THE INTERIOR DESIGN CHALLENGES OF A HYPERLOOP POD HOW TO ENHANCE THE PASSENGER EXPERIENCE

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ABSTRACT

Although still in its infancy, the Hyperloop project aims to develop a new type of public transport. The concept is to send a capsule, called "pod", at about 1000km/h in a vacuum tube that would connect two places separated by 500km. One issue is that the pod will be windowless and travel inside a tube made of steel which will influence passenger comfort. This article brings together various domains to explore the different characteristics that can influence the travel experience. As the Hyperloop concept is still in an early stage of development, methods for analyzing the interior design of transportation vehicles, such as Kansei Engineering, Mayr's circle, and the comfort model by Looze have been proposed. Moreover, typical characteristics, such as "Environment", "Running Factors" and "Service & Installation" have been discussed with respect to "passengers" experience, comfort and safety.

Keywords: User centred design, Conceptual design, Emotional design, Hyperloop, Interior design

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1 INTRODUCTION

Hyperloop is a new type of transport proposed by Elon Musk in 2012 (Grasso, 2021). The concept concerns a capsule, called the "pod", moving inside a low evacuated pressure tube made of steel, which connects at high speeds (exceeding 1000 km/hr) to different locations that are approximately 500 km apart (Piip, 2021). The hyperloop aims to be the next green transportation solution that could potentially replace short-haul flights and long train rides, using a network allowing passengers and cargo to reach various cities. Distance will then no longer be an issue, as this mode of transportation significantly reduces travel time (Shift Hyperloop). As the Hyperloop development is a relatively new concept driven by systems thinking and design, actors from different disciplines have adopted an "Open Source Design" approach, where knowledge and insights are freely shared within the community of practice.

Many articles concerning the technical research on the Hyperloop concept were published, but only a few (7%) regarding the interior design of the pod (Mitropoulos et al., 2021).

Only two people, from Virgin Hyperloop, (Hitti, 2020) have experienced a short-distance journey by pod, which does not provide enough results regarding passenger experience. Shaaban (2022) recommends exploring some key aspects (criteria) such as claustrophobia, comfort, and safety to create a more reliable and environmentally friendly pod interior design:

- Claustrophobia: As the pod travels inside a steel tube without windows, how should the interior be designed to reduce claustrophobia among travelers as they are confined to an enclosed space for about 30 minutes?
- Comfort: Excessive noise through high-speed travel may cause discomfort and should be considered in the choice of capsule propulsion.
- Entertainment: This capsule will travel at about 1200 km/hr: Would it be conceivable to walk around or are the passengers expected to wear a seatbelt throughout the journey, because of high G-forces due to acceleration and deceleration (Piip, 2021)? Would it be feasible to install a bar with different kinds of entertainment? (Crouse, 2017)
- Safety: How should information about safety procedures be communicated to travelers? Should it be presented by staff, or can they be excluded from the vehicle, as in a metro ride? Additionally, what measures should be put in place within the pod to prevent any accidents or injuries to passengers?

This article aims to explore the different criteria for designing the interior of a Hyperloop Pod and has led to the following research questions:

- RQ1. What methods and tools should be used for pod interior design?
- RQ2. What are the specific characteristics of pod interior design?
- RQ3. How to enhance the passenger experience?

2 LITERATURE REVIEW

Several literature searches were made with respect to determining criteria for Hyperloop interior design as well as its specific characteristics. The following figure (fig.1) illustrates the process of choosing different topics or keywords prior to conducting research for this article. The text in the boxes represents examples of brainstorming that pertains exclusively to the Hyperloop vehicle, but this procedure could also be employed for other interior designs of public transportation vehicles:

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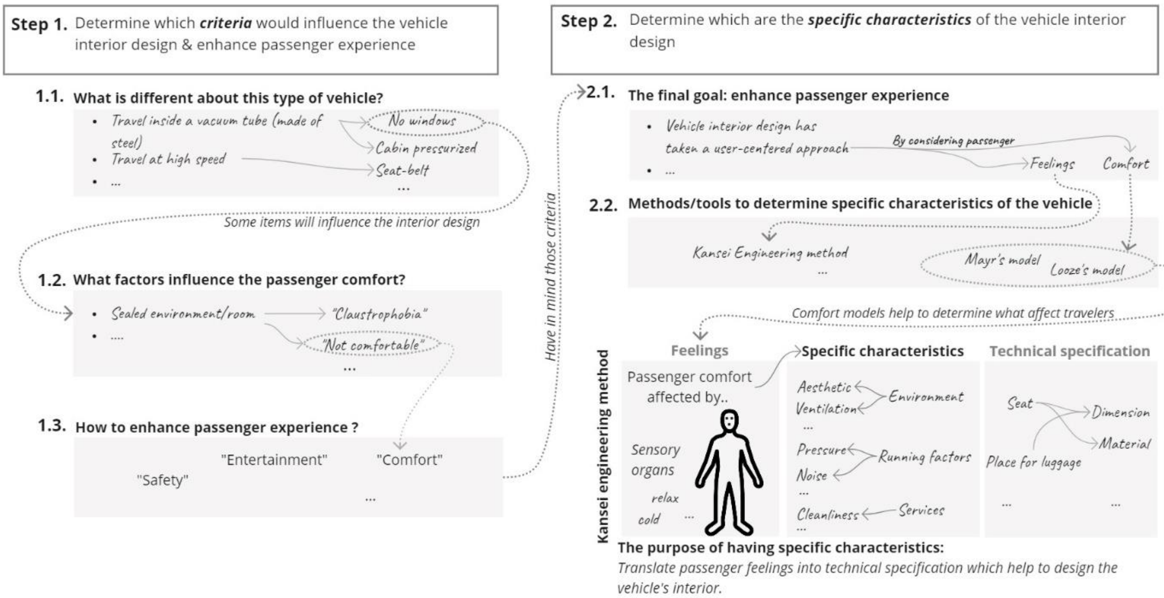

Figure 1. Procedure sample for Hyperloop interior design case

A literature review "Hyperloops" was conducted based on selected sources from 2013 onwards. Various databases such as Google, Google scholar, Oria.no, Proquest, Science direct, and Springer link were used to find articles, article reviews, research papers, and conference papers. Additionally, newspapers, and companies' and organizations' websites, such as Shift Hyperloop and Virgin Hyperloop, were consulted. Moreover, a broader article search was conducted leading to a wider span of publication dates to assess the evolution and current state of passenger comfort and well-being (e.g. claustrophobia). Search themes and keywords were juxtaposed according to several combinations in order to search papers on different databases (e.g. Proquest and Google scholar).

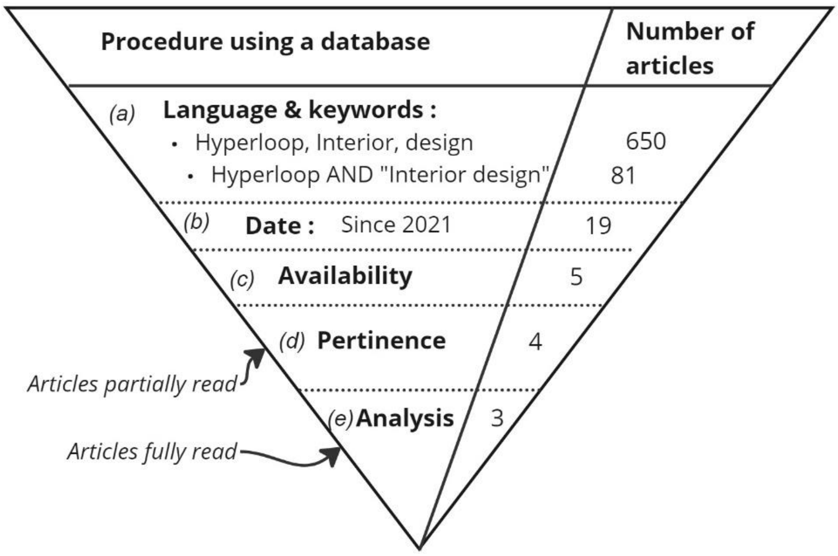

Figure 2. Procedure sample for google scholar database. Article selection has been based on prioritizing: (a) Language (English). (b) Date: research time period. (c) Availability: whether the text is fully available or not. (d) Pertinence: the title and keywords have been considered at first to have an idea of the topic, then the abstract, and lastly a quick lecture. (e) Analysis: the extent of which the article answered the research questions (RQ).

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3 RESULTS

The reporting of "Results" is classified into (1) tools and methods that can be used for pod interior design and (2) factors that influence travel experiences.

3.1 Methods and tools for pod interior design

The Hyperloop pod is still in its early stages. Since the capsule does not exist yet, this paper explores different approaches and tools to design the interior such as Kansei engineering, Mayr's circle, and the comfort model by Looze.

Kansei Engineering (1995)

Kansei engineering (KE) is a tool for translating users' emotions to specific parameters (Nagamachi, 1995). Companies that want to consider customers' feelings in the design process adopt the Kansei engineering method to transcribe them into specific requirements (Schütte et al., 2004). One of the first automotive companies to implement KE in its development process was Mazda in 1986. The KE approach observed the behavior of potential users during a particular task using recorded photographs or videos (Kang, 2010). The figure below shows how to translate feelings (KE words) into technical specifications.

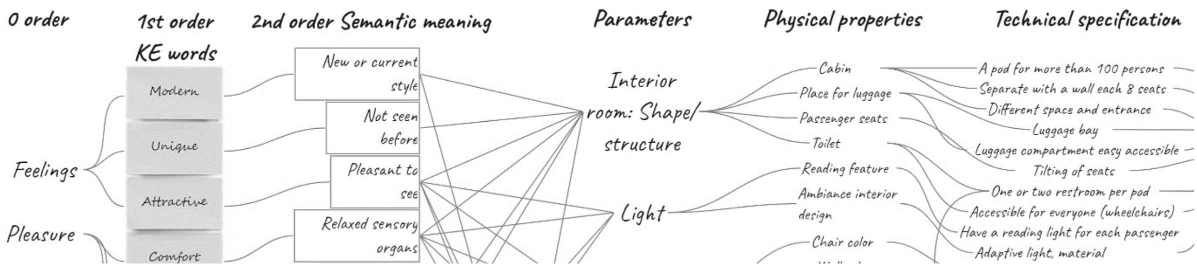

Figure 3. An illustration of the application of Kansei engineering -Translation of Kansei words into Hyperloop pod traits

Related to the subject, the product or service is dissected by keywords derived from brainstorming (1st column) For each word, the process is iterated to find the technical specification (last column).

Mayr's circle (1959)

According to Mayr's circle (1959), and reiterated by Osborne (1978), different external factors affecting travelers involve the environment of the transport (atmosphere, interior design). This comprises of running characteristics (external factors that are not provided by the transport company, such as noise and vibrations), and general installations (attendance and sanitary installation).

Looze model (2003)

Sinha (2016) refers to Looze's model (2003) (see figure 4) to compare people's comfort and discomfort provoked by the product and/or the environment influencing the sensory organs: the discomfort is caused by physical characteristics (from the product), effort (e.g. physical capacity); The comfort comes from aesthetic, emotions, expectation (e.g. service, cleanliness), physical features (e.g. chair).

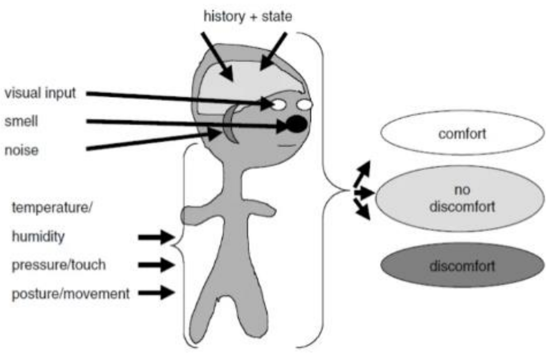

Figure 4. Note. Reprinted from "Attributes of passenger comfort in Rail transport" by Sinha, K., 2016, Looze's model (2003)

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3.2 Specific characteristics of pod interior design

Designing the pod interior requires thinking about different factors influencing passengers' well-being (Kang, 2010) This section explains the different dimensions, which may influence the travel experience when designing the interior of the Hyperloop pod. These characteristics have been defined as environment, running factors and services.

- Environment; Consisting of the interior design and the atmosphere: The aesthetic aspect which can have an effect on passengers, and the air and light that complete the environment of the interior design.
- Running factors; Factors that affect passenger comfort but would not be made intentionally by the transport company.
- Service and installation; these are provided by the transport company.

3.2.1 Environment

Needed measures against claustrophobia, illumination and air-conditioning are factors to be considered when designing the hyperloop pod interior.

Claustrophobia – The absence of windows and material selection to sustain the low pressure and "keep the expenses as low as possible" (Piip, 2021), may affect people´s well-being, especially those suffering from claustrophobia. Mitropoulos et al. (2021) and Piip (2021) proposed to explore journeys with window simulation on the walls, which would simulate nature outside the tube. However, according to Oborne (1978) and Shaaban (2022), the passenger may feel nauseous when looking at the landscape while traveling at high speed. This reaction, called Photokinetic nystagmus and optical rotary nystagmus, appears when successive objects pass by at a high rate (Oborne,1978). Furthermore, providing enough space, having clear exit signs, and if necessary, facilitating assistance reassures travelers suffering from claustrophobia (Mackett, 2021).

Illumination - A study has explored the emotional impact of light on enclosed (windowless) and open rooms and found that chromatic color influence participants' emotions, while saturation affects arousal level (Zhang et al., 2022). In fact, chromatism can stimulate people's dynamism and be used to relax passengers in the Hyperloop pods (Ou, 2015). Besides, Kharismawardani et al. (2022) mention that color and light work together to create an atmosphere and can affect mood and boost health. Light can bring about discomfort or dizziness in people if the flicker frequency is above 50 Hz (Oborne, 1978). However, this also depends on the light distribution in the room (Sinha, 2016). It can influence people's perceptions through the intensity and diffusion of light on different textures or materials (Kharismawardani et al., 2022). Therefore, research on the art of light is used to improve health conditions, since it "influences biochemical and hormonal processes, body temperature, mood, and brain activity" (Tomassoni et al., 2015).

Air conditioning - Air temperature and air velocity can be a source of discomfort if it is not continuously vented in an enclosed area in accordance with Oborne (1978) and Sinha (2016). A poorly regulated temperature negatively affects people´s well-being. "The ASHRAE standard 55--66 (1966) suggests that "air motion, should not exceed 45 ft/min [0.23m/s] and shall not be less than 10 ft/min [0"06 m/s] at any time". McFarland (1969) " (Oborne, 1978). Additionally, air quality may cause fatigue: it should be controlled with "Air Quality Index (AQI) – Central Pollution Control Board (CPCB)".

3.2.2 Running factors

Running factors are the external elements transport companies (such as trains, airplanes, and buses) cannot control but may impact travelers' comfort. Here is a non-exhaustive list of these factors that are considered for Hyperloop design:

Noise - Conforming to Shaaban (2022) and Piip (2021) sending the pod at high speed in the tubes will generate noise inside the pod. However, noise cannot be audible in a vacuum. Further research needs to be set on "measuring the noise level within the cabin during a journey" (Mitropoulos et al., 2021).

Since there is no vacuum within the pod, noise may come from various sources, including capsule vibration, suspension systems, or motors.

Pressure change - Another factor that affects passenger comfort is the rate of pressure change. According to Oborne (1978), it appears at high speed from 0,4kPa. As the pressure is felt in the ears, it causes discomfort to travelers.

G-force - Acceleration and deceleration expose passengers to G-force (Shaaban, 2022). Musk (2013) mentioned in his first paper, Hyperloop Alfa, that the G-force should be limited to 0.5 g.

3.2.3 Services

To facilitate a pleasant travel experience among its users, hyperloop travel adequate service measures need to be put in place. The effectiveness of these measures is dependent on "Staff Skills", "On-board Installations", "Safety" and "Cleanliness".

Staff skills - Travelers are often under stress throughout the journey. Therefore, being exposed to efficient, skilled and helpful personnel is essential and would make life easier for them. (Carreira et al., 2013). For example, in a study on "Trust and acceptance of self-driving buses" by Stålhane (2021), passengers feel more comfortable having a host present in an autonomous vehicle, in case of harassment, robbery, or other unexpected events.

On-board installations - According to Carreira et al. (2013), having entertaining installations on-board will enhance the passenger experience, for instance: proposing a screen presenting information about the journey, such as the route, the time left, and the Hyperloop pod speed (Piip, 2021); Also, having Wi-Fi on board, or other facilities (e.g., table and light reading) that could be used by the travelers to do an activity (e.g., read, work and play) will influence their perception of journey length (Oborne, 1978).

Safety – Safety measures have to be set up both on and offboard the pod to ensure passenger safety including an emergency evacuation plan (Shaaban, 2022). Safety and first aid equipment such as an oxygen tank, lighting, and a phone to contact the station must be provided (Hitti, 2020; Hyde et al., 2016). In case of depressurization, the system should stabilize the cabin pressure, deploy oxygen masks, and extra air stored in tanks should be furnished (Hyde et al., 2016). Mitropoulos et al. (2021) state that travelers should remain seated and wear a seatbelt to protect themselves from deceleration and acceleration.

Cleanliness - Foul odors and dirty spaces impact people's sensory organs (e.g., olfactory and sight) (Carreira et al., 2013). To resolve this, Spence (2021) suggests that incorporating scents such as pine and citrus perfume can help to enhance the freshness of the room. Also, the air ventilation scent can displease users (Sinha, 2016). However, in the same way, it can be used to perfume and relax passengers in an enclosed space (Spence, 2021).

4 DISCUSSION

To design a new interior type of transport such as the Hyperloop pod, the designer should consider the psychological and physiological needs of passengers. Moreover, as the hyperloop pod is still under development, reference should be taken from the interior design of similar means of transport. This section discusses what methods and tools are to be used for designing the future hyperloop pod interior, as well as its characteristics.

4.1 What methods and tools should be used for pod interior design?

Kansei engineering (KE) is a tool, which is often used in transportation design to understand customers' emotions and translate them into concrete parameters. (Hartno, 2021). Moreover, as space affects various cognitive functions (e.g., visuospatial capacities), Kansei engineering can be used to target customers' perceptions and improve the traveler experience.

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Kansei engineering can be implemented in the immersion and ideation phases of the Design process when it comes to the development of the interior of the Hyperloop capsule. In the immersion phase, KE can be used to target the market by breaking down the topic of pod interior design into “Kansei words”, which means brainstorming different factors influencing passengers’ emotions. Then coefficients will be assigned to Kansei words to evaluate which of them should be delved into through further observations, interviews, and surveys. From this information gained, the designer will have a clear idea of the direction to take, and which features need to be considered. For example: In the ideation phase, KE can be used to define physical features such as specific dimensions or which lighting effect should be used for the pod interior to create an airy space that can help avoid feelings of claustrophobia.

Besides KE, several other models have been developed to determine passenger comfort. These models function as a guide to think about what features are essential when designing the pod interior.
Mayr’s circle creates an overview of the different elements affecting travelers’ comfort, such as the interior environment (e.g., aesthetic, atmosphere), running factors (e.g., vibrance, G-force felt during acceleration or deceleration), and general installation (staff’s skill, toilet).

Looze model considers external factors such as the environment (that affects sensory organs) as well as the interplay between the person and the task, to evaluate what contributes to comfort or discomfort.

4.2 What are the specific characteristics of pod interior design?

Passenger transport in a Hyperloop presents various challenges that must be addressed to ensure a positive travel experience. These include ensuring traveler comfort and safety as well as considering the characteristics of the Hyperloop, such as high-speed and vacuum environment, which can also impact the passenger experience.

A model adapted from Mayr’s model has been specifically developed for the Hyperloop system (see figure 5). The model is read from the inner to the outer circle: starting with the sensory organs to dimensions that incorporate both internal factors and external factors that influence passenger comfort. These dimensions that determine the characteristics of the Hyperloop pod include “Environment”, “Running Factors” and “Services”.

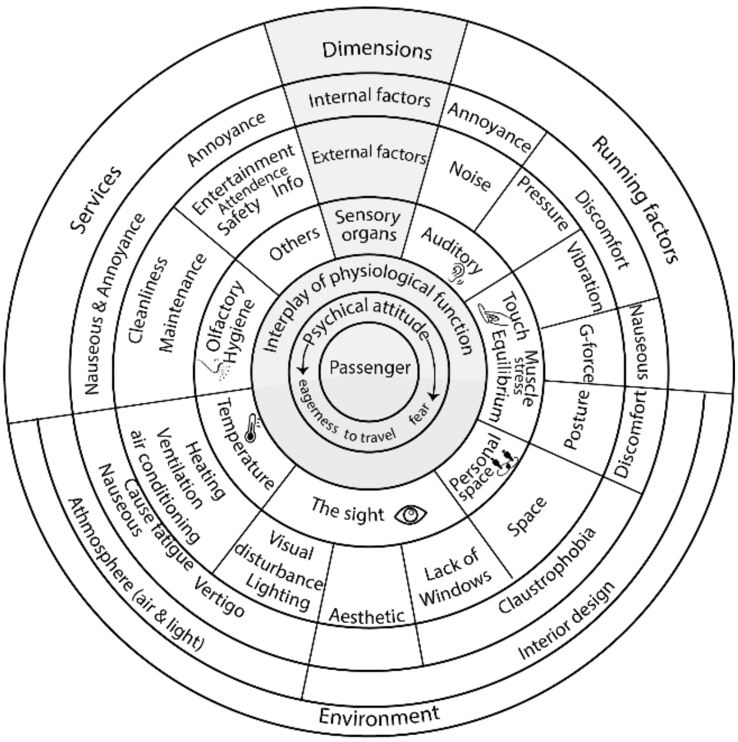

Figure 5. Passenger comfort model for Hyperloop pod interior design, adapted from Mayr´s model (1959).

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4.2.1 Environment
The environment refers to the interior design and the atmosphere that emanates from it. These have an impact on passenger comfort, as they will be traveling in a windowless room for thirty minutes. To minimize the sense of claustrophobia the Hyperloop pod should provide "fake" windows that simulate nature using dynamic screens corresponding to the area (Mitropoulos et al., 2021; Piip, 2021). The dynamic screens need to move at a low speed to prevent nausea. Lighting and chromatic color can be used to relax travelers, by using the intensity of light (Kharismawardani et al., 2022) and also the impact on people's emotions (Zhang et al., 2022; Ou, 2015).

4.2.2 Running factors
Some external factors such as changes in pressure and G-force can cause nausea and discomfort. The G-force applied to travelers will be limited to 0.5 g to avoid nauseous feelings during acceleration or deceleration (Musk, 2013). Passengers may remain seated and with seatbelts for the entire trip for safety reasons (Mitropoulos et al., 2021).

4.2.3 Services
Good transportation service has been more and more sought after by users, whereas companies find it necessary to enhance the passenger experience (Carreira et al., 2013). According to Carreira et al. (2013), the service offered to customers starts from the moment the user plans to purchase a ticket until the end of the trip (Off /on board). Therefore, staff competence is paramount to offering a good service. Maintaining good service means putting forward a welcoming and safe place. This is by keeping the pod clean as the odor influences people's perceptions (Spence, 2021). Bad scents would have a negative impact on their travel experience. Also, providing a safe environment for travelers will have a positive impact on them as they will feel protected. This will be possible by implementing a security plan and having safety devices present in the pod in case of an incident such as first aid, defibrillator, and oxygen masks.

4.3 How to enhance the passenger experience?
Passengers´ experiences are influenced by both external factors (e.g., vibration, G-force), as well as internal factors (elements that are controlled by the transport service such as ventilation, interior design, and light). Furthermore, passengers' loyalty depends on their travel experience. This means that based on how good the service is perceived for this reason it is essential to evaluate their emotional responses to factors unrelated to transportation (Carreira et al., 2013). As the travel experience may vary by region and culture these responses may also change (Sakya et al., 2017).
For instance, purchasing a ticket may be reflected in the passenger's attitude (e.g., getting stressed) (Schmitt et al., 2015). Therefore, "Virgin Hyperloop" and "Here Technologies" worked together to create an "app" that informs passengers in advance about their journey, enhancing their travel experience (e.g., time duration and route) (Mass transit, 2018).
Trust is key for enhancing passengers´ experience. In order to establish this trust, attrition of onboard personnel should take place gradually (Bentdal et al., no date). Being in a pod without a driver means travelers have to rely on technology when it comes to safety. Therefore, having attendants on board is still necessary for safety, especially in an autonomous vehicle. (Stålhane, 2021).

5 CONCLUSION AND FURTHER RESEARCH
Hyperloop projects are still in their early stages and rely much on private and public initiatives. Exploring the interior design challenges of a hyperloop pod is not easy, because this mode of transport does not exist yet. Therefore, studies on Hyperloop passenger experiences are hypothetical. However, it is still relevant to develop a methodology and requirements for designing the interior of the pod by taking reference from other forms of transportation (such as airlines and trains).

Further research should investigate cost reduction measures when developing the infrastructure of a low-pressure vacuum system (The biggest challenges that stand in the way of Hyperloop, 2017). One of the difficulties of designing the Hyperloop is estimating the return on investment (Shaaban, 2022). Although there are no government regulations for hyperloops, it should not be taken for granted that

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safety regulations and technical recommendations can be derived from existing means of transportation such as airplanes, subways, trains and other communication systems.

To find the right balance between "safety and security" on one hand and "Comfort and Freedom of Movement" on the other hand, more research should be done on the consequences of "Inside the Pod" passenger mobility: *Is it responsible to only wear a seatbelt at the beginning and end of the trip? Would it be possible to walk around during the journey or would the G-force be too big? (Crouse, 2017). Should airbags be provided for passengers if an accident occurs, and the pod decelerates too quickly?*

On a short-term basis, transportation of goods through the hyperloop system should also be explored as safety regulations are less stringent and costs more affordable than accommodating the system for the transportation of people (Rümeysa & Yasin, 2021; Wuthrich, 2018).

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