

## Practice-Based Research Approach to Designing and Developing the Cabin of a Fully Autonomous Passenger Drone for Intracity Commute in India

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### Abstract

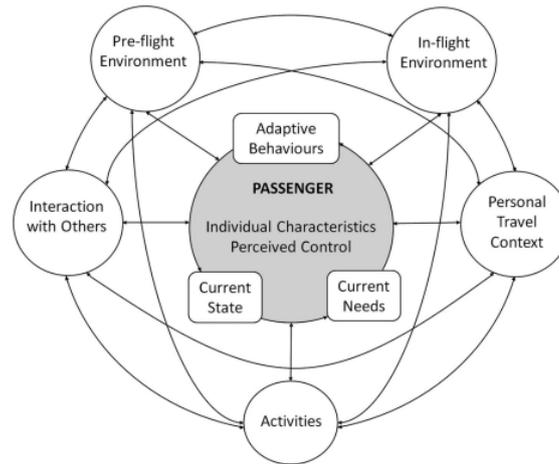
Passenger drones are currently being developed to solve the purpose of point-to-point commute. User interaction for futuristic vehicles will play a vital role in enhancing the experience and making the passenger feel safe. The interior of the drone cabin should be passenger-centric, giving the user various experiences to choose from on the fly. This research paper aims to document the process of designing and developing a cabin for a fully autonomous passenger drone using practice-based research approach. Several methodologies were used to predict the user requirements for a futuristic travel experience including practice-based, agile design research, and design thinking to determine the design requirements. The paper shows the documentation of various stages of the development of the full-scale cabin in prototype. The future scope of this study is to conduct user research on the developed full-scale cabin prototype for fully autonomous passenger drones.

**Keywords:** 1.Practice-based design, 2.futuristic passenger drone design, 3.transportation design, 4.futuristic passenger drone cabin design,5.user experience design, 6.practice-based research, 7.futuristic vehicle design

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### 1 Introduction

For a country like India, where there is congestion due to clogged roadways, overcrowding, and public transport inadequacy, a new mobility solution is needed. As the cities are getting more populated, traffic is getting more congested on the road, the only solution now left is to explore the airways for intrastate travel. Passenger drones are currently being developed in some countries to solve this purpose. Even though passenger drones have been developed and are developing in some countries, the studies done on designing the interiors have focused on the western audience. With drone evolution already taking place, the public acceptance of this technology plays a significant role. Research shows that safety is a critical factor that plays an important role (Aydin, 2019). "User diversity strongly influences both acceptance and perceived barriers" (Lidynia et al., 2017). Therefore, an in-depth study is required to create cabin interiors for passenger drones, which can suit the country's varied aspects like India. With the transportation industry aiming to achieve fully autonomous level 5 (SAE, 2021) vehicles, user interaction with the interiors plays a vital role (Miaskiewicz & Kozar, 2011). Fig1 explains the various factors which influence the aircraft passenger's comfort. The passenger is represented in the centre of the model including their individual characteristics and perceived control over meeting their needs – both of these, the contextual factors (pre-flight and in-flight environments and personal travel context), activities and interaction with others can potentially interact with each other, or directly influence a passenger's current state, their needs and adaptive behaviours (Patel & Cruz, 2017).



**Fig 1. factors Influencing passenger aircraft (Patel & Cruz, 2017)**

The cabin interior plays a vital role in the journey of the passenger. The interior of the vehicle should be able to define the passenger's personality and thus raise their self-esteem. Some of the factors that need to be highlighted while designing the vehicle interiors are functional storage, spatial aesthetics, digital device, comfort, safety, and cleanliness (Tu et al., 2018). Features that dominate the purchase of a vehicle are the interior design, comfort, and value for money (Shende, 2014).

According to the author, (Ab & Fjeld, 2019) the human-centered concerns when designing a passenger aerial vehicle are: (1) Appeal: People's acceptance of drones is a vital part while designing it. It is observed that the smaller the cabin space, the more comfortable people are. People are generally not very comfortable when "they are told what to do by a drone" when the drone is intended to motivate a particular behaviour. It is suggested the design should have subtle cues of what to be done. The interiors should be soundproof so that the noise coming from the propellers is eliminated. (2) Ergonomics: Research shows that gesture control should be avoided. User movements like standing and walking inside should be restricted for a better experience. A modest interaction space, roughly 1 m in each direction, and positioned between elbow and chest height, provides for good ergonomics as per WoZ method. (3) Intuitive Comprehensions states to what extent people can interpret the messages given by a drone. This can be motivated by the comfort and safety of the drone. Also, the lighting system inside plays a vital role in changing the behaviour patterns on the passenger. The defined front within the cabin space in the direction of the motion makes the passenger feel safe. (4) Intuitive Control and Perceived Social Role states up to what degree the passenger can intuitively control the drone without any documentation. Gestures and voice commands emerged as the most common control methods, but it can be tedious. Research suggests that giving a command to a drone is metaphorically similar to interacting with a pet. There is a broad scope of opportunity for future work around cognitive and behavioural interaction with the drone. (5) Tactility Perception states the extent to which people can perceive the drone design when they can manually touch the surfaces and feel safe when the moving part is enclosed in the protective exterior.

### 1.2 Luxury Segment Cabin Design for Passenger Air Vehicle (PAV)

As there is very little information on passenger drone interior design, the research extended to luxury segment air travel cabin space and luxury segment fully autonomous concept vehicles to gather insights on design trend forecast. The luxury segment air travel interior space also emphasizes on giving the passenger the highest level of comfort. The compact cabin sometimes can lead to one of the stress factors. The futuristic aircraft cabin design is to give a real-time adaptive environment experience to the passenger and can adapt to the needs and moods of the passenger (David, 2004). Volvo 360c, a futuristic, fully autonomous car concept, has identified three key activities that people will prefer on the go. The first mode is comfort and relaxation, the second mode is the work mode, and the third mode is sleep mode.

The design of the roof and windshield derives the interior space for the user. It can make the user feel roominess or oppressiveness. The colour and shape of the interiors can drastically change the mood of the user. Elements like windshield rake angle, H point, and distance from driver to instrument cluster are prominent design

elements that determine the comfort inside the vehicle(Ergonomics et al., 1997). The daylight opening providing the 360-degree panoramic view and the sense of space in the cabin makes the passenger feel safe and reduces the feeling of vertigo and claustrophobia(Rautray et al., 2020).

This research paper focuses on the design and development of passenger drones interior cabin using practice based approach. Practise based approach focuses on gaining novelty by the means of creative outcomes. The purpose of this paper is to study the existing literature on interior design aspects of a fully autonomous passenger vehicle which is then used as inputs for developing a full scale 1:1 physical prototype as a creative outcome and documenting the same.

## 2 Literature Review

Literature review plays a critical role as it distinguishes what has been already done and what needs to be done, helps in discovering variables related to the topic, acquiring a new perspective, identifying various practices and identifying the methodology used for the research, establishing a context for the statement of problem, rationalizing the significance of the problem, historically placing the research to show familiarity with the state of the art developments(Boote & Beile, 2005).Product reviews are an essential source of information that helps describe the product and its attributes. It allows the customers to find an opinion of the product and designers to get feedback to build better products. In the past few years, many companies and organisations have demonstrated and built prototypes of passenger drones. The following are the product reviews of a few of the passenger drones interior cabin space available different parts of the world.The color scheme extraction for each product is done using the software Adobe Color.

### 2.1 Ehang 184

Ehang184is a fully autonomous passenger drone designed to fly at low altitudes of less than 500m. With a fully autonomous navigation system, there is no requirement for a professional pilot. The cabin features adjustable in-cabin temperature control, 4G wifi, dual-colored reading light, four-arm lights, signal light, headlight, and a 96V charging port.With two gull-wing doors for the entry and exit, there is enough room for the passenger. The passenger seat is similar to an F1 racing car seat. Passengers can easily input commands through a 12 pin control pad attached conveniently to the seat arm(*Ehang 184 Autonomous Aerial Vehicle (AAV) - Aerospace Technology*, 2019). The interiors are kept minimal with fixed seats and zero degree recline. Currently there is just one interactive screen to do all the tasks. Cool color palette of blue and grey's as shown in fig 2.



### INTERIOR

- Seat: 1 pc
- Manipulation of the tablet: 12 Inch
- Adjustable temperature(Depends on the outdoor temperature )
- 4G Network
- The Luggage Trunk(can put in one 16 inch bag)
- Reading Light Color: Custom-made

Fig 2. Ehang 184(Tibu, 2016)

### 2.2 Ehang 216

Ehang 216 is similar to Ehang 184, with a capacity of 2 passengers. They are mainly designed for fire fighting. It has large windows for a spectacular view of the passenger with two gull-wing doors(Transportup, 2020)(*Ehang 184 Autonomous Aerial Vehicle (AAV) - Aerospace Technology*, 2019). The interior has a warm and neutral color palette as shown in fig 3.



Fig 3. Ehang 216 (Lim, 2019)

### 2.3 Volocopter 2x

Volocopter 2x is designed for two passengers with an interior cabin space following the theme "simple, safe, and green." It has a dimension of 3200mm length, 2150mm height, and 9150mm width. It has a load-carrying capacity of 290kgs and a flight duration of 27 minutes. It promises to be an environmentally friendly, technologically advanced, and downright fun way to enjoy the recreational and practical potential of combining drone and helicopter flying in one machine. The fully autonomous vehicle has a simple joystick in the interiors used for easy manoeuvring, and adjustments can be made to take off, land, and fly which does give a sense of fear to passenger sitting inside without any aviation experience. Though the design is minimal, there is no information regarding the human machines interface and its features which plays an essential role in invoking a connect and emotion. The interior has a neutral color palette of browns and greys as shown in fig 4. Volocopter has introduced various versions like VC100 for a single passenger, VC200 for 2 passengers, and VC400 for four passengers (*Volocopter\_ The Drone of the Future - Drone and Quadcopter*, n.d.).



**Fig 4. Volocopter 2x (H., 2017)**

#### **2.4 Lilium Jet**

Lilium Jet is a semi-autonomous passenger drone. It has a passenger carrying capacity of four people and one pilot. Lilium Jet has a dimension of 11000mm width. It has a load-carrying capacity of 640kgs and a flight duration of 60 minutes, covering a range of 300kms. The current cabin design is quite minimal. The cabin space is designed for four passengers and a controller, which will give the passengers an extra level of safety. Once the passengers are used to the flight, the company states to transition to a fully autonomous five-passenger drone with extra space for luggage and another passenger. This five seater passenger drone has not revealed the interior features, human machine interaction or the color, material and finish apart from the gell filled seats(Lilium, 2020).



**Fig 4. Lilium Jet(Zart, 2019)**

## 2.5 Bell Nexus

Bell Nexus is a semi-autonomous helicopter designed for four passengers and one pilot. It has a dimension of 12000mm length and 12000mm width. It has a load-carrying capacity of 272kgs and a flight duration of 20 minutes, covering a range of 80.46kms. Its sleek cabin offers a comfortable space to relax, or work, or socialize. The interior space is well equipped with video calling, wifi, artificial intelligence, and wireless charging. The human machine interface is designed for the pilot, and does is not user friendly to the passenger. The space inside feels more of an economy class than compared to a luxury segment(Sherman, 2020). The interior has a color palette of blue and grey as shown in fig 5.



Fig 5. Bell Nexus (Boeing, Safran Invest in Electric Power Systems - Evtol, 2019)

## 2.6 Pop Up Next

Pop Up Next is the "first modular, fully electric, zero-emission concept vehicle system designed to relieve traffic congestion in crowded megacities." It has a passenger carrying capacity of 2 people and has a dimension of 4419.6mm length, 838.2mm height, and 5029.2mm width. It has a load-carrying capacity of 272kgs, covering a range of 50kms in 20 minutes time duration. With the Pop.Up Next, Airbus, Audi, and Italdesign have combined a self-driving car and autonomous passenger drone. The Pop Up Next system is comprised of an air capsule, a cabin, and a ground module. An electric car drivetrain with the mobility of an all-electric drone, the passenger cabin is transported on land by an Audi chassis and allows air travel via an Airbus drone. It's a modular all-electric drone vehicle that transforms from a car to a flying passenger drone and back to a car again. The interior space has a 49-inch screen. The interaction between passengers and the drone is performed by speech and face recognition, eye-tracking, and a touch function. It offers a seamless travel experience. They also have various interior themes to select from(Filippo Perini, 2019). The interior has a monochromatic color palette as shown in fig 6.



**Fig 6. Pop Up Next (Vlad Savov, 2018)**

### **2.7 Surefly**

Surefly is a semi-autonomous drone with two passengers seating space or one passenger and a little bit of luggage space. It has a load-carrying capacity of 181kgs, covering a range of 110kms in 60 minutes time duration. The interior cabin is equipped with a joystick and moves the aircraft forward. In case of any emergency, it has a ballistic parachute to catch you before you hit the ground (Vertical Flight Society, 2020). The interior has a grey and blue color palette as shown in fig7.



**Fig 7. Surefly (FAIR LIFTS, 2018)**

## 2.8 Uber Elevate

Uber Elevate is a semi-autonomous passenger drone with four passengers and one pilot. “ It has a dimension of 7300mm length, and a load-carrying capacity of 446kgs, covering a range of 246.4kms. It aims to create an aerial taxi service by 2023. The concept is designed for "rider-first mentality," and is "pedestrian friendly". The high propeller blades leave ample room for the ingress and egress of the passengers. The high placement of the wings also provides sheltered entry into the cabin. The interior features have yet to be given by the company. From the picture below, it does follow a boxy design with minimal intervention of design elements(Hawkins, 2020). The interior has a monochromatic color palette as shown in fig 8.

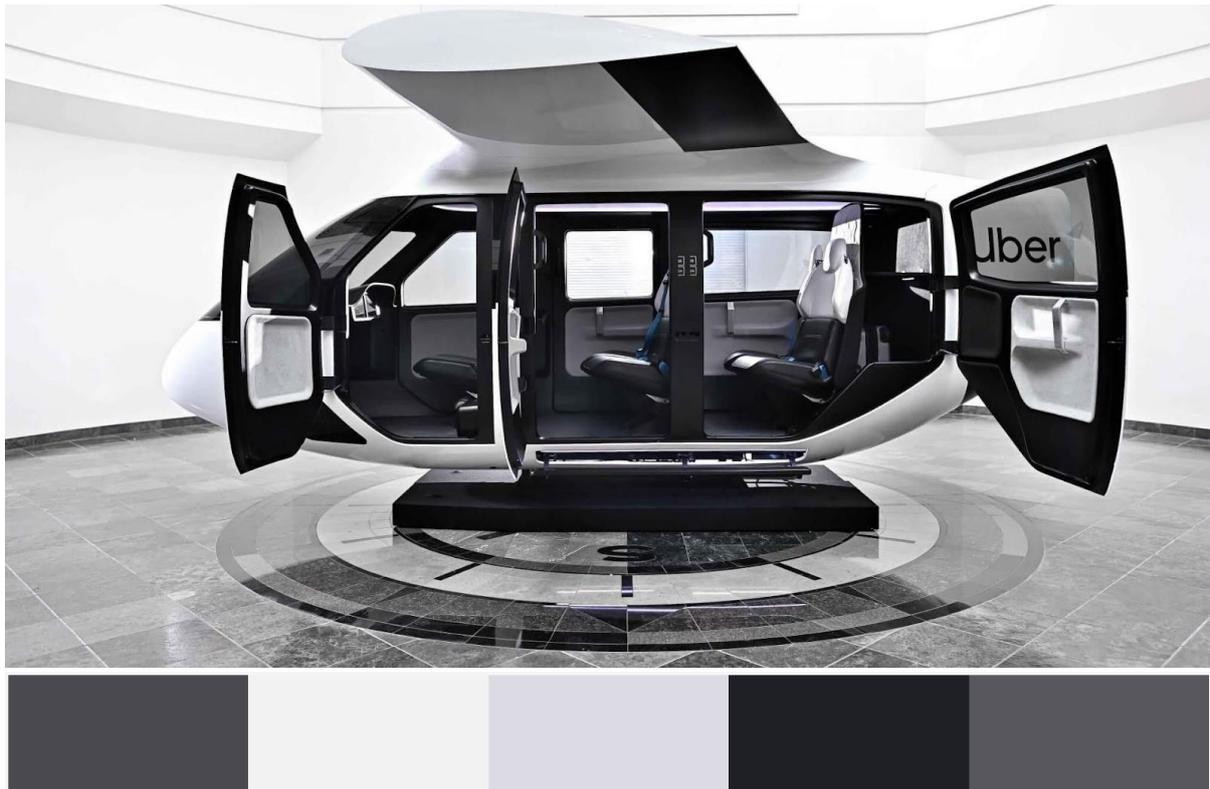


Fig 8. Uber Elevate (O’Kane, 2019)

The literature reviewed so far has revealed the advancement of technology and its interaction with human. The development of passenger drones in various parts of the world has given us a possibility of a new mode of transportation for intracity commute in urban sectors. Literature review has revealed the work done so far is mainly in the area of the exterior design of passenger drones. The researcher could not find much research in cabin interior design. The research available is in interior cabin design of luxury segment cars and airplanes. As the interior cabin design of passenger drones is not explored vividly, the researcher has decided to undertake this study and explore further in the design and development of the passenger drone interior cabin design for India.

## 3 Methodology

Several methodologies were combined together to design and develop the passenger cabin. “The research was undertaken in order to gain new insights partly by means of practice and the outcomes of the practice is called practice-based research” as stated by the author (Candy, 2006). The final study should claim original documentation of new knowledge through creative outcomes that may include artifacts such as images, music, designs, models, digital media, or other outcomes such as performances or exhibitions. In addition, the document should include the significance of the above outcomes described in words along with direct references.

As developing a full scale passenger drone required constant design changes, the researchers also followed Agile Design Research. The Agile Design Research methodology lays down the framework to come up with empirically driven solutions in the most meaningful way to unanticipated problems(Conboy et al., 2015). Fig 9 explains the various steps in this process.

Step 1: Problem identification

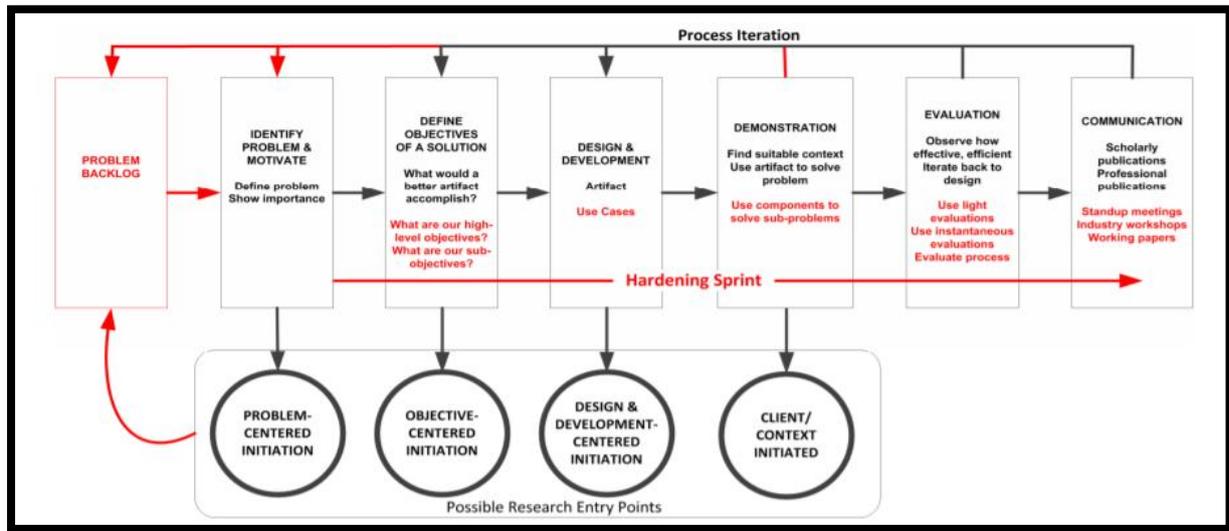
Step 2: Defining objectives of a solution

Step 3: Design and development

Step 4: Demonstration and implementation of the design and analysis of the test.

Step 5: Evaluation of the design as the fifth step, and then communication of the above via documentation .

Step 6: Balancing agility and rigour or Hardening the Sprint.

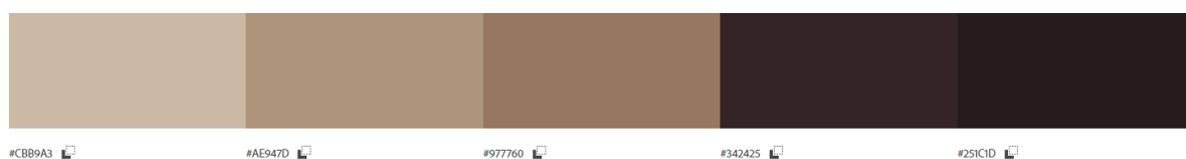


**Fig 9. Agile Design Science Research Model**

The methodology used was practice-based research along with agile design research. This involves creative outcomes within a short time span of the sprint in design of passenger drone interiors and documentation of the process. Design thinking was also applied to create innovative solutions(Design et al., 2017). The five stages of design thinking which were applied are: define, research, ideate, prototype and test helped the researcher create innovative solutions.

**4 Building the Prototype:**

As a part of the practice-based approach, the researcher started with ideas for the futuristic passenger drone cabin for a single seater with dimensions of 1500mm height\*1200mm width\*1500mm length. The vehicle package was first designed to get an overall idea of space. The researcher then started with making the mood boards and inspiration boards. Each phase of design was an iterative phase done in a sprint cycle of 14 days following the agile design research methodology. The keywords taken for the inspiration were minimalistic and smart. The interior color scheme for the existing products from the literature gave insights on the futuristic color trends and schemes. The color schemes chosen for this prototype were warm and neutral minimalistic color palette. The researcher chose the color trend for this futuristic passenger drone to be minimal, sophisticated, and safe as shown in the figure below(BASF’s 2020-2021 Automotive Color Trends, n.d.)(Liu, 2020).The exact color values were extracted using the software Adobe Color.



**Fig 10. Monochromatic color palette**

The researcher then started with the ideations of the dashboard as shown in the fig 11.

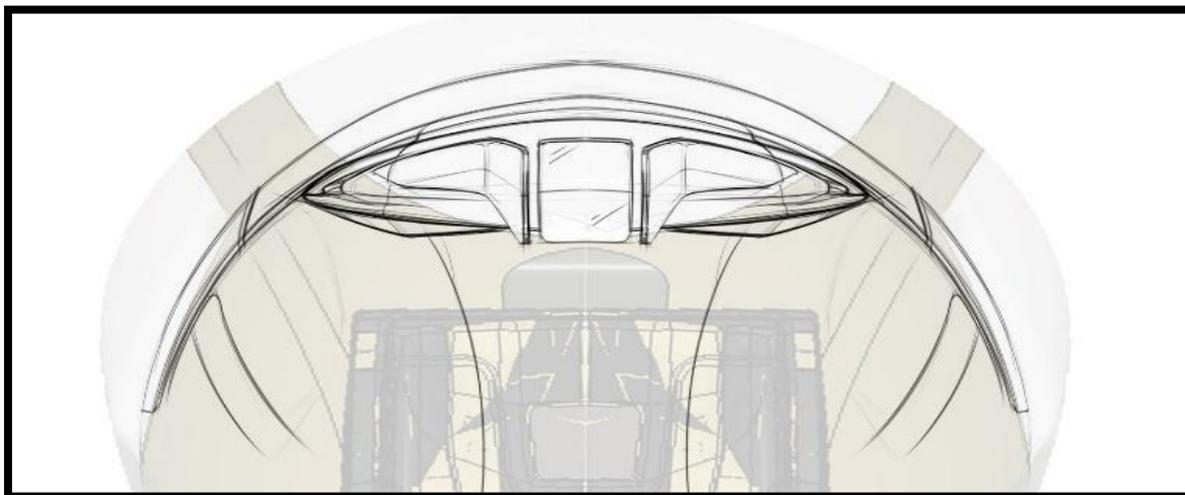
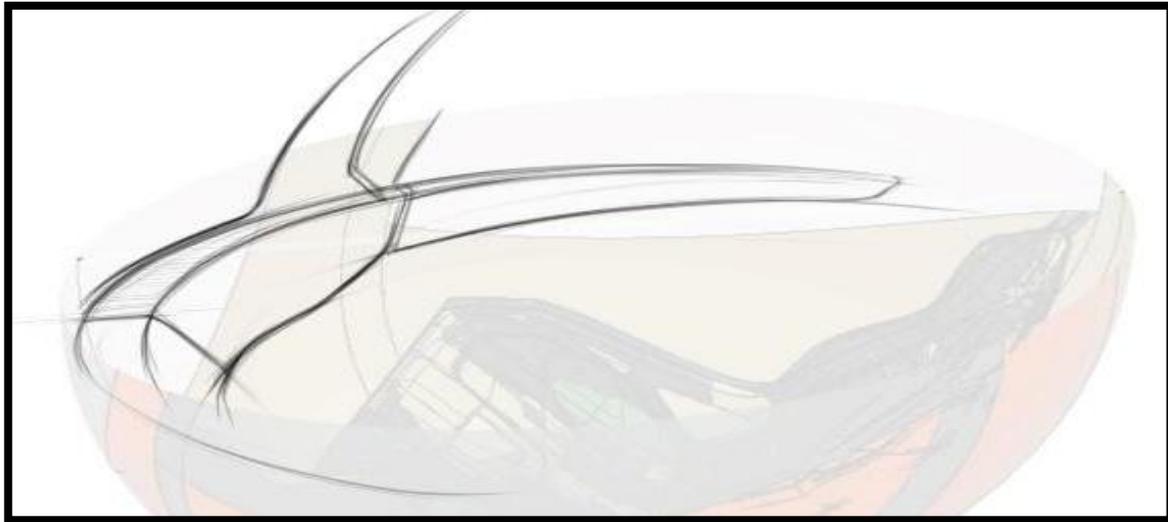
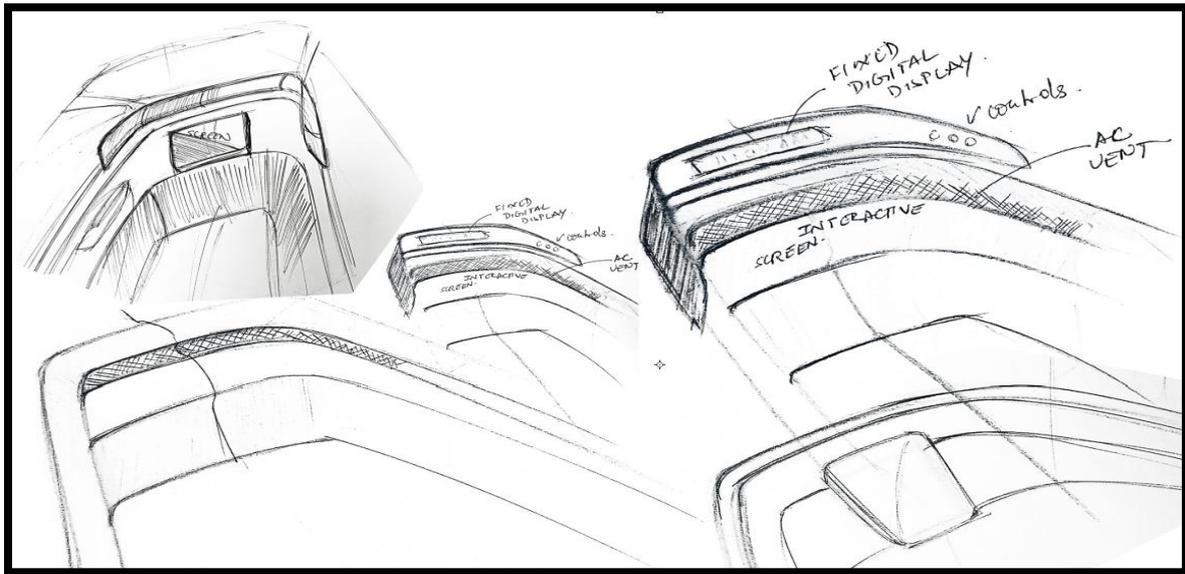
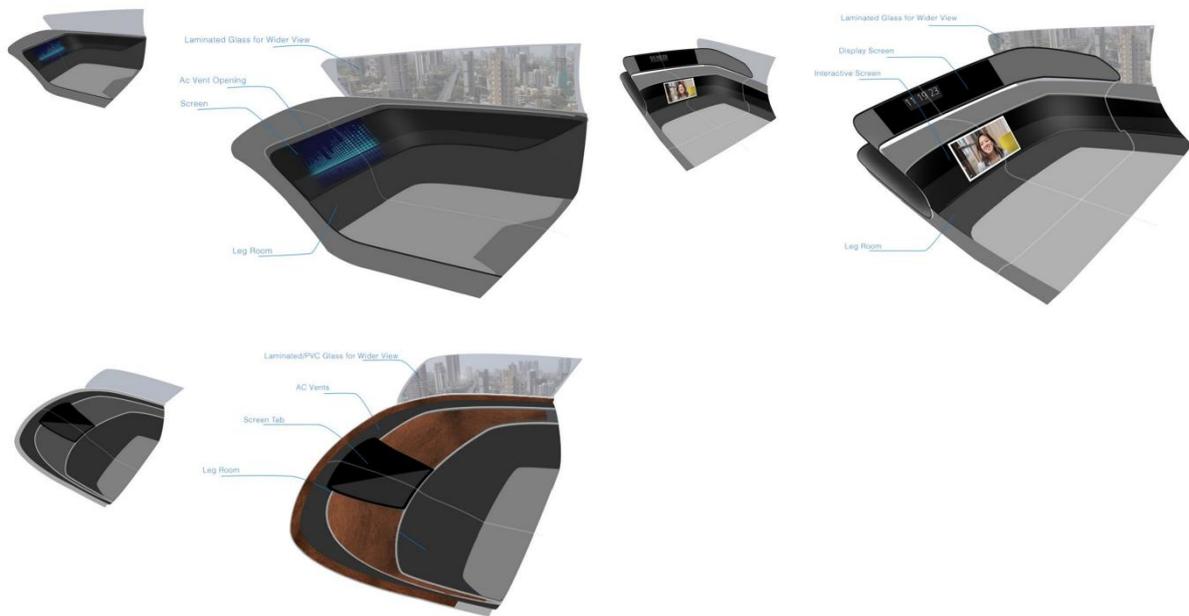


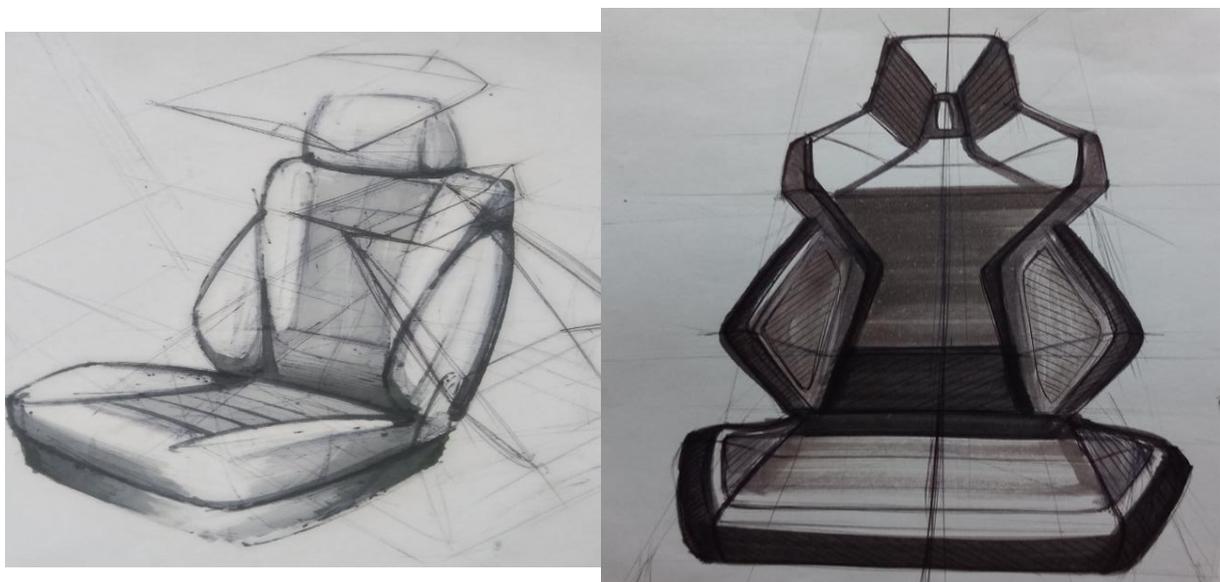
Fig 11. Dashboard Ideations

The researcher made photoshop renders to get better understanding of the surfaces in grey scale and also added wooden texture to one to gain better insight as shown in fig12.

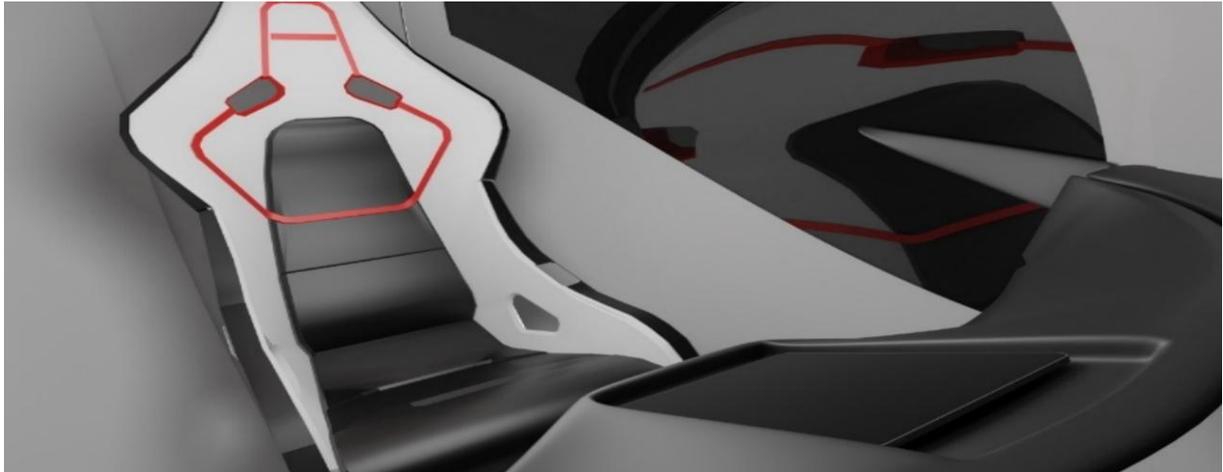


**Fig 12. Dashboard Renders**

Once the dashboard was explored vividly, the researcher then moved to ideating the seat as shown in fig 13. The seat was designed as per the ergonomics data (Reed, 2022). The dashboard design was later simplified further to give an openness feeling to the user in a compact space. Thus, creating an illusion of a bigger space.



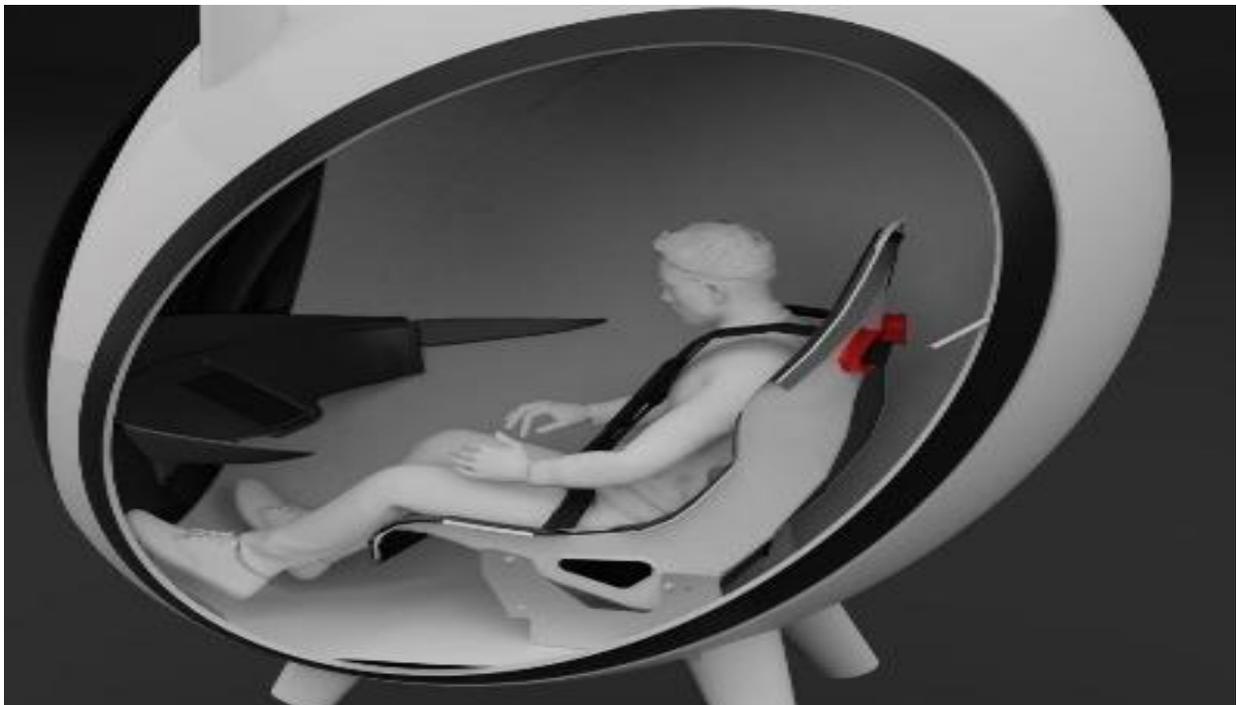
**Fig 13. Seat Ideations**



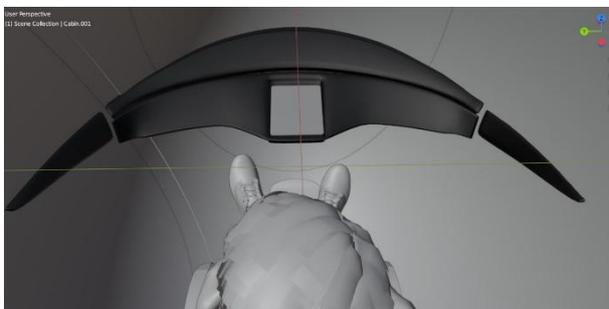
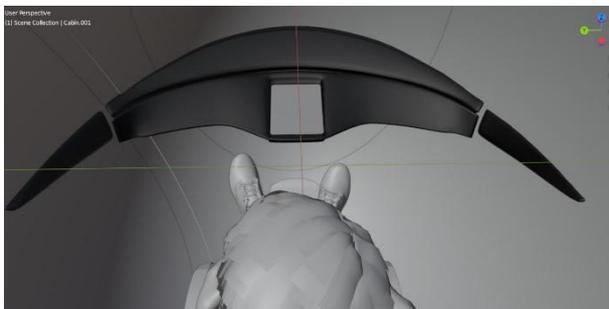
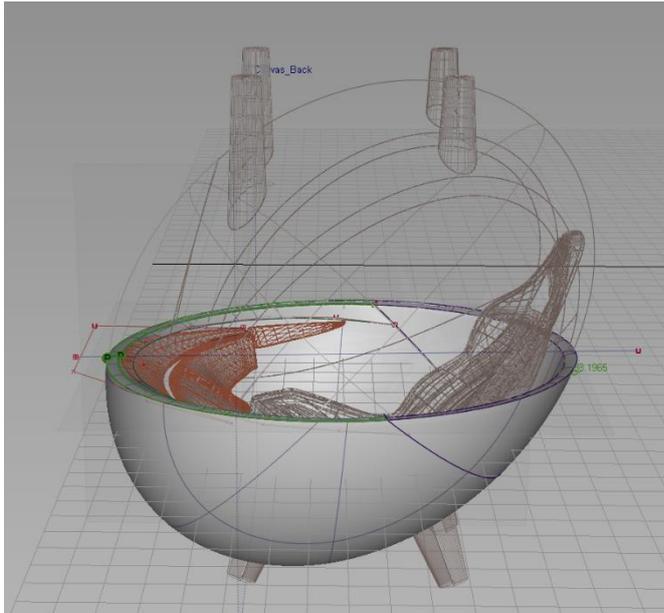
**Fig 14. SeatRender**

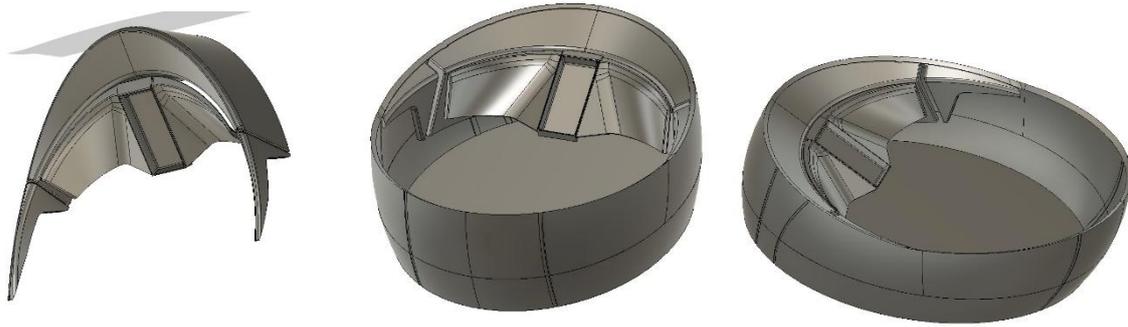
#### **4.1 Development of Interior Model**

The interior space design started with vehicle packaging. The seat was first defined. Due to space constraint, non-reclining seat was chosen with a fixed recline angle. The battery was kept below the seat. A 3 point seat belt was chosen similar to that of a car. As the result of the survey, some of the basic accessories required like mobile holder, cup holder, and a magazine holder were then placed. To give a illusion of bigger space the researchers designed the dashboard with just a tablet and light. All the accessories were designed embedded within the side panels. The large windshield and side windows were chosen for a wider visibility. Once the final render was decided as shown Fig 15, 3D modelling was done.



**Fig 15. Inter Cabin Render**





**Fig 16. 3d Models of Interior parts**

#### **Development of Interior Scaled Model**

A 1:6 scale model was developed to get a better understanding of the interior space in the software's: Fusion 360 and blender. The model was 3d printed as shown in fig 17. This model gave the understanding of the space inside the cabin. The placement of various accessories were then decided.



**Fig 17. 1:6 scale 3d printed Model**

A full-scale 1:1 physical cabin prototype was further built with light weight materials. Carbon fibre was used for building light weight structure. The materials used in the interior followed the color combination as shown in fig10. Soft fabric dual tone was used for the seat to give the user extra comfort. The entire cabin fabric was covered with rexine. The materials used were all easy to maintain. Lighting was added in the dashboard area and in top section. A push button was designed for the user to operate the lights. Fan was provided inside this prototype for ventilation.



**Fig 18. Full Scale Fabrication of Interior Cabin**

## 5 Conclusion and Future Scope

As a practice-based approach to designing and developing a passenger cabin for fully autonomous passenger drone, the researchers used several methodologies to predict the user requirements for a futuristic intracity travel experience. Several methodologies including practice-based approach, agile design research, and design thinking were used to determine the design requirements. The researchers started with the design thinking and brainstorming, then based on the user survey; the interior design parameters were decided. Multiple user surveys were conducted to understand the current travel experience and project the same for the future. The interior accessories and color scheme was chosen as a result of survey analysis conducted. The materials chosen were as per the aerodynamic standards. Once all the data was collected, the researchers started with ideations, followed by renders. A full scale digital 3d model was developed to visualise the entire cabin with all ergonomic details. This was an input for the 3d printed prototype in 1:2 scale. The final physical model prototype was then designed in a duration of two and a half months.

Practice based approach led to making multiple creative outcomes like ideations, renders, 3d models, physical 1:2 scale prototype and full-scale physical prototype. This approach along with the agile design reach methodology gave the researcher freedom explore various possibilities in short time duration of a sprint cycle. The future scope of this project is to conduct user testing on this prototype and document the results.

## 6 Research Funding

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