# Examining Virtual Reality As An Empathizing Tool for Early Ideation Stage in Design


Master of Industrial Design
Project by

Alex Christopher Velasquez
Advisor: Dr. Wei Wang
2020

# Contents


**1. Overview**

1.1 Background
1.1.1 Design Thinking of Today
1.1.2 Virtual Reality
1.2 Research Question
1.2.1 Hypothesis
1.3 Methods
1.4 Objectives

**2. Literature Review**

2.1 Virtual Reality in Product Design
2.2 Virtual Reality in the Design Space
2.3 Early Stages in Design
2.4 Empathizing Tools in the Early Ideation Phase

**3. Research Design**

3.1 Process of Testing Hypothesis
3.2 Design Context

**4. Study Preparations and Conducation**

4.1 Study Preparations
4.1.1 Prototype and Preparations
4.1.2 Current Technologies in Autonomous Shuttles
4.1.3 Persona and Journey Map Development
4.1.4 Structure of Workshop
4.1.5 Tools and Definitions of Workshop
4.2 Study Conducation
4.2.1 Workshop Preparation
4.2.2 Design Briefing
4.2.3 Observations
4.2.4 Design's from Teams

**5. Result Analysis**

5.1 Data Breakdowns
5.2 Evaluations

**6. Discussion**

6.1 Analysis of Hypothesis
6.2 Observations of Findings
6.3 Where V.R. Stands in Early Design Phase
6.4 Impact

**7. Summary**

7.1 Summary
7.2 Call for Future Research

**Acknowledgement**

**Appendix**

Reference
Image Reference
Sample of Task Analysis, SUS, and Design Evaluations
Evaluation Data

## Key Contribution

- Researched the potential benefits of Virtual Reality in the industrial design work space

- Focused research space on the first phase of the double diamond design method

- Compared Virtual Reality versus traditional design conceptualization methods in the initial design space

## Methodology

- Desktop research: Analyzed the double diamond method and how the design conceptualization phase fits in the design thinking model

- Designed virtual reality scenarios to use in a design sprint setting.

- Conducted a design workshop to test validity and effectiveness of virtual reality in design conceptualization

- Evaluation: Analyzed process and outcomes generated from the workshop.



# 1. Overview

# 1.1.1 Design Thinking of Today

Designers are constantly being tasked with coming up with new ideas and solutions based on new problems spaces that are arising in society. Problem spaces like how to improve a shopping cart design in the grocery shopping experience or designing an interactive exhibit in a predetermined space, situations like these would ideally require a substantial amount of field observation, user study and team collaboration in order to perfectly understand the problem space to effectively come up with ideas and concepts that can be narrowed down into final executable concepts. Designers have been taught to use traditional "tried-and true" methods of problem space identification and ideation in order to become empathetic or immersed into a design situation to effectively come up with ideas. The most well known tools are:

- Journey mapping
- Sketching
- Paper Modeling
- Story telling/boarding
- Persona Mapping
- Mind Mapping
- Field Observation
- Pain/Gain Point Maps
- Survey analysis

These tools are well known tools that have been "tried and true" to most designers and have given them fairly good, consistent results. In combination with design thinking strategies like the Double-Diamond method (Design Council), these tools can be very effective in allowing designers to become empathetic and immersed into a design situation that will in turn allow them to come up with novel ideas. There are, however, some possible drawbacks to these tools.



For one, these tools can be categorized as slow because a substantial amount of mental effort is required to even come up with the preliminary resources needed before a designer can begin to become empathetic towards the design situation. Obviously a design team can quickly "sprint" through these design tools in order to cut down on the time it takes to gather these resources, but in order for these tools to be effective a design team must take their time with them. A good example of this is persona mapping. Personas are fictitious characters that represent real stakeholders with their own unique demographics, desires, issues and goals. A good persona map requires meticulous research and may even require field research in order to effectively identify relevant traits to these persona characters and all of this requires time.

A second related drawback is that in the real design world, there may not be enough time in order to utilize these tools to their fullest effect. Design teams may be pressed to ideate new concepts in relatively short time. In an academic studio setting students are given enough time to thoroughly go through every part of the design process, but in a real world design environment, design teams will face quick deadlines, unexpected hurdles and different levels of understanding from different members. These tools may not necessarily be flawed, but an interesting question can be brought up : does the effectiveness of these tools to help designers ideate concepts diminish as the amount of time that's given becomes shorter?

The third drawback is simply the mental effort required to use these tools. If a lot of time and energy is spent on creating resources that is meant to help designers identify problem spaces and ideate solutions that may in turn negatively impact the quality and quantity of the designer's ideas.

With V.R., this could potentially solve these drawbacks by allowing the designer to be immersed in the design context. The context can be re-visited and replayed which takes the mental load of making astute observations the first time out. This immersive context, through recording 360 degree videos, are easy to produce and offer a field observation experience in relatively short amount of time. Point and shoot 360 degree cameras takes the guess work out of creating resources and allow for quick review of the context.

That is where field observation can come in handy and indeed it does. However this too involves time and energy because a design team would have to travel to the environment the team plans to design in, take notes or pictures or video, possibly even interview people in the environment, then take all of that information back to the studio. But the information recorded is only good if it is detailed and thorough enough. If not then the team would either have to go back and re-record their observation (which, chances are, the elements can not be reproduced) or reimagine what that environment is like which is where certain details may “fall through the cracks” simply because human memory is never perfect.

Again, these tools are not necessarily flawed to the point where they need to be completely re-imagined but as newer more complex design opportunities start to arise, the question is asked: is there a way to supplement these tools to make them more effective or even replace them?



