1000–2000 €	22.4	17.5	
	2000–3000 €	7.9	15.5	
	3000–4000 €	3.3	3.6	
	4000–5000 €	3.3	3.5	
	5000–6000 €	4.5	3.5	
	6000–7000 €	2.1	2.6	
	>7000 €	5.8	2.5	
	Prefer not to answer	11.2	13.2	
Main mode-long-distance	Bus	18.5	7.05	
	Car	28	16.6	
	Flight	17.2	23.7	
	High-speed train	33.9	41.3	
	Ridesharing	0.4	0.7	
	Other	1.8	0.9	

A.2 Survey results of the thesis dataset

The main mode of transport for long-distance travel

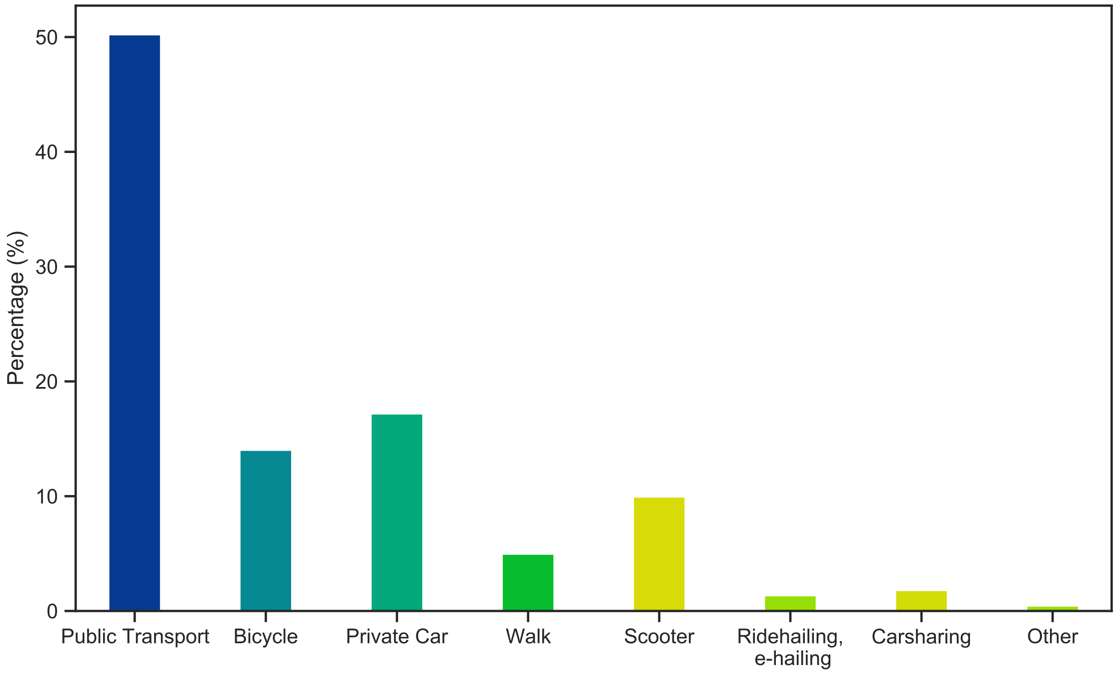

Figure A.1 Main mode of transportation (N= 254)

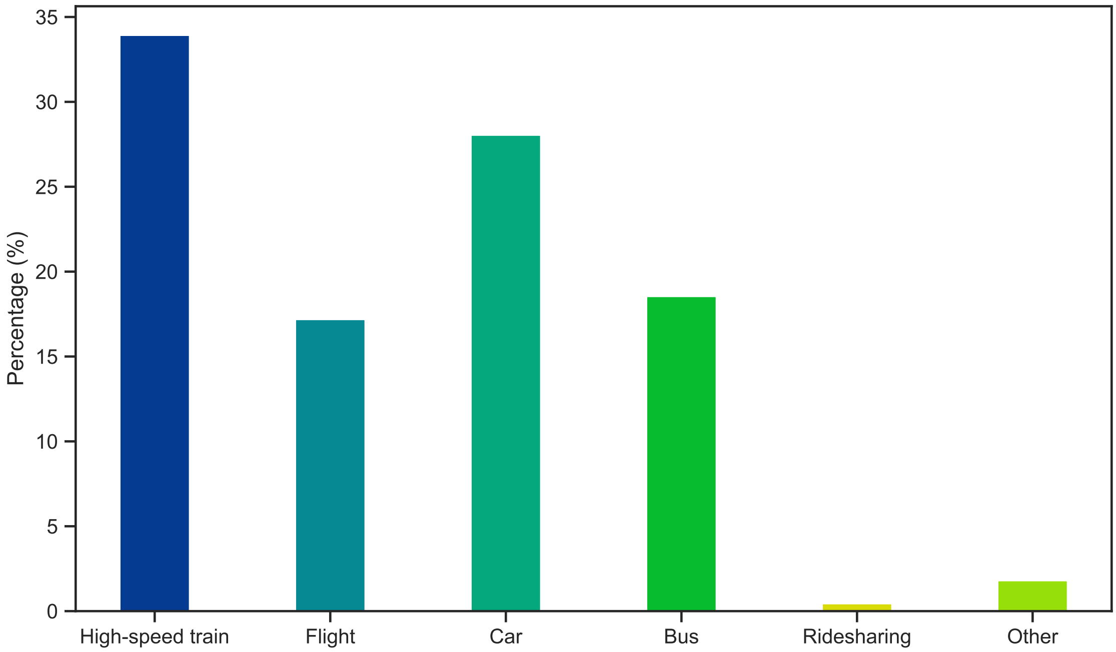

Figure A.2 Main mode of transportation for long-distance travel (N= 254)

Level of satisfaction for current modes

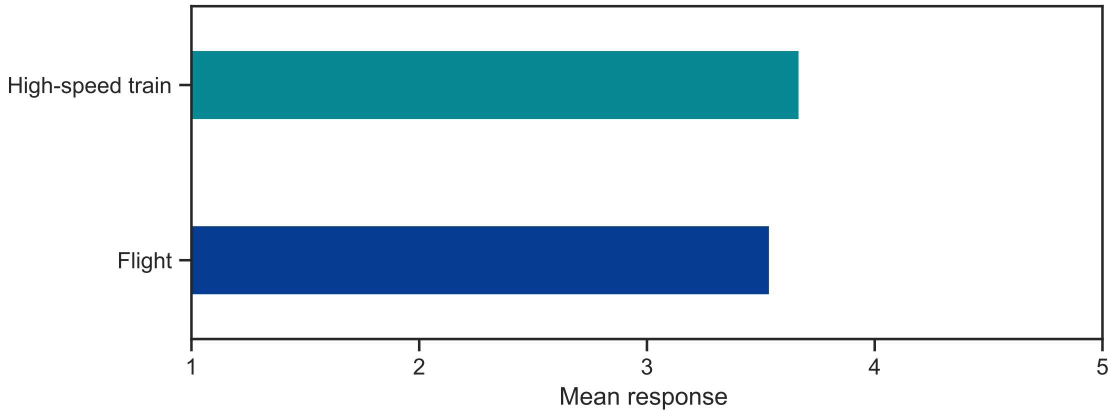

Figure A.3 Level of satisfaction for current modes (N= 254)

Mode choice factors

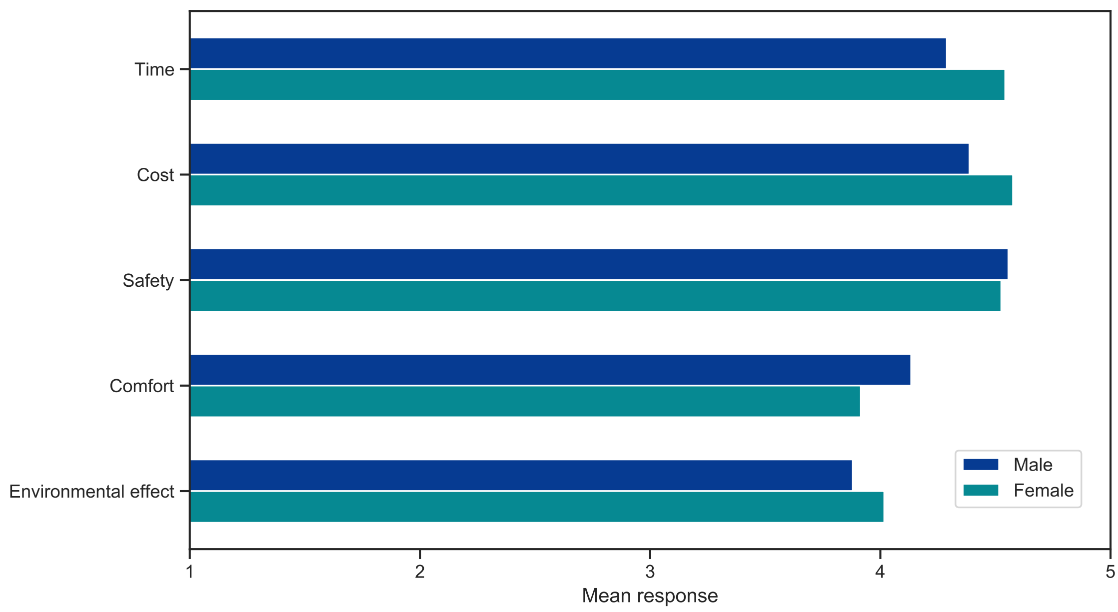

Figure A.4 Mode choice factors (N= 254)

