

AUTONOMOUS PUBLIC TRANSPORT AND ITS EFFECTS ON CITY DEVELOPMENT

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Raghav Ragotham
(2100353)
MA Transportation Design

PART 1 – EFFECT OF AUTONOMOUS VEHICLES ON DEVELOPMENT OF SMART CITIES

INTRODUCTION

Urbanisation is a modern problem that is plaguing many major cities around the world. The synergy between cities and technology is a possible solution for the challenging issues that come with urbanisation. The rise in population in cities is increasing alarmingly and is expected to rise exponentially soon (Buhaug & Urdal, 2013), the advancement of information and communication technology (ICT) can possibly yield a solution for the development of future smart cities. Smart cities need to tackle crucial concerns of urban living such as energy, transportation, the environment, government, and unrestricted access to citizens (Ismagilova, Hughes, Dwivedi & Raman, 2019). Adopting ICT in the transport domain provides for intelligent transportation that plays an important role in the development of smart cities by solving serious concerns with respect to travel time, energy efficiency and environmental issues.



Figure 1 Future mobility and smart cities

Exhaustive research has been carried out with respect to technological and developmental aspects of smart cities (Chatterjee & Kar Arpan, 2018). Research that impacts future generational and educational systems of smart infrastructure will be imperative so that the public will accept autonomous vehicles without much apprehension (Ismagilova et al., 2019). The latter is essential development of autonomous vehicles and public transport as smart mobility will be an important foundation of future smart cities. Smart cities will incorporate and develop infrastructure that can act as a catalyst to improve the lives of the citizens residing within it by providing a benchmark for future services, including autonomous mobility (Haboucha, Ishaq & Shiftan, 2017). The research done till now was focussed more on studying singular terms related to autonomous vehicles, their interaction with or an effect on the environment, whereas detailed research on the full-scale adoption of autonomous vehicles is lacking. There are long term advantages to the adoption of full-scale AV, therefore, it is important to spread awareness to early AV believers so that they may promote their usage (Pettigrew, Dana & Norman, 2019) while

strategically mapping out areas of a city that need to be developed further to accommodate and refine vehicle automation (Nielsen & Haustein, 2018).

There isn't much research or case studies done on the effects of autonomous vehicles on urban landscapes, infrastructure, and development patterns. Every change in the history of transport technology has had great impacts on city development, whether it is road vehicles, trains, airplanes or ships. Some autonomous vehicle induced changes would likely be as follows.

- Improved road spaces for other uses
Road systems in general make up 30 percent of a city's built-up area in developed countries. Theoretically, autonomous vehicles will be able to efficiently use road systems compared to user-controlled vehicles and thus will free up some road space. This additional space can be used to further develop infrastructure for social functions, such as walkways, bike lanes and tree lined streets etc.
- Converting unused parking spaces into social and community uses
Increase in the use of autonomous vehicles will subsequently reduce the need for the need of significant amount of parking spaces that are currently necessary to accommodate all vehicles on the road. This reduction in parking lots and buildings makes way for the potential to convert them into social spaces, such as parks, community centres or affordable housing.
- Redesigning building & street interfaces
In a smart city dominated by autonomous vehicles, city development will have to adapt to new patterns for the flow of traffic. New interfaces will need to be designed for door-to-door services, mainly to accommodate multiple drop-off and pick-up points throughout a travel line. High density sites will need a larger interface for multiple AVs to accommodate for the high population, while lower density locations will potentially no longer require street-level parking. This frees up kerb space for other uses.
- New land uses for former fuel stations
It is largely envisaged that electric vehicles are the future of transport and mobility. These can be charged overnight at public or private charging stations. This implies that fuel stations will become a thing of the past and will be irrelevant for cities. These locations will require treatment to be environment friendly before they can be converted for other uses. Once approved, they can be used as storage facilities or convenience stores.
- Increasing the footprint of cities
Autonomous vehicles will no doubt have the potential to be a direct cause for the expansion of urban footprints, as more effortless and less time-consuming travel becomes more accessible to people. This could lead to the re-evaluation of living in proximity to city centres and major employment centres. This could lead to an inflation in residential property prices and might shift preference from properties in urban centres to those in suburban areas.

FUTURE AUTONOMOUS MOBILITY

The co-dependence of technology and city development is considered a possible solution for the issues of rapid growth of urbanisation. Autonomous vehicles are considered to be a top contender for many smart city solutions.

Going off recent trends, it is predicted that by 2040, autonomous vehicles will account for up to half of all road transport, both private and public. A large number of recent studies are exploring autonomous vehicles as a primary source of mobility. Some advantages of pushing for autonomous vehicles are (The Conversation, 2017):

- reduces private ownership of motor vehicles, traffic congestion and air pollution
- increases carpooling, road safety, accessibility and mobility
- redesigning and restructuring traffic rules, or completely eliminate the need for them

- improving mobility for people who are transport-disadvantaged

Improved road safety is a potential key benefit of autonomous vehicles. These systems are in charge of important safety tasks, especially ones that are usually prone to human error (NHTSA, 2017). The general public's willingness to use autonomous vehicles is directly proportional to the potential for improved safety features as per multiple recent surveys conducted (Casley, Jardim & Quartulli, 2013).

Urban mobility has had a relatively linear evolution. It still requires a major jump in technological development; it encourages a paradigm shift in urban mobility. This makes it imperative to assess the pros and cons of autonomous mobility at the same rate as smart cities and infrastructure. Autonomous vehicles and interconnectivity between them and smart cities will generate positive changes in public transportation and mobility (Kohli & Willumsen, 2016), but will also be some negative impacts that will generate some less desirable effects. Bahamonde-Birke et al. (2016) gather the impacts in effects of autonomous vehicles of the first and second order.

Direct / first order effects

Impacts of autonomous vehicles that are widely discussed by researchers are as follows:

- reduced pollution due to focus in development of electrification of vehicles.
- automating the process of driving will reduce the general costs of travel.
- improved road safety due to interconnectivity between vehicles as well as with active road safety systems.
- increased efficiency in the use of public transport as compared to private motor vehicles.

Indirect / second order effects

- better accessibility for new users (minors, elders, people with disabilities).
- reduction in driving disutility will improve the value of travel time due to autonomous vehicles.
- AVs will increase vehicle-kilometre travelled (VKT) due to trips without users (Smith, 2012).
- reduction in costs, congestion levels and the value of travel time will generate longer trips.

PUBLIC UNDERSTANDING AND ACCEPTANCE OF AVs

There is abundant research and investigative reports available on the factors that affect public interest in autonomous vehicles. Many such studies have reported that young adults and men are typical demographics that generally are more willing to accept autonomous vehicle technology (Nielsen & Haustein, 2018). They have shown to agree that future autonomous vehicles will improve road safety, have fewer inhibitions about vehicle safety and have increased willingness to use the technology. However, these same demographics are also responsible for the majority of road accidents and risky pedestrian behaviour taking place currently. Due to this correlation, Hulse, Xie & Galea (2018) state that the acceptance of autonomous vehicles among young adults and males could have a direct impact on more rapid manifestations of road safety benefits, should they adopt AVs once the technology is introduced.

Along with young adults and men, college graduates and citizens residing in urban environments also have a positive attitude towards autonomous vehicles, with a high percentage willing to give the technology a trial (Smith & Caiazza, 2017) and try to understand the better perceptions of road safety. A recent survey found that being informed about autonomous vehicle technology and its perceived benefits has a direct impact on people being able to accept them as a replacement for current mobility services.

Furthermore, several studies have uncovered underlying factors that attitude towards AVs can also explain these perceptions. A particularly relevant study in Denmark identified several classes of

respondents based on a survey conducted: enthusiasts, sceptics and an indifferent group in between. Enthusiasts were reported to be significantly more likely to have a college degree, try out new technologies sooner than others, live in major urban areas of the Copenhagen area and be a young male. Among the reported advantages of AVs, road and passenger safety showed the largest gap between enthusiast and sceptic respondents; while 56 percent of enthusiasts reported a belief that self-driving vehicles would improve safety, only 7 percent of sceptics and 27 percent of indifferent people believed the same (Nielsen & Haustein, 2018).

Perceptions of safety

While the advancement of technology and infrastructure will direct the improvement of AV safety systems, the significance of public awareness of autonomous vehicles cannot be overlooked. The understanding of how public behaviour for travel may be influenced due to the introduction of autonomous vehicles on public roads is just as important to their success. Public knowledge of relations between safety perceptions and willingness to use AVs to travel can help bolster the potential safety benefits of the system (NHTSA, 2017).