# 1.1.2 Virtual Reality

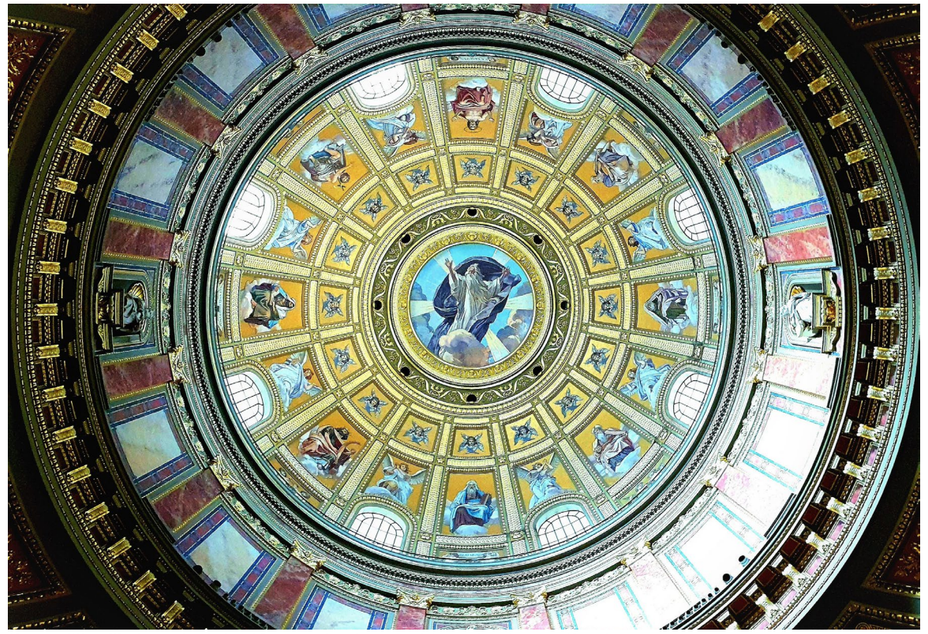


Fig. 1. The Tribunal of the King in Budapest. Photo by James Finch

Virtual Reality (V.R.) is a term being used more frequently in today’s society as both a tool for productivity and a form of entertainment. The most common definition of virtual reality involves using computer generated graphics to create a 360 degree artificial environment where one can feel immersed in using the user’s sensory stimuli as defined by Merriam Webster (Merriam-Webster). While this is indeed a true definition, virtual reality is nothing new, in fact, virtual reality has existed in one form or another since man first harnessed the ability to express himself creatively.

It can be said that paintings were one of the first forms of virtual reality as they depict a scene or environment that is meant to immerse the viewer into what the artist wants them to experience. Early paintings offer merely a window into the scene or environment. Over time as the scale of paintings increased, so did the effectiveness of the immersion effect. Some famous early examples of immersive paintings were the famous basilica dome paintings in St. Peter’s in Rome or the Tribunal of the Kings in Budapest (fig. 1). These dome frescoes depict many 360 degree scenes such as famous battles or the story of Christ. Visitors were meant to look up and feel like a heavenly scene was taking place above them.

Panoramic paintings of the 19th century were more purposefully meant to immerse views into the scene (Virtual Reality Society). These paintings are meant to fill the field of vision of a viewer and make them feel fully immersed into the scene. Locally, Atlanta has a cyclorama theatre that features a 360 panoramic painting depicting the Battle of Atlanta (fig. 2, Atlanta History Centre).

Fast forward to the 1990's, companies like SEGA and Nintendo (fig. 4, ibid) developed virtual reality headsets for entertainment and gaming. However, by this time virtual reality was starting to shift from pure entertainment to serious applications. In 1997, Georgia Tech and Emory collaborated to use V.R. in treatment of PTSD patients (ibid, Emory). Movies such as "The Matrix" helped push the topic of immserive simulated world to the mainstream (V.R. Society). In 2007, Google develops "Street View" add-on to its Google Maps platform to view landmarks and city streets in a 360 degree view. In 2012, The Oculus launched a kickstarter campaign to create a revolutionary stand alone hand-set that brings V.R. to the households of many. Two years later, Facebook buys Oculus for its potential and Google also launches Google Cardboard, a simple aparatus meant to turn a ordinary smart phone into a V.R. headset.

Other examples of Virtual Reality being used include:

- Google Maps Street View (fig. 3)
- Youtube VR Videos
- Emory using V.R. to treat PTSD patients (Emory)
- Architecture firms using V.R. and A.R. to visualize designs (Medium)

It is clear because of V.R. 's ability to immerse someone into the design, it is a unique tool in validating and testing out ideas and designs. Ideally collaborative design should take place in a high-interactive creative space such as a virtual reality design space. But can V.R. help in creating empathy and inspiration as a way to discover design opportunities in the early design phase?

Industrial design always requires creativity and a level of innovation. Ideally, a designer would always produce innovative and game-changing concepts in a relatively short amount of time to then be narrowed down into a well rounded and solid design. However, humans are inconsistent and are not always able to generate top drawer ideas off the top of their heads. That is why design tools and methods exist in order to help designers be consistent and cut down the time it takes to generate ideas.



Traditional design tools and methods like simple pen and paper sketches, storyboarding, persona generation, journey mapping and acting out scenes among others are tried and true methods that designers have used to help become empathetic to the design situation and be able to come up with effective ideas. However with the passage of time these methods may start to become outdated compared to newer methods of design, especially if the design situations involve thinking well ahead of the future. Traditional design methods in themselves require effort and creativity from the designer to imagine.

Fig 2. The Battle of Atlanta as depicted in an immserive 360 degree painting Image; AHC)

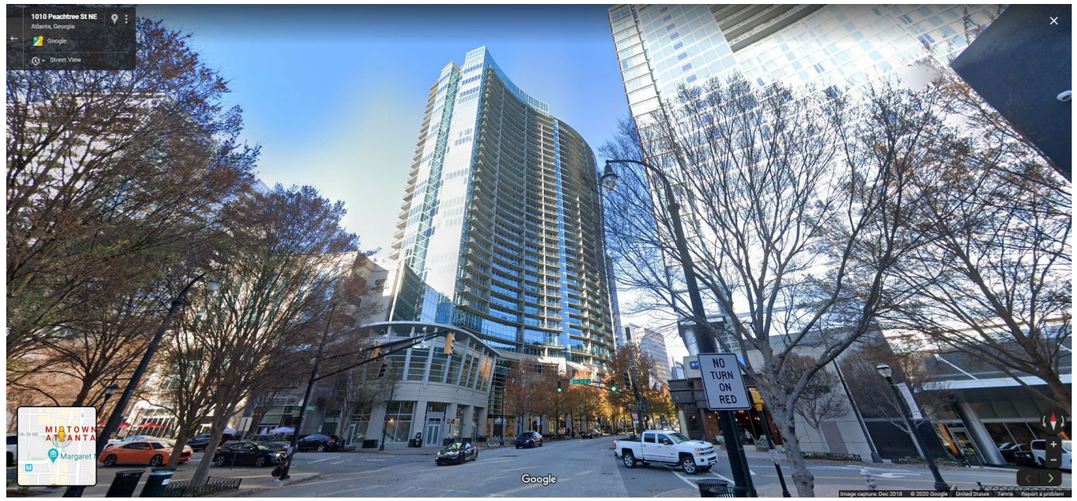
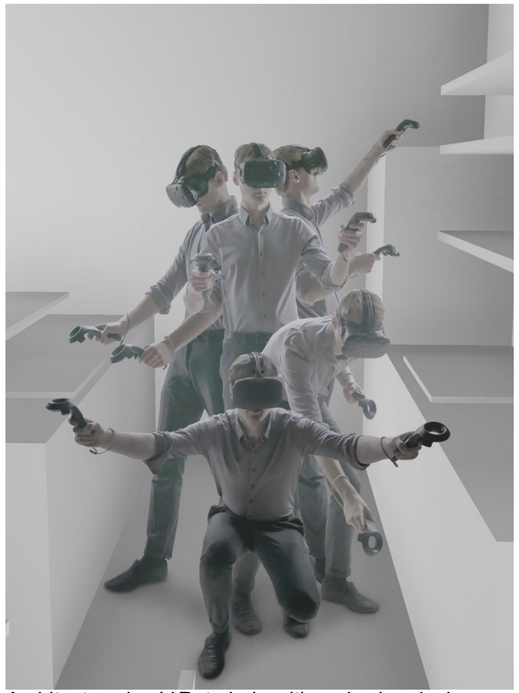