Understanding about Hyperloop

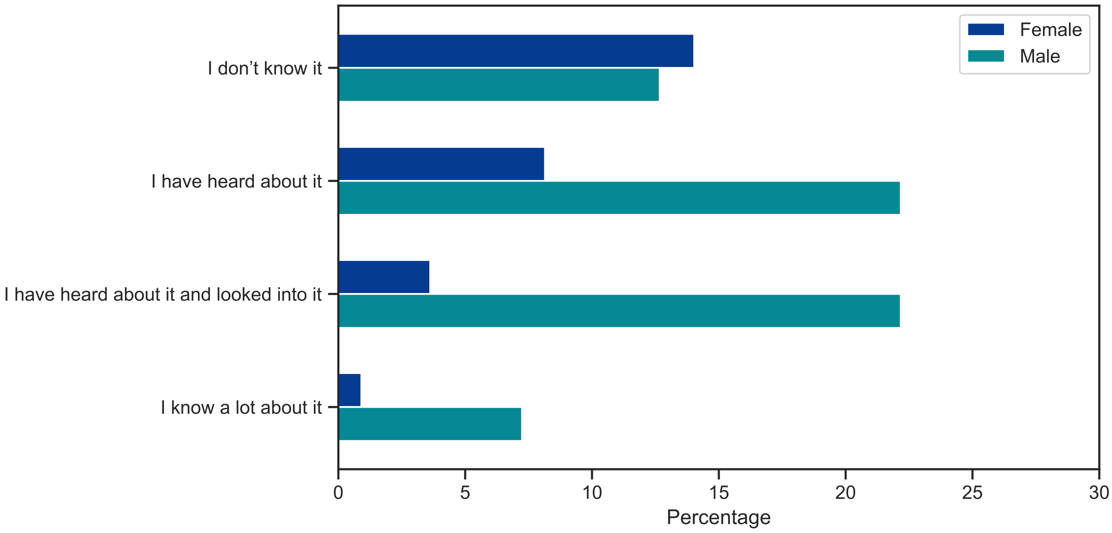

Figure A.5 Understanding about Hyperloop systems prior to the study (N= 254)

A.2.1 Stated choice analysis

Mode choice by gender

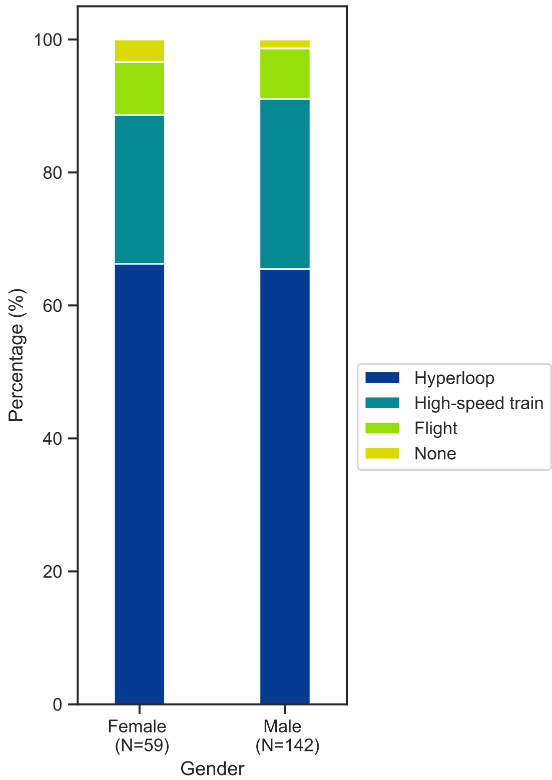

Figure A.6 Mode choice decision of different gender (N= 254)

Mode choice by age

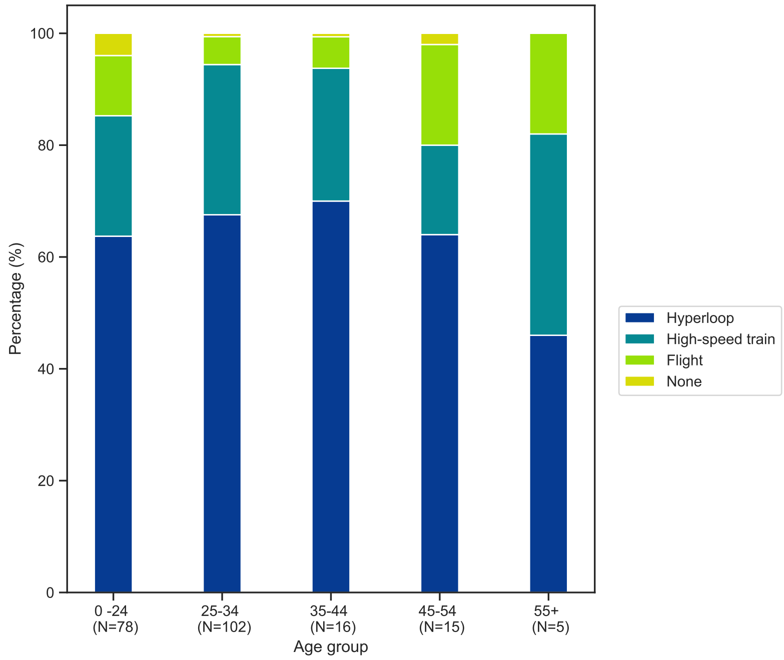

Figure A.7 Mode choice decision of different age groups (N= 254)

Mode choice by occupation

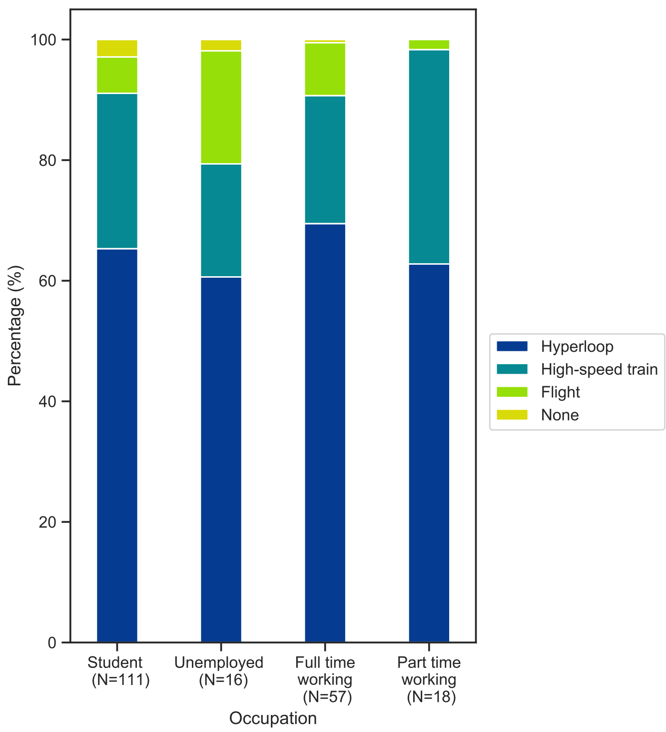

Figure A.8 Mode choice decision of different occupation groups (N= 254)

Mode choice by education

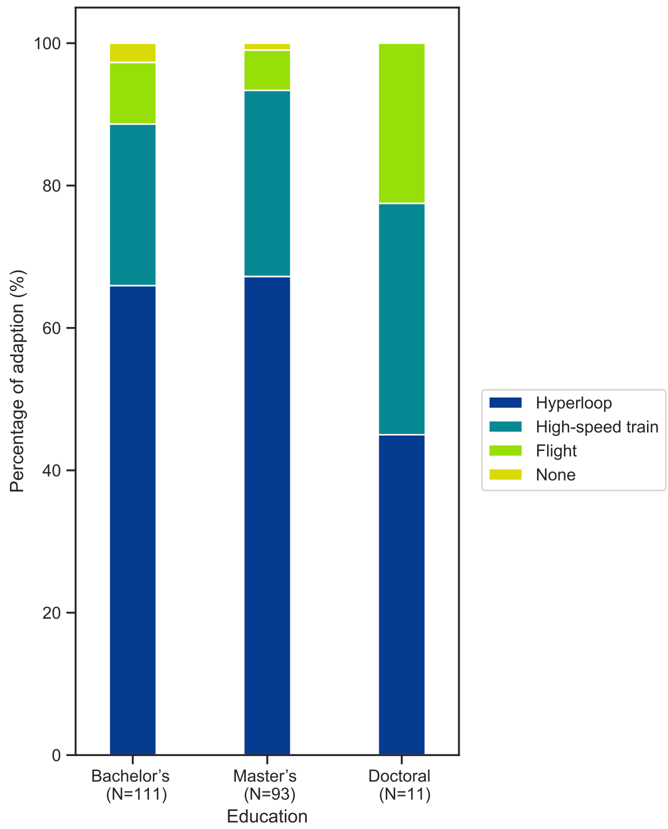

Figure A.9 Mode choice decision of different education groups (N= 254)

Mode choice by income

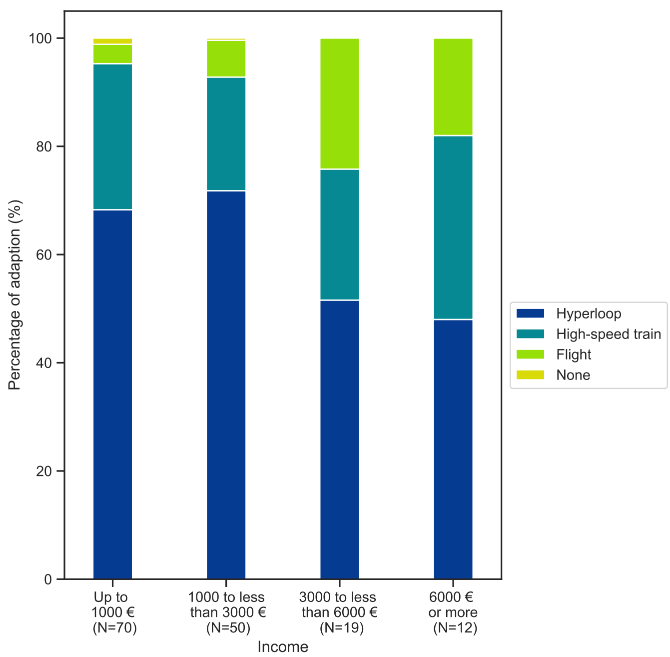

Figure A.10 Mode choice decision of different income groups (N= 254)

A.2.2 Adoption and attitudes of different demographics

Adoption by gender

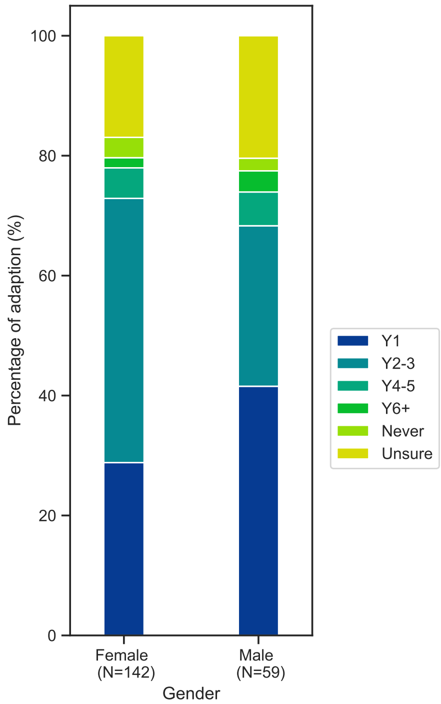

Figure A.11 Hyperloop adoption by gender (N= 254)

