
VOYAGE

CONTENTS

ABSTRACT

With 68% of the population living in cities by 2050, last mile delivery expected to witness a CAGR of 20.3% and more people taking private rides than ever, urban environments are expected to endure an unsustainable level of congestion. This project aims to address these pressing issues through design engineering practices in order to develop a product service system viable to implemented in 2041. To achieve the objective of reducing congestion, targeting a premium user group, who resist shared mobility such as public transport, as well as developing the novel idea of ride-parcel pooling would lead to reduce the overall number of vehicles on urban roads along with higher utilisation of vehicles.

Three main areas of development were explored. User experience designed for premium users was developed through human centred techniques and rigorous user testing with a VR demonstration, with the outcome being a private experience within a shared vehicle that can be personalised to the user though AR, audio experience and deliverables such as food/drinks directly to the passengers. To enable parcel delivery using the same vehicle, a novel concept of a flexible vehicle structure was designed and developed, which enabled users to be transported during peak travel periods, and parcels to be delivered at off peak times. Through discussion industry experts, the basis for the systems algorithm was developed and through use of economics for systems design, the financial impact as well as the urban impact. It was realised that through the PSS, named VOYAGE, with a fleet of 4000 deployed in London, 6 privately owned cars would not be required for every Voyage vehicle in urban areas along with a 30% decrease in traffic during peak time from rescheduling and optimising delivery could be achieved.

MEET THE TEAM

The Voyage team comprises of 5 Design Engineering students from Imperial College London. The team worked closely with project tutor Stephen Green, as well as collaborating with students from Technische Universität München (TUM) during the project. Industry experts were also consulted during the development of Voyage in order to ensure feasibility and validation.

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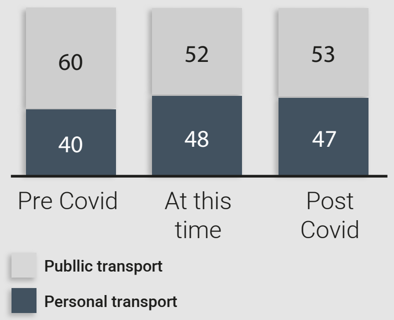
THE CONGESTED FUTURE OF CITIES

A report from the United Nations estimates that **68% of the world population will be living in cities by 2050** (UN, 2021), double the current urban population. With urbanisation increasing, cities are becoming the focal points of the world. It is therefore crucial to predict future trends in these areas, and identify potential issues, in order to mitigate challenges in this setting. To get a well rounded view on future urban areas, a STEEP analysis was undertaken, and from this key related issues were picked out and researched further. **Congestion was found to be the key challenge of future urban environments.**

USERS DEMAND FOR PRIVATE RIDES

From a report by Mckinsey (McKinsey, 2021), the COVID-19 pandemic has **increased the proportion of urban users taking private rides**. This increase and high percentage of users taking private rides directly correlates to higher urban congestion. It is evident from data in the Mckinsey report that **higher number of people using personal transport contributes to a higher traffic congestion, in many major cities**.

There is an increase in services such as Zipcar (Zipcar, 2022), but this still leads to users using an individual vehicle, with no significant improvement to cities public transport, or ride-sharing schemes such as Uber Pool and Lyft (Onde, 2019), **this proportion of people using private rides is not likely to decrease in the near future**.



FUTURE SCOPE WHEEL

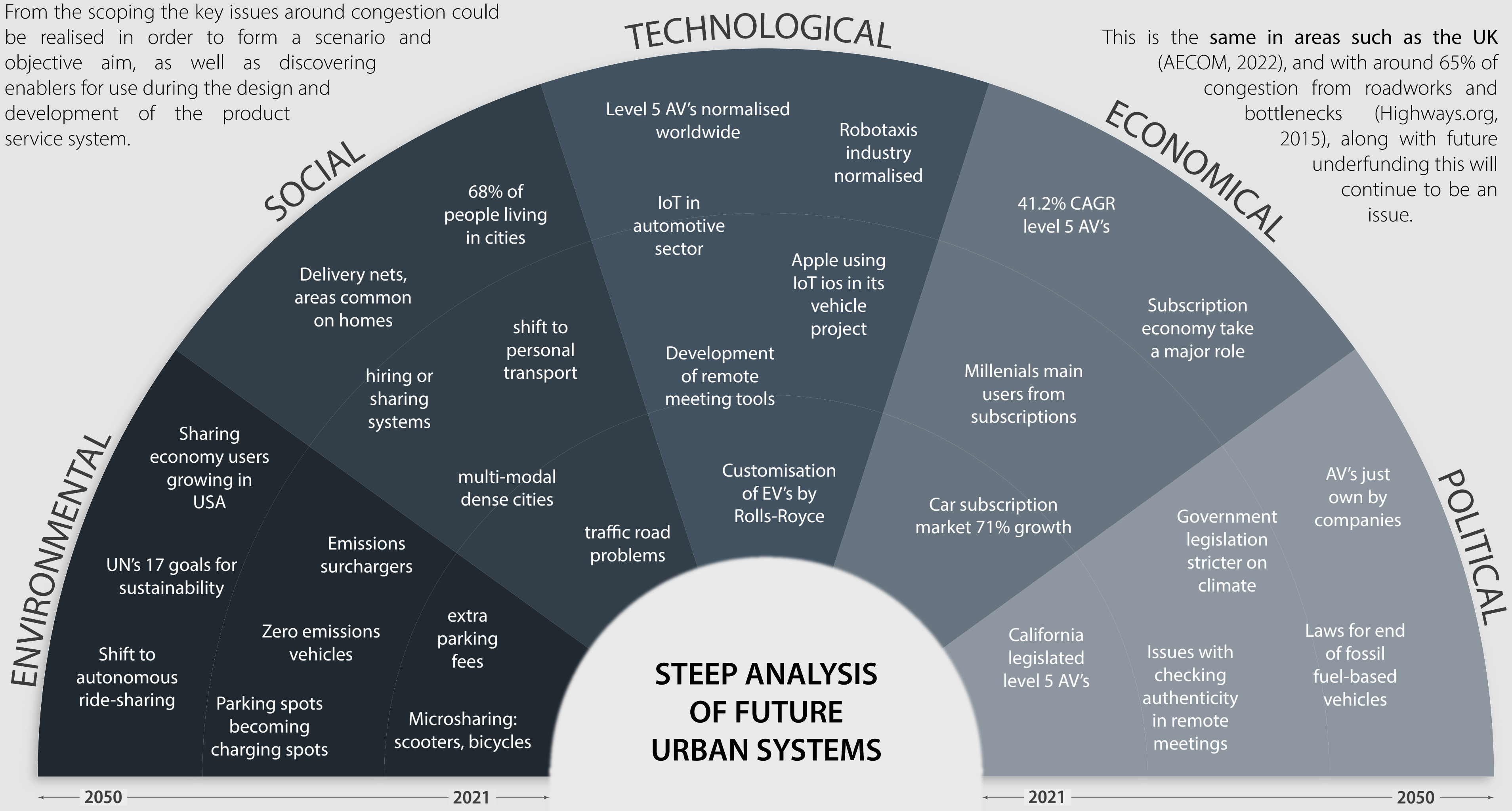
By producing a future scope wheel, future issues could be identified, as well as future technology and other enablers in the social, environmental, economical and political categories which will be utilised throughout the project in the developing the solution.

From the scoping the key issues around congestion could be realised in order to form a scenario and objective aim, as well as discovering enablers for use during the design and development of the product service system.

UNDERFUNDED TRANSPORT INFRASTRUCTURE

In many countries, the infrastructure is heavily underfunded.. American Society of Civil Engineers published a report (TTNews, 2020) stating that **transportation infrastructure has been underfunded for years** and that **$4.1 trillion will be needed from 2020 through 2039** to sustain infrastructure. During this period, about $2 trillion spending is projected, leaving a gap of $2.1 trillion.

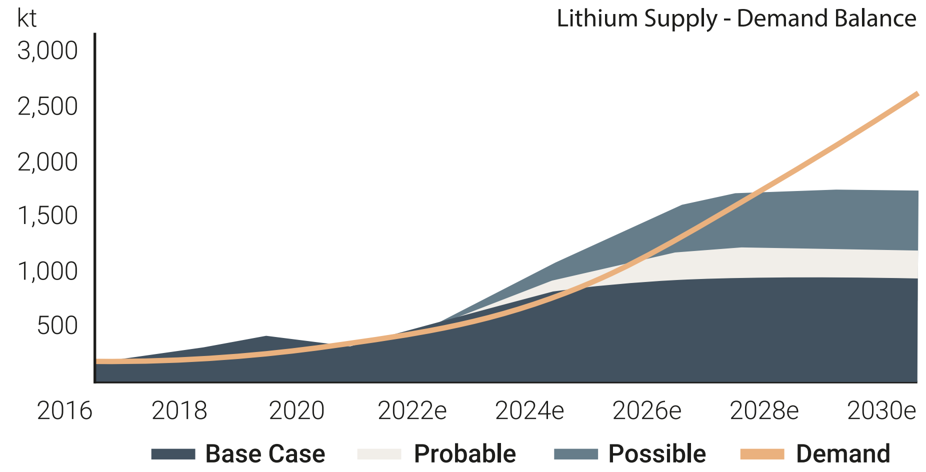
This is the **same in areas such as the UK** (AECOM, 2022), and with around 65% of congestion from roadworks and bottlenecks (Highways.org, 2015), along with future underfunding this will continue to be an issue.



UNSUSTAINABLE VEHICLE UTILISATION

With users owning their own vehicles, it is a known fact that cars are heavily under utilised. On average, **cars are parked 96% of their life** (RAC, 2021), and in cities such as London, they **take up over 14km² in space** (City Monitor, 2020).

Not only is valuable urban space being taken up by vehicles, but the amount of resources in a future car such as the lithium batteries are also being heavily under utilised. With the prediction that **lithium is due to run out potential as soon as 2040** (Pv Magazine, 2020), and due to increasing demand, the **supply of it could be under stain within the next few years** (The Irish Times, 2021), this utilisation issue is a crucial issue to resolve.



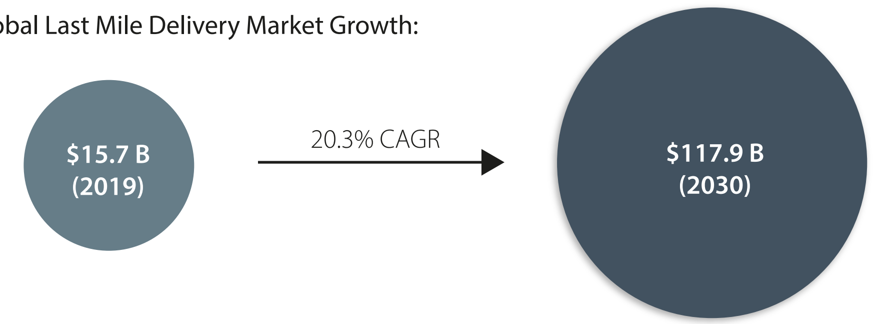
INCREASE IN DELIVERY DEMAND

Between 2020 and 2030, the global market for last mile **delivery is expected to witness a CAGR of 20.3%** (P&S Intelligence, (2021). There are also more varieties of deliveries, and with increasing consumer demand of deliveries in terms of the speed of the service, so it is critical there is infrastructure to meet this.

It is likely that there will be disruptor's in this delivery industry, with companies such as Magway (Magway, 2022) revolutionising **middle mile delivery by using underground tunnels to deliver parcels** from warehouses to 'portals' in urban areas, 3000 articulated lorry loads through a single 1m diameter pipe, every single day. However, this **does not solve last mile delivery**.

Magway are planning to interface with other future vehicles such as electric delivery vans, as well as autonomous delivery bots, however these last mile delivery forms could still have a negative impact on traffic flow.

Global Last Mile Delivery Market Growth:



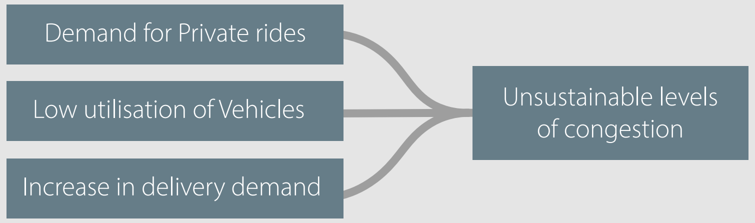
Another solution to delivery is **drone technology,** which has undergone trials from global companies such as Amazon (Wired, 2021) to solve this last mile delivery issue, but issues with drones **range and air traffic pollution are large limitations for this technology.**

PROJECT DEFINITION

From the future scoping, it is clear to see that **urban congestion is going to become a huge issue in 2040.** This is **made up of 3 main drivers;** users lack of wanting to move to share mobility, the low utilisation of vehicles, and the increase in the delivery sector.

MAIN DRIVERS AND TRENDS

The demand for private rides, the low utilization of vehicles and the increase in delivery demand have a huge impact on urban environment, resulting in unsustainable levels of congestion.



SCENARIO - PREMIUM MOBILITY AND DELIVERY ISSUES

Level 5 fully autonomous vehicles have been legislated in urban environments, but companies operating these **services have trouble meeting needs of private travelling users d**ue to the public feel of their shared mobility vehicles. Therefore congestion is worsening due to high private vehicle usage, and also due to an **increase in delivery demand**.

From this there are 2 challenges; **ensuring private mobility users, defined as 'premium users' shift to shared mobility** and **dealing with the increase in delivery demand to prevent higher congestion**. These are combined to form an overarching project aim.

OVERARCHING PROJECT AIM

"Reduce urban congestion by designing an efficient product service system combining shared premium mobility and last mile parcel delivery"

ENABLERS FOR FUTURE DEVELOPMENTS

Future enablers, not only technological but also political and social, will aid in the design solution of both shared premium mobility services and also last mile parcel delivery. A literature review detailing additional enablers can be found in the phase of this project (report A).

2021

Autonomous Vehicle Technology

With AV's already being tested in urban cities (Engadget, 2021), it is expected that they will be ready for commercial use, with advanced sensors and data making them safe to implement.

Subscription Economy

This is projected to make a significant contribution to global GDP in 2040. In the last 9 years, it has grown 435% across all areas (Kalim, 2021), and notably, in 2018, the car subscription market was predicted to grow by 71% by 2022. (PYMNTS, 2018).

Autonomous vehicles Legislation

California has already legislated Level 5 Autonomous Vehicles on public roads (State Scoop, 2021), however, this only applies to company-owned vehicles.

5G Connected Systems Tech

Implementation of IoT in the automotive sector could facilitate the fast transmission of data between autonomous vehicles related to location, speed, and dynamics (BizIntellia, 2021).

AR/VR Technology Adoption

Headsets are expected to decrease in size (PRNewswire, 2021), and become a standard piece of tech for many consumers in urban areas, and also be able to contain more advanced connectivity features.

Smart Materials

Advances and availability of materials such a E-ink (BMW, 2022) allows exterior and interior of vehicles to be customised and given improved cleanliness factors, due to advances including photo-catalytic coatings

UAV Technology

Delivery of parcels and user goods can be performed by unmanned aerial vehicle (UAV) technology. By 2040 users will also be expected to accept drone deliveries to their house or flat.

Middle Mile Delivery Revelation

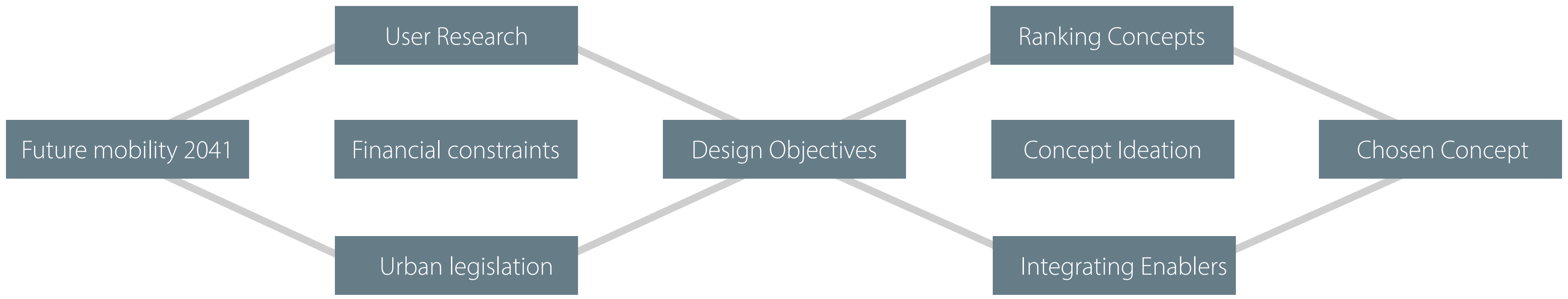
Magway (Magway, 2022) revolutionising middle mile delivery using underground tunnels to deliver parcels from warehouses to 'portals' in urban areas, 3000 articulated lorry loads through a single 1 m diameter pipe, every single day.

2041

FORMULATING DESIGN OBJECTIVES

To be able to create an innovative futures concept, the overarching project aim had to be broken down into smaller design objectives. From the work done in phase 1 (Phase 1 Report, 2021) the user specific objectives were curated from user interviews and research. Other objectives were identified in order to ensure the system could be financially viable, as well as meet standards for road vehicles including size and safety.

From the design objectives, a range on concepts were produced, when can be found in the phase 1 report (Phase 1 Report, 2021).



SYSTEM DESIGN OBJECTIVES

- Reduce congestion by decreasing the number of private cars on the road, using shared mobility
- Reduce courrier congestion by integrating parcel delivery into a passenger vehicle
- A novel solution utilising future tech in 2041. Shift the paradigm of what sharing a vehicle looks like
- VOYAGE should not exceed current vehicle dimensions (2.1m x 4.7m) or be exceedingly heavy.
- Ensure that vehicle can accommodate parcels and users 'on the fly' without requiring no additional infrastructure for this 'transformation' to happen.

USER SPECIFIC OBJECTIVES

- Empower users to create their own space within a shared vehicle
- Provide a service in which the user feels safe, in terms of the vehicles capability and environment
- Design a seamless and reliable service from when the user requires VOYAGE, to when the ride ends

DELIVERY SPECIFIC OBJECTIVES

- Create a economically viable system that businesses will use for delivery
- Aim to deliver not all parcel sizes, but the most common in urban areas
- Ensure that for customers, the service is safe and convenient

INITIAL PSS - PHASE 1

An initial concept was designed during the first phase of the project, consisiting of a modular pods with an adjustable chasis depending on user demand. This initial vehicle concept and the feedback explained below was then utilized as a starting point for the project's second phase development.

DEFINING DESIGN REQUIREMENTS - SARM METHODOLOGY

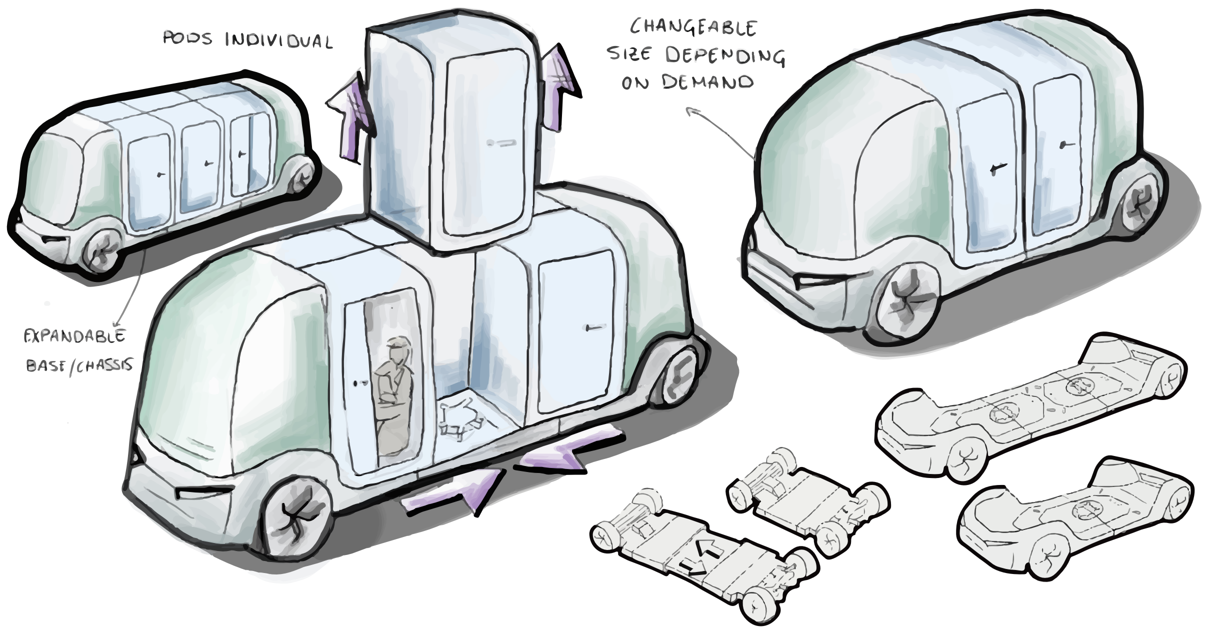
Initial brainstorming and concept ideation to fulfil the previously stated design objectives resulted in three types of vehicle layouts; social space where passengers interact, individual vehicles for each user or a hybrid mode where various users share a vehicle but have private ride experiences. To validate this, the "Solution Architecture Review Method" (SARM) was used. It provides a means of exploring alternative ways of implementing (or acquiring) a solution in a structured manner, taking into account the different stakeholder interests in the solution, and ensuring that the relative merits and disadvantages of competing solutions are properly considered (Field, 2018). The design objectives were user to evaluate our three designs from the perspectives of four key stakeholders. With the stakeholder interests relative to the system-level requirements complete, SARM shows that our most important stakeholder is our own business system.

Stakeholder	Social	Individual	Hybrid
User	10.70	6.00	6.30
Vehicle System	9.78	9.91	7.30
Transport Authority	7.56	11.56	7.56
Other road users	3.00	15.00	7.56
Risk	31.04	42.47	27.16

Characteristic	Social	Individual	Hybrid
Functionality	5.67	7.33	3.67
Usability	10.75	7.50	7.00
Security	13.00	9.00	7.00
Reliability	15.00	5.00	10.00
Efficiency	5.67	13.00	8.33
Sustainability	12.50	9.50	6.50
Risk	62.58	51.33	42.50

MODULAR VEHICLE CONCEPT

From the SARM analysis, the hybrid concept was chosen, given its lowest overall risk burden, and its ability to provide a happy medium between the two opposing options in many cases. This was then explored in depth throughout the first phase and resulted in the Modular Vehicle Concept, a PSS for level 5 autonomous vehicles that enables a private ride experience within a shared mobility service. Multi person electrically powered modular cars divided into individual interchangeable body pods that can be attached to a standardized base containing the battery, power-trains and sensors. The pods are designed to cater for the needs of businesspeople commuting to work daily, therefore following a premium design. The adoption of AR/VR headsets will greatly enhance the users experience. The usage of smart materials including E-ink will also help to achieve the feel of a private ride, despite sharing the vehicle with other people.



TERM 1 FEEDBACK

Modular Design Technical Feasibility

- How easily can the pods be installed to/decoupled from a chassis? Where are extra pods stored to make sure one is free if needed?
- Single person pods within a modular design imply complex design engineering and system challenges, is there a better hybrid solution?
- Premium sharing service for businessmen is likely to be the case of sharing cars rather than sharing trips as businessman's time is valuable.

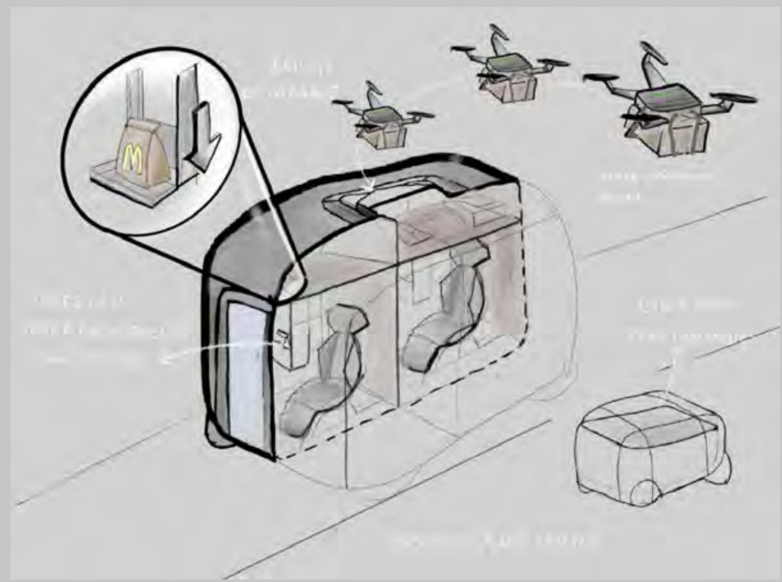
Urban Impact: Environment and congestion

- Apart from shared mobility, how might we make the system more efficient in terms of urban impact?
- What is the environmental impact of the concept? Link this data to system level logistical considerations related to the concept direction

From this feedback, a new vision for a vehicle that enables individual premium experience within a shared mobility system was created. The modular design was changed due to the complex system and unoptimised nature of removable pods that need to be stored/maintained.

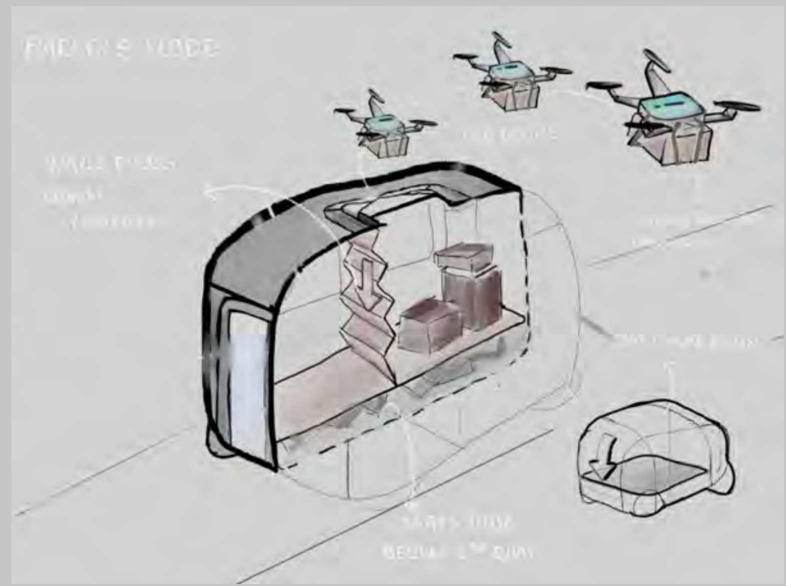
CONCEPT ITERATION: VOYAGE

The idea of having the private experience within shared mobility system was kept as the focus was to maximize the environmental impact by reducing the number of cars on the road. This is achieved by using the car's dead hours. During those off peak times there is little demand from users but high demand from parcels. Last mile delivery is predicted to grow exponentially in the following years and by using the same vehicles as the ones that transport users not only is congestion significantly decreased, but also less cars have to be manufactured. How might we design a vehicle that transforms?



TRANSFORMABLE STRUCTURE: the USP feature in our PSS that will allow this innovation in urban mobility is the 'on the fly' transformation between the user and parcel delivery 'mode'.

IOT CONNECTED SYSTEM: with the advance of 5G in urban areas and connected systems (BizIntellia, 2021), this new service can predict demand both for passenger rides and for parcel delivery while minimising congestion using machine learning, and plan optimal routes by communicating with middle mile delivery services, user journey patterns and traffic data.



PARCEL MODE: through the vehicle transformable structure, the vehicle can be optimised to deliver parcels. These will be parcels that are classed as 'large standard size' which measure up to 18x14x8 inches (Amazon Seller Central, 2022) and a study in China showed that over 50% of delivery items where less than 2kg (Kang, et al. 2021)and were small or medium corrugated boxes, or large and small plastic bags. Pipedream, who are a similar company to Magway, states that 85% of non-furniture e-commerce purchases and 95% of grocery items is 10" in or less in diameter and less than 16" long (Pipedram, 2022). With the middle mile delivery revelation and UAV technology, the service can pickup goods from the middle mile 'portals' within urban areas and deliver them. The advanced connected systems will also allow our service to communicate with the middle mile services and learn route patterns, along with the demand for last mile delivery.

REQUIRED DEVELOPMENT AREAS

- System design: developing the system implementation, the service and the impact that our system could have on urban areas.
- Human factors, UX and UI: hyper customised user experience design tailored to each user within the car
- Concept functionality and feasibility: detailing the mechanism and logistics of the transformation and the parcel mode delivery

SYSTEM LEVEL CONCEPT

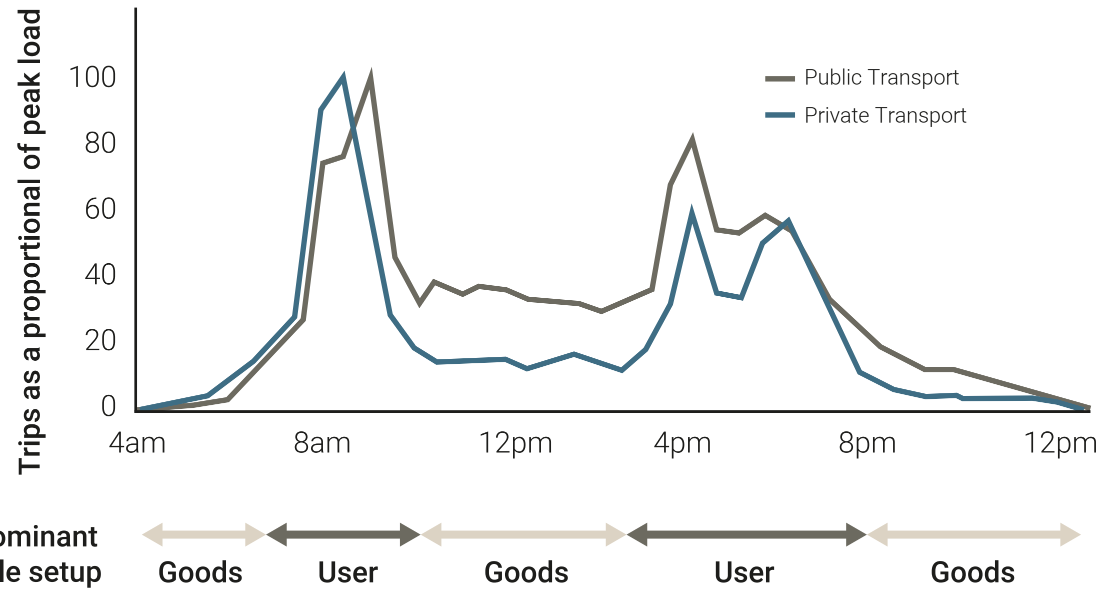
Before moving forward with the design engineering development process, it is important to show the **system that the service will be based on**. This was also developed throughout phase 1 and at the beginning of phase 2.

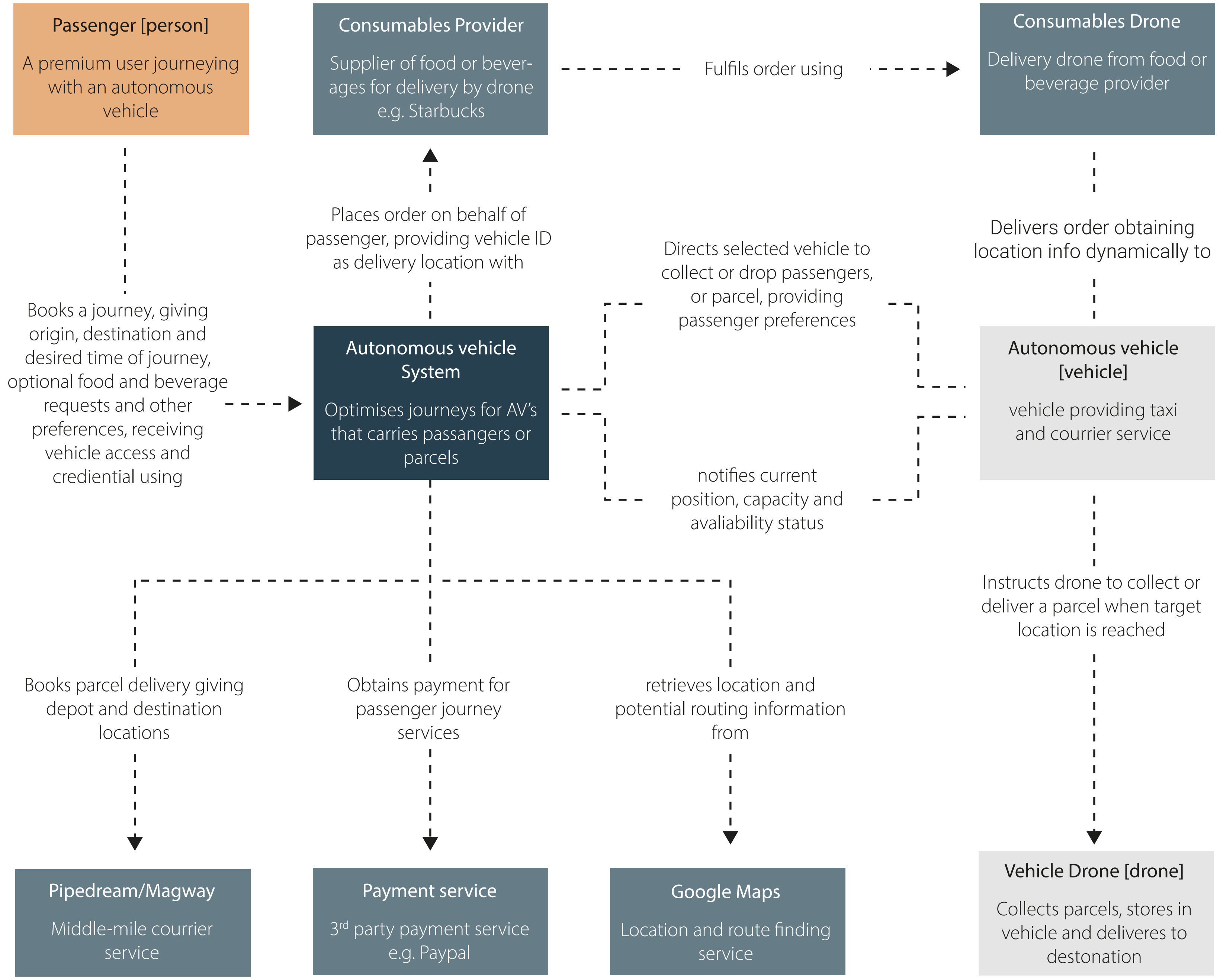
SYSTEM BREAKDOWN - C4 METHODOLOGY

From the two design aims, of parcel delivery and shared premium mobility, they were combined to form an overall proposed system. This system makes use of technology enablers such as drones, revolutionised middle mile delivery, and connected vehicles as well as infrastructure through 5G. The breakdown is done using the C4 method. This is 'level 1' of the system which is a simplified version so that an overview of all aspects can be clearly seen. For example, in the next level of the C4 diagram, the AV system box can be broken down further.

SYSTEM PRINCIPLE

The principle of the operation of the system is that the fleet of vehicles in the urban areas will be predominantly setup to user 'mode' during the peak demand for travel, and at off peak times they will mostly transform to parcel mode. With the enabler of 5G in urban areas so that cars are connected to a central system, which can optimise the fleet of vehicles depending on the demand. This optimisation will be further developed.



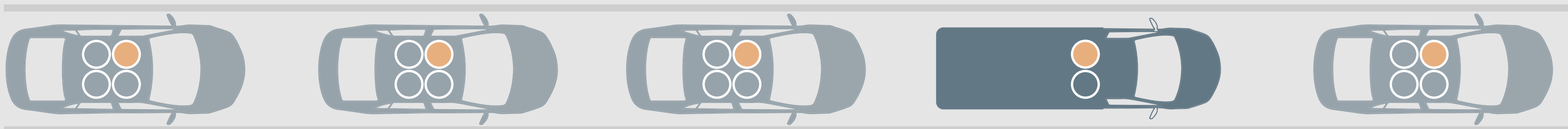


WHY WILL THIS HELP TO REDUCE CONGESTION?

By using this system principle, the vehicles will be utilised more and therefore less dead hours. There will also be less vehicles manufactured, and the vehicle is designed to be a '2 in 1' multi-purpose vehicle, leading to environmental benefits including a reduction in lithium battery manufacturing as this is a resource likely to become scarce or even run out in 2041 (Pv Magazine, 2020). By getting private mobility users to share, there is potential to fit users from 4 separate vehicles into 1, greatly reducing congestion. By delivering goods at off peak times, the number of delivery vehicles on the road at peak times will also be decreased. It will also allow goods to be delivered outside of normal delivery driver hours, but at time when people are likely to be home.

PREDICTED FUTURE SCENARIO

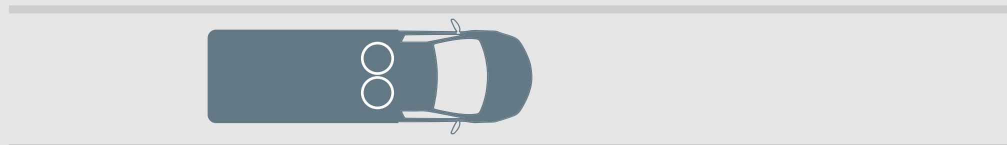
On-peak Road - Congested with private vehicles and delivery vans with the orange dots highlighting the people in the vehicles



POTENTIAL SYSTEM IMPACT

On-peak Road - Passengers combined into a single vehicle

Off-peak Road - Deliveries moved to off-peak times with no need for a driver

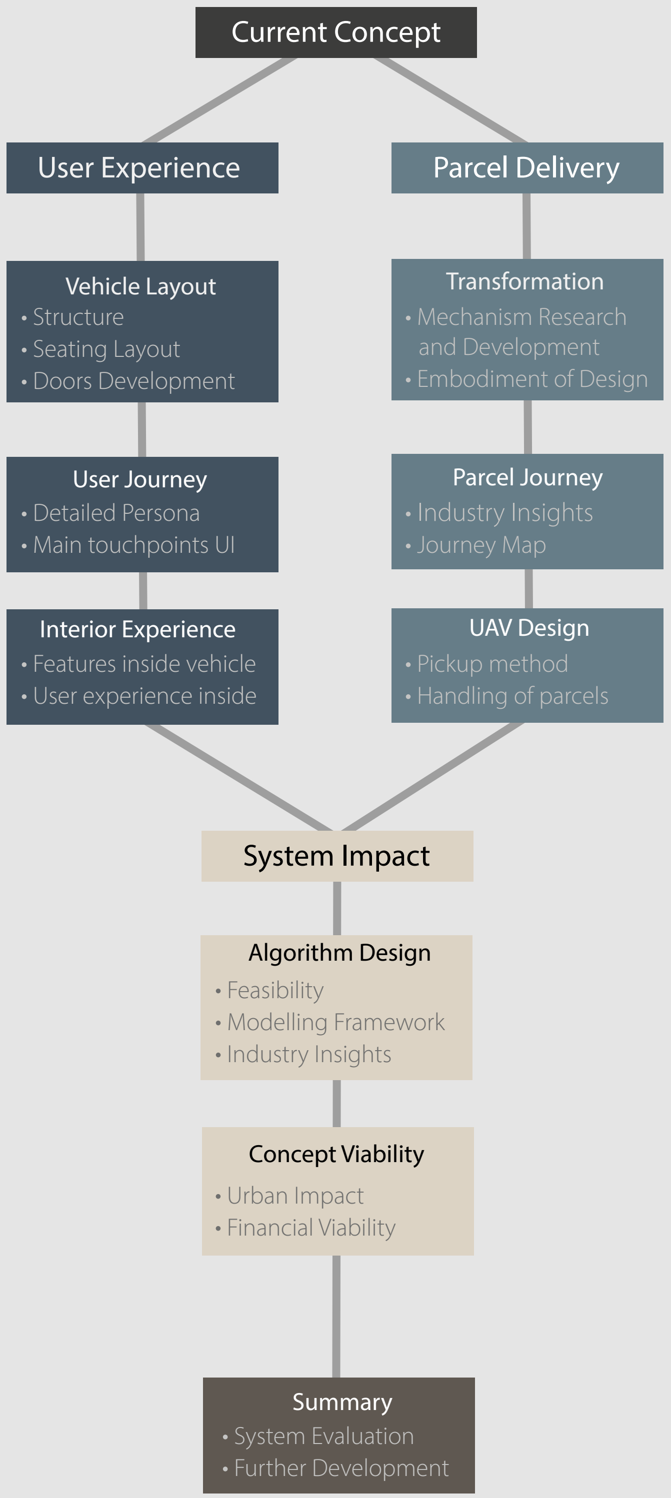


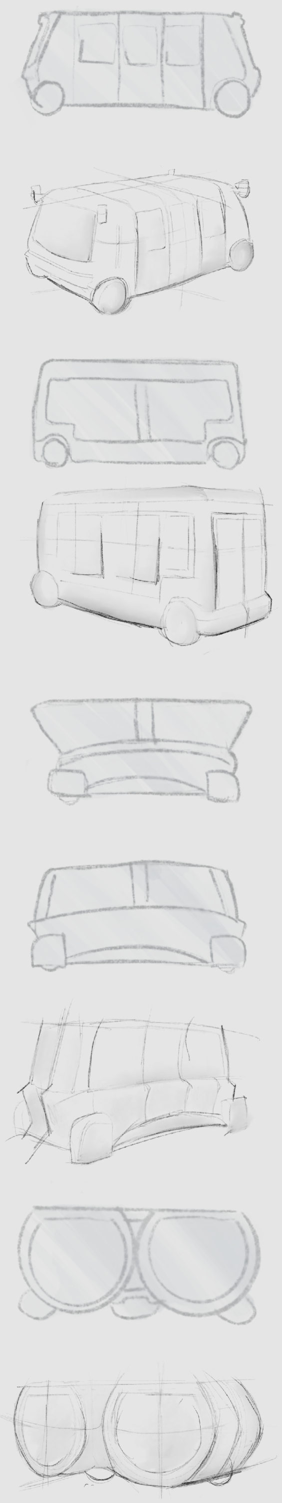
DEVELOPMENT PLAN

Transitioning from the Phase 1 of the project (term 1) to the Phase 2 of the project and utilizing the feedback obtained to iterate the ideas and develop the concept.

PROJECT DEVELOPMENT PLAN

The following diagram demonstrates the engineering design process in order to develop the constrains from phase 1. The two sides of parcel 'mode' and passenger mode will be developed, as well as the overall system design to optimise the service. With the final design financial, business and environmental analysis will be carried out to ensure viability.

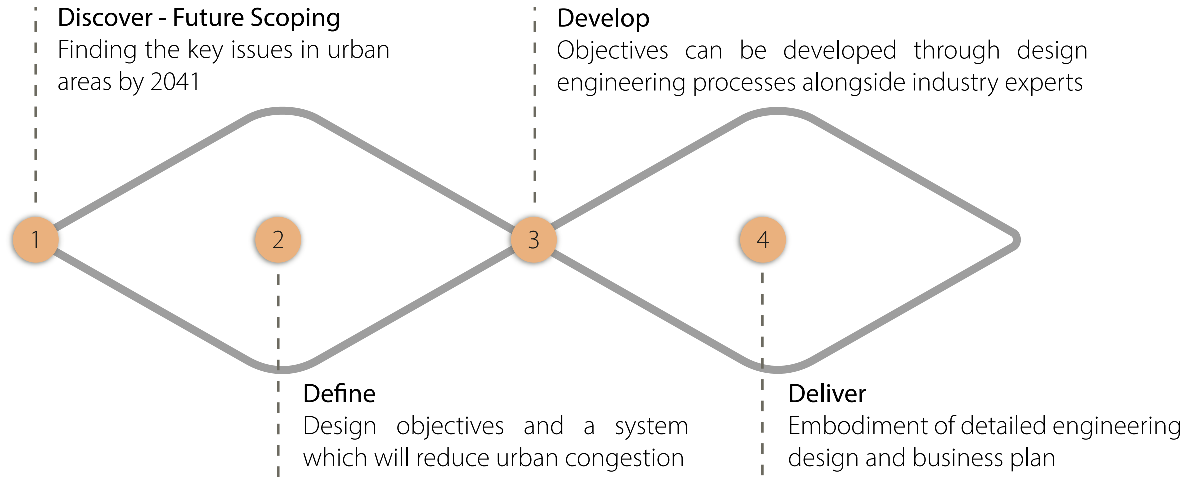




NEXT STEPS

By using the design engineering double diamond with the use of the Petra tool, the project is at stage 3 where the objectives have been stated, and the identified areas can now be developed and delivered in a digital embodiment.

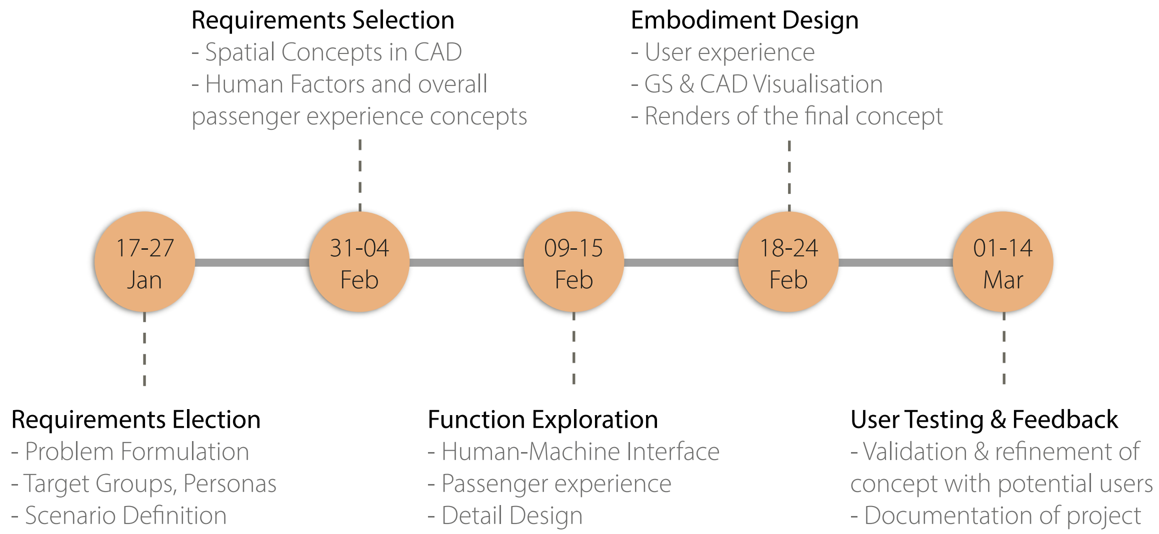
To start, we will explore the design challenge of the premium user sharing, and then continue the development by refining the addition of the last mile delivery challenge.



TERM 2 TECHNICAL UNIVERSITY OF MUNICH PARTNERSHIP

During the second phase of the project (term 2), a partnership with the Technical University of Munich was established.

Methodologies such as Agile were used and the team's time was divided into 5 sprints detailed in the graphic to the right. At the end of each sprint, a presentation was given to an expert from the mobility sector: Adam Pinkstone (Arrival), Maria Jose Perez Calvo (Zoox), Annette Böhmer (BMW) and Tom Child (Hyundai). They provided valuable feedback and validation which shaped the concept. Insights and feedback given can be found within the report.



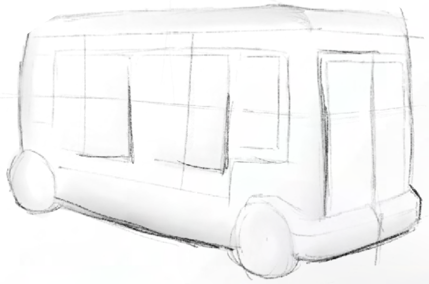
ENGINEERING DESIGN PROCESSES AND TOOLS

It is important to plan the processes and tools that the team are familiar with and where they will be applied during the development stage.

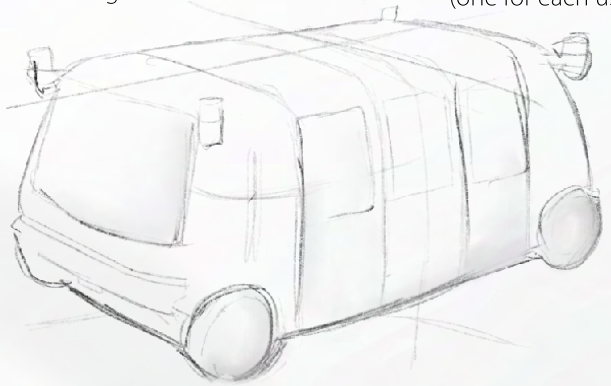
	DEVELOPMENT AREA	PROCESS	TOOLS
User Experience Design	Vehicle Layout - Wheels, Doors	Human Centered	Gravity Sketch, Procreate
	Vehicle Layout - Evaluation	Industrial - CAD & Rendering	Blender
	Persona and their user journey	Intro to Design Engineering - Personas	Illustrator
	Interior Elements	Human Centered - Ergonomics	Procreate, Gravity Sketch
	Visualisation	Industrial - CAD & Rendering	Blender
	User Immersion Design	Human Centered - Usability	Procreate, Blender, Unity
	Demo and Evaluation	Human Centered - Validation	Unity
Parcel Delivery Design	Mode Transformation Mechanism	Solid Mechanics	Procreate
	Parcel Journey	Intro to Design Engineering - Personas	Illustrator
	UAV Development	Industrial - CAD & Rendering	Fusion 360, Keyshot 10
System Level Detailing	System Implementation	Optimisation	
	Urban Impact of the system	Sustainable Design Engineering	Excel
	Financial opportunity	Econ and Finance for System Design	Excel

VEHICLE DEVELOPMENT

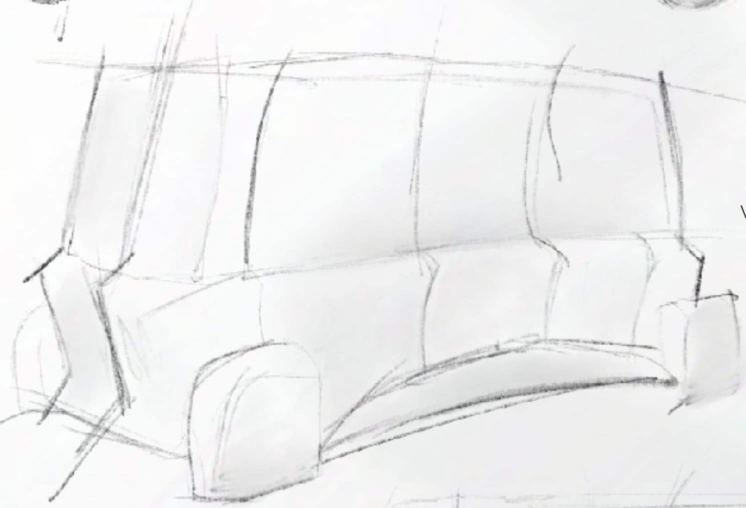
The vehicle exterior went through many modifications which can be seen in this page. The main iterations were the exterior shape, the wheels and structure and the doors.



Bus-like idea, too big and not innovative enough

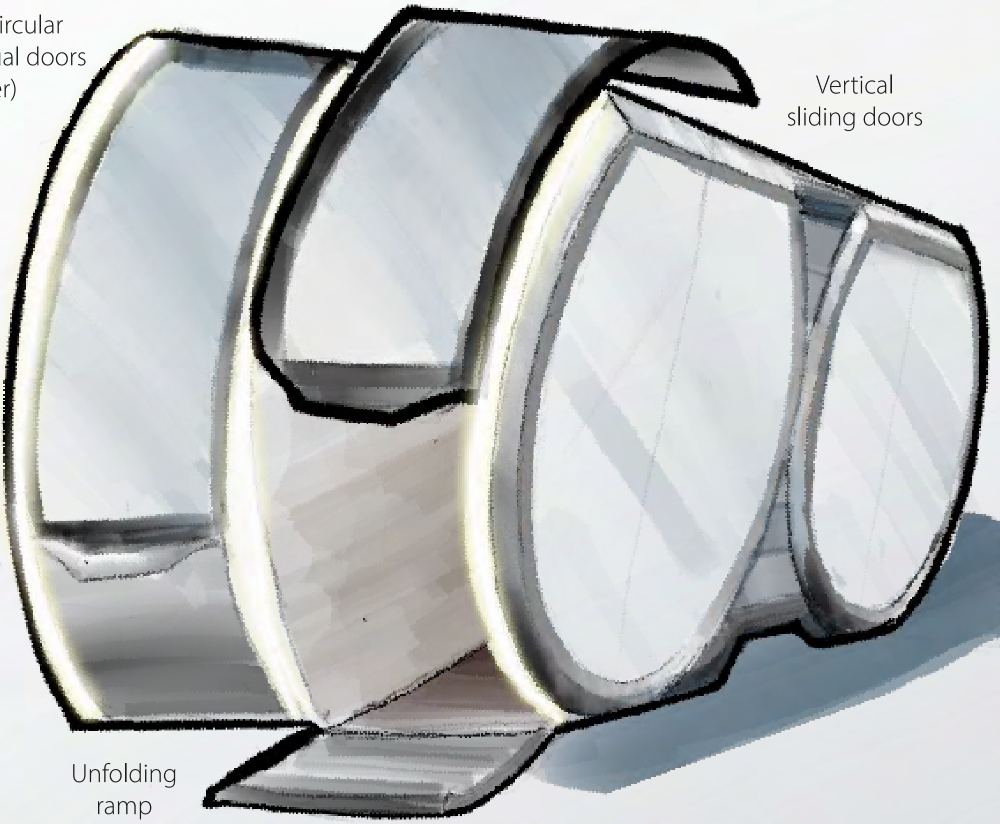


Modular curvy concept, too big, not efficient and traditional wheel style



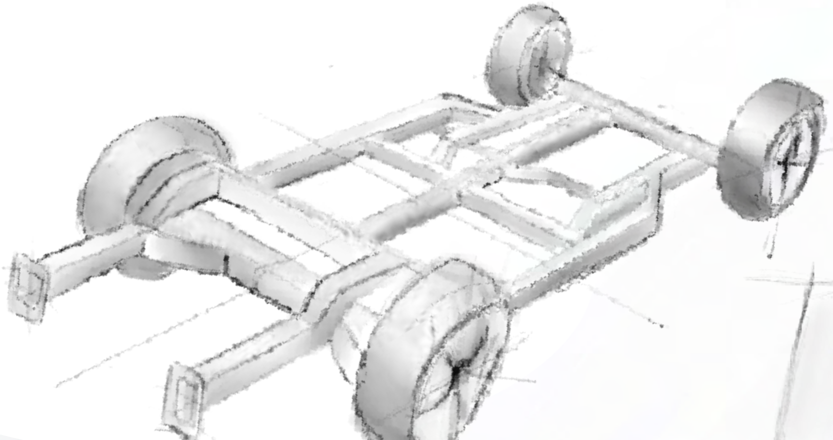
Very sharp and aggressive design especially for an autonomous vehicle, still too big

The final design is a circular concept with 4 individual doors (one for each user)

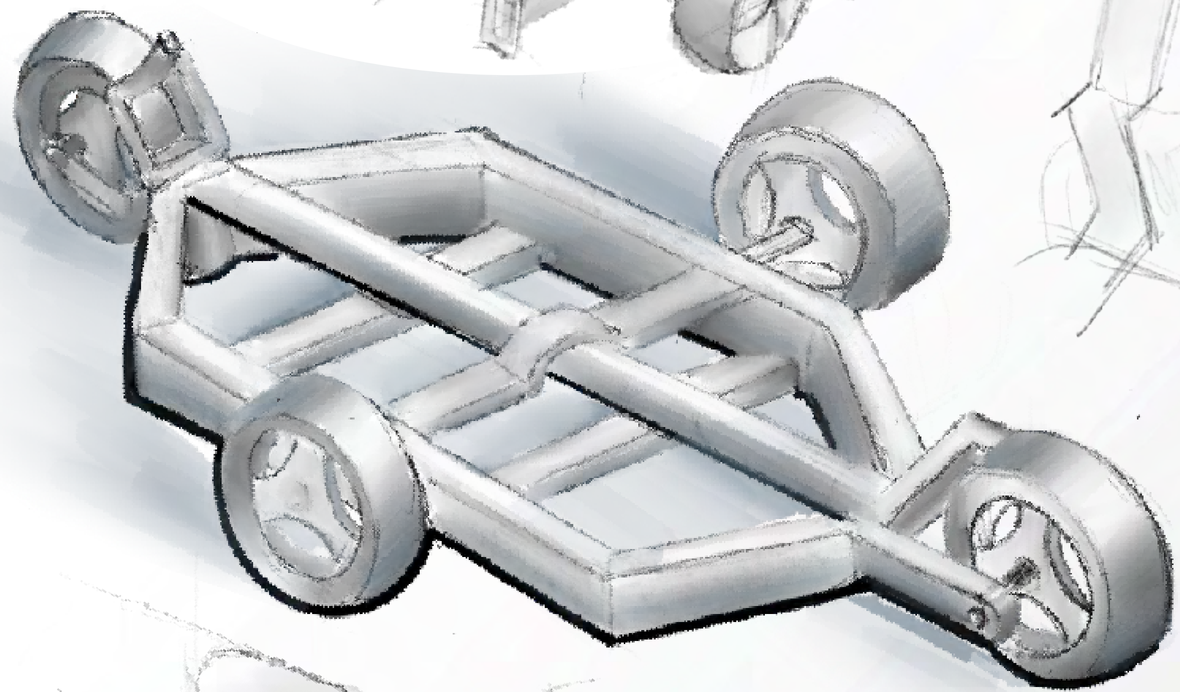


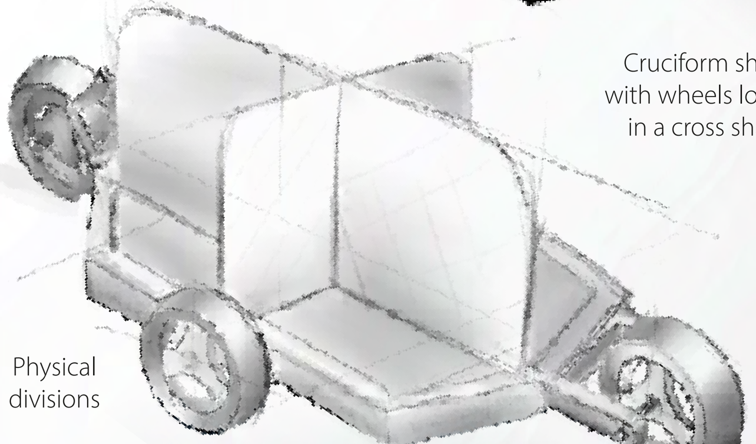
Vertical sliding doors

Unfolding ramp

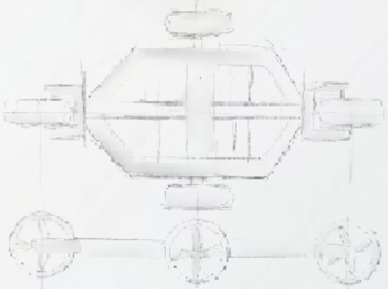


Development of the chassis from traditional vehicle structure with the wheels in a rectangle layout to a cruciform shape with the wheels in the shape of a cross.

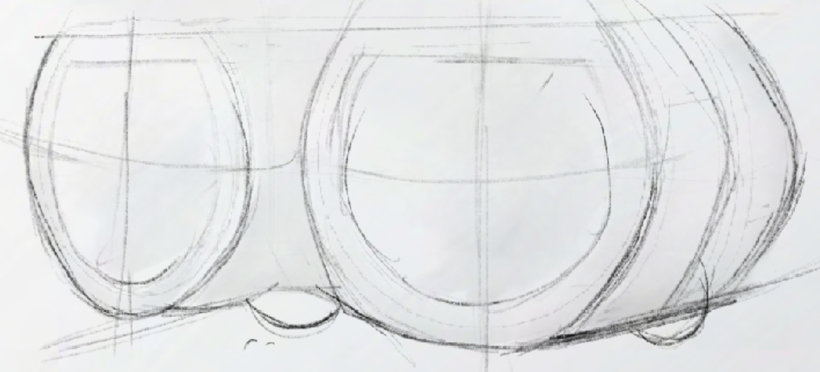




Physical divisions



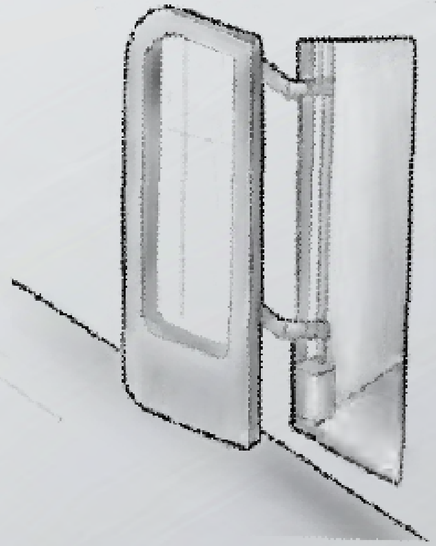
Cruciform shape with wheels located in a cross shape



Final circular design, approachable, efficient and original with non traditional wheel layout

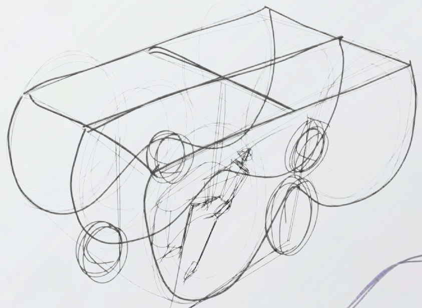
The doors have been designed in a non-traditional vertical mechanism follwoing VOYAGE'S unique circular design. One for each suite, located at the front and back of the vehicle, enbling users to enter and descend from the vehicle safely

Wing-style doors



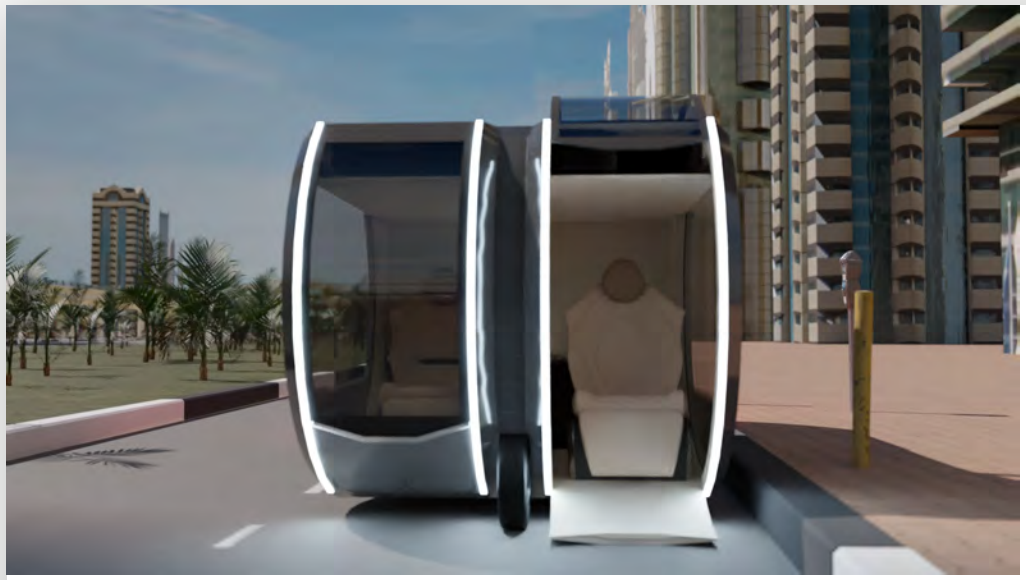
Automatic but can also be controlled via the app or the control panel inside in case of malfunctioning or emergency

GRAVITY SKETCH



Gravity sketch diagrams used to ensure the dimensions and proportions of the suites is realistic and spacious enough

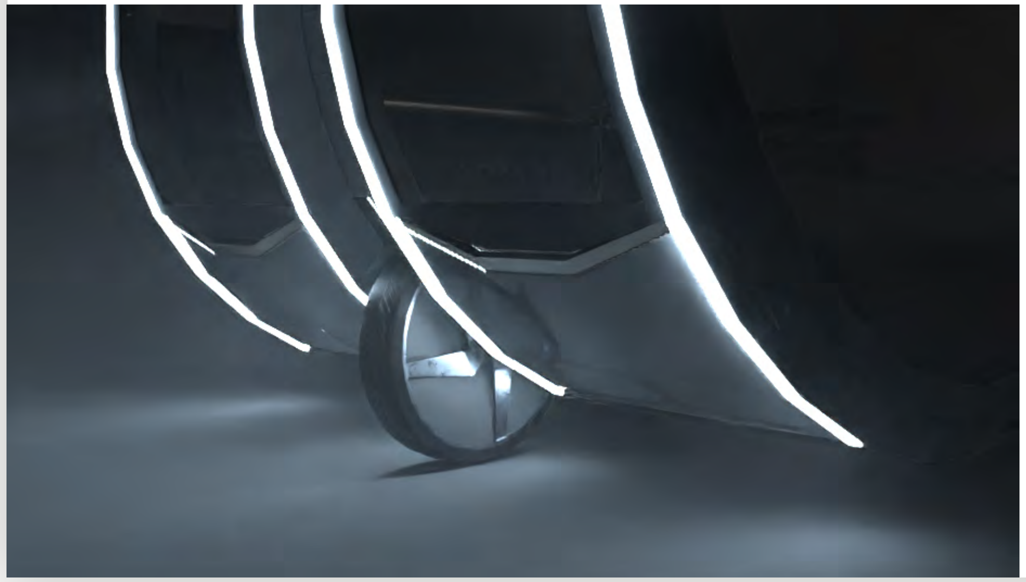
EXTERIOR DESIGN DIGITAL EMBODIMENT



The LEDS follow VOYAGE's elegant sleek design, and light up green to welcome each user to their allocated suite.

The four circular suites are designed from following a cruciform structure, offering four luxurious spaces.

VOYAGE is elegance. Premium. The unique circular exterior design and non-traditional vertical doors combined with the innovative wheel layout result in an futuristic and sleek design tailored to the needs of the users.



VOYAGE is the first brand to offer four simultaneous individual premium ride experiences within a shared AV mobility system.

The wheels follow the cruciform shape, and stability is ensured due to the seat layout (weight is mainly focused in the middle).

ON-PEAK MODE

PASSENGER MODE

VOYAGE has two modes depending of demand. During peak times and rush hour, many users request rides so VOYAGE transforms to passenger/on-peak mode. In this mode, the vehicle is able to transport 4 users simultaneously, but providing a compeltely individual ride experience. Each passanger is picked up and dropped off at their desired location, utilizing a powerful algorithm to optimise the route.

WHO ARE THE USERS?

The main opposers of shared mobility are premium users. These users are solo riders with a high socio-economic status that have the ability to be able to afford private travel and will disregard the option of sharing a space in favor of traveling in their own private vehicle.

VOYAGE targets these users by providing a more premium experience than the one users can have in their private vehicles. The final goal is for VOYAGE to be the vehicle these users choose over their private car, enabling an individual premium ride within a shared mobility system.

Over 20 interviews were conducted to validate this idea. Out of everyone interviewed, only the people classified as 'premium' were reluctant to sharing a car instead of owning their private vehicle. They value privacy, cleanliness, comfort, customisation, safety and efficiency, factors which are controllable in private vehicles, but not prevalent in shared mobility.

These features were identified and classified as 'essential' by users in order to provide a customised, individual and comfortable premium ride experience. This user feedback was collected and divided in 5 categories: 1) cleanliness and hygiene, 2) safety and control, 3) customisation, 4) comfort and entertainment, 5) privacy, and shaped the design of VOYAGE. See next page for further explanation and vehicle design development.

MEET JO - USER JOURNEY MAP

NAME	Jo Malone
AGE	29
NATIONALITY	English
OCCUPATION	Startup CEO
STATUS	Single
LOCATION	London, UK
ARCHETYPE	Creator

"I would still own a private vehicle even if always taking an Uber was cheaper in the long term."

- Productive
- Hard working
- Intelligent
- Creative

Attitudes: his private car is better than any ride-hailing, ride-sharing services or public transport, these are crowded, slow and inefficient. Values customised products and premium services.

Frustrations: public transport, wasting time, slow things, sharing his space/vehicle with other people.

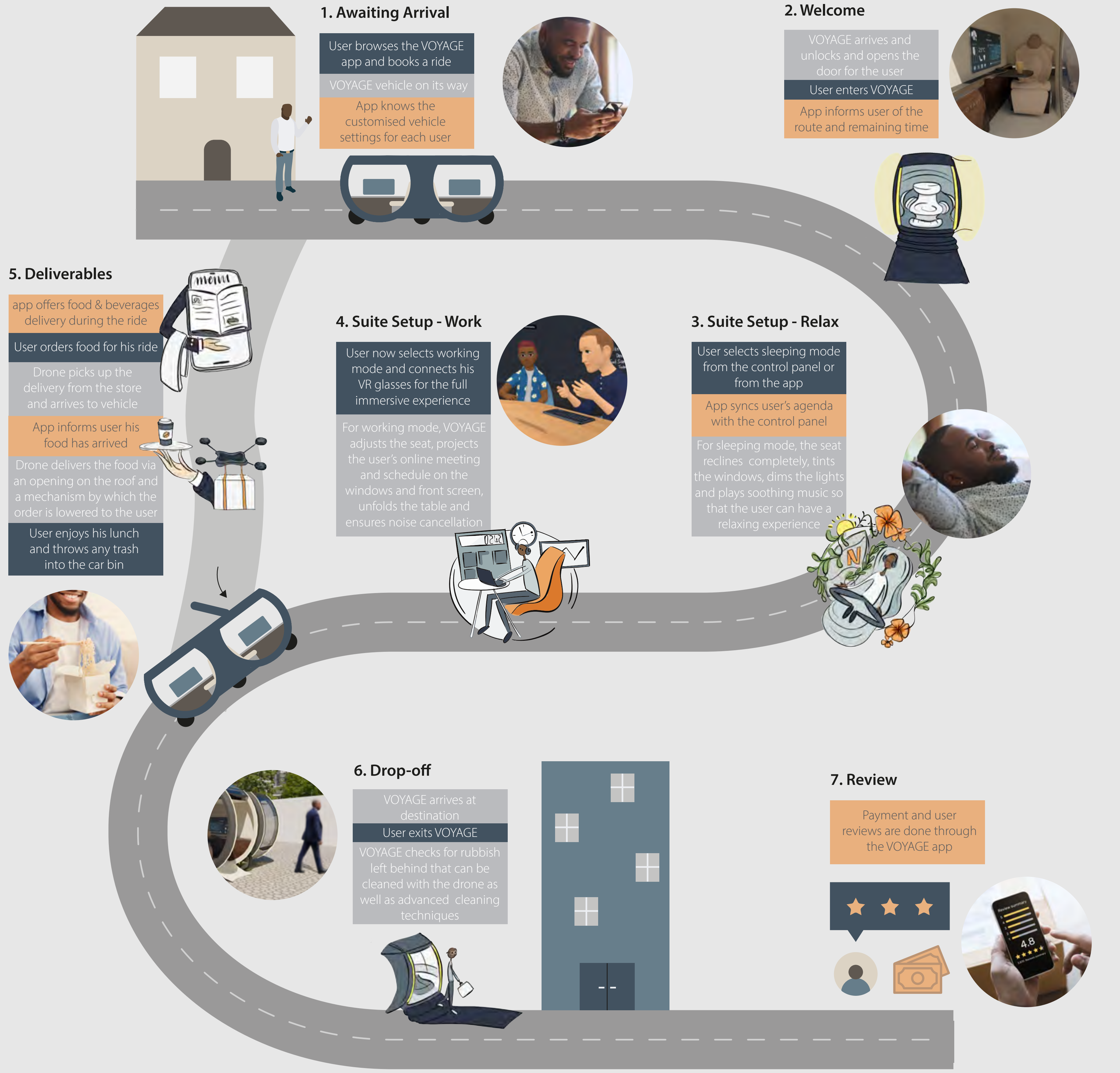
What Voyage Offers

VOYAGE offers a product service system for Jo to have the experience the premium ride he seeks but within a shared mobility concept. The journey map to the right shows Jo's journey from his home to his work.

JOURNEY MAP OF THE PARCELS

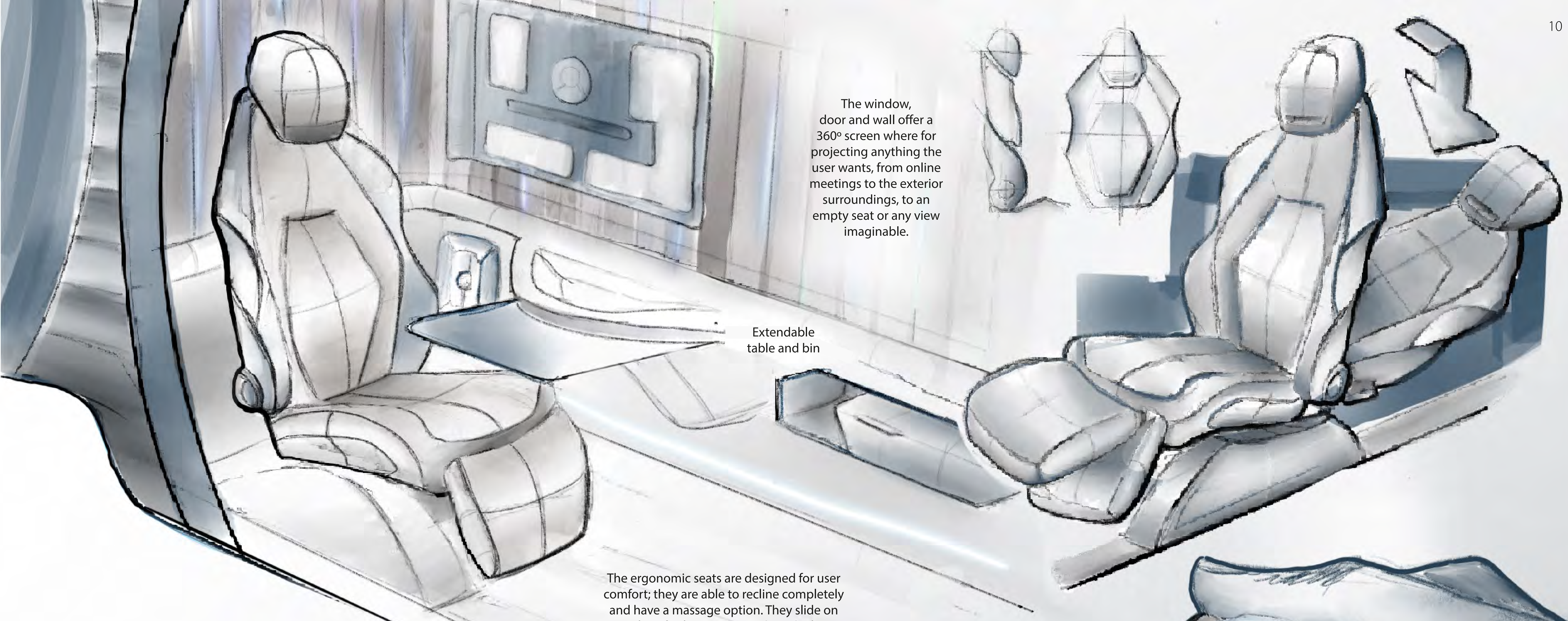
To visualise the key areas for development in the interior user experience, an end to end journey map was created based on Jo.

Key: USER - JO | VOYAGE VEHICLE | VOYAGE - APP



BASIS FOR DEVELOPMENT

Having mapped out the ideal user journey for the premium based persona, this will allow for the specifics of the interior to be identified and developed, such as a multifunctional space for different kinds of activities, as well as the potential to deliver consumables to the vehicle.



INTERIOR ELEMENTS

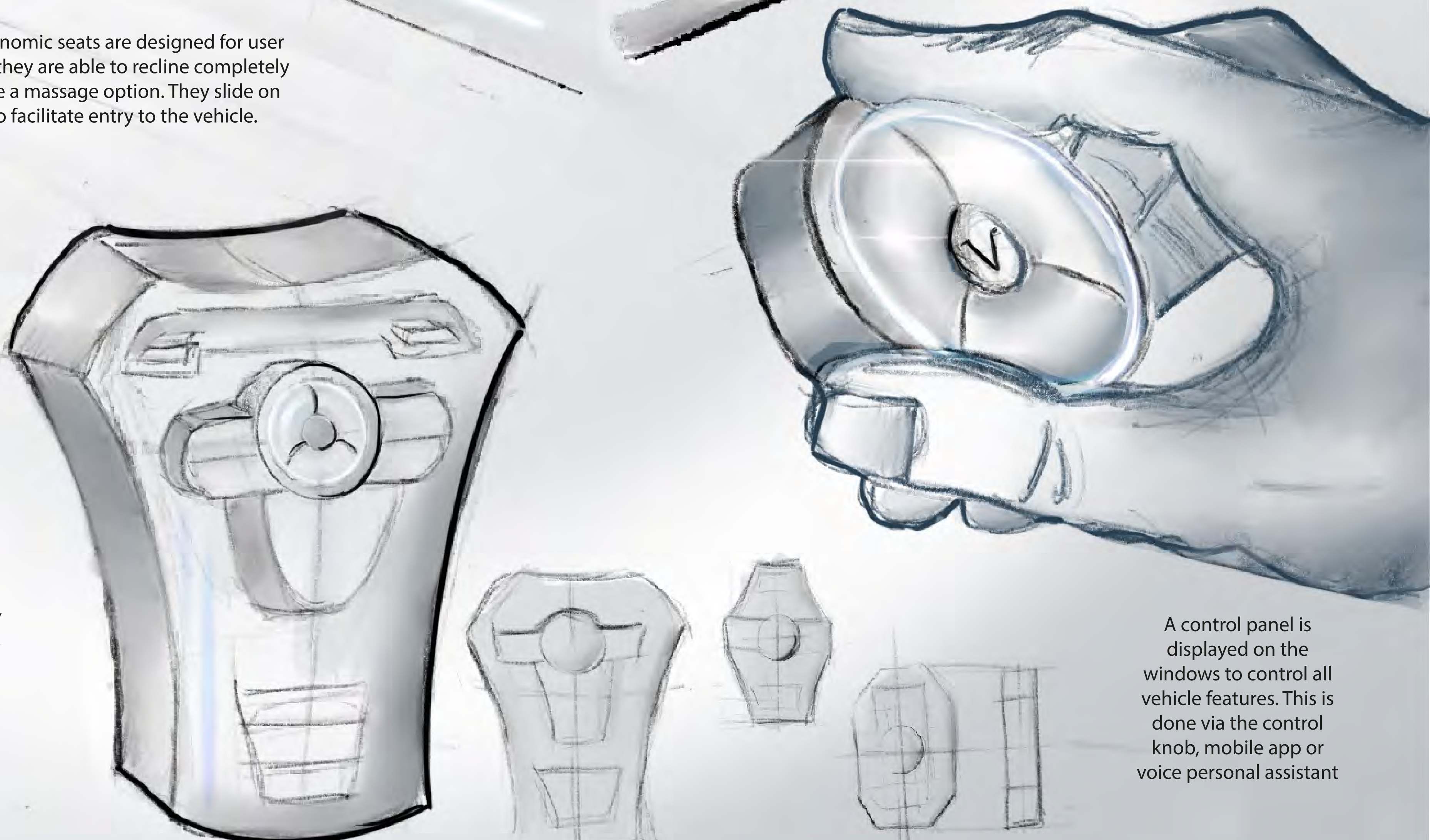
From user interviews during phase 1, the main human factors associated with ownership and features needed to provide a customised, individual and comfortable premium ride experience were identified and incorporated into VOYAGE:

Cleanliness and hygiene: to ensure air quality and hygiene after each user, **disinfectant thermo- fogging** will clean the air against viruses including Covid-19 (Transport Focus , 2021). To ensure clean surfaces, **self sanitizing handles** are covered in a photocatalytic coating made from titanium dioxide able to decompose bacteria via a chemical reaction that is activated by UV light (Dezeen, 2019). Vacuums are integrated into the floor and lower part of the seat, activated when the seat moves.

Safety and control: the user is in full control of VOYAGE via the **app**, the **control panel** or the **control knob**. The latter controls the **personal assistant** voice within the vehicle as well as the **emergency button or distress alarm** which stops the car and sends an SOS message to authorities or medical services. Other safety measures include mandatory seats belts for the car to start, GPS tracking device, cashless payment made through the app, visible user profiles and background checks on the users.

Customisation, comfort and entertainment: the experience is completely personalised for each user. From the light intensity, to music, temperature, seat inclination or window display, every feature is controlled and chosen by the user through the control panel, app or voice activation. Furthermore, VOYAGE is in sync with the user's devices to display meetings, schedules or any projection on the windows and screens. VOYAGE also offers unique entertainment experiences such as immersive VR or in-vehicle deliveries (further explained in later pages).

Private and solo-ride: to ensure a private ride experience for the users, active noise canceling systems are incorporated as well as physical separation between the 4 passengers in the vehicle. AR and VR technology are utilized to display anything and provide a panoramic screen view.



INTERIOR DESIGN VISUALISATION

VOYAGE'S interior was described as 'sleek', 'incredibly clean' and 'premium' by users after showing them the renders in this page. The suites have been designed to offer a luxurious and customised ride experience with unique activities such as ordering deliveries during the ride or enjoying a VR immersive experience.

INTERIOR DESIGN FEATURES

As explained previously, 5 human factors gotten from user interviews shaped the inside of VOYAGE: cleanliness and hygiene, safety and control, customisation, comfort and entertainment, and private ride. From these design objectives, the main features were created. The pictures on the right show the interior in default mode and the following features can be seen: the luxurious massage seat capable of fully reclining to horizontal position, an unfolding table, a control panel projected on the wall, a control knob, and an elegant arm rest illuminated with LEDs. The window is fully transparent in default mode but the lower half can be made opaque to avoid user's perception of going faster by being able to see the road beneath.

ORDERING DELIVERIES

Users have the option to order food or beverages before or during their trip through the VOYAGE app or the control panel inside the car. When the order is ready, the vehicle's drone will pick it up and drop it off on a platform on the second roof that lowers down and reaches the user.

LEVELS OF REALITY - VIRTUAL REALITY IMMERSIVE EXPERIENCE

1) Reality (level 1): default mode layout with the seat in the upright position, the control panel, knob and all windows clear.

2) Augmented Reality (level 2): atmosphere projection on the ceiling, walls and window such as the field shown below as well as complete audio immersion. The experience is interactive giving entertainment tasks for the user with hand tracking (gamification) and the animation looks are categorized and adapted to the user's age. The user feels immersed through visual and audio experience (ex. Spaceship, submarine).

3) Virtual Reality (level 3): sets the user in a complete virtual environment by connecting their headset to the vehicle. Once the experience starts the user gets fast visual feedback from the vehicle's movement to prevent motion sickness

SOCIAL ISSUES AND POTENTIAL PROBLEMS DURING RIDES

Worst case scenarios were created to ensure that VOYAGE has a solution to all possible negative situations, see list below:

- **Vandalism**: surveillance system and ID identification when entering the vehicle
- **No care with service**: surveillance system and ID identification before entering. Inner System Feedback on status
- **Health emergency**: report Option in Menu in case it can be accessed. Emergency button inside vehicle
- **Fire hazard**: vehicle alerts all users, moves to the side of the road and opens all doors
- **Crash**: vehicle notifies users and asks them for any injuries. If yes, authorities must be notified and send for assistance.
- **Suite overload (2 passengers)**: if sensors detect two people inside one module, the ride pauses and users get notified.
- **Hygiene**: user can report any spilling or unhygienic inconvenient via menu.
- **Vehicle malfunction**: in case from vehicle malfunction, closest stop should be reached and a new vehicle should pick the users. New ride option should be delivered to users and ride should not be charged

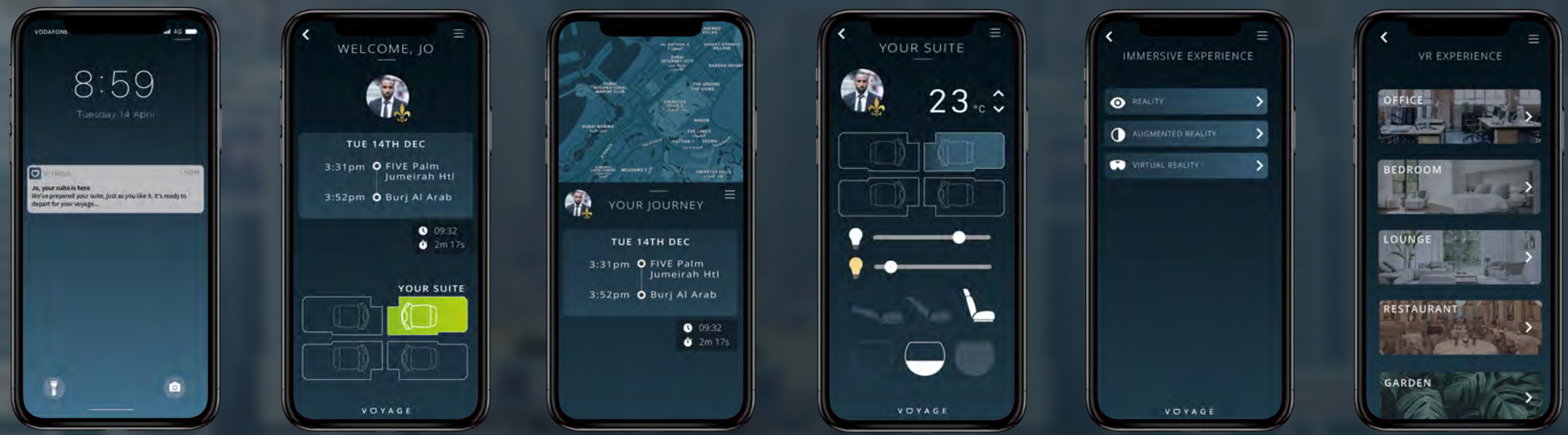
TOUCHPOINT - USER INTERFACE

The user can interact with VOYAGE via the phone app or the control panel within the vehicle. They are both in sync with each other and the vehicle, and control every aspect of the journey, from temperature to music to lighting or ride mode.

THE VOYAGE APP

The VOYAGE app is intuitive, easy to navigate and premium. These mock-ups showcase some of the main app screens in chronological order. Row one depicts the pre journey screens: 1) the user profile screen, 2) booking screen where the user inputs the time, location and preferred suite, 3) once the user has selected the preferred journey the system displays the available routes, 4) optimal journey options for the user.

Row two shows screens during the Voyage the journey: 1) car arrival notification, 2) allocated suite, 3) journey information during the trip displaying the ETA and route, 4) vehicle features that can be customised for that individual suite such as temperature, light, seat inclination and window opacity, 5) immersive experience levels, 6) different modes available for the user during the ride.



THE VOYAGE CONTROL PANEL

The VOYAGE control panel is displayed virtually on the wall of each suite as shown in the image to the left. When the user first boards the vehicle, it displays the home screen with the user's profile picture and name, the suite allocated to them, the current temperature, seat inclination, light intensity, location, route and time left to arrive at the destination (default mode).

Through the control panel the user can also control the unique ride experiences VOYAGE offers such as ordering deliveries throughout the ride, or an immersive experience. The latter has three options: reality (default mode), augmented reality (anything can be projected to the walls, ceiling and window), or virtual reality (mode that creates a 360º experience for the user). For hygiene and maintenance, the vehicle doesn't provide virtual reality glasses, instead, the user must bring their own set which will connect to VOYAGE in order to experience this VR ride experience.

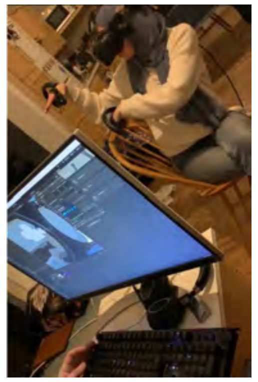
All in all, the control panel displayed to the left enables a fully customised ride experience for each user, creating 4 very different and unique environments simultaneously within one VOYAGE vehicle (as there are 4 users travelling at the same time), and infinitely many possibilities.

USER VALIDATION - VR DEMO

In order to validate our concept, a VR demo was created in Unity for users to be able to get inside VOYAGE, ride in the vehicle and test all available features. As seen in the images, a lo-fi cardboard prototype of the seat was created to make the demo as realistic as possible. Two demo days took place which allowed testing of every vehicle aspect, both exterior and interior, and iterate our concept to the final result.

1. CODE AND DEVELOPMENT

The demo was coded and developed in Unity, The steam VR compatibility layer with Unity was used to enable VR support with the valve index. Scripts were written in C Sharp to control demo functionality, for example player teleportation or vehicle movement. The city was built using assets from the unity store and each building, road segment and tree was placed by hand into the set. The most challenging code scripts were to ensure the player moves with the car as it rides and the script to allow the user to pick up objects (useful to test deliverables and throwing rubbish into the trash at the end of a journey).

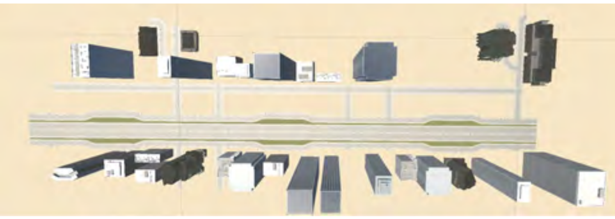


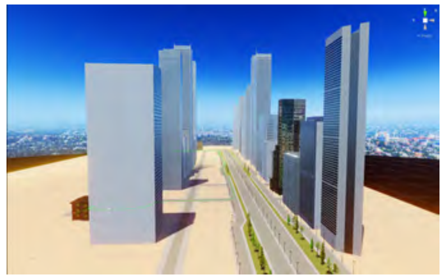
2. INITIAL TESTING

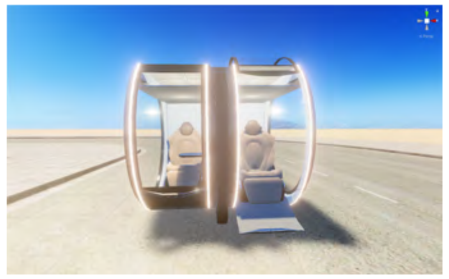
Initial tests were done to validate the city, the concept functionality (such as the opening of the doors and the changing lights) and the interaction with the control panel, ensuring all buttons worked. The most important feature to test was the three levels of reality and the virtual experience during the ride, a very unique concept within a vehicle that needed user validation and feedback.

3. FINALISING THE DEMO & SETTING UP WITH PROTOTYPE

A big space in Dyson Level 2 was cleared to set up the demo. A cardboard prototype was made with the accurate VOYAGE seat dimensions and shape to provide a more realistic experience. When the space was set up, it was time for calibration. A VR controller was set on top of the cardboard seat in the physical space and the camera rig was moved so that it was in the correct position. 2 trackers were also placed as the valve index works with lighthouses to track the players.







4. USER TESTING AND VALIDATION

Over 20 different people, 9 shown in the photos to the right, were interviewed and then tried the demo to give feedback on the concept design and functionality.

The majority of comments were positive such as:

"As soon as I got inside the car and started interacting with all the features it has to offer, I forgot I was travelling with other users even if I saw the 4 doors at the start of the simulation". This validates the ride-experience that was aimed for at the beginning of the project. Another user said *"I can see this concept becoming a reality in the future and I think most people (like me!) would prefer VOYAGE over owning a private one as it gives you the possibility of doing anything you want during the ride time".*

Every element in the final design was validated with users but a few needed to be changed based on their feedback. These iterations have been incorporated throughout the report but their origin and reason behind is explained below.

A) Vehicle exterior communication - green LEDs feedback

At the start of the demo the player is standing on a sidewalk in Dubai and the vehicle arrives slowly. Users were asked to give their opinions and many described the appearance as 'out of a futuristic sci-fi' and 'very premium indeed'. When asked about the design, one said "the circular structure makes it much more approachable and less scary than other autonomous cars". The only problem observed was that many doubted which suite they had to go into as there was no feedback from the car's side to indicate which seat was allocated to each user. ITERATION: the LEDs of the individual door to the specific seat turn bright green instead of white so that users can clearly know where they have to go.

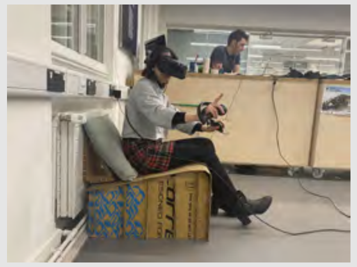
B) Ease of entry to the vehicle - sliding seat

The cardboard prototype enabled a realistic entry to the vehicle. Due to the second roof design, the taller users that tried the demo mentioned it was not very comfortable to get inside the vehicle and sit down since they bumped their heads into the ceiling. ITERATION: to ensure it is easy to climb in and out of the car with the doors located at the front and end, the seats were changed to be movable. They slide forwards and backwards on two rails to facilitate getting in and out of the car.

C) Distance to the control panel - physical knob

As shown in the picture to the right, users had to stretch their arms very far when they tried to interact with the control panel projected on the wall of the vehicle. ITERATION: the control panel was made smaller and moved to a closer location to the seat. But, what if it malfunctions? ITERATION: the app was adapted to be used inside the car too and have the same functionality as the control panel even though in the before it was only used to book the car before the journey. What if my phone battery dies? ITERATION: a physical knob was incorporated into the design, located near the table, so that users have a third way of interacting with the vehicle.

D) Lack of control - personal assistant voice & emergency button



When riding in the demo, a couple users mentioned they would appreciate if they felt like they had a bit more control as they were a bit uncomfortable riding in an autonomous vehicle. ITERATION: to make voyage more human, a personal assistant voice was added, which welcomes the user and refers to them by their first name. This change made users feel more "safe" and in control in case of emergency. But, what if something goes wrong and the voice breaks? ITERATION: a manual and physical emergency button was designed so that in case of emergency, the users are able to manually and mechanically stop the vehicle and get outside.

E) Feeling unsafe when driving - window opacity option

Interestingly, opposite opinions were given about the windows to the floor. Some users loved the fact that the windows permit you to see the road underneath very closely as you are driving because they really enjoy that perception of thinking they were going faster. However, some others said they felt very unsafe and the fact that they could see the road made the whole ride experience scary. ITERATION: users are given the choice of 1) having the window entirely transparent as in the initial design, 2) having it partially transparent by making the lower half opaque and therefore reducing visibility and eliminating that feeling of velocity, and 3) making the window entirely opaque.

MODE TRANSFORMATION MECHANISM

VOYAGE transports users during peak hours and transforms to Parcel Voyage (PV) mode during off-peak hours to provide last mile delivery for parcels from Magway depots to people's homes. The transformation between modes is achieved by a second roof mechanism that lowers and the foldable seats that maximise storage. The aim of this multi-mode design is to reduce congestion and the two modes are differentiated by the car's exterior colour.

VOYAGE, ON PEAK MODE - USERS

PARCEL VOYAGE (PV), OFF PEAK MODE - PARCELS

VOYAGE, ON PEAK MODE - USERS

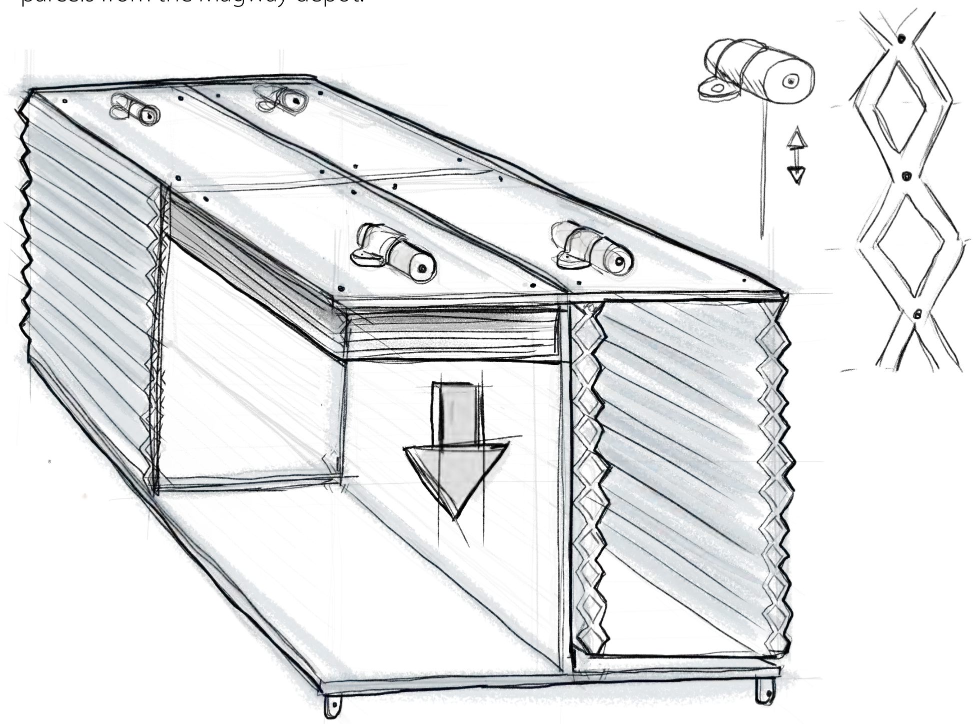
During peak-hours, when there is high demand for transportation, VOYAGE operates as a taxi service for users. The autonomous vehicle consists of 4 individual premium suites customised to each user and their unique ride-experience, tailored to them. VOYAGE has a characteristic circular exterior design, following a minimalist and elegant style, complemented by the dark bodywork and automated vertical doors. The interior is equally luxurious, with fully reclinable seats, and a panoramic immersive VR experience available for the user. The vehicle interacts with the user via a personal assistant and communication to pedestrians on the road is ensured by digital projections on the exterior windscreen.

TRANSFORMATION

The vehicle's transformation is both exterior and interior, ensuring a very distinct appearance from the outside as well as a completely different inner functionality/utilisation. Using BMW's color changing technology, the black premium color transforms to bright delivery orange. On the inside, the seats fold completely and the double ceiling descends, creating a huge storage space ready to transport parcels to their destination.

PARCEL VOYAGE (PV), OFF PEAK MODE - PARCELS

PV is the fully transformed vehicle during off-peak hours. It is designed for last mile parcel delivery, transporting parcels from Magway depots (where it first charges) to their destinations. The parcels are picked-up by the vehicle's drone, inserted into the car via the opening roof and stacked in compartments according to destination location. Each compartment has its own automatic roof door for the drone to insert or extract the corresponding parcel. Stacking is also not a problem as packages are always delivered to a depot that's near to its final destination, therefore sorting into appropriate stacks is already mostly done by just collecting parcels from the Magway depot.



ROOF MECHANISM

The transformation is achieved thanks to Voyage's unique roof mechanism. Essentially, it consists of folding concertina plastic divisions that are connected to the secondary roof as shown in the diagram below creating a prismatic joint. This joint is raised and lowered to transform between the user and parcel mode by a motor and a cable.

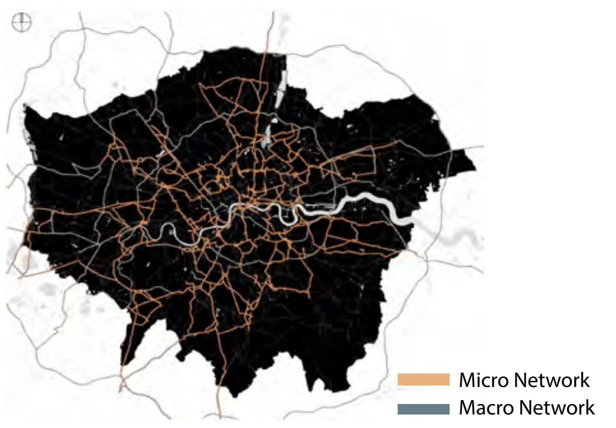
PARCEL JOURNEY

RUPERT CRUISE - MAGWAY CEO

Magway's CEO discussed the potential to integrate Vogage's service with their revolutionary middle mile delivery, as well as some validation for the development of our service. Magway's testing facility was visited to gain an insight into the "physical internet" for delivery.

MAGWAY'S FUTURE URBAN SYSTEM

Magway's **plans for routes designed to be implemented around 2040** show their urban network of pipes and also the location of their 'nodes', which are mapped based on the residential population, to be **within 15 minutes cycle of 97% of London's population**. This shows their potential to serve the urban population, but also the **potential to integrate a last mile service for delivery of their packages directly to consumers homes** from the 'nodes'.

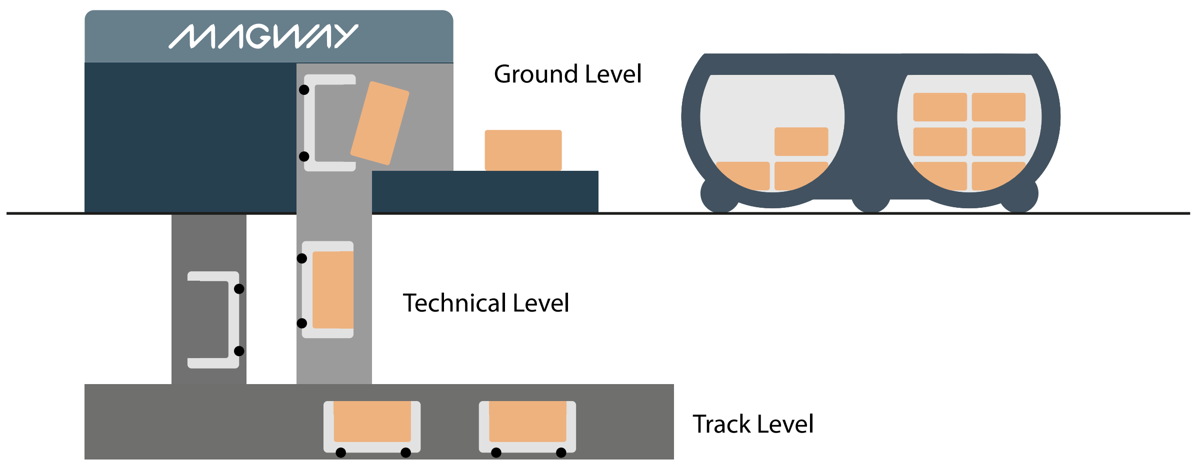


Macro and Micro Networks

Urban Nodes

VOYAGE'S DELIVERY POINT INTEGRATION

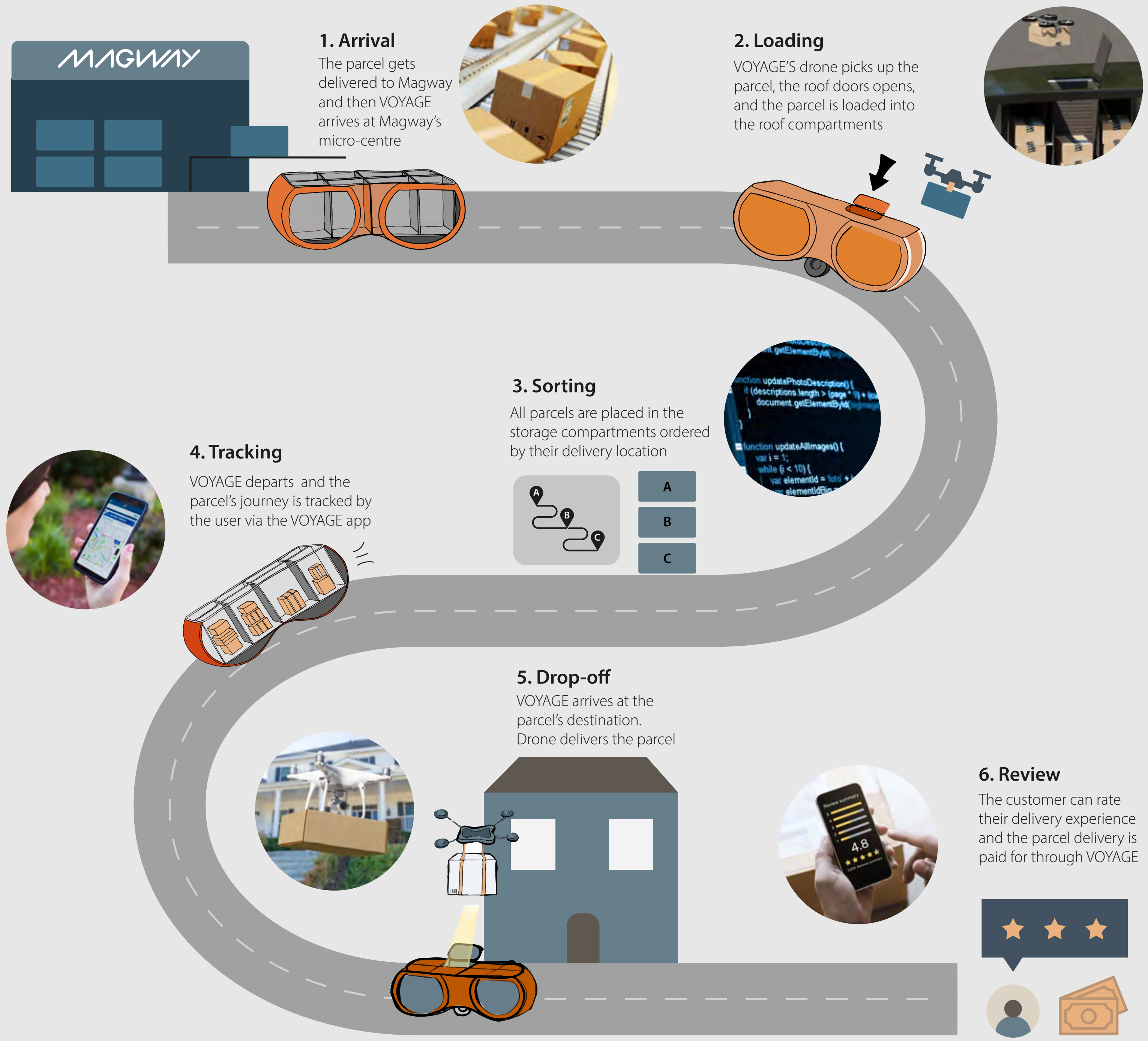
The magway nodes have 3 sections, track level, technical level and ground level. At the track level, Rupert described **the ability to use loops in the track, in order to get the carts in the correct sequence** for when they come to the ground level, and **can be loaded into a delivery vehicle in a specific order**. Other ground level features include delivery point integration and auto collect, making it designed to integrate vehicles like Voyage.



JOURNEY MAP OF THE PARCELS

To get a better end to end view of the parcels, a journey map was created, which would be used to pinpoint the most crucial areas for development.
By using Magway's connected system which can control and sequence the system of parcels, the parcels can be sorted depending on the optimal route for Voyage's vehicle to drive along.

They will be loaded into the vehicle using two of the drones and then the drone will sit inside of the vehicle until the vehicle reaches the destination. Once the vehicle pulls up as close to the customers house as possible, the drone will pick up the package from the top of the 'stack', and deliver it into the customers parcel net or another secure location in their property.



INSIGHTS FOR DEVELOPMENT

Having evaluated the user journey, there are areas that are already common in product service systems such as tracking and reviewing but there are two main areas that will require development to be embodied due to their novelty. This includes:

- The mechanism that will allow the drone to attach to the parcel in order to delver it, as well as to fit into the vehicles roof compartments safely
- The method for delivering the parcel to the end user, in a safe and reliable manner.

UAV DESIGN AND EMBODIMENT

Having detailed the journey of parcels from pickup to drop off, the **drone (UAV) that is used to load** and unload the parcels as well as **the location for delivery** should be developed.

INTEGRATION WITH VOYAGE WITH UAV'S

The main challenge is how to load and unload these parcels into the Voyage parcel mode. With the enabler of UAV's, drones will be able to carry higher payloads, as well as being compact enough to fit into the Voyage vehicle to pick up parcels. However, the specific design for the drone and the mechanism to attach to the parcels must be developed.

DRONE DESIGN DEVELOPMENT

Current drones used for delivery include the basic drone form of four propellers, as well as a mechanical component on the bottom to grip the parcel.

To be able to fit into the 14x18 inch holes in the roof of the vehicle to unload and load parcels, there must be minimal risk of drone failure. A lightweight cage was designed around the drone to mitigate failure of the drone.

Due to the parcels being stacked on top of each other, and lack of space at the sides of the parcel for a mechanical grip, industry specification suction technologies were studied. Suction is commonplace in industry to move goods, but this has not yet been explored in the drone deliver sector, making it a novel solution.

With industry vacuum gripper robots, many require compressed air fed through a vacuum generator, but with the drones operating for long periods of time, refilling the drone with compressed air is not an option. Instead, the system used by a compact VGC10 vacuum gripper (Onrobot, 2022) can be integrated onto the bottom of the drone, utilising the drones battery as a power source. With a weight of 800 grams and potential to carry up to a 15kg Payload, this is a more than suitable to lift parcels. The embodiment can be seen below.

FUTURE UAV DELIVERY INFRASTRUCTURE

The other large design challenge of drone delivery is the **drop off at the customers address**. The two main issues are around security and safety, as there must to a procedure that prevents people taking the package in order for it to be safely delivered to the customer.

Standard Industry Methods

Companies have come up with various different methods such as landing pads that the drone can recognise, or parachuting the package down to the users garden. However, in urban areas this is more of a challenge, with many residents living in flats and therefore not having a landing space.

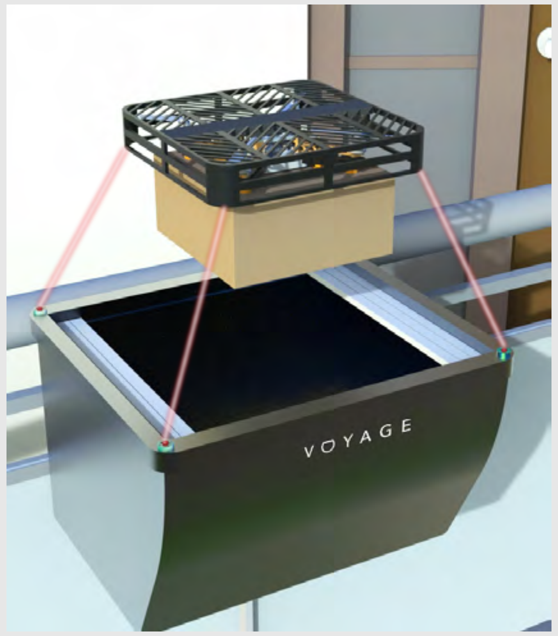
Delivery Nets Innovation

A company called Skynet (Idea Connection, 2014) came up with a system to deliver packages into 'nets' which could be installed on the side of flats to allow direct delivery of parcels. These nets are secure and keep the parcel from getting near pets or other people and with a unique bar code being tagged to them, the drones cameras can line-up to the corners and release the parcel within millimetre accuracy, all done without any human interaction required.

It may seem like an additional home product required for the home, but if it reduces the cost of delivery to the customer and as a application could serve as a place to have parcels picked up by drones and delivered, the approach could be feasible. The CAD of the idea was developed to show how Voyage's drone could deliver a parcel.

With 'roll-up' shutters, the parcels can be protected from rain, as well as allowing a parcel to be placed on top of the box for the drone to pickup if the customer wanted to send a parcel.

Sensors on the corners of the box, these can line up with the drone cameras to accurately position the drop for releasing the parcel.



EVALUATION FROM RUPERT CRUISE ON VOYAGE'S SYSTEM

Magway's CEO evaluated our system in the integration with middle mile delivery, backed up the idea of connected logistical systems and validated the use of out drones in last mile delivery, rather than middle mile:

*"**Magway gets the goods in to the many distribution hubs**, and then **you can do your last mile distribution** around city centres."*

*"Magway put the predictability back, in and we can track and control the system within a millimetre, **all in real time all connected to the internet**."*

*"In terms of capacity, 12 million (drones) a week flying past your house, drones can't. We will interface with them but you **can't get the capacity or energy efficiency for middle mile delivery**."*

SYSTEM IMPLEMENTATION

Having developed and embodied the vehicle and the two modes that it operates in, the method that the service operates in must now be considered. This includes communication methods for the vehicle, and the algorithm considerations for operation.

INTERVIEW WITH LEANDRO PARADA

To get insights into the system implementation part of the project, the team spoke to Leandro Prada who is undertaking a PhD in Multi-Agent Reinforcement Learning at Imperial College London. The idea was explained to him, with a special focus on the system optimisation algorithm concept.

OPTIMISATION ALGORITHM CONCEPT VALIDATION

After presenting our product service system, he provided the following feedback, insights and validation:

"The basic process to make an algorithm is to work through a VRP, a routing program which is a basic optimisation program you have in transportation and one of the most relevant where you have a set of vehicles and customers and you want to deliver all of the goods to the customers in the minimum time, and you can have several objectives there"

"I see the algorithm on several levels, so on a higher level a decision is made whether to be a passenger mode or parcel mode at any point in the day, based on the demand, and then once you decide that you go through the low level routing, so delivering parcels optimally. It's one then the other sequentially"

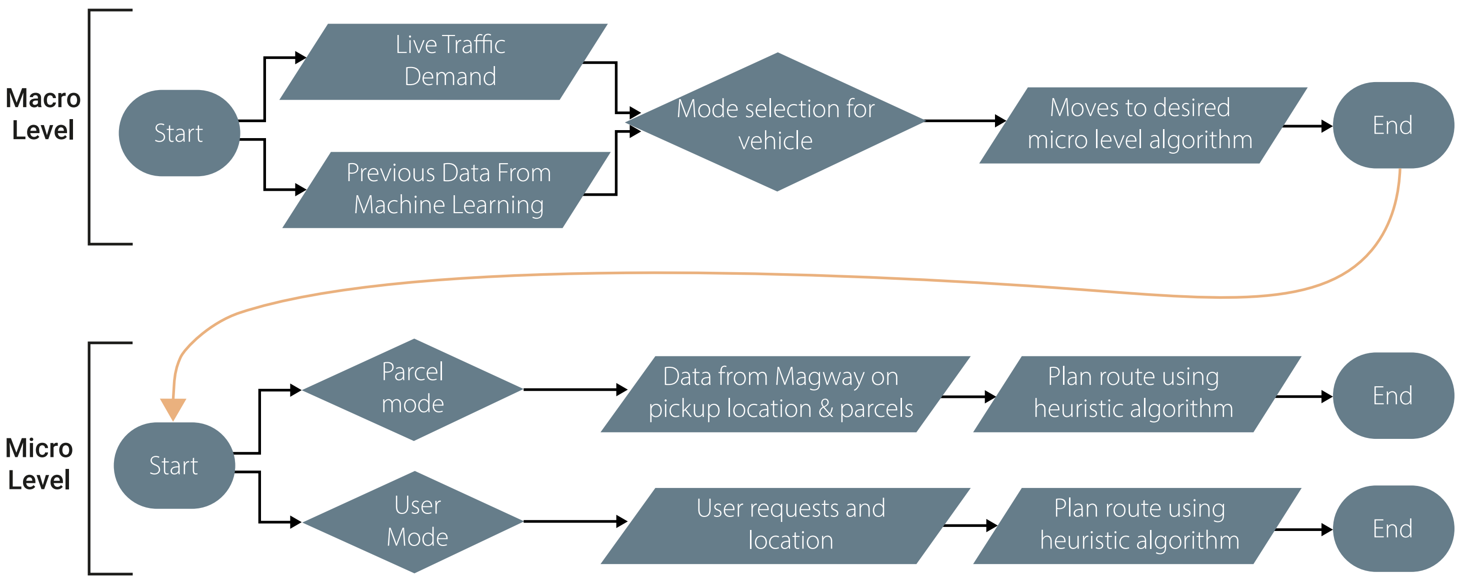
"I think (your system) is definitely feasible and with all the technology coming like 5G, many services will come in like this and its just a matter of time for them to be deployed."

"I believe that the SHIFT project took more thank a year to complete so therefore approximately a year or two may be an appropriate time window for your team (to develop the algorithm relevant to your project)."

From this feedback, it gave confidence that our system is feasible, and gave a basis to develop aspects of the algorithm. It also showed that it would not be realistic to attempt to design a whole algorithm in our time frame, but instead focus on the basic architecture of it.

ALGORITHM STRUCTURE - ENGINEERING FLOW DIAGRAM

As the service serves customers in real time, it is important that these route optimisations are finding the solution fast, in a few seconds between the user ordering a ride and then being assigned a vehicle to pick them up. Therefore it is important to use a heuristic method, which may not find the optimal solution, but it does it far quicker than an exact approach. A simple flow diagram was developed based on this information:

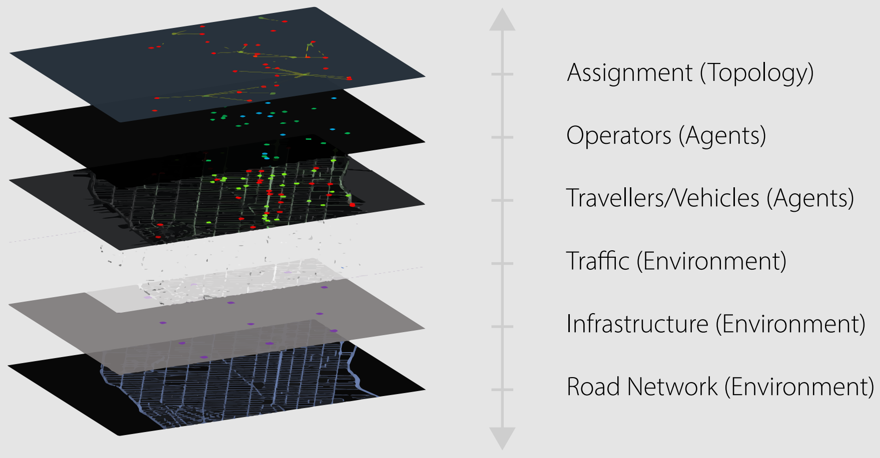


AGENT BASED MODELLING (ABM) FRAMEWORK

The model used to simulate the system can be broken down into a number of layers, which will be required for the system to function. This is a similar breakdown that the TSL uses in their SHIFT project (TSL - Imperial College London, 2021).

Voyage's modelling would be agent based, and this allows the evaluation of key performance indicators related to the different agents.

The key agents in Voyage's system were detailed to demonstrate that if the system was modelled, what the main properties, behaviours including state logic (which is what state the agents are in e.g. waiting for pickup), and their KPI's. By running ABM simulations before deploying the system, the behaviour can be understood better as well as what governs its outcomes.



Agent	Properties	Behaviours	KPI's
Traveller/parcels	- Unique identifier - Origin and destination - Request time - Utility function - Reservation price	- Mode choice - State logic	- Wait time (traveller) - Travel time - Detour (traveller) - Cost - Trips shared (traveller) - Order accuracy (parcel) - Damage claims (parcel)
Vehicle	- Unique identifier - Location - Capacity - Range and charge - Schedule - Revenue function - Cost function	- Charging park station choice - Parking station choice - State logic	- Mileage - Revenue - Cost - Trips served - Service rate
Operator	- Unique identifier - Fleet (vehicles) - Assignment strategies - Pricing strategies - Routing algorithm	- Assignment/pricing choice - Fleet management strategy - State logic	- Mileage - Revenue - Cost - Trips served - Service rate

IMPORTANCE OF 5G: Leandro also highlighted the importance of the 5G internet enabler:

"B2X capabilities in the future will enable many of these types of services where you need information in real time and only through 5G will you get to these volumes of information flow you need to have, so definitely connected autonomous vehicle would make this possible. 5G allows for network slicing, so chunks of the network are specifically saved for applications so you can have a chunk of networks saved for autonomous vehicles and it would be of high priority and very fast, so applications that you have that 5G will make a difference for."

NEXT STEPS - FURTHER ENGINEERING DEVELOPMENT

Having developed the framework for Voyage's system modelling and implementation as well as validation for its feasibility, the actual overall product service system can now be studied to see how impactful on urban areas to reduce congestion, as well as how financially viable it is.

QUANTIFYING THE IMPACT

The urban systems impact including the final reduction on the congestion, and the potential savings in energy and lithium are critical to the success of the Voyage concept, hence the impact of the system was explored in detail. The potential profitability and business opportunity was developed through an economic model and explained to ensure the concept is viable and feasible.

IMPACT OF A VOYAGE FLEET ON PRIVATE VEHICLES

Luxury taxi service Addison Lee currently have around 4000 vehicles in their fleet (Addison Lee, 2022). If Voyage had a similar size fleet in London, and it's estimated that each vehicle operates for 16 hours/day (same as Zoox vehicles (Hindustan Times , 2020)), 8 hours in user mode and 8 hours parcel mode, then with average ride times of 20 minutes (Finder UK, 2017) at a conservative estimation of 50% efficiency, it can provide around:

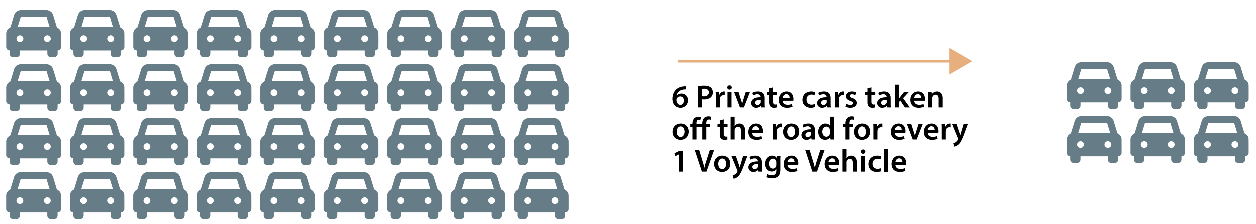
8*60/20*0.5*4*365*4000 = 70,080,000 rides provided per year

The average user drives for around an hour per day (Motor1.com, 2021), which equates to three 20 minute rides. Per year this is around 1000 trips per user. Therefore it can be estimated that:

70,080,000/1,000 = 70,080 Active users annually can be served.

Lyft, a car sharing service published a report detailing the impact of their service (Lyft, 2017). 34% say that they would avoid owning a car completely because of Lyft and 56% use their cars less because of Lyft. If these figures were used for the user base, from a fleet of 4,000 Voyage vehicles it can be predicted that:

70,080*0.34 = 23,827 would sell their car, freeing up parking, and saving more new cars being brought
70,080*0.56 = 39,244 cars used less
23827/4000 = 6 cars less for every 1 Voyage

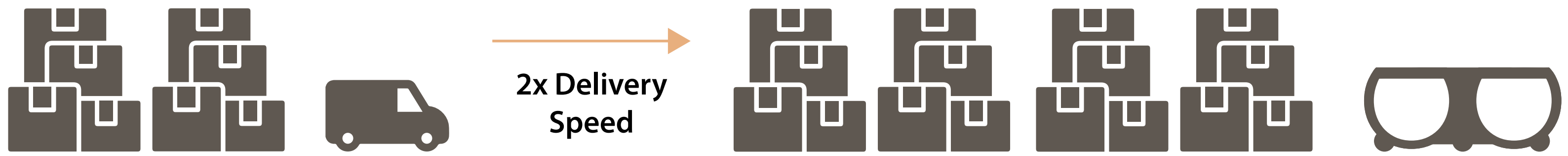


IMPACT OF A VOYAGE FLEET ON DELIVERY VEHICLES

24 Parcel stacks, 6 parcel per stack at maximum capacity = 144 parcels at capacity. Looking into Amazon flex blocks, for a 3 hours flex block it equates to on average 50 deliveries (Ridester.Com, 2022). With drone delivery it is predicted that parcel delivery could be greatly spread up due to the vehicle not needing to stop and hand deliver the parcel, so it can be estimated that 144 deliveries could be completed in 4h:

Voyage system delivery rate: **240 minutes/144 deliveries = 1.66 minutes/delivery**
Current Amazon delivery rate: **180/50 = 3.6 minutes/delivery**

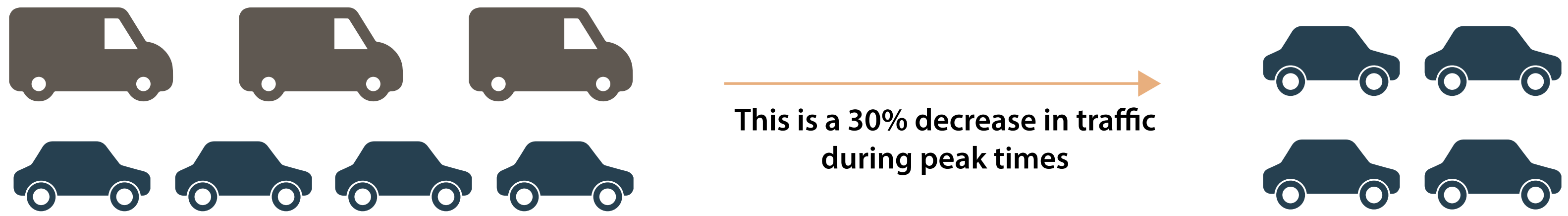
This shows voyage is roughly 2 times more quick the current delivery. Therefore a fleet of 4000 vehicles could deliver, the same amount of goods as 8,000 Amazon vehicles in an 8 hour time period.



More than 90% of London's freight is transported by road. In the morning peak hour (07:00 - 10:00) deliveries and servicing vehicles account for about one-third of all traffic (TFL, 2022).

Last year around 450 million packages will have been delivered in London (Centre for London, 2021). With the 4000 Voyage vehicles, they can deliver a total of 4000*1.66*365=420 million parcels. This could cover most of the required deliveries in London, and therefore make a significant reduction to the third of total vehicles that are for delivery and servicing purposes.

Peak traffic could be reduced by up to 30% just from removing delivery vehicles and rescheduling deliveries with Voyage at off-peak times.



ECONOMIC FEASIBILITY

WHAT AN INDIVIDUAL VOYAGE CAR COULD GENERATE IN GROSS PROFIT

Looking again at Amazon flex blocks, drivers get paid from $54 for a 3 hours block, which equates to on average 50 deliveries (Ridester.Com, 2022). That is around $1 per delivery. For voyages system, we assume that a middle mile system such as Magway would take a cut, so we can assume Magway take around 50% (OptimoRoute, 2020). This is $0.50 per delivery.

So in 1 delivery round, with a parcel capacity of 144, a single voyage vehicle could make **0.50x144 = $72 dollars**

With drone delivery it was predicted that 144 deliveries could be completed in 4h: **$18 dollars revenue/hour = £14 per hour**

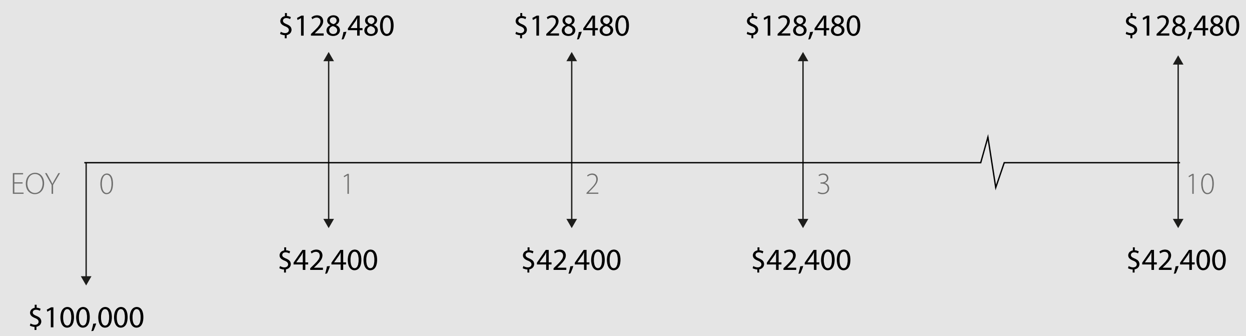
The average Uber fare is just under £12 pounds (Finder UK, 2017). If the average revenue per ride for voyage is around 50% less, say £5 for the average 20 minute ride, then for 4 people in the vehicle per hour it equates to: **5*4*60/20= £60 per hour**

If we assume 50% utilisation due to the car not having 4 riders 100% of the time, plus the time when the vehicle is empty driving to the next pickup, the revenue becomes £30 per hour. With time needed to charge the vehicle, there is likely to be around 16 hours use per day. Therefore if there is a 50/50 split of user mode and parcel mode, revenue per day could be around:

8*30+8*14 = £352 revenue per day per vehicle = £128,480 revenue per year per vehicle

This is validated by Seeking Alpha, who predicted shared robo taxis could earn around $85,000 (Seeking Alpha, 2020), which is boosted to around our value with the potential to deliver parcels when there is lower demand.

Tesla predicted that their robotaxi's may be able to cost around on $25,000, and the price per mile is around $0.18 (CleanTechnica, 2020), so even with these values doubled, there is an upfront cost of $50,000 dollars and assuming same annual mileage as Tesla (90,000), the cost per year amounts to $32,400. An additional $10000 costs was added for the additional features such as the drone and roof mechanism. If the car is assumed to last for 10 years, and no salve value with a MARR of 12%, the net present value can be calculated using economics and finance for system design:



The calculated NPV is $428,924 per vehicle. See the excel file for the breakdown of calculations. This is of course without R&D, employee costs and other costs, but it shows that the vehicles can be profitable after break-even during year 2.

PROJECT SUMMARY

Looking back at the objective aim, "Reduce urban congestion by designing an efficient product service system combining shared premium mobility and last mile parcel delivery" it can be seen how this goal was achived:

KEY ELEMENTS TO ACHIEVE PROJECT AIM

Having a Large Focus on Premium User Experience

By investing a large amount of the projects time into this element, and performing user testing, it meant that we had a PSS that stood out from other shared mobility product by targeting a specific customer.
With this the vehicle could be designed to stand out and be an original design, moving away from other future concepts.

Developing an 'on the fly' Transformable Structure

The most novel aspect of Voyage is the fact that it is a '2 in 1' vehicle, and can therefore solve the pressing issues of low utilisation of vehicles. In the way that the smart-phone combined a number of individual physical products and changed the paradigm of what a phone is, this transformation element could shift the paradigm of what a passenger vehicle is, and inspire further innovation in the industry.

Most importantly though relating to the original design challenge, it reduces congestion through being flexible in when it delivers parcels, unlike delivery vans today that operate during set hours.

Detailing the Parcel Journey, to Ensure Drone and System Consideration

By looking in more detail at how parcels would actually be handled by Voyage, it opened up more innovative opportunities to collaborate with innovative middle mile services such as Magway who also have the same aim of reducing congestion.

It also presented a new way in looking how delivery drones could be implemented. For short range trips from a moving vehicle to a nearby building means there is less issues around the battery range, and being utilised in this way would reduce air 'traffic' as the drones travel short distance, and potential prevent the stopping of vehicles to deliver at the side of the road, which is also a contributor to congestion.

Impact of the System in Urban Environments in Relation to Congestion

From using data on current shared mobility providers, some foundation values could be found on how much Voyage really reduces congestion. With the results being promising, as well as the financial potential, it meant that the project aim could be realistically achieved in a sustainable manner.

POTENTIAL FURTHER DEVELOPMENT STEPS

Although the demo of the car was realistic in terms of spatial and interaction, by producing a physical model, the real scale and feel of the vehicle could be demonstrated, as well as how the mechanism would physically work.

Building accurate system simulation model was out of the scope for this project as Leandro mentioned, but in order to gain realistic data this could be developed in conjunction with TSL - Imperial College.

Further mechanical development of the car such as the drive-train, chassis as well as the drone suction mechanism could all be developed and modelled further. For the time allowed for this project, these were not critical elements to develop as it was more about producing a future concept, but they are certainly areas to work on it further development.

POTENTIAL FURTHER DEVELOPMENT STEPS

"I really like the concept" and "I think its a great idea with a lot of potential" ... Leandro Parada
"This is a visionary concept, and I really like the idea" ... Annette Böhmer
I like the idea of a premium vehicle where your deliverable is already there, rather than being transported with parcels ... Maria Jose Perez Calvo

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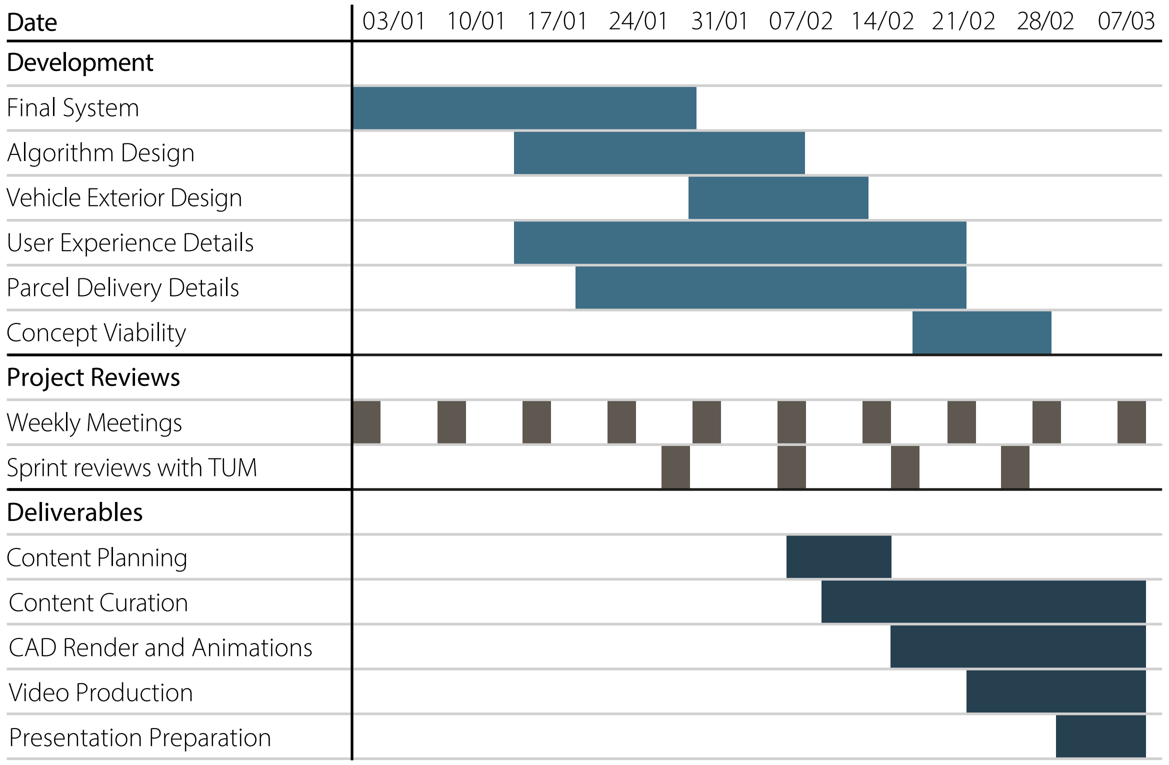
PROJECT MANAGEMENT REVIEW

GANTT CHART (SHOWING TIME USE)

Time was managed by using a Gantt chart.



MEETING MINUTES LINK

Link to the meeting minutes folder: link 1

PROJECT BUDGET

Purchased product	Price (Euros)
Unity CSape city system	40.20
Ukraine asset Bundle	35.73
Dynamic city ambience	17.86
Beautify 2:advanced post processing	49.31
Trees package	8.49
Modular roads	13.40
Urban building set 3	13.40
Total	178.59

EXPLAINING OUR DIFFERENT ROLES (HR)

To ensure effective development, the team used the **Petra tool which is a team-centric planning and management tool**. This tool structures the design development process into 4 sections, as already shown in the **development plan** section.

The i**ndividual roles were split into different roles**. They comprised of Component Designer, Technical Designer, Architect and Business Development. These individual roles did not necessarily mean that the individual were responsible to do all of the work in the given areas, but more to take charge and responsibility to ensure that the work was completed.

In terms of what went well during the project, the use of **Miro boards for each different sprint made accessing each other information and work very easy**. We also enjoyed the experience of **learning each others multidisciplinary skills** and how they could be applied to a Futures project while collaborating with TUM. By keeping the weekly minutes, it was easy for each team member to be updated rather than asking each other, although overall the enthusiasm of the team meant that members rarely missed meetings.

There were some things that could have been done better during the project. Although meeting agendas were often followed, **something the length of discussion was too long** meaning that other important topics did not have time to be discussed in detail. It was also found to be harder working remotely in the final stages of the project, as rapid exchange of information and discussion is useful, but not as easy to do remotely. The different roles of the members were overall met, but at some points in the project some team members had more to do than others due to the nature of their role, so potentially **defining more flexible roles** or **planning out the intensity of the different roles** before undertaking the project would be useful.

END OF PROJECT - INDIVIDUAL TEAM MEMBERS CRITICAL REFLECTION

Each member gave thoughts their own development thought the project, matched with their role.

Harry - Business Development

For the **business responsibility**, I oversaw the development of the impact and financial prediction, as well as branding aspects.
Professionally, I developed through talking and presenting to a number of industry professionals, with a personal highlight being to visit the CEO of Magway at their HQ and engage with him to get insights about the company.
Personally the teamwork has helped me to develop my planning ability, which had previously been a weakness as I used to just take one task at a time and not plan in time for it. With so many areas of development and deliverables in the project during the sprints, having a team plan and delegation throughout has improved this element.

Esther - Function Designer

As the teams **functional designer**, my main focus was on the physical interior and exterior elements where I took the lead in designing and developing them.
Professionally, I learnt a lot through collaboration with TUM, and what methods of communication work and do not work, and made some valuable connections.
Personally, having had the opportunity to lead in the design of a car, a sector I am very enthusiastic about as well as hearing from experts in the industry has boosted my desire to work in the automotive sector.

Robert - Technical Designer

Overseeing the development of mechanisms in Voyage such as the transformer roof as well as taking the lead in the coding of the Demo allowed me to gain experience in the **technical designer** role.
Professionally, working with new people on projects and gaining experience with new tools and methods such as the Petra tool system was very insightful.
Personally, having produced the animations for the video as well as the Unity demonstration really caught my interest and to have produced a good outcome while in collaboration on a group project made it interesting to hear other inputs on the digital embodiment.

Leila - Architect

As the **architect** I took charge of the system mapping, including picking up a lot of knowledge learning about C4 diagrams and explaining it to other team members
Professionally, I enjoyed the sprints with the industry professionals, to learn more about how design engineering is performed in the workplace.
Personally, I feel that through developing the Unity user interface I learnt a lot as well as working in a team where everyone is committed and has a valuable input

Itziar - Operations Manager

During the project, **communication and organisation** was key, especially for the work done with TUM student in different time zones. By being proactive in organising sections of the project I felt that I help speed up the progress and improve the understanding of others on specific tasks.
Professionally, I enjoyed the formality of keeping minutes and learnt how valuable it can be in a larger team where people occasionally miss meetings.
Personally, helping to contribute to a project with an outcome that I am proud of through efficient operation was invaluable