Fig. 3 Screen shot of a 360 degree street view in Google Maps. *Image: Google Maps*

Fig. 4 Nintendo Virtual Boy *Image: Nintendo*


Architects using V.R. to help with reviewing designs. *Image: Medium*



For example, if a designer chooses to storyboard and/or journey map the design problem spaces, he or she would have to imagine the problem space, the environment, the context among other things on top of creating solutions. If a designer feels that it is important to conduct field research, then he or she would have to travel to the environment, and make observations by note taking, photography or videography or sketches. Some details of the environment could “fall through the cracks” of the designer’s mind or elements of the environment can not be replicated or reproduced for re-observation.

This is where Virtual Reality (V.R.) can be a major advantage in helping designers become more immersed into their design space in order to come up with ideas. This project aims to compare virtual reality versus traditional design methods in the early conceptualization phase of design in order to gauge the effectiveness and efficiency of virtual reality to see if V.R. has an advantage over traditional I.D. methods when it comes to generating ideas and early concepts.

# 1.2 Research Question

*“Can Virtual Reality help designers in the early design phase better identify problem spaces and design opportunities in order to create novel design ideas compared to just using traditional ID tools and methods?”*



This project began in August of 2019 and involved conducting literature review, deploying a preliminary survey, analysis of autonomous shuttle companies, field observations and culminating with a design study workshop involving participants divided into two teams according to the design methods they will use and comparing the amount of ideas generated and comparing how innovative those ideas were

Design process in industrial design has stayed fairly consistent over the years. It follows a process of phases; Empathize, Define Problem Spaces, Ideation, Prototype (Interaction Design Foundation), Evaluation and Final Design with micro phases in between each phase. The early design phase can be defined in phases 1 through 3 and these phases typically rely on traditional industrial design methods of empathizing and ideation such as sketching and storyboarding and slightly more immersive ones like persona and journey mapping and field observation. Some of these tools however involve tapping into experiences, imagination, surveying (which in a rapid ideation session would probably not be possible), and interpretation which could all leave room for incorrect judgement and harder/longer time in developing novel ideas. Field observation could serve as an ideal tool to help designers be immersed in the context of their design brief and see first hand what problem spaces/design opportunities could arise as well as collect valuable data about its potential stakeholders that could also inform more accurate persona profiles. However, field observations require designers to make accurate and detailed observations the first time since elements about field observation (such as a person’s actions, weather, real life conditions) are not replicable. Photos and videos are only effective if a lot are taken from many different angles and points of views. Controlled field observations (such as a design workshop study) allow designers to control elements and allow for replicable scenarios but these tend to be time intensive, costly, inauthentic, and cumbersome. The question is raised; what tool can be supplemented with other tried and true tools that could help designers in the early design phase be empathetic and immersed into the design space?

360 videos offer immersive experience in being in a space and 360 cameras are relatively affordable to buy and easy to use. Taking 360 videos a step further, virtual reality headsets are increasingly becoming popular, affordable and easier to use which 360 videos can be experienced in. Therefore there is an opportunity for virtual reality to play a key role in the early design process in immersing designers into the design space where they can run group discussions, rewind and fast forward and repeatedly observe actions which could help in giving a new perspective on the design context.

## 1.2.1 Hypothesis

Empathetic and ideation phases will benefit from virtual reality to help designers identify and learn from potential problem spaces and design opportunities quicker and easier than using prior industrial design tools of ideation.



## 1.3 Methods

This project will analyze the initial part of the double diamond method to figure out how virtual reality can be integrated into the early design process. The double diamond method is an effective design thinking method that is an ideal method to test virtual reality within the early design phase. A contextual design brief would be created to simulate a real design project that requires designers to use their critical thinking skills and incentivize designers to use virtual reality.

Once a design brief is created, then a design workshop is structured and participants recruited to partake. The workshop will be divided into two teams; team 1will be instructed to use 360 degree virtual reality videos to help with the problem space discovery/ideation phase and team 2 will use traditional industrial design methods familiar to them to do the same. Both teams will brainstorm the problem space discovery/ideation phase with their respective teammates and then break off to design individually.

Each participant will be given a SUS/TLX task analysis evaluation to fill out and in later weeks a design evaluation survey will be distributed among both teams, industry experts, and general master's of industrial design students in order to gauge how each design method influenced the final design concept. Data will be cross analyzed with the SUS/TLX evaluations and with observations made from the workshop to come up with final conclusions about how virtual reality plays a role in the early design phase.