Adoption by age

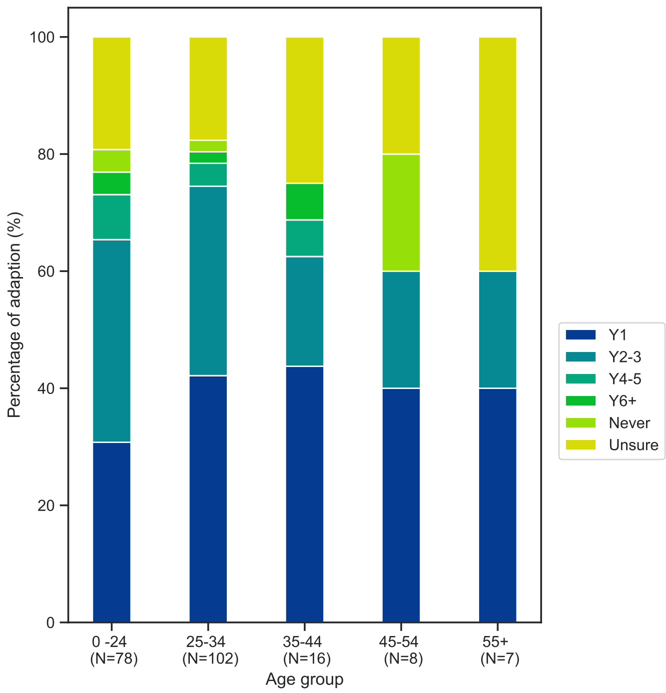

Figure A.12 Hyperloop adoption by age groups (N= 254)

Adoption by occupation

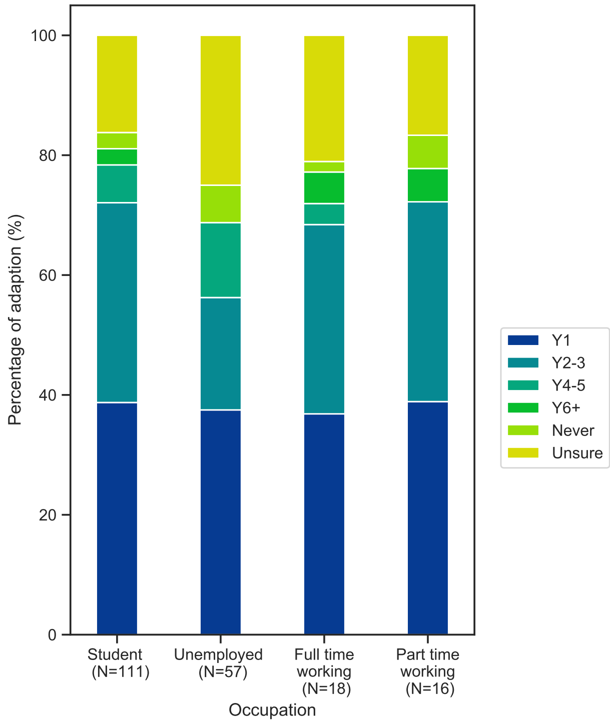

Figure A.13 Hyperloop adoption by occupation (N= 254)

Adoption by income

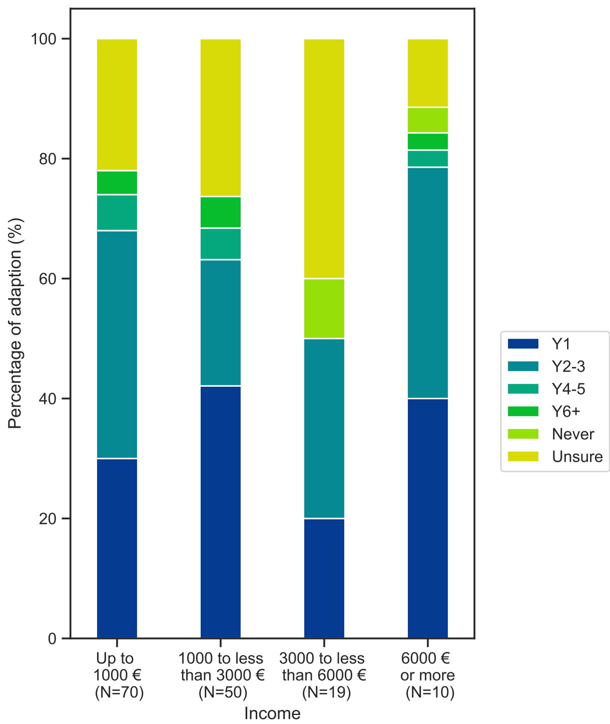

Figure A.14 Hyperloop adoption by income groups (N= 254)

Adoption by survey language

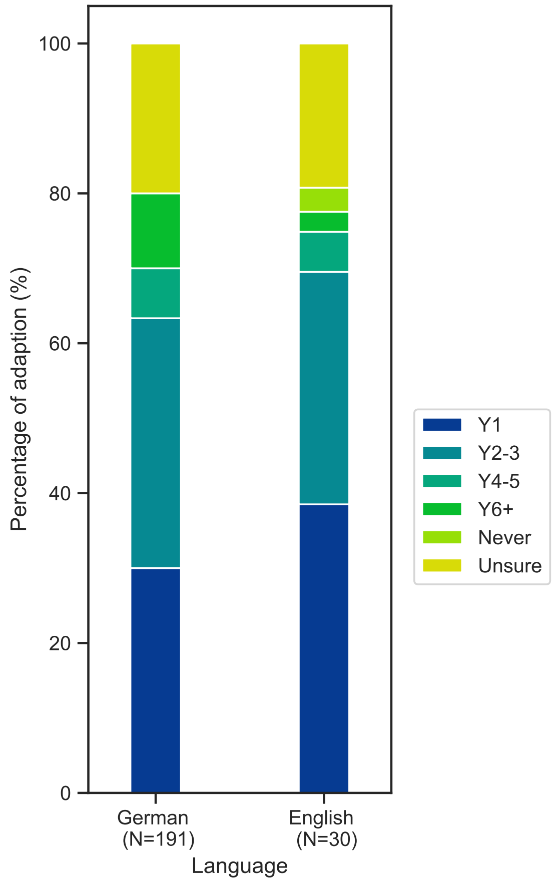

Figure A.15 Hyperloop adoption by survey language (N= 254)

A.2.3 Attitudes towards automation, safety, and data concerns

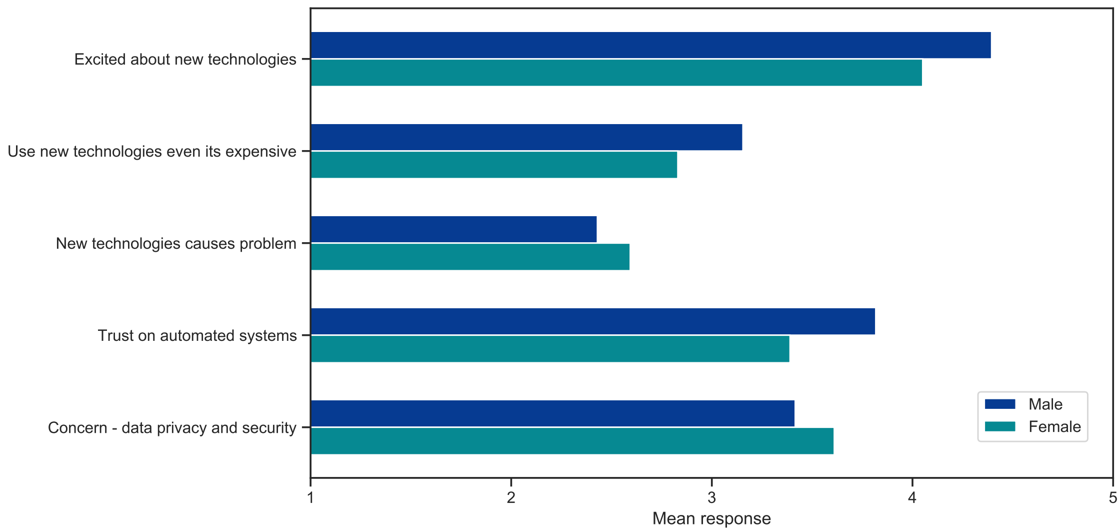

Figure A.16 Attitudes towards trust and data concerns (N= 254)

A.2.4 Personalities/psychological well-being

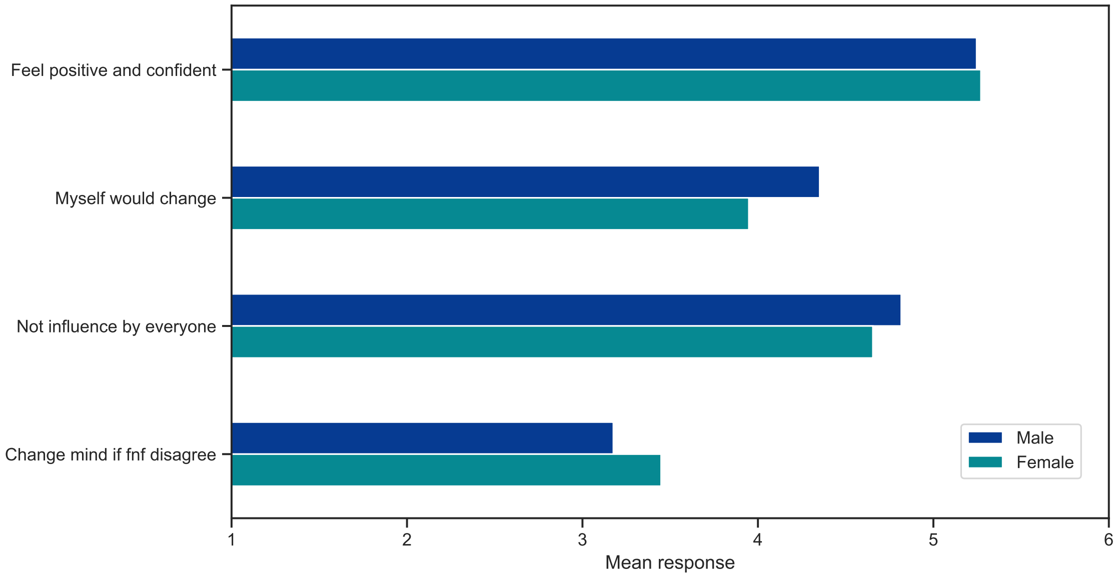

Figure A.17 Psychological well-being of respondents (Mean value, scale - 1 to 6) (N= 254)

Hyperloop project in Germany

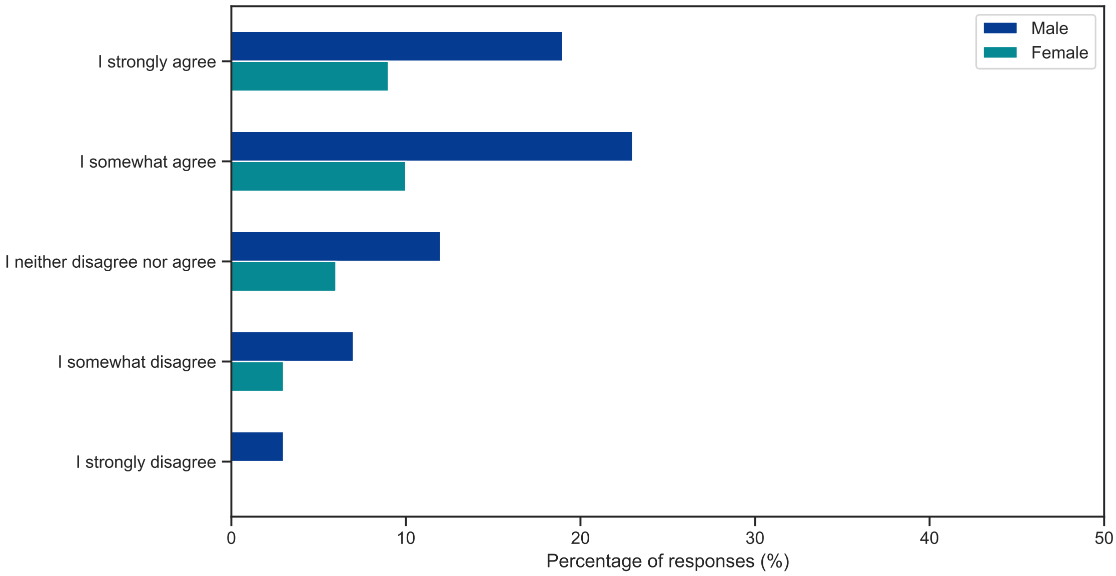

Figure A.18 The success of the Hyperloop system in Germany (N= 254)

B Summary statistics of different analysis

B.1 Summary statistics of factor analysis

Table B.1 Summary statistics of factor analysis

Variables	Mean	Std. Deviation	Analysis N
How important for a mode choice decision - Time	4.3	0.734	8280
How important for a mode choice decision - Cost	4.41	0.737	8280
How important for a mode choice decision - Safety	4.31	0.85	8280
How important for a mode choice decision - Comfort	3.94	0.838	8280
How important for a mode choice decision - Env. impact	3.75	1.015	8280
Excited about new technologies	4.27	0.895	8280
Use new technology even its expensive	3.05	1.126	8280
Trust automated systems	3.69	0.982	8280
Feel confident and positive about self	5.07	1.05	8280
Not influenced by others decision	4.46	1.319	8280

Table B.2 Variables (questions) of proposed technology model

Construct	Variables	Questions
Perceived Usefulness (PU)	Safety, value of time	- How important is the safety consideration for a mode choice decision. - Value of travel time.
Perceived Ease to Use (PEU)	Technological concerns, cost	- I am excited about new technology. - I often use new technology even it is expensive. - How important is the safety consideration for a mode choice decision.
Perceived Trust (PT)	Trust on automated systems, data security, and privacy concerns	- I trust high-speed automated systems. - I have concerns regarding privacy and data security.
Social and personal behavior (SI)	Personal behavior	- I am not influenced by other's decisions. - Feel confident and positive about self.
Behavioral Intention to Use (BIU)	Mode choice, Hyperloop adoption	- When you are mostly going to use Hyperloop. - Mode choice decisions.

C Additional Models

C.1 MNL model with all attributes and latent variables

C.2 Nested model model with all variables

C.3 Adoption MNL 1

C.4 Adoption OLM 2

Table C.1 Estimated coefficients and model information for MNL model with all attributes and latent variables

	Hyperloop			High-speed train			Flight		
Coefficient	**Value**	**Rob. Std err**	**Rob. t-test**	**Value**	**Rob. Std err**	**Rob. t-test**	**Value**	**Rob. Std err**	**Rob. t-test**
ASC				-1.07	0.274	-3.91	-4.22	0.379	-11.1
Travel cost	-0.412	0.022	-18	-0.361	0.019	-18.3	-0.072	0.014	-5.2
Total travel time	-0.093	0.008	-10.9	-0.087	0.004	-19.1	-0.080	0.010	-7.49
Safety (reference = driving level safety)									
At least two times safer than driving	4.08	0.637	6.4	5.43	0.728	7.46			
At least four times safer than driving	5.57	0.662	8.42	5.79	0.716	8.08	7.62	1.06	7.22
Frequency of the trip (reference =base)									
Level 2				-1.35	0.717	-1.88			
Level 3				1.32	0.714	1.85			
Age (reference = 18-24)									
25-34	0.872	0.461	1.89	0.933	0.518	1.8	-1.81	0.762	-2.37
35-44									
45-54	-5.95	1.77	-3.37						
55+				3.79	1.95	1.94			
Educational level (reference = <= Bachelor)									
Masters				1.23	0.617	2			
PhD	-6.11	1.53	-4						
Employment (reference = Student)									
Full time working				-2.97	0.671	-4.42	6.9	1.86	3.7
Unemployeement	-3.04	1.26	-2.41	-3.85	1.43	-2.69			
Monthly household income (reference = <1000€)									
1000€ - 3000€									
3000€ - 6000€	-2.62	0.598	-4.38	-1.38	0.675	-2.04	3.99	0.891	4.48
>6000€				-5.46	2.1	-2.6			
Driving licence (reference = No)									
Yes	2.27	0.456	4.99	0.939	0.515	1.82	-3.21	0.759	-4.24
Current long distance mode (reference = car)									
High-speed train				3.5	0.585	5.98			
Flight				-6.22	1.17	-5.31			
Latent variables									
Psychological well-being	0.0473	0.02	2.36				-0.066	0.032	-2.09
Sample size				**7907**					
Nr of estimated parameters				**37**					
Initial log-likelihood				**-8686.727**					
Final log-likelihood				**-5281.823**					
Adjusted rho square				**0.392**					
Rho-square-bar				**0.388**					

Table C.2 Estimated coefficients and model information for MNL Model with all attributes and latent variables including NONE

	Hyperloop			High-speed train			Flight			NONE		
Coefficient	**Value**	**Rob. Std err**	**Rob. t-test**	**Value**	**Rob. Std err**	**Rob. t-test**	**Value**	**Rob. Std err**	**Rob. t-test**	**Value**	**Rob. Std err**	**Rob. t-test**
ASC			-1.04	0.268	-3.88	-4	0.372	-10.7	-7.93	0.312	-25.4	
Travel cost -0.398	0.0223	-17.8	-0.355	0.0194	-18.3	-0.0735	0.0139	-5.27				
Total travel time -0.0886	0.00833	-10.6	-0.0865	0.00455	-19	-0.0798	0.0107	-7.49				
Safety (reference = driving level safety)												
At least two times safer than driving	4.13	0.624	6.61	5.47	0.724	7.56						
At least four times safer than driving	5.61	0.646	8.69	5.8	0.71	8.17	7.54	1.05	7.19			
Frequency of the trip (reference =base)												
Level 2			-1.37	0.71	-1.93							
Level 3			1.2	0.709	1.7							
Age (reference = 18-24)												
25-34 2.89	1.03	2.82	3.13	1.1	2.83							
45-54 -5.8	1.7	-3.41										
55+			3.94	1.88	2.09							
Educational level (reference = <= Bachelor)												
Masters			1.32	0.614	2.15				-6.02	2.64	-2.28	
PhD -6.42	1.51	-4.26							18.2	3.06	5.96	
Employment (reference = Student)												
Full time working			-2.9	0.628	-4.62				-13	2.34	-5.56	
Monthly household income (reference = <1000€)												
1000€ - 3000€												
3000€ - 6000€						5.92	1.33	4.46				
>6000€			-5.8	2.07	-2.8							
Car access (reference = No)												
Yes									-5.13	2.46	-2.08	
Driving licence (reference = No)												
Yes						-4.96	1.11	-4.48	6.79	2.56	2.65	
Current long distance mode (reference = car)												
High-speed train									3.6	0.569	6.32	
Flight									-6.29	1.17	-5.4	
Latent variables												
Psychological well-being							-0.091	0.055	-1.64			
Sample size				**8015**								
Nr of estimated parameters				**36**								
Initial log-likelihood				**-11111.15**								
Final log-likelihood				**-5826.692**								
Adjusted rho square				**0.476**								
Rho-square-bar				**0.472**								

Table C.3 Estimated coefficients and model information for nested model

	Hyperloop			High-speed train			Flight			MU		
Coefficient	**Value**	**Rob. Std err**	**Rob. t-test**	**Value**	**Rob. Std err**	**Rob. t-test**	**Value**	**Rob. Std err**	**Rob. t-test**	**Value**	**Rob. Std err**	**Rob. t-test**
ASC				-0.358	0.124	-2.88	-1.67	0.528	-3.17	2.99	0.804	3.72
Travel cost	-0.163	0.0417	-3.9	-0.134	0.0354	-3.79	-0.0746	0.0135	-5.52			
Total travel time	-0.0362	0.0101	-3.59	-0.0296	0.00803	-3.69	-0.0697	0.00995	-7			
Safety (reference = driving level safety)												
At least two times safer than driving				0.627	0.208	3.01						
At least four times safer than driving	0.843	0.333	2.53	0.718	0.208	3.45	5.79	1.22	4.73			
Frequency of the trip (reference =base)												
Level 2	0.498	0.264	1.89									
Level 3				0.476	0.265	1.8						
Age (reference = 18-24)												
25-34							-3.25	1.06	-3.07			
Educational level (reference = <= Bachelor)												
Masters												
PhD	-2.36	0.898	-2.62									
Employment (reference = Student)												
Unemployeement	1.29	0.376	3.43									
Monthly hh income (reference = <1000€)												
1000€ - 3000€												
3000€ - 6000€												
>6000€	-8.5	2.33	-3.65	-9.5	2.4	-3.96						
Car access (reference = No)												
Yes				-0.702	0.301	-2.33						
Driving licence (reference = No)												
Yes	1.04	0.347	3	0.852	0.361	2.36	-1.85	0.671	-2.76			
Sample size				**8164**								
Nr of estimated parameters				**27**								
Initial log-likelihood				**-8969.071**								
Final log-likelihood				**-5466.041**								
Adjusted rho square				**0.391**								
Rho-square-bar				**0.388**								

Table C.4 Estimated coefficients and model information for adoption MNL 1

Coefficient	Value	Rob. t-test	Rob. p-value
ASC Y45	-2.43	-19.7	0
ASC Y6	-2.77	-8.53	0
ASC YNever	-4.06	-24.7	0
ASC YUnsure	-1.01	-10.4	0
Y1 Age group 24-34	1.74	3.64	0.001
Y1 Flight Cost	-0.024	-5.43	0.001
Y1 Main mode as PuT	-1.83	-3.86	0.001
Y1 Occupation Unemployed	-3.3	-1.65	0.098
Y1 Occupation working	1.44	2.85	0.004
Y2-3 Survey Language German	-3.17	-5.43	0.001
Y2-3 Education MSc	3.17	5.72	0.001
Y2-3 Females	3.1	6.38	0.001
Y2-3 Frequently Long-distance travel	-0.979	-3.89	0.001
Y2-3 Main mode as PuT	-0.98	-2.11	0.035
Y4-5 Age group 35 -44	7.15	5.23	0.001
Y4-5 Education MSc	6.19	6.37	0.001
Y4-5 Females	4.34	4.53	0.001
Y4-5 Income group 6000+	-3.48	-2.63	0.008
Y4-5 Main mode as PuT	-1.28	-2.28	0.022
Y6 Education PhD	12.8	5.35	0.001
Y6 Hyperloop Travel time	-0.039	-1.84	0.065
Y6 Income group 6000+	5.56	3.01	0.002
Y6 Existing mode satisfaction	0.109	1.52	0.130
Y6 Occupation Unemployed	8.32	2.34	0.019
YNever Education MSc	-16.8	-5	0.001
YNever Mode choice consideration	-0.234	-2.01	0.044
YNever Main mode as PuT	2.78	4.6	0.001
YUnsure Age group 45-54	6.98	4.41	0.001
YUnsure Education MSc	2.4	3.5	0.001
YUnsure Frequently Long-distance travel	-0.724	-2.06	0.039
YUnsure Income group 6000+	2.74	3.24	0.001
YUnsure Main mode as PuT	-1.68	-3.38	0.001
YUnsure Occupation Unemployed	3.67	1.83	0.067
Sample size		**8015**	
Number of estimated parameters		**33**	
Initial log-likelihood		**-14360.95**	
Final log-likelihood		**-10675.75**	
Adjusted rho square		**0.257**	
Rho-square-bar		**0.254**	

Table C.5 Estimated coefficients and model information for adoption OLM - 2

Coefficient	**Value**	**Rob. t-test**
Data privacy and security	0.519	2.98
Familiar with Hyperloop	-2.03	-9.12
Frequent long-distance travel	-0.803	-3.33
Hyperloop safety	0.782	7.9
Long-distance mode- HST	-0.65	-3.34
Main mode PuT	0.495	3.19
Safety consideration during the mode choice	0.929	3.38
Technology concerns	-3.74	-15.4
Y1|Y23	-1.78	-18
Y23|Y45	0.025	63.7
Y45|Y6+	0.3863	22.7
Y6+/Ynever|YUnsure	0.572	18.5
Sample size		**8015**
Number of estimated parameters		**14**
Initial log-likelihood		**-14330.39**
Final log-likelihood		**-10433.05**
Adjusted rho square		**0.271**
Rho-square-bar		**0.271**
Akaike Information Criterion		**20896.09**
Bayesian Information Criterion		**21000.93**

D Specification of the utility functions

D.1 Description of variables included in the utility functions

D.2 Specifications of the utility functions

Specifications of the utility functions of MNL Model with all attributes excluding NONE alternative

```
V1 (HYPERLOOP) = ASC_HP +B_HP_TIME * HP_TT_SCALED + B_HP_COST * HP_COST_SCALED
+B_HP_AGE2* AGE2 + B_HP_AGE3 * AGE3 + B_HP_AGE5 * AGE5 +B_HP_SFT2 * HP_SAFETY2
+ B_HP_SFT4 * HP_SAFETY4 +B_HP_OCCUUNEMP * OCCUUNEMP + B_HP_OCCUSTU * OCCUSTU+
B_HP_INCOME6K * INCOME6K +B_HP_DR_LIC * DR_LIC + B_HP_EDUPHD * EDUPHD

V2(HST) = ASC_HST +B_HST_TIME * HST_TT_SCALED +B_HST_COST * HST_COST_SCALED +
B_HST_SFT2 * HST_SAFETY2 + B_HST_SFT4 * HST_SAFETY4 +B_HST_FRE3 * HST_FREQ3 +
B_HST_FRE4 * HST_FREQ4 + B_HST_FRE5 * HST_FREQ5 +B_HST_AGE2 * AGE2 + B_HST_AGE3
* AGE3 + B_HST_AGE6 * AGE6 +B_HST_OCCUWORK * OCCUWORK + B_HST_OCCUUNEMP *
OCCUUNEMP + B_HST_OCCUSTU * OCCUSTU +B_HST_INCOME1K * INCOME1K + B_HST_INCOME6K
* INCOME6K + B_HST_INCOME6KP * INCOME6KP +B_HST_DR_LIC * DR_LIC +H_HST_LN_DISMODE
* H_LN_DISMODE +B_HST_EDUBACHE * EDUBACHE + B_HST_EDUMSC * EDUMSC

V3 (FLIGHT) = ASC_FL +B_FL_TIME * FL_TT_SCALED +B_FL_COST * FL_COST_SCALED +
B_FL_SFT4 * FL_SAFETY4 +B_FL_DR_LIC * DR_LIC +B_FL_AGE2 * AGE2 + B_FL_AGE3
* AGE3 +B_FL_OCCUUNEMP * OCCUUNEMP + B_FL_OCCUSTU * OCCUSTU +H_FL_LN_DISMODE
* H_LN_DISMODE +B_FL_INCOME6K * INCOME6K
```

Specifications of the utility functions of MNL Model with all attributes including NONE alternative

```
V1(HYPERLOOP) = ASC_HP +B_HP_TIME * HP_TT_SCALED +B_HP_COST * HP_COST_SCALED
+B_HP_AGE2* AGE2 + B_HP_AGE3 * AGE3 + B_HP_AGE5 * AGE5 +B_HP_FRE5 * HP_FREQ5
+ B_HP_FRE15* HP_FREQ15 +B_HP_SFT2 * HP_SAFETY2 + B_HP_SFT4 * HP_SAFETY4 +
B_HP_DR_LIC *DR_LIC +B_HP_EDUPHD * EDUPHD

V2 (HST)= ASC_HST +B_HST_TIME * HST_TT_SCALED +B_HST_COST * HST_COST_SCALED +
B_HST_SFT2 * HST_SAFETY2 + B_HST_SFT4 * HST_SAFETY4 +B_HST_FRE3 * HST_FREQ3
+ B_HST_FRE4 * HST_FREQ4 + B_HST_FRE5 * HST_FREQ5 +B_HST_AGE2 * AGE2 +
B_HST_AGE3 * AGE3 + B_HST_AGE6 * AGE6 +B_HST_OCCUWORK * OCCUWORK +
B_HST_OCCUSTU * OCCUSTU +B_HST_INCOME1K * INCOME1K + B_HST_INCOME6KP *
INCOME6KP +H_HST_LN_DISMODE * H_LN_DISMODE + B_HST_ACESS_CAR * ACESS_CAR
+B_HST_EDUBACHE * EDUBACHE + B_HST_EDUMSC * EDUMSC

V3 (FLIGHT)= ASC_FL +B_FL_TIME * FL_TT_SCALED +B_FL_COST * FL_COST_SCALED
+B_FL_SFT4* FL_SAFETY4 +B_FL_DR_LIC * DR_LIC +B_FL_AGE2 * AGE2 +
```

```
H_FL_LN_DISMODE * H_LN_DISMODE +B_FL_INCOME6K * INCOME6K

V4 (NONE)= ASC_NONE +B_NONE_AGE2 * AGE2 +B_NONE_OCCUWORK * OCCUWORK +
B_NONE_OCCUSTU* OCCUSTU +B_NONE_INCOME1K * INCOME1K + B_NONE_INCOME6K *
INCOME6K +B_NONE_DR_LIC* DR_LIC + B_NONE_ACESS_CAR * ACESS_CAR +
B_NONE_EDUPHD * EDUPHD + B_NONE_EDUBACHE* EDUBACHE + B_NONE_EDUMSC * EDUMSC
```

Specifications of the utility functions of MNL Model with all attributes and latent variable including NONE alternative

```
V1 (HYPERLOOP)= ASC_HP +B_HP_TIME * HP_TT_SCALED +B_HP_COST * HP_COST_SCALED
+B_HP_AGE2* AGE2 + B_HP_AGE3 * AGE3 + B_HP_AGE5 * AGE5 +B_HP_SFT2 * HP_SAFETY2
+ B_HP_SFT4* HP_SAFETY4 +B_HP_OCCUUNEMP * OCCUUNEMP + B_HP_OCCUSTU * OCCUSTU
+B_HP_INCOME6K* INCOME6K +B_HP_DR_LIC * DR_LIC + B_HP_EDUPHD * EDUPHD +
B_HP_FCT3 * FCT3

V2 (HST)= ASC_HST +B_HST_TIME * HST_TT_SCALED +B_HST_COST * HST_COST_SCALED +
B_HST_SFT2 * HST_SAFETY2 + B_HST_SFT4 * HST_SAFETY4 +B_HST_FRE3 * HST_FREQ3
+ B_HST_FRE4 * HST_FREQ4 + B_HST_FRE5 * HST_FREQ5 +B_HST_AGE2 * AGE2 + B_HST_AGE3
* AGE3 + B_HST_AGE6 * AGE6 +B_HST_OCCUWORK * OCCUWORK + B_HST_OCCUUNEMP
* OCCUUNEMP + B_HST_OCCUSTU * OCCUSTU +B_HST_INCOME1K * INCOME1K + B_HST_INCOME6K
* INCOME6K + B_HST_INCOME6KP * INCOME6KP +B_HST_DR_LIC * DR_LIC +H_HST_LN_DISMODE
* H_LN_DISMODE +B_HST_EDUBACHE * EDUBACHE + B_HST_EDUMSC * EDUMSC

V3 (FLIGHT)= ASC_FL +B_FL_TIME * FL_TT_SCALED +B_FL_COST * FL_COST_SCALED
+B_FL_SFT4* FL_SAFETY4 +B_FL_DR_LIC * DR_LIC +B_FL_AGE2 * AGE2 + B_FL_AGE3
* AGE3 +B_FL_OCCUUNEMP * OCCUUNEMP + B_FL_OCCUSTU * OCCUSTU +H_FL_LN_DISMODE *
H_LN_DISMODE +B_FL_INCOME6K * INCOME6K + B_FL_FCT3 * FCT3
```

Specifications of the utility functions of MNL Model with all attributes and latent variable including NONE alternative

```
V1 (HYPERLOOP)= ASC_HP +B_HP_TIME * HP_TT_SCALED +B_HP_COST * HP_COST_SCALED
+B_HP_AGE2 * AGE2 + B_HP_AGE3 * AGE3 + B_HP_AGE5 * AGE5 +B_HP_SFT2 *
HP_SAFETY2 + B_HP_SFT4 * HP_SAFETY4 +B_HP_EDUBACHE * EDUBACHE + B_HP_EDUPHD
* EDUPHD + B_HP_FCT3 * FCT3

V2 (HST)= ASC_HST +B_HST_TIME * HST_TT_SCALED +B_HST_COST * HST_COST_SCALED
+B_HST_SFT2 * HST_SAFETY2 + B_HST_SFT4 * HST_SAFETY4 +B_HST_FRE3 * HST_FREQ3
+ B_HST_FRE4 * HST_FREQ4 + B_HST_FRE5 * HST_FREQ5 +B_HST_AGE2 * AGE2 +
B_HST_AGE3 * AGE3 + B_HST_AGE6 * AGE6 +B_HST_OCCUWORK * OCCUWORK +
B_HST_OCCUSTU * OCCUSTU +B_HST_INCOME1K * INCOME1K + B_HST_INCOME6KP
* INCOME6KP +H_HST_LN_DISMODE * H_LN_DISMODE + B_HST_EDUBACHE *
EDUBACHE + B_HST_EDUMSC * EDUMSC +B_HST_FCT3 * FCT3

V3 (FLIGHT)= ASC_FL +B_FL_TIME * FL_TT_SCALED +B_FL_COST * FL_COST_SCALED
+B_FL_SFT4 * FL_SAFETY4 +B_FL_DR_LIC * DR_LIC +B_FL_AGE2 * AGE2 +
H_FL_LN_DISMODE * H_LN_DISMODE +B_FL_INCOME6K * INCOME6K + B_FL_FCT3 * FCT3
```

V4 (NONE)= ASC_NONE +B_NONE_AGE2 * AGE2 +B_NONE_OCCUWORK * OCCUWORK + B_NONE_OCCUSTU * OCCUSTU +B_NONE_DR_LIC * DR_LIC + B_NONE_ACESS_CAR * ACESS_CAR +B_NONE_EDUPHD * EDUPHD + B_NONE_EDUBACHE * EDUBACHE + B_NONE_EDUMSC * EDUMSC

Specifications of the utility functions of MNL model of highly educated people

V1 (HYPERLOOP)= ASC_HP +B_HP_TIME * HP_TT_SCALED +B_HP_COST * HP_COST_SCALED +B_HP_AGE2 * AGE2 + B_HP_AGE3 * AGE3 + B_HP_AGE4 * AGE4 + B_HP_AGE6 * AGE6 +B_HP_SFT1 * HP_SAFETY1 + B_HP_SFT2 * HP_SAFETY2 + B_HP_SFT4 * HP_SAFETY4 +B_HP_DR_LIC * DR_LIC

V2 (HST)= ASC_HST +B_HST_TIME * HST_TT_SCALED +B_HST_COST * HST_COST_SCALED +B_HST_SFT1 * HST_SAFETY1 + B_HST_SFT2 * HST_SAFETY2 + B_HST_SFT4 * HST_SAFETY4 +B_HST_FRE4 * HST_FREQ4 +B_HST_AGE5 * AGE5

V3 (FLIGHT)= ASC_FL +B_FL_TIME * FL_TT_SCALED +B_FL_COST * FL_COST_SCALED +B_FL_SFT4 * FL_SAFETY4 +B_FL_INCOME3K * INCOME3K + B_FL_INCOME6K * INCOME6K + B_FL_INCOME6KP * INCOME6KP +B_FL_ACESS_CAR * ACESS_CAR + B_FL_HEDU * HEDU

Specifications of the utility functions of MNL model of medium educated people

V1 (HYPERLOOP)= ASC_HP + B_HP_TIME * HP_TT_SCALED + B_HP_COST * HP_COST_SCALED + B_HP_SFT2 * HP_SAFETY2 + B_HP_SFT4 * HP_SAFETY4 + B_HP_OCCUUNEMP * OCCUUNEMP + B_HP_INCOME1K * INCOME1K + B_HP_INCOME6K * INCOME6K +B_HP_DR_LIC * DR_LIC

V2 (HST)= ASC_HST + B_HST_TIME * HST_TT_SCALED + B_HST_COST * HST_COST_SCALED + B_HST_SFT2 * HST_SAFETY2 + B_HST_SFT4 * HST_SAFETY4 + B_HST_OCCUUNEMP * OCCUUNEMP + B_HST_INCOME1K * INCOME1K + B_HST_ACESS_CAR * ACESS_CAR + B_HST_DR_LIC * DR_LIC

V3 (FLIGHT)= ASC_FL + B_FL_TIME * FL_TT_SCALED + B_FL_COST * FL_COST_SCALED + B_FL_SFT4 * FL_SAFETY4 + B_FL_OCCUWORK * OCCUWORK + B_FL_OCCUUNEMP * OCCUUNEMP + B_FL_INCOME1K * INCOME1K + B_FL_INCOME3K * INCOME3K + B_FL_INCOME6K * INCOME6K +B_FL_DR_LIC * DR_LIC

Specifications of the utility functions of Nested Model

V1 (HYPERLOOP)= ASC_HP +B_HP_TIME * HP_TT_SCALED +B_HP_COST * HP_COST_SCALED +B_HP_SFT1 * HP_SAFETY1 + B_HP_SFT4 * HP_SAFETY4 +B_HP_FRE10 * HP_FREQ10 + B_HP_OCCUWORK * OCCUWORK + B_HP_OCCUSTU * OCCUSTU +B_HP_INCOME1K * INCOME1K + B_HP_INCOME6KP * INCOME6KP +B_HP_DR_LIC * DR_LIC +B_HP_EDUPHD * EDUPHD

V2 (HST)= ASC_HST +B_HST_TIME * HST_TT_SCALED +B_HST_COST * HST_COST_SCALED +B_HST_SFT1 * HST_SAFETY1 + B_HST_SFT2 * HST_SAFETY2 + B_HST_SFT4 * HST_SAFETY4 +B_HST_FRE4 * HST_FREQ4 + B_HST_OCCUSTU * OCCUSTU +B_HST_INCOME1K * INCOME1K + B_HST_INCOME6KP * INCOME6KP +B_HST_ACESS_CAR * ACESS_CAR +

B_HST_DR_LIC * DR_LIC

V3 (FLIGHT)= ASC_FL +B_FL_TIME * FL_TT_SCALED +B_FL_COST * FL_COST_SCALED +B_FL_SFT1 * FL_SAFETY1 + B_FL_SFT4 * FL_SAFETY4 +B_FL_AGE3 * AGE3 + B_FL_OCCUSTU * OCCUSTU +B_FL_INCOME1K * INCOME1K + B_FL_DR_LIC * DR_LIC

Specifications of the utility functions of adoption MNL 1

V1(Y1) = ASC_Y1 + B_Y1_AGE2 * AGE2 + B_Y1_AGE3 * AGE3 +B_Y1_OCCUWORK * OCCUWORK + B_Y1_OCCUUNEMP * OCCUUNEMP + B_Y1_OCCUSTU * OCCUSTU +B_Y1_M_Mode * M_Mode +B_Y1_FL_COST * FL_COST_SCALED + B_Y1_AFNEWTECH * AFNEWTECH + B_Y1_MSATIS * MSATIS

V2(Y2-3) =B_Y23_MALE * MALE + B_Y23_FEMALE * FEMALE +B_Y23_EDUBACHE * EDUBACHE + B_Y23_EDUMSC * EDUMSC +B_Y23_M_Mode * M_Mode + B_Y23_FREQ_LNDIS * FREQ_LNDIS +B_Y23_DELANG * DELANG + B_Y23_ENLANG * ENLANG

V3(Y4-5) = ASC_Y45 + B_Y45_MALE * MALE + B_Y45_FEMALE * FEMALE +B_Y45_AGE2 * AGE2 + B_Y45_AGE4 * AGE4 +B_Y45_EDUBACHE * EDUBACHE + B_Y45_EDUMSC * EDUMSC +B_Y45_INCOME1K * INCOME1K + B_Y45_INCOME6K * INCOME6K + B_Y45_M_Mode * M_Mode

V4(Y6+) =ASC_Y6 + B_Y6_EDUBACHE * EDUBACHE + B_Y6_EDUPHD * EDUPHD +B_Y6_INCOME1K * INCOME1K + B_Y6_INCOME6K * INCOME6K +B_Y6_HP_TIME * HP_TT_SCALED + B_Y6_MSATIS * MSATIS

V5(YNEVER) =ASC_YNE + B_YNE_M_Mode * M_Mode + B_YNE_MCCONI * MCCONI

V6(YUNSURE) = ASC_YUN + B_YUN_AGE2 * AGE2 + B_YUN_AGE5 * AGE5 +B_YUN_EDUBACHE * EDUBACHE + B_YUN_EDUMSC * EDUMSC +B_YUN_OCCUUNEMP * OCCUUNEMP + B_YUN_OCCUSTU * OCCUSTU +B_YUN_INCOME1K * INCOME1K + B_YUN_INCOME6K * INCOME6K +B_YUN_M_Mode * M_Mode + B_YUN_FREQ_LNDIS * FREQ_LNDIS

Specifications of the utility functions of adoption MNL 2

V1(Y1) = ASC_Y1 + B_Y1_AGE2 * AGE2 + B_Y1_AGE3 * AGE3 +B_Y1_OCCUWORK * OCCUWORK + B_Y1_OCCUUNEMP * OCCUUNEMP + B_Y1_OCCUSTU * OCCUSTU +B_Y1_M_Mode * M_Mode +B_Y1_FL_COST * FL_COST_SCALED + B_Y1_AFNEWTECH * AFNEWTECH + B_Y1_MSATIS * MSATIS

V2(Y2-3) =B_Y23_MALE * MALE + B_Y23_FEMALE * FEMALE +B_Y23_EDUBACHE * EDUBACHE + B_Y23_EDUMSC * EDUMSC +B_Y23_M_Mode * M_Mode + B_Y23_FREQ_LNDIS * FREQ_LNDIS +B_Y23_DELANG * DELANG + B_Y23_ENLANG * ENLANG

V3(Y4-5) = ASC_Y45 + B_Y45_MALE * MALE + B_Y45_FEMALE * FEMALE +B_Y45_AGE2 * AGE2 + B_Y45_AGE4 * AGE4 +B_Y45_EDUBACHE * EDUBACHE + B_Y45_EDUMSC * EDUMSC +B_Y45_INCOME1K * INCOME1K + B_Y45_INCOME6K * INCOME6K + B_Y45_M_Mode * M_Mode

```
V4(Y6+) =ASC_Y6 + B_Y6_EDUBACHE * EDUBACHE + B_Y6_EDUPHD * EDUPHD +
B_Y6_INCOME1K * INCOME1K + B_Y6_INCOME6K * INCOME6K

V6 (YUNSURE) = ASC_YUN + B_YUN_AGE2 * AGE2 + B_YUN_AGE5 * AGE5 +B_YUN_EDUBACHE
* EDUBACHE + B_YUN_EDUMSC * EDUMSC +B_YUN_INCOME1K * INCOME1K +
B_YUN_INCOME6K * INCOME6K +B_YUN_M_Mode * M_Mode + B_YUN_FREQ_LNDIS
* FREQ_LNDIS
```

Specifications of the utility functions of adoption OLM - 1

```
U = B_M_Mode * M_Mode + B_FREQ_LNDIS * FREQ_LNDIS + B_LN_DISMODE * LN_DISMODE
+ B_FAML * FAML + B_DATAP * DATAP +B_FL_COST * FL_COST_SCALED + B_safety *
safety + B_tech * tech + HP_SFT_SCALED + B_HP_SFT
ChoiceProba = {\\
    1: 1 - dist.logisticcdf(U - tau1),\\
    2: dist.logisticcdf(U - tau1) - dist.logisticcdf(U - tau2),\\
    3: dist.logisticcdf(U - tau2) - dist.logisticcdf(U - tau3),\\
    4: dist.logisticcdf(U - tau3) - dist.logisticcdf(U - tau4),\\
    5: dist.logisticcdf(U - tau4) - dist.logisticcdf(U - tau5),\\
    6: dist.logisticcdf(U - tau5)}
```

Specifications of the utility functions of adoption OLM - 2

```
U = B_M_Mode * M_Mode + B_FREQ_LNDIS * FREQ_LNDIS + B_LN_DISMODE * LN_DISMODE
+ B_FAML * FAML + B_DATAP * DATAP +B_FL_COST * FL_COST_SCALED + B_safety *
safety + B_tech * tech + HP_SFT_SCALED + B_HP_SFT
ChoiceProba = {\\
    1: 1 - dist.logisticcdf(U - tau1),\\
    2: dist.logisticcdf(U - tau1) - dist.logisticcdf(U - tau2),\\
    3: dist.logisticcdf(U - tau2) - dist.logisticcdf(U - tau3),\\
    4: dist.logisticcdf(U - tau3) - dist.logisticcdf(U - tau4),\\
    5: dist.logisticcdf(U - tau4)}\\
```

Specifications of the utility functions of adoption OLM - 3

```
U = B_M_Mode * M_Mode + B_FREQ_LNDIS * FREQ_LNDIS + B_LN_DISMODE * LN_DISMODE
+ B_FAML * FAML + B_DATAP * DATAP +B_FL_COST * FL_COST_SCALED + B_safety *
safety + B_tech * tech + HP_SFT_SCALED + B_HP_SFT
ChoiceProba = {\\
    1: 1 - dist.logisticcdf(U - tau1),
    2: dist.logisticcdf(U - tau1) - dist.logisticcdf(U - tau2),
    3: dist.logisticcdf(U - tau2) - dist.logisticcdf(U - tau3),
    4: dist.logisticcdf(U - tau3)}
```

Table D.1 Description of variables included in the utility functions

Variables	Description
HP_TIME	Hyperloop total travel time [minutes]
HP_COST	Hyperloop total travel cost [Euros]
HP_SFT	Hyperloop safety
HP_FRE	Hyperloop frequency
HST_TIME	High-speed train total travel time [minutes]
HST_COST	High-speed train total travel cost [Euros]
HST_SFT	High-speed train safety
HST_FRE	High-speed train frequency
FL_TIME	Flight total travel time [minutes]
FL_COST	Flight total travel cost [Euros]
FL_SFT	Flight safety
FL_FRE	Flight frequency
SFT 1	Driving level safety
SFT 2	Two time higher than driving level
SFT 4	Four time higher than driving level
FRE3	3 time/day
FRE4	4 time/day
FRE5	5 time/day
MALE	Male
FEMALE	Female
AGE2	Age 18-25
AGE3	Age 26-35
AGE4	Age 36-45
AGE5	Age 46-55
AGE6	Age 55+
BSC	Bachelor or lower than bachelor
MSC	Masters
PHD	PhD
OCCUWORK	Full time working
OCCUSTU	Student
OCCUUMP	Unemployed
INCOME1K	Household income 1000 Euros
INCOME3K	Household monthly income between 1000 and 3000 Euros
INCOME6K	Household monthly income between 3000 and 6000 Euros
INCOME6KP	Household monthly income more than 6000 Euros
M_Mode	Main mode of transport
FREQ_LNDIS	Freqently travel long-distance trip
LN_DISMODE	Main mode for long-distance
SATIS_FL	Level of satisfaction for Flight
SATIS_HST	Level satisfaction for HST
DR_LIC	Driving license
ACESS_CAR	Access to a car

E Survey questionnaires

Acceptance of Hyperloop Systems 1B

The Hyperloop is a proposed mode of transportation. Since Hyperloop does not exist yet, it would be crucial to understand users' preferences for market demand and future development. We are interested in your opinion.

Dear respondents,

Thank you for your participation in our survey.

I would like to invite you to participate in a research study. The research is about mode choice and future mobility (Hyperloop) in Germany and it is supervised by the Chair of Transportation Systems Engineering (Prof. Dr. Constantinos Antoniou) at the Technical University of Munich.

We kindly ask you to take about 10 - 15 minutes to complete this questionnaire. Participation in this research study is completely voluntary. You have the right to withdraw at any time or refuse to participate entirely.

All the information you provide is solely for research purposes and will be kept confidential. All responses will be handled anonymously.

For any concerns or suggestions, please do not hesitate to contact us via mail: ashraful.islam@tum.de (mailto:Ashraful.islam@tum.de). Thank you very much for your support!

If you understand the above information and agree to participate in this study, please click "Next" to continue.

There are 31 questions in this survey.

Part 1 of 4

General questions

Before introducing you to the survey tasks, please answer the following questions:

What is your main mode of transport? (Inside the city, or in your daily commute) *

Please choose **only one** of the following:

- Public Transport
- Private Car
- Ridehailing, e-hailing (Taxi, Uber)
- Carsharing
- Scooter
- Bicycle
- Shared bike
- Walk
- Other (please specify)

How frequently do you travel a long-distance travel? (> 400 km) *

Please choose **only one** of the following:

- 1-3 days per week
- 1-3 days per month
- Less than once a month
- Never or almost never

What is your main mode of transport for long-distance? (>400 km) *

Please choose **only one** of the following:

- High-speed train (e.g. ICE)
- Flight
- Car
- Bus
- Ridesharing (BlaBlaCar, etc.)
- Other (please specify)

Please indicate your level of satisfaction with the High-speed train, Flight system in your region. *

Please choose the appropriate response for each item:

	Very dissatisfied	Rather dissatisfied	Neither dissatisfied nor satisfied	Rather satisfied	Very satisfied
Flight					
High-speed train					

Do you have driving license valid in the country of your residence? *

Please choose **only one** of the following:

- Yes
- No
- I prefer not to answer

Do you have access to a car? *

Please choose **only one** of the following:

- Yes
- No
- I prefer not to answer

When considering a mode of transportation how important are the following considerations? *

Please choose the appropriate response for each item:

	Not important at all	Not important	Neither important nor unimportant	Important	Very important
Travel time	○	○	○	○	○
Travel cost	○	○	○	○	○
Safety	○	○	○	○	○
Comfort	○	○	○	○	○
Environmental impact	○	○	○	○	○

Part 2 of 4

Questions about Hyperloop and technological concerns

In this part of the survey, we have few general questions about Hyperloop and your understanding about Hyperloop. Please answer the following questions:

Are you familiar with Hyperloop systems? *

Please choose **only one** of the following:

- I know a lot about it
- I have heard about it and looked into it
- I have heard about it
- I don’t know it

How much do you agree with each of the following statements regarding your technological concern? *

Please choose the appropriate response for each item:

	I strongly disagree	I somewhat disagree	I neither disagree nor agree	I somewhat agree	I strongly agree
I am excited by the possibilities offered by new technologies	○	○	○	○	○
I often use new technology products, even when they are expensive	○	○	○	○	○
New technologies causes more problems than it solves	○	○	○	○	○

Please indicate your level of agreement with the following statements.

*

Please choose the appropriate response for each item:

	I strongly disagree	I somewhat disagree	I neither disagree nor agree	I somewhat agree	I strongly agree
I trust high-speed automated systems	○	○	○	○	○
I have concerns regarding personal privacy and data security for my trip	○	○	○	○	○

Part 3 of 4

The Hyperloop is a proposed mode of passenger and freight transportation, first used and designed by a joint team from Tesla and SpaceX. Elon Musk first publicly mentioned the Hyperloop in 2012. Hyperloop is described as a sealed tube or system of tubes with low air pressure through which a pod may travel substantially free of air resistance or friction. The Hyperloop could potentially convey people or objects at airline or hypersonic speeds while being energy efficient compared to existing high-speed rail systems.

In this part of the survey, you are given 10 scenarios, designed to determine how your transportation choices would change if the attributes of the modes were altered. You will be asked to choose from three modes (Hyperloop, High-speed train, Flight), given a set of attributes. Please base your evaluation only on the following attributes:

Travel time: *The time spent in the vehicle, to go from point A to point B (Total trip time).*

Access, egress time, and waiting time: *The total amount of time spent in access to the mode (at the beginning of the trip in reaching your mode) and egress from mode to your destination. Waiting time is waiting for the mode at station.*

Total travel time: *Travel time including access, egress time, and waiting time.*

Travel cost: *The amount of money you spend on this trip. (Ticket cost only)*

Safety Level: *The likelihood of having an incident in Hyperloop, High-speed train and Flight.*

Service frequency: *Number of trips per day between the origin and destination*

You are asked to state your preference between the three modes for a set of scenarios, considering the following hypothetical situation:

- *You are in Munich and you would like to make a trip to Berlin. The distance between Munich and Berlin is around 600 km.*

Please keep in mind that there are no right or wrong answers: we are solely interested in your opinion.

Hyperloop train illustration

Source: https://www.railway-technology.com/features/hyperloop-project/

High-speed train illustration

Source: https://www.bahn.com/en/view/trains/long-distance/ice-ice-sprinter.shtml

Flight illustration

Source: https://www.lufthansagroup.com/en/newsroom/media-relations-north-america/news-and-releases

Given the following options for the trip above, which would you choose?

Scenario 1	Hyperloop	High-speed train	Flight
Total travel time	1 hour 40 min	6 hour 30 min	3 hour
Travel cost (EUR)	69	46	90
Safety level (compared to car)	Driving level	2 x more safety than driving level	Driving level
Frequency of trip per day	Every 10 min	Every 4 hour	Every 5 hour

*

Please choose **only one** of the following:

- Hyperloop
- High-speed train
- Flight
- None

Given the following options for the trip above, which would you choose?

Scenario 2	**Hyperloop**	**High-speed train**	**Flight**
Total travel time	2 hour 20 min	5 hour 10 min	3 hour
Travel cost (EUR)	69	46	140
Safety level (compared to car)	2 x more safety than driving level	Driving level	2 x more safety than driving level
Frequency of trip per day	Every 10 min	Every 3 hour	Every 4 hour

*

Please choose **only one** of the following:

- Hyperloop
- High-speed train
- Flight
- None

Given the following options for the trip above, which would you choose?

Scenario 3	Hyperloop	High-speed train	Flight
Total travel time	2 hour 20 min	6 hour 30 min	3 hour
Travel cost (EUR)	92	46	90
Safety level (compared to car)	4 x more safety than driving level	2 x more safety than driving level	Driving level
Frequency of trip per day	Every 15 min	Every 5 hour	Every 4 hour

*

Please choose **only one** of the following:

- ◯ Hyperloop
- ◯ High-speed train
- ◯ Flight
- ◯ None

Given the following options for the trip above, which would you choose?

Scenario 4	**Hyperloop**	**High-speed train**	**Flight**
Total travel time	2 hour 20 min	6 hour 30 min	4 hour 10 min
Travel cost (EUR)	92	46	90
Safety level (compared to car)	4 x more safety than driving level	2 x more safety than driving level	Driving level
Frequency of trip per day	Every 5 min	Every 4 hour	Every 4 hour

*

Please choose **only one** of the following:

- Hyperloop
- High-speed train
- Flight
- None

Given the following options for the trip above, which would you choose?

Scenario 5	Hyperloop	High-speed train	Flight
Total travel time	3 hour	3 hour 50 min	3 hour
Travel cost (EUR)	92	46	90
Safety level (compared to car)	Driving level	Driving level	2 x more safety than driving level
Frequency of trip per day	Every 15 min	Every 3 hour	Every 3 hour

*

Please choose **only one** of the following:

- Hyperloop
- High-speed train
- Flight
- None

Given the following options for the trip above, which would you choose?

Scenario 6	Hyperloop	High-speed train	Flight
Total travel time	3 hour	6 hour 30 min	4 hour 10 min
Travel cost (EUR)	92	92	90
Safety level (compared to car)	2 x more safety than driving level	Driving level	4 x more safety than driving level
Frequency of trip per day	Every 10 min	Every 5 hour	Every 5 hour

*

Please choose **only one** of the following:

- ◯ Hyperloop
- ◯ High-speed train
- ◯ Flight
- ◯ None

Given the following options for the trip above, which would you choose?

Scenario 7	Hyperloop	High-speed train	Flight
Total ravel time	2 hour 20 min	6 hour 30 min	4 hour 10 min
Travel cost (EUR)	92	46	140
Safety level (compared to car)	4 x more safety than driving level	4 x more safety than driving level	Driving level
Frequency of trip per day	Every 5 min	Every 4 hour	Every 5 hour

*

Please choose **only one** of the following:

- Hyperloop
- High-speed train
- Flight
- None

Given the following options for the trip above, which would you choose?

Scenario 8	**Hyperloop**	**High-speed train**	**Flight**
Total travel time	3 hour	3 hour 50 min	4 hour 10 min
Travel cost (EUR)	92	92	190
Safety level (compared to car)	Driving level	2 x more safety than driving level	4 x more safety than driving level
Frequency of trip per day	Every 10 min	Every 3 hour	Every 3 hour

*

Please choose **only one** of the following:

- ◯ Hyperloop
- ◯ High-speed train
- ◯ Flight
- ◯ None

Given the following options for the trip above, which would you choose?

Scenario 9	Hyperloop	High-speed train	Flight
Total travel time	2 hour 20 min	3 hour 50 min	5 hour 20 min
Travel cost (EUR)	69	46	190
Safety level (compared to car)	4 x more safety than driving level	Driving level	Driving level
Frequency of trip per day	Every 15 min	Every 3 hour	Every 4 hour

*

Please choose **only one** of the following:

- ◯ Hyperloop
- ◯ High-speed train
- ◯ Flight
- ◯ None

Given the following options for the trip above, which would you choose?

Scenario 10	Hyperloop	High-speed train	Flight
Total Travel time	3 hour	5 hour 10 min	5 hour 20 min
Travel cost (EUR)	92	69	190
Safety level (compared to car)	2 x more safety than driving level	Driving level	4 x more safety than driving level
Frequency of trip per day	Every 15 min	Every 5 hour	Every 4 hour

*

Please choose **only one** of the following:

- ◯ Hyperloop
- ◯ High-speed train
- ◯ Flight
- ◯ None

Here, we have few additional questions about Hyperloop.

When are you most likely going to use Hyperloop? *

Please choose **only one** of the following:

- During 1st year of operation
- During 2nd or 3rd year of operation
- During 4th or 5th of operation
- Starting the 6th year of operation
- Never
- Unsure

Please indicate your level of agreement with the following statements. *

Please choose the appropriate response for each item:

	I strongly disagree	I somewhat disagree	I neither disagree nor agree	I somewhat agree	I strongly agree
I believe that Hyperloop will be successful in Germany	○	○	○	○	○

Part 4 of 4

Demographic questions

Finally, we have a few additional questions which will help us sort the questionnaire results and that are like the previous questions in no way used for any purpose outside this research study.

How much do you agree or disagree with each of following statement regarding your personality. *

Please choose the appropriate response for each item:

	I strongly disagree	I disagree somewhat	I disagree slightly	I agree slightly	I agree somewhat	I strongly agree
In general, I feel confident and positive about myself	◯	◯	◯	◯	◯	◯
Given the opportunity, there are many things about myself that I would change	◯	◯	◯	◯	◯	◯
My decisions are not usually influenced by what everyone else is doing	◯	◯	◯	◯	◯	◯
I often change my mind about decisions if my friends or family disagree	◯	◯	◯	◯	◯	◯

Please indicate your gender. *

Please choose **only one** of the following:

- ◯ Female
- ◯ Male
- ◯ Other
- ◯ I prefer not to answer

Which age group represents you? *

Please choose **only one** of the following:

- ◯ 0 - 17
- ◯ 18 - 24
- ◯ 25 - 34
- ◯ 35 - 44
- ◯ 45 - 54
- ◯ 55 -64
- ◯ 65 +
- ◯ I prefer not to answer

What is the highest level of education you have completed? *

Please choose **only one** of the following:

- ◯ Less than high school
- ◯ High school diploma (Abitur)
- ◯ Apprenticeship
- ◯ Bachelor’s degree (or Hochschule diploma)
- ◯ Master’s degree
- ◯ Doctoral degree
- ◯ Other (please specify)
- ◯ I prefer not to answer

Make a comment on your choice here:

What is your main occupation? *

Please choose **only one** of the following:

- Working (Full-time)
- Working (Part-time)
- Self-employed
- Unemployed
- Student
- Homemaker
- Retired
- Other (please specify)
- I prefer not to answer

Make a comment on your choice here:

What is the average monthly net income (after deducting all taxes) of your household (people you live with and with whom you share your income)? *

Please choose **only one** of the following:

- Up to 500 €
- 500 to less than 1000 €
- 1000 to less than 2000 €
- 2000 to less than 3000 €
- 3000 to less than 4000 €
- 4000 to less than 5000 €
- 5000 to less than 6000 €
- 6000 to less than 7000 €
- 7000 € or more
- I prefer not to answer

Where do you currently reside? Please indicate the country and the city.

Please write your answer here:

e.g,: Munich, Germany

What is your nationality?

Please write your answer here:

e.g.: German

Finally, do you have additional comments, feedback, or recommendations regarding our survey?

Feel free to comment here. Alternatively, you can send me an email on ashraful.islam@tum.de

Please write your answer here:

Thank you once again for taking the time to fill this survey.
Your opinion is highly valuable and appreciated.

Submit your survey.
Thank you for completing this survey.