Multiple studies have recognised that the same demographic of social factors correlate with the increasing awareness on the safety of autonomous vehicles. This same demographic is also associated to be willing to be early adopters of AV technology (Hulse, Xie & Galea, 2018). Further studies have suggested that the public's perception of autonomous vehicles safety is associated with their interest in use AVs. This means that spreading information about the benefits of AVs and the implied safety of them is beneficial in implementing the future acceptance of the smart mobility technology. According to a survey conducted in the US in 2013, 60 percent of respondents believed that the safety implications of AVs had a positive influence on their decision in purchasing the technology when it becomes available. 82 percent of respondents said that the safety of AVs was more a more important appeal, ahead of even cost (Casley, Jardim & Quartulli, 2013). Further surveys have been conducted from people in different parts of the world. For example, polls were taken from 347 adults in Austin, Texas (Bansal et al., 2016); 1661 adults in the United Kingdom through an online poll (Smith, 2016); and 4886 adults from 109 other countries (Kyriakidis et al., 2015). With the exception of the British survey, all these polls proved the public's recognition that AVs would improve road and pedestrian safety wherever they are introduced. All three surveys, however, reported several concerns, including high maintenance costs of such systems, possible failures and susceptibility to foul play, such as hacking or misuse. There are two notable issues with most surveys being conducted till date:

- (i) they focus on autonomous vehicles meant to be used in the future and do not take into account current trends of motor vehicles and road safety.
- (ii) they focus on the opinions of people who are educated on autonomous vehicles and their projected features. Pedestrians and people who do not have an opinion on the matter are, for the most part, ignored or looked over.

All these surveys suggest that perceptions of safety are major barrier to the adoption of AVs, but may can also be a motivator among certain open-minded groups.

Multiple reports indicate that the perceptions of safety lead users to shift their choices to the most popular modes of transport. A preference stated in Israel found that the perceived risk of road accidents is directly related to the intention of the public to shift from private transport to more public ones (Elias & Shifan, 2012), showing that travellers are willing to adjust their travel plan in order to reduce the risk to personal safety. A recent study found that the perceived safety risk was a significant contributor to how the public reacts towards AV technology, and that this trust was the strongest contributor towards intention to use and purchase AVs in the future (Zhang et al., 2019). All this proves is that the perception of the masses towards autonomous vehicles are a major factor in encouraging the adoption and use of autonomous vehicles and is an important factor in spreading awareness on the impacts this technology will have on road and pedestrian safety.

International comparisons

Studies organised over a number of countries have indicated that the perception on autonomous vehicles and the demographics of society that predict them differ widely among the public of various nations. It was found that gender played a significant role in the US in stating the interest in AVs. In India, women reported to have a greater willingness to ride autonomous vehicles compared to men, while the opposite was true in the U.S (Anania et al., 2018). This could be attributed to major cultural differences between the two countries. A survey with respondents from China, Japan, Germany and the US found significant differences among attitudes towards autonomous vehicles and automated driving in general in these countries (Sommer, 2013). Autonomous driving was considered too disconcerting to 42 percent of respondents in Japan but by 66 percent from the US; 43 percent of Japanese respondents reportedly believe that the technology will come to become commonplace in the future compared to 74 percent in China; and only 37 percent of respondents in Japan believed that AVs will be part of everyday life by 2028, while 68 percent in China believed the same. A different study conducted in the US and UK reported promising views of autonomous vehicles, but also higher percentage of concern for riding AVs compared to other countries (Schoettle & Sivak, 2014).

Although multiple surveys, like the ones stated above, compare average attitudes towards autonomous vehicles among mostly first world countries, not many survey the trends among countries with a relatively lower quality of life. An analysis spread over 40 countries, with at least 25 respondents from each, showed minimal but positive relations between national level rates of traffic related deaths and inhibitions about the reliability and safety of autonomous vehicle technology (Kyriakidis, Happee & de Winter, 2015). Subsequent research surveys involving a significant number of participants across multiple countries used principal component analysis to assign a general acceptance score indicating an individual's positive outlook towards autonomous vehicle technology. It also found that the general acceptance score correlated negatively with a country's GDP per capita and motor vehicle density around heavily concentrated urban areas (Nordhoff, 2018). However, there are conflicting results on countries where road safety is a primary issue for the local governments, such as most third world countries. Furthermore, these correlations did not account for minority representation or other sociodemographic influences. In spite of these variations, these studies focus on the co-dependency on the relations between individual sociodemographics and the perception that the public has on autonomous vehicle safety, leaving it up to discussion as to how much this variation will affect the adoption of the technology at the national level (Bailey, Moody & Zhao, 2019).

CONCLUSION

These multiple surveys reveal that the autonomous vehicles are, at present, perceived in a generally optimistic way. They were considered to be placed higher compared to existing modes of transport in terms of risk perception. There was little to no resistance in terms of the attitude towards them. It would appear that the idea of autonomous public transport already has a significant number of believers and supporters in the current age. Despite all this, there are still much to do to encourage even more acceptance and willingness among the public to adopt and use autonomous vehicles. Concerns about the technology will always exist, not just road related safety issues, but the technology in general. It is of utmost importance that the public's perception on them improve so that when the technology eventually does get introduced, there is relatively low pushback from opposing groups (Hulse, Xie & Galea, 2018).

A multi-layered approach to perspective must be adopted by researchers in future studies and surveys as well as real interactions between the public and this technology. Real life exhibition of the technology used to make AVs viable for public roads would greatly increase widespread acceptance of them by the public.

PART 2 – AUTONOMOUS PUBLIC TRANSPORT PROJECT

MOOD BOARDS

The first step in the process of developing a concept is doing research. A lot of projects take inspiration from other works that are available to the public, and in some cases, internally within a company. The best way to group research is by creating a mood board.

A mood board is a visual tool that helps a designer or artist in communicating their ideas and concepts visually. It consists of well thought out and planned arrangement of images, materials, pieces of text, etc., that are meant to evoke or project a particular style or concept (Interior Style Hunter, 2022). We use a mood board because:

- it helps in expressing the vision a person has in mind for their project.
- it is a good starting point your visual ideas to others that might not understand it at first glance.
- it gives a process to build a clear design intent.



Figure 2 Future autonomous transport mood board

As depicted in figure 2, the inspiration for my project comes from the idea that autonomous vehicles will become the majority mode of transportation in the future. The development of smart cities greatly improved the use of self-driving vehicles. The goal of the future is to simplify the quality of life of people by improving and developing technology to a point where most tasks can be automated and controlled from a smartphone in your hand.

The mood board also suggests ideas for improving the environmental effects vehicles. Electric cars will become a norm in the future and will completely replace the internal combustion engine. Public transport will also have developed to a point where owning a private motor vehicle will not be a necessity.



Figure 3 Mood board for future public transport

Public transport, as shown in figure 3, will become the norm in the future. Countries like the Netherlands already have a fantastic public transport system that reduces the need for private motor vehicles, at least within certain parts of a city. The goal of this project is to create a form of transportation that can be used for both journeys that are short as well as long distance.

CONCEPT IDEATION

Ideation is the process of creative thinking that consists of generating, developing, and communicating new ideas, where an idea is understood to be the basic element of thought that can be either visual, concrete, or abstract (Garfield S, 2019). It can be separated into abstract ideas that help you reach a certain goal in the development process, or it can be clearly defined steps, to take you from the initial problem-finding right through to implementing solutions to the problem at hand. During ideation, generating a large number of ideas is the primary aim that can be filtered down based on the project scope and cut down into the most practical or most innovative ones (Basadur).

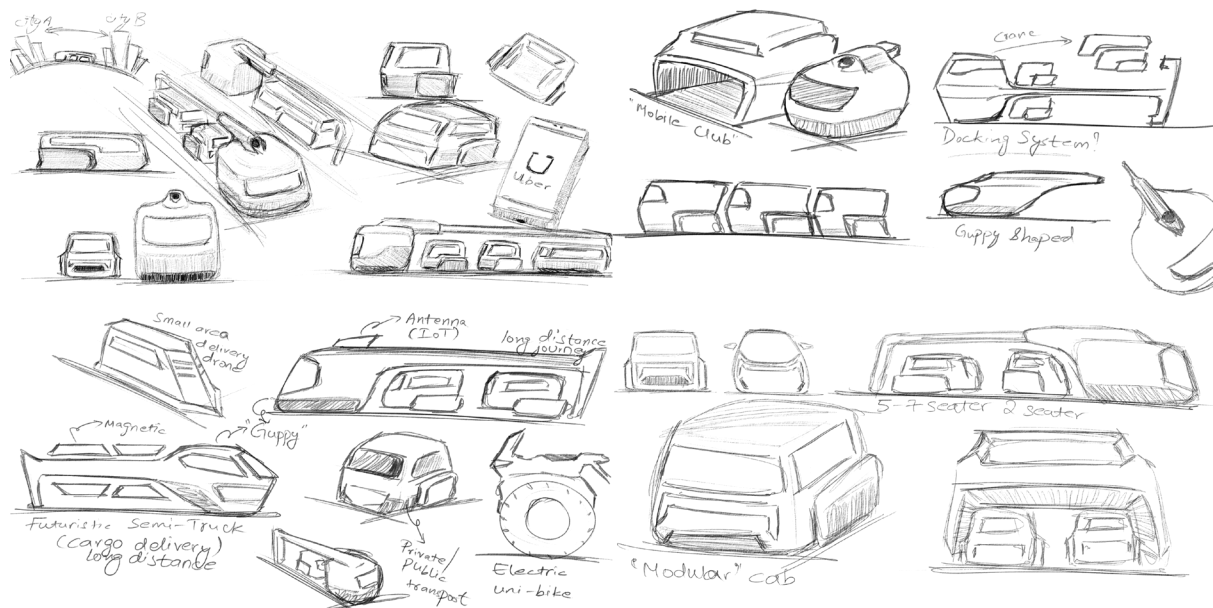


Figure 4 Ideation for future public transport

Initial ideas for the project included autonomous vehicles that would act as standalone cabs and taxis within the city. They would be connected to the Internet of Things (IoT) of the smart city and would help reduce traffic congestions and promote proper road safety within large urban areas. These vehicles would also be capable of long-distance travel. This would have been possible by connecting to a larger 'mother-ship' like vehicle that acts as the primary control unit. Subsequent vehicles travelling in the same direction would connect to this chain, forming a road-train of sorts.

There were some downsides to this concept. The whole idea of this project was to simplify public transport. I felt as though this concept would have complicated matters by adding in too many variables. There was also the issue of how vehicles who were part of the chain would be able to de-link from the group, when necessary, without causing any disruptions to the travel experience of other passengers. These are all hypothetical situations, but need to be considered regardless, since this concept could potentially be used.

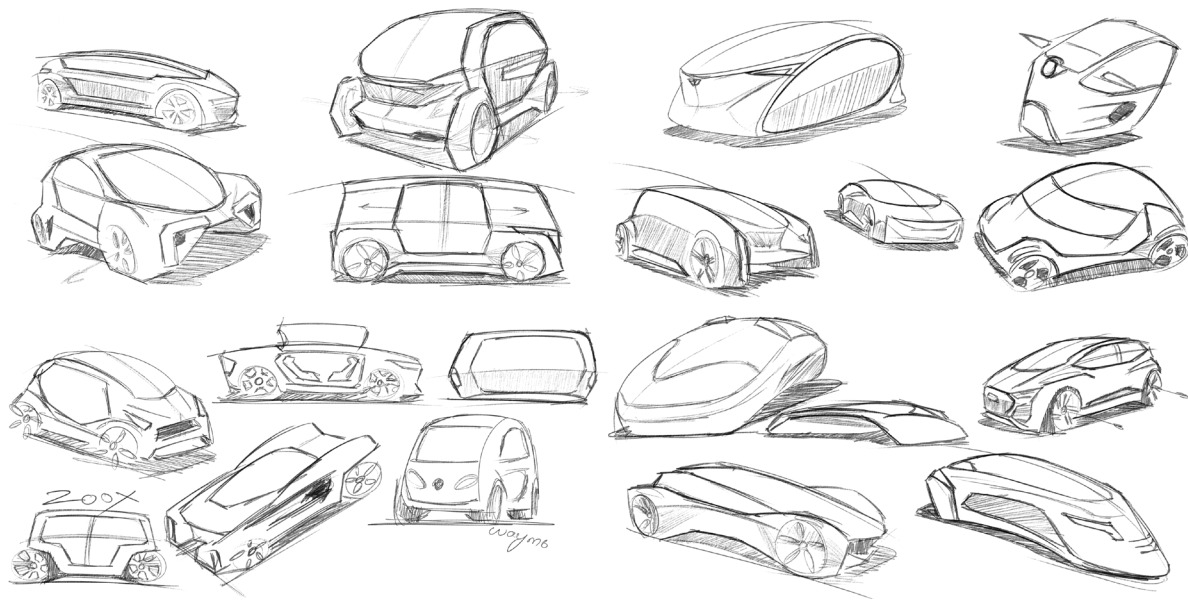


Figure 5 Reassessment of concept

As seen in figure 5, the idea of a main control vehicles was scrapped, and the individual cabs were focussed on. Extensive research on futuristic vehicles and public transport was conducted. Many concept designs for future autonomous vehicles were radical, since there are no rules present at the moment to govern them. I came to a realisation that most concepts for future transportation were for privately owned vehicles and there was not much source material in terms of public transportation. I concluded that simplifying the design to a minimalistic exterior was necessary and more focus should be placed on improving the rider experience rather than the driver experience, as that would be a redundant feature in the future.

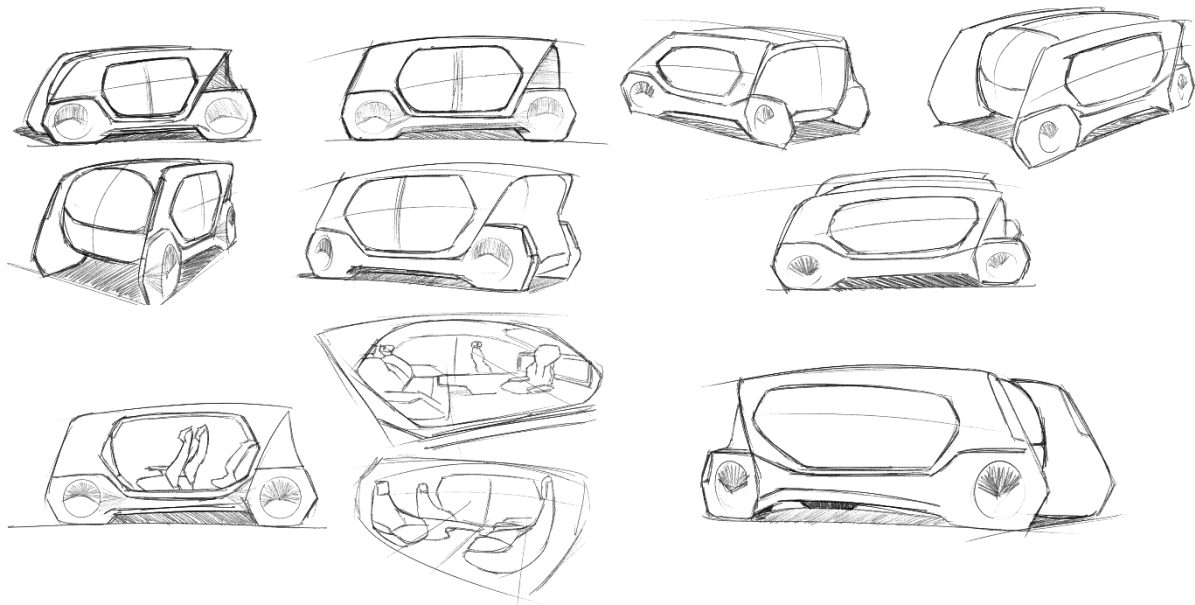


Figure 6 Finalisation of concept

The final concept was decided to be very discreet in terms of the exterior styling. It is meant to be part of the smart city infrastructure. The design allows for spacious interior features that improve the ride quality and experience of the passengers using it, regardless of travel time and distance. While this may seem as the final concept, it will still go through many iterations and changes as feedback will be received from other departments such as engineering design or studio modellers will point out issues that do not translate well from 2D to 3D.

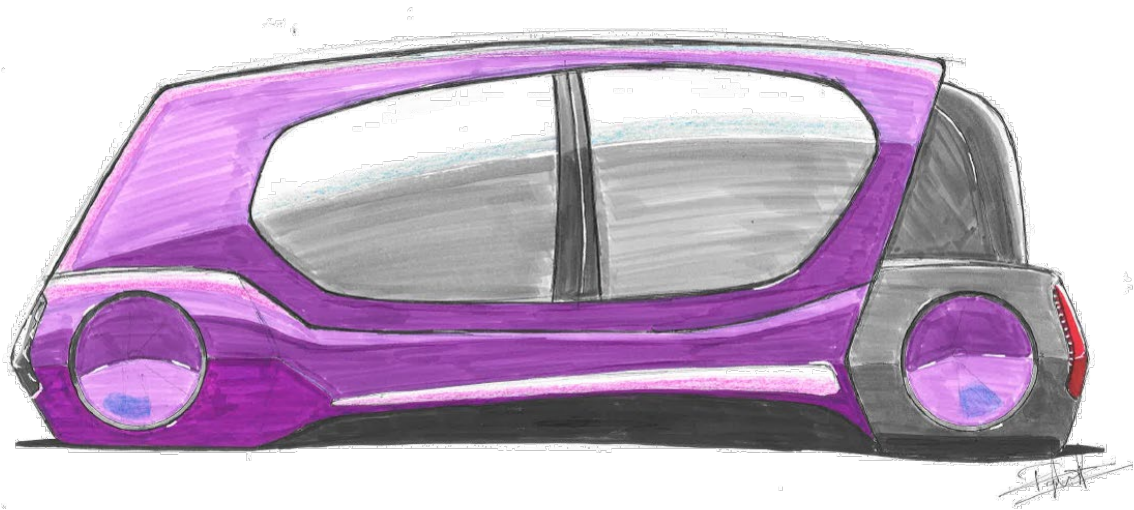


Figure 7 Final concept render

3D MODELLING, DIGITAL VISUALISATION AND BENCHMARKING

The next step in the design process is to make virtual 3D models of the concept using various software such as Autodesk Alias and CATIA V5, to name a couple. Most of the time, what looks good in 2D may not translate that well in 3D, which is why this step is crucial in the design process, not just of vehicles, but in any product design field. These digital models help us understand how the vehicle will look in actuality, while also providing feedback to designers so that they may tweak the design to fit engineering requirements without compromising the essence of the design.

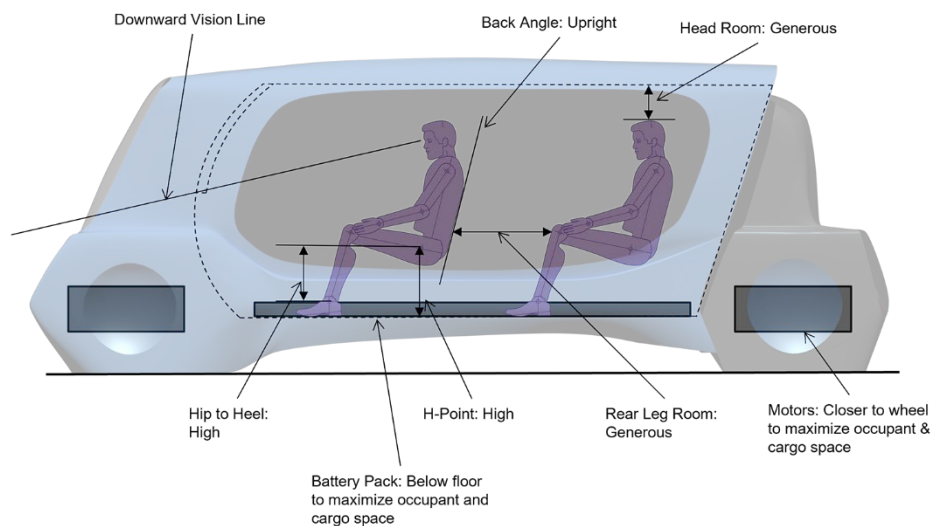
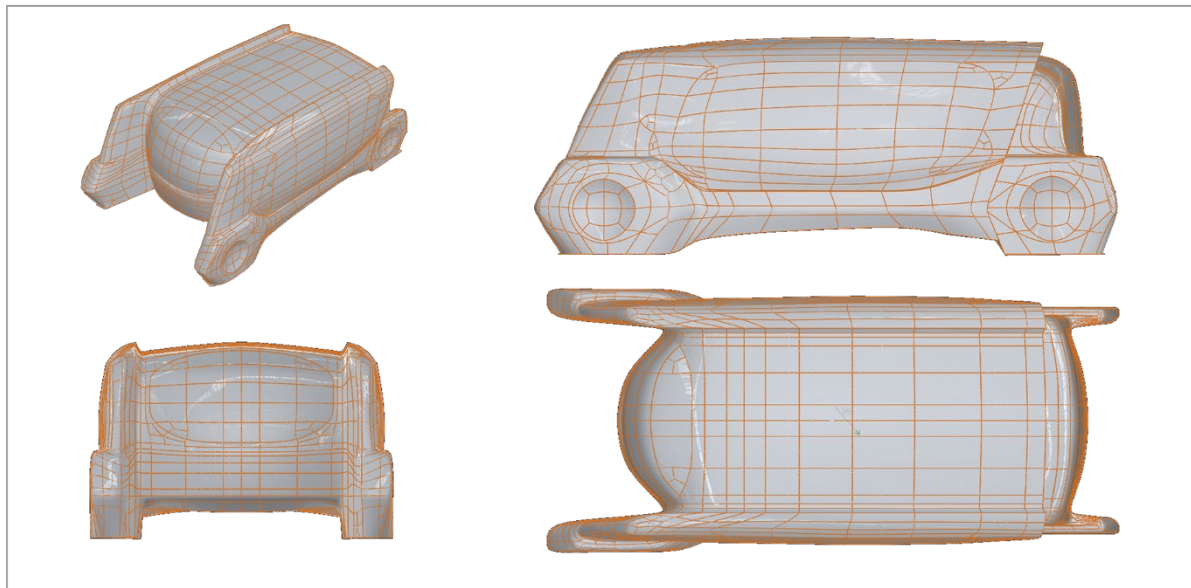


Figure 8 (above) 3D modelling using Alias. (below) Package drawing for final concept

As seen in the first image in figure 8 above, 3D models help us understand the aesthetics of a concept in ways that can never be understood in 2D. There are various departments that come under engineering design. Some of them are:

- **Digital Modelling**

One of the biggest steps in the design process is making the important jump from 2D sketch to 3D mode. This is where computer aided styling (CAS) comes into the picture. The CAS team consists of digital sculptors, working on the very first 3D models in the design process. The craft is digital, the software typically used is Alias, but the work demands the same attention to detail and aesthetic comprehension as any other part of the design process.

- **Design Visualisation**

Visualisation is a key element in the design process showcasing the digital models created by the CAS and surfacing teams in animations, images and real-time reviews. Visualisation brings the concept to life, making them look photo-real in realistic environments and adding dynamism to the models by animating them. VRED is the proving ground for design decisions, allowing designers to test multiple options quickly and make informed choices for development. It is also the preferred method for public facing content. Visualisation methods are developing

rapidly as hardware and software improve and the move into real-time engines like Unreal and Blender brings with them a whole new opportunity for creative design.

- Studio Engineering

Studio engineers, as part of the creative team, enables the design vision. They are the bridge between design and engineering. From the first blank sheet idea, through to final concept finalisation, they work to deliver the vision for the car, maintain the integrity of the design and come up key decisions that would improve the overall vision of the concept.

The second image in figure 8 is known as a vehicle package drawing. It cannot be emphasized enough how vital the driver and passenger packaging is to the design of a vehicle. A common phrase used in automotive design is that cars and trucks should be designed from the inside out. Vehicle packaging is necessary to improve the comfort and safety of passengers. The goal is to create an envelope around them and use key reference data within their geometries to set up the rest of the vehicle package (Macey & Wardle, 2009, p.88). As quoted by Macey & Wardle,

“The main objective for package ideation is to study as many system configurations as possible in a short period of time. The process is similar to design ideation where each concept is sketched out loosely on paper and evaluated as a cluster of ideas. It is easy to jump to conclusions and rely on paradigms that have been applied on previous projects and walk backwards into the future. So, make good use of this phase of the project and don’t hold back. Don’t worry if some ideas are bad, what appears to be a dumb idea during brainstorming can often lead to the development of a very good one later one.”

After the functional thresholds of the project have been set, there is often very few opportunities in the project development phase to be innovative with the vehicle architecture. These can often times be missed or looked over due to time constraints, and therefore need to be communicated clearly and precisely.

Design visualisation is also an essential part of the design process. As stated above, it is a key element that allows digital models to be showcased in animations, images and real-time reviews. The software used in this project was Autodesk VRED. It allows for real-time editing of various factors and effects that when rendered out, put out a near photo-realistic image or video of the concept. It used 3D assets to make high quality 2D images that give designers and studio engineers an insight into how the vehicle could look in a real-time situation with natural lighting or other environmental or simulated scenarios.



Figure 9 Photorealistic render using VRED

3D PRINTING



Figure 10 3D print of the design concept

3D printing is an optional method of making a physical model of the design concept, most of the time scaled down. This also allows designers and studio engineers to get a visual idea of what the concept would like in real-time. This is not commonly used in the design process, since full-scale clay models are typically created to help with understanding the physical scale of a concept.

PART 3 – SYSYGY 2022 EXHIBITION



Figure 11 Project display at SYSYGY 2022 exhibition

As part of our confirmative praxis, we were given the opportunity to display our project for a total of 3 weeks over the course of December 2022 - January 2023. This was a unique experience that was open to the public. It was a great experience as I was able to interact with people and collect some feedback as well as their perspective in terms of what could be improved in the concept from the perspective of an end user instead of a designer or engineer. This will prove crucial in improving the design and creating a product that would be easily understood by the public.

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