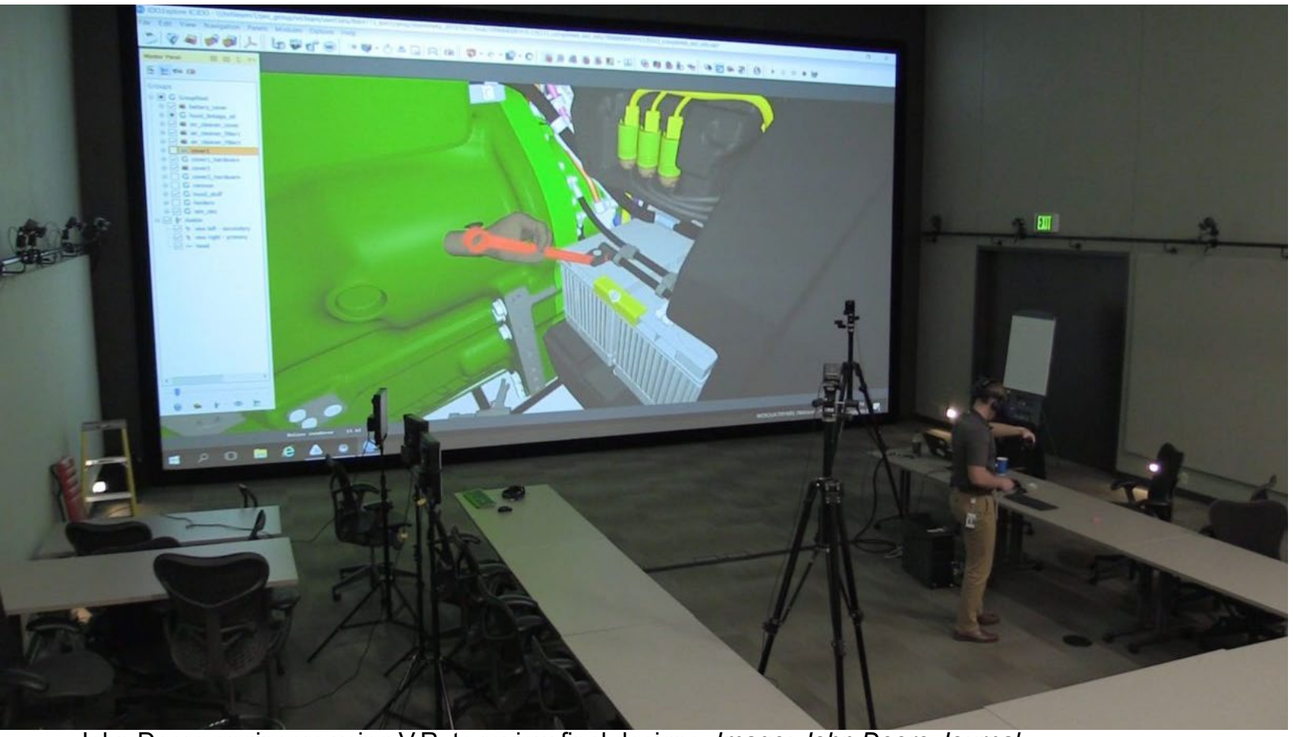
## 1.4 Objectives

- Study in what way virtual reality can play a role in the early design phase
- Assess what current ideation tools current industrial designers use to empathize and familiarize themselves with the design context
- Evaluate designs developed by each team
- Evaluate task analysis of virtual reality vs. traditional industrial design methods
- Make final observations.



# 2. Literature Review

# 2.1 Virtual Reality in Product Design



John Deere engineers using V.R. to review final designs. *Image: John Deere Journal*

It is important to understand what research has been done on virtual reality in relation to industrial design and industrial design methods. Has there been any significant exploration in virtual realities impact on the design process? Is there any specific way virtual reality is used already in said process? Has there been any successful uses of virtual reality to engage people in the design process better than traditional methods?

One of the most effective ways to gauge the effectiveness in virtual reality is by gauging the acceptance of the tool in the design process. A tool, no matter how revolutionary or novel, is not effective if it is not accepted in use. Fred Brooks did just that in 1999 when he launched a survey detailing the current state (current for his time) of virtual reality in the industry (What is Real about Virtual Reality? 1997).



He chronicled the progress made in virtual reality from 1994 to 1999. Where as in 1994 Fred Brooks concluded that virtual reality almost worked, in 1999 he notes that virtual reality has arrived, meaning that its use in the industry is now either accepted, known about or common and that it "barely works" meaning that while there are still aspects of virtual reality, from a hardware, software, and accessibility standpoint, that could be improved there are real values to using virtual reality in product design and engineering.

Cadillac using VR to visualize its cars *Image: Automotive News*

Two notable product design examples he used was that of automotive design and Daimler-Chrysler and design review at John Deere. In Fred's tour of Daimler-Chrysler's automotive technical centre he observed how user engineers used a head-mounted display to provide the virtual reality environment combine with what is a called a "buck" which is a real car seat complete with real steering wheel and a mock up of the instrument panel and centre console to help give researchers a more immersive experience when testing different design concepts such as interior colour, positioning of cup-holders and other ergonomic and aesthetic elements of the car's interior design.

The second example, the John Deere design review, is quite interesting because Fred Brook's observation of how John Deere uses virtual reality follows the use pattern this study aims to test. John Deere used virtual reality to review safety technologies, handholds and steps on their prototype tractor

A review process that normally takes around two days because not only does a mock-up need to be constructed but each reviewer would need to test out the mock-up one by one. Now with the use of virtual reality, each of the reviewing members can watch on screen as another member using a head mounted display conducts the different actions that showcases the different elements John Deere wants to review. This, Fred Brooks explains, not only saves on man-power and time it would take to construct but also offers a way for the review panel to group discuss and see the actions performed all at the same time and "from a common eyepoint". This is an idea that this study aims to study, using virtual reality in a group setting to foster group discussion and see if it results in novel ideas or an increase in quantity of ideas.

Fred Brooks does point several areas where virtual reality has yet to improve on including:

- Getting latency [of environments] down to acceptable levels
- Interacting most effectively with virtual worlds
- Making model worlds more efficiently
- Rendering models in real time

In 2014, Leif Berg and Judy Vance decided to re-examine where virtual reality stands in industry since Fred Brooks last investigated in 1999. In short, they found that V.R. has indeed advanced enough to the point where "...virtual reality has arrived: it works! It's mature, stable, and most importantly, usable" (Berg and Vance, p.1). Across different disciplines, such as engineering, educational, design and marketing, V.R. has shown potential to bridge the gaps that would otherwise be hard to cross in a 2-D environment or through simply writing (Berg and Vance, p.24).

Companies surveyed for their V.R. use include: General Motors, Ford, New Holland (a tractor company), Caterpillar, Tank-Automotive & Armaments Command, PSA Peugeot Citroen, Lockheed Martin, National Renewable Energy Laboratory, John Deere, and the Idaho National Labs (Berg and Vance).




Some of the companies surveyed for their use of virtual realities. (All logos sources from their corporate trademark and IP websites).

It is clear that virtual reality is so far heading in the right direction and seems to be finding use in the engineering and industrial design industry. However, the companies surveyed by Berg and Vance are big multinational corporations with vast resources and designers and engineers that are able to operate virtual reality machines and understand the internal design process and projects. The next question would then be how can virtual reality help those who are novices at design or virtual reality? Virtual reality could also help bridge the design knowledge gap and allow designs to be more immersed and empathetic towards its stakeholders.

In 2007, a block of houses were demolished on the Tibbington Estate in Tipton (commonly referred to as the 'Tibby'). The Tibby is known for its industrial decline and its low standard of living in comparison to the rest of the United Kingdom. The idea was conceived to let the residents of Tibbington Estate help dictate what should be built on the now empty plot of land. Through the Midlands Architecture and Design Environment (MADE), Sandwell's Safer and Stronger Communities Programme (SASCP) and serious gaming company Digital Native Academy (DNA), together they created a virtual reality game that engages the community, particularly the younger population, to envision and create what should be built on the new site. They hope to recruit the community and young people to participate

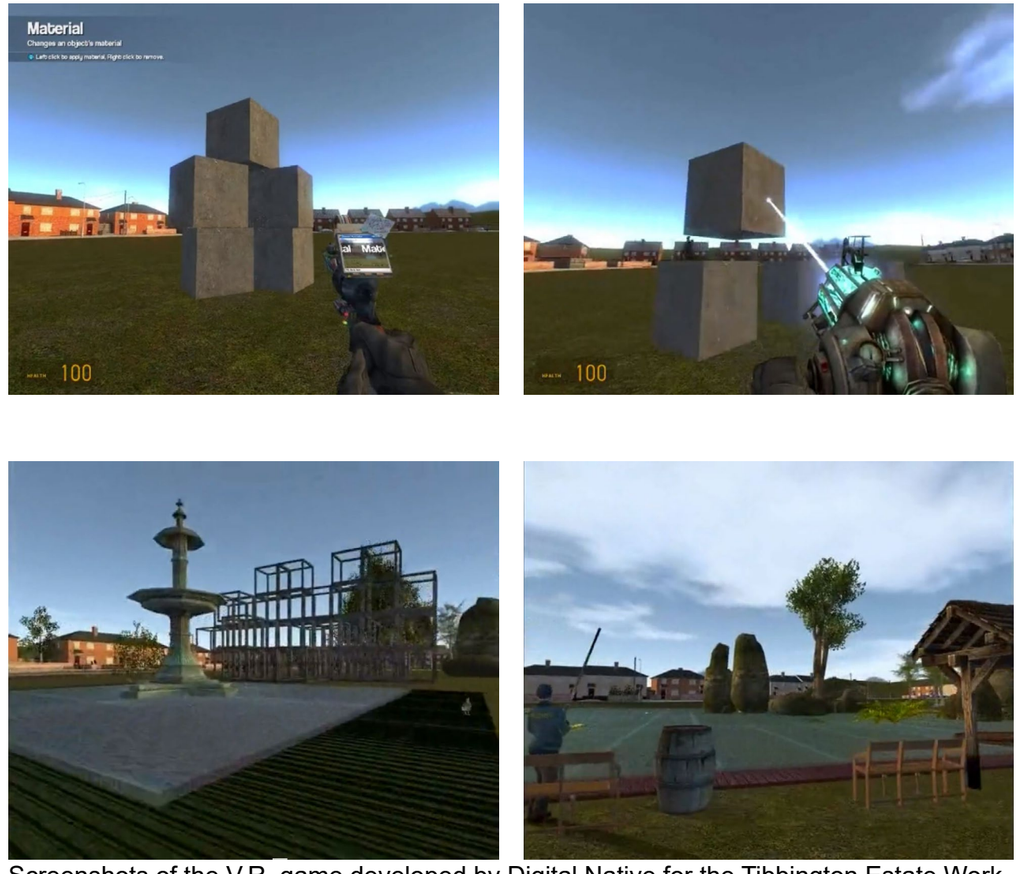
The resulting game is similar in nature to Maxis' The Sims where can design architecture and homes with appliances, shrubbery and terraforming and Microsoft's Minecraft where the player can roam the site in first person to get a better sense of scale of the environment, what they build in that environment and what they build on said environment.

The facilitators created 2 phases; the first phase consisted of a practice run where participants get to practice getting familiarized with the game's controls and functions and the extent of what they can do. The second phase consists of the actual designing of the plot of land.

The results were successful not only in participation rate but also in the variety of ideas they generated.Some examples of designs generated included a football pitch and play area surrounded by a people mover (light rail), a maze and pool, a community centre and play area, and a fishing pool. Because of the V.R. nature of the game, it allowed participants to become more immersed into the design process.

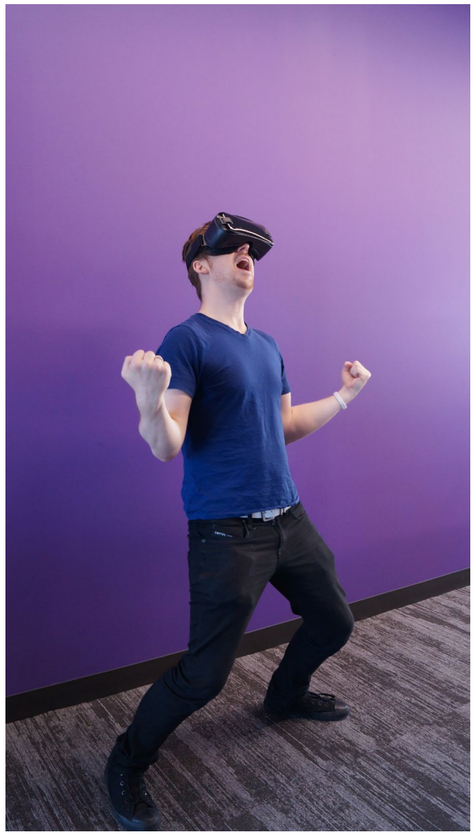


This allows future designs to become more sustainable because the ideas are generated from the practical needs and desires that surfaced from this design exercise. Whether or not any of these concepts were eventually built is a separate issue because according to google street views, all that was built was a small play area and large green spaces. Besides the sociological benefit this project had of giving low-income and marginalized residents a voice through V.R. gaming, it empowered residents to give their design opinions in a more immersive way that probably would have never come about with other more traditional methods of design brainstorming. Most importantly, V.R. allowed residents with little to no design experience and not much initial information to have a level playing field with architects and city planners in the design process.




Screenshots of the V.R. game developed by Digital Native for the Tibbington Estate Workshop. *Image: Vimeo Video by Digital Native*

# 2.2 Virutal Reality in Design Space



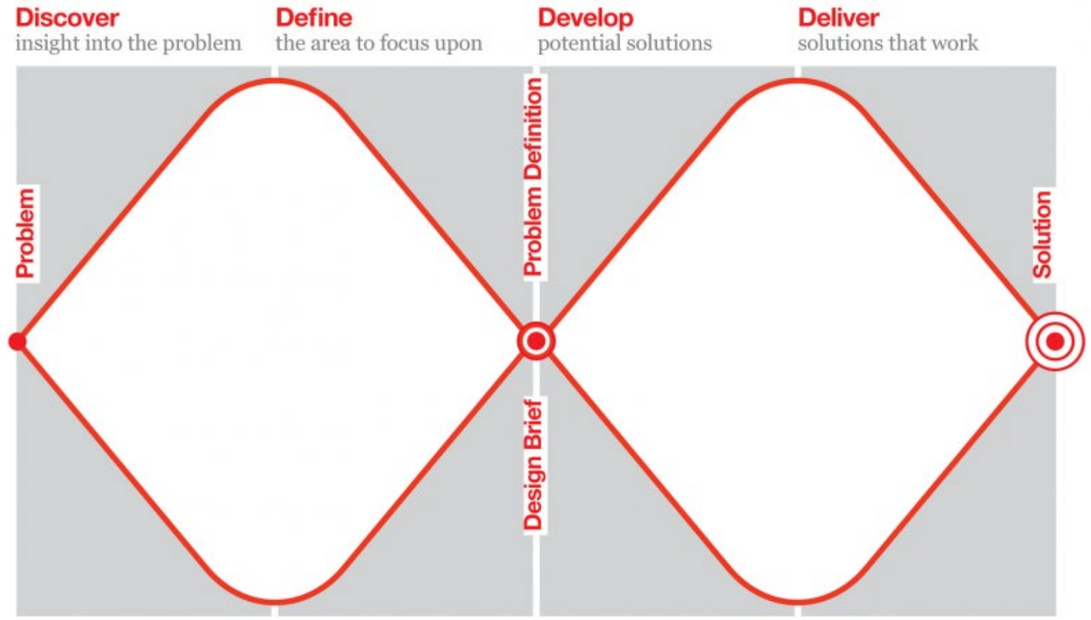
It is gathered through current literature review that virtual reality has been adopted in industry and has an important role in helping companies see their designs in new light. We also see virtual reality being used as a design tool to allow non-designers to freely design. However, there are two key factors to point out;

1. In the case of big firms, V.R. is used as a reviewing tool to observe designs and brainstorm improvements or review concepts in the later stages of design. V.R. was probably not used in the early stages of design where designers would ideate and help discover problem spaces/design opportunities.
2. In Gaming the Tibby, V.R. was used in an unstructured setting where participants designed "as they go". Their imagination and needs/desires for what should be built on the site was the main driver of their design. V.R. was used as a tool to give a more immersive point of view to help the residents convey what they think should be built so architects and designers can have a better idea of what the needs of the residents are and drum up support for the construction project. V.R. was not used as a tool in the design process like how sketching, storyboarding, journey mapping or other investigative tools are used by designers to ideate concepts that would be refined and iterated for the final design. What the residents created is, in a way, separate to the design process the architects and city planners will use. In fact, not much news followed the successful design V.R. workshop. Through google maps street view it seems that nothing other than a very simple play area was constructed which would seem to indicate that the project fell through before more serious design sessions were held.



In these two situations, in the first V.R. is used in the industry towards the tail end of the design process, in the second V.R. was used in the very beginning of the design brief but in an unstructured workshop setting where the results would help give architects and city planners a sense of direction for them to begin the real design process (the one that would actually garner real concepts that could be later refined). The question arises; can virtual reality be used in the early ideation stages of the design process, instead of the later parts, to help drive ideation and empathy towards finding problem spaces and design opportunities?

# 2.3 Early Stages in Design




Double Diamond Method Diagram developed by the British Design Council

This project will ultilize the Double-Diamond method as a framework for the design workshop. While there many other design thinking methods to model the design workshop on, the double diamond methods allows for a cognitive exploration divergence phase that fits in perfectly for comparing virtual reality and traditional design methods during the empathy early design stage of design.

The double diamond method was developed by the British Design Council in 2004. It is a revolutionary framework for design that has been used by many designers and design firms through the years (Design Council). The framework exists as a sort of "chassis" for designers to take and modify and tailor to their own design process.

As a brief summary of the double diamond method, it comprises 4 touchpoints;

- Discover: This phase is where designers take time to understand what the problem is rather than to guess or assume what it is
- Define: Through research, empathy tools and other means of understanding, designers arrive at a point where they can define what the design challenge should be.
- Develop: Designers now go out and find or ideate different solutions/concepts to further develop
- Deliver: Ideas/concepts that don't work are rejected and the ones that do are further refined to arrive at a final, fully polished solution.

Double Diamond Process in Relation to Design + VR

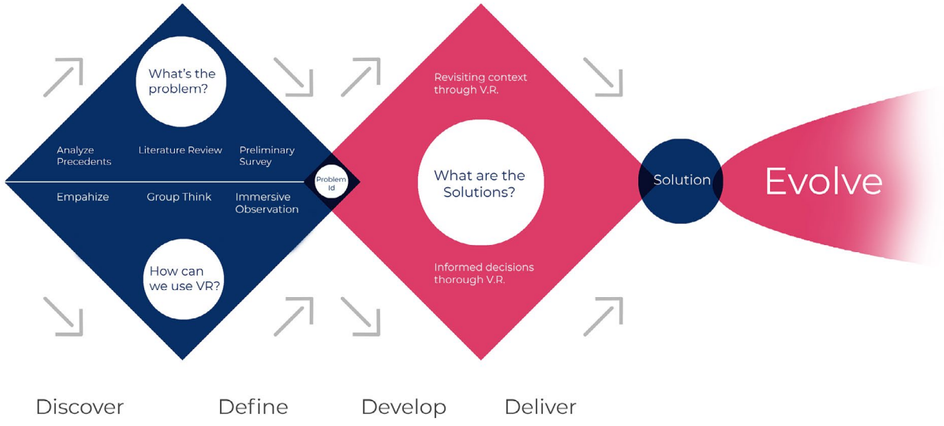


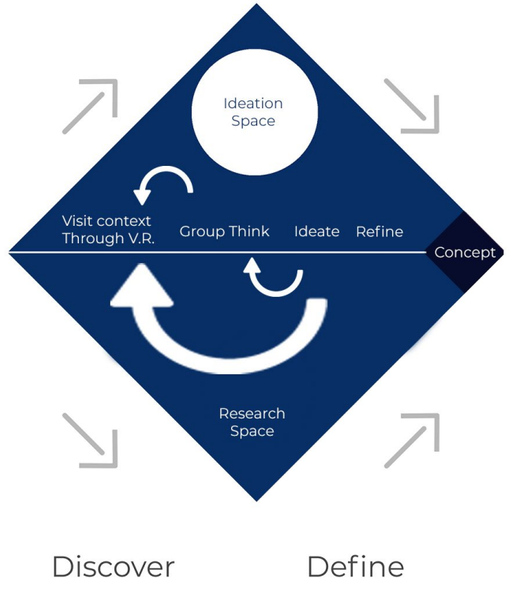

Diagram of the Double Diamond method in relation to Virtual Reality



Like two adjacent double diamonds, these touchpoints diverge to simulate open thinking space, wide scope of discovery, acceptance of as many ideas as possible and convergence where the scope is narrowed, focus is more centralized and ideas are further refined.

Because so many designers either work with or are familiar with this thinking framework, this project will utilize this framework to model how the early design process should be. Thus, this project will be heavily focused on the first diamond; what I call the "Discover-Ideation" diamond. The second diamond or the "Develop-Execute" diamond would be much smaller because ultimately what this project aims to see is what kind of initial ideas/concepts could arise when virtual reality is being introduced in the early design phase to help designers empathize with the design challenge and can help focus their attention on novel design opportunities. A drawback that should be avoided when using the Double Diamond method is to not treat this process as a strictly linear process. Designers should be encouraged to view this process as cycle within the diamond as shown in the diagram below. Method and resources can and should be revisited during the empathetic stage before arriving to an initial concept.

Discover-Ideation Phase in Relation to V.R.



The Discover-Ideation is the first diamond in the double diamond phase. This early ideation stage is where designers become familiar with the design brief and empathize with the design context in order to define a problem and begin ideating designs and solutions. Within the first diamond thinking space, designers should have an open scope of cognitive thinking space (AKA an open mind) in order to empathize as much as they can to the design brief. Empathizing is a key factor in the early ideation phase because it allows designers to really be in touch with stakeholders and situations that could lead to more accurate concepts. In Gaming the Tibby we see architects and city officials use V.R. as a tool for empathizing with the needs and desires of the Tibbington Estate residents. Without this key factor in the early ideation stage, designers can be misled very easily early on which could lead to further deviation from the core stakeholders. An example can be a car company designing a car with a manual transmission for a market that values automatic transmission cars over manual cars and is unable to sell cars because designers did not take the time to empathize with the stakeholder's needs and desires early on in the early ideation phase.

## 2.4 Empathizing Tools in the Early Ideation Phase

Before diving into how this project aims to test this idea, it is important to understand current design process and design thinking methods used in traditional design.

The traditional industrial design method can be defined into 6 phases (Comprehensive Guide to Product Design):

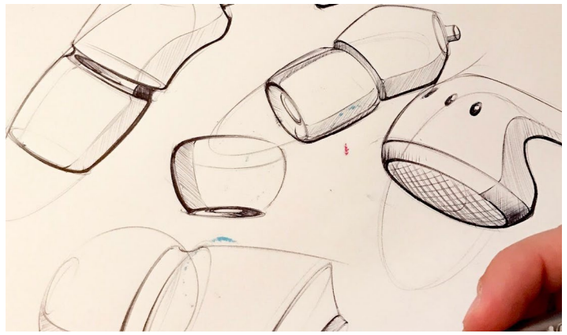
1. Empathize: Collect information of stakeholders, conduct market research and research design environment in order to gain better understanding of the design space.
2. Define Problem Spaces: Through the empathizing phase, designers should define problem spaces/design opportunities.
3. Ideation: Generate as many concepts as possible.
4. Prototyping: Building prototypes of different concepts and refining concepts based on prototypes.
   -This phase may even include a micro-phase of in-house testing to help evaluate validity of concepts.
5. Evaluation: Gauge concepts and ideas and identify best performing ideas or ideas with potential for refinement.



6. Final Design: The concept at this point should be well refined and ready for launch
   -This phase may include a micro-phase of evolution where designers make small adjustments and refinements to the design as needed.

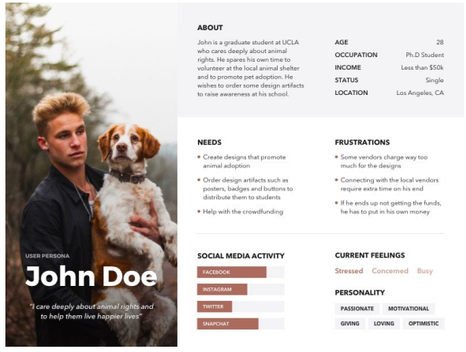
The "empathize" and "define" phase are the two crucial phases in the design process because those are the phases where the designer has the most freedom to define their course in problem solving. After all how would one know what problem to solve if they do not define it first? But how does a designer or design team go about navigating through the empathize and define phase? In industrial design, these are some of the traditional tools designers use to navigate these phases.

1. Sketching
2. Journey Mapping
3. Persona Profiles
4. Role-Play
5. Post-It Note Brainstorming
6. Story-Boarding
7. Field Observation (use striker commercial screenshot)



1.

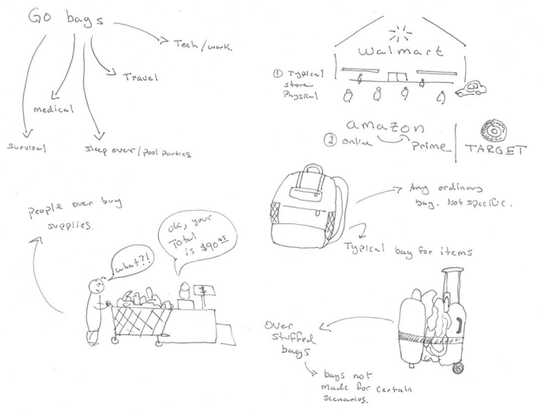

2.



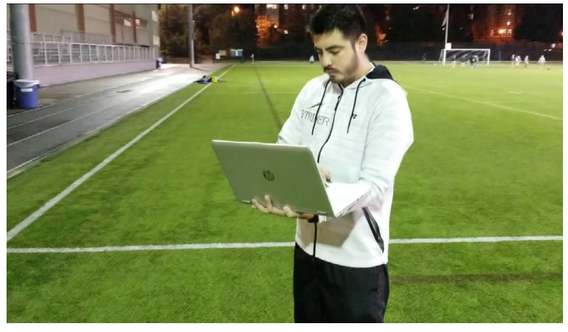

3.

4.


5.




6.



7.

In designing concepts or ideation there are different modes of fidelity, or levels of quality. Low fidelity generally offers the lowest quality but almost always allows for speed and quickness. Low fidelity could be napkin sketches, rapid role play using matchbox cars and legos as stand ins for real life elements, etc.

Medium fidelity offers more detail, but requires slightly more time to produce. Adding colour to sketches or 3-D printing quick mockups that may not have all the details or features are examples of medium fidelity.

High fidelity offers the highest level of detail and clarity but takes the most time to produce. High quality renders, or mock-ups utilizing finished materials and functional features falls under this level of fidelity. However this level of fidelity is not ideal for the early design stages that involves quick ideation and documentation.

Therefore, low fidelity ideation is always preferred in the early stages of the design process because of the quickness and relatively low effort to produce. The main point of using low fidelity ideation is simply to convey the general point of the idea. In combination with the traditional industrial design tools, low fidelity ideation has advantages:

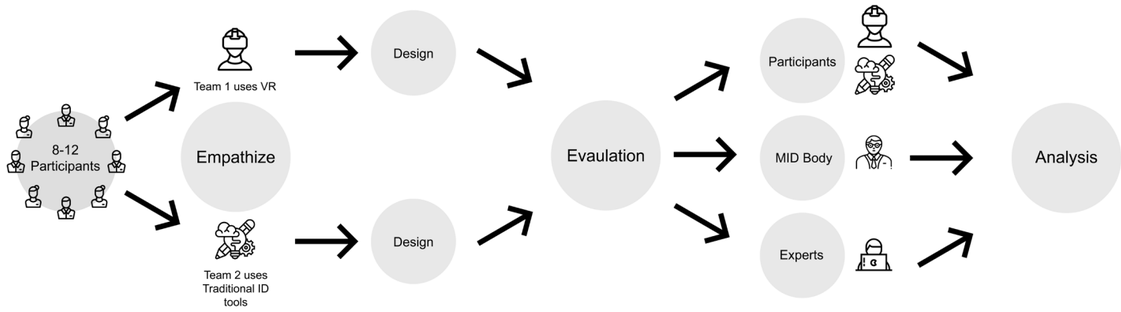


Traditional I.D. tools could be qualified as “low-fidelity/high interactivity”. Meaning that the quality may not be fully realized but because these tools require the designer to be interactive with tools such as legos or matchbox cars, storyboarding scenarios or acting out scenarios, it helps unleash creativity that could lead to novel ideas. An example of “low-fidelity/high interactivity” is Playmobil’s PRO modeling kit that features writable figurines, notes and markers to help designers act out scenarios and problem spaces in order to find design opportunities (playmobil pro).

Low fidelity ideation has one big drawback, however, and that is it leaves room for information or details to be missing. Early ideation tools such as sketching, role-playing, and storyboarding requires designers to use their imagination and/or tap into their own prior experiences in order to base design opportunities and ideas off of that. Memories of experience can be failing and everyone has different interpretations of what their experiences might be. Research helps bridge the gap between knowledge and what is unknown. Persona, Journey-Mapping, and Field Observation are useful ways for designers to become more familiar and empathetic in the design process and help accurately pin-point problem spaces and design opportunities. However there is still room for important information to “fall through the cracks”. Field observation requires detailed and comprehensive documentation, photography, videography, and attention to detail. As mentioned before elements of field observation may not be duplicated. The feeling of those moments may be lost. If information is lost, designers would need to revisit the location and that is only more effort and time taken. As the hypothesis mentioned, virtual reality could cut time and effort by having designers film 360 degree video once so the team can examine it as much as they want in an immersive way without the need for repeated visits. V.R. could be supplemented with the traditional I.D. tools to help designers be more empathic to identify problem spaces and design opportunities which could lead to more novel concepts.

# 3. Research Design

## 3.1 Process of Testing Hypothesis




As mentioned before, the hypothesis is that virtual reality will assist designers in the “Discovery-Ideation” phase of the double diamond method that will potentially lead to novel ideas. Therefore, virtual reality should be tested within a design challenge. This design challenge will be in a workshop setting with direct observation from me and also using audio and video recordings.

The design challenge will be made up of between 8-12 participants (however many can be recruited) from the MID student body. MID student body is recruited because of their experience in design and thus are aware of the different ID empathizing tools that exist. Of the 8-12, 2 teams will be formed; one that will use virtual reality to help identify problem spaces/design opportunities and the second team will use traditional industrial design methods to do the same. Each team will empathize with the design challenge amongst their teammates then once the design opportunities have been identified each team member will design ideas individually.

After which teams will do a quick TLX/SUS task analysis evaluation. These surveys will evaluate the sustainability (how well participants are accustomed to the empathizing methods used by team) and also the mental workload/comfort levels of both methods used. This will be completed right after the design challenge in order to keep the feeling and memory of the design challenge fresh in the participants mind and give an accurate evaluation.

Lastly, design evaluations will be handed out a week later to participants, the general master's of industrial design body and industry experts to evaluate the design concepts generated during the workshop. Data between the TLX/SUS task analysis and the design evaluations will be analyzed to make final observations about whether the hypothesis was proven or not.

## 3.2 Design Context

The Olli shuttle doing test trials. *Image: WAMU/Olli*

The context of the design challenge will be related to autonomous shuttles, specifically in relation to designing a visual communication system for an autonomous bus in a college campus setting to convey important information and communicate with passengers during the pick-up phase of the bus ride.

In choosing the context for the design challenge, it needed to be a challenge that relates to a future need. This will force the designers to think creatively about an unfamiliar problem. People may have prior experience in riding the current campus bus service but because autonomous shuttles are not currently common, it is an interesting design brief to test out virtual reality as a tool to better empathize a design challenge.

The pick-up phase is defined as the portion of the ride where the shuttle arrives and boards passengers. This phase of the autonomous shuttle ride is important because this is the first point of interaction that passengers have with the autonomous shuttle. Because there are no human drivers or human touch points between passengers and the shuttle, passengers may become afraid, anxious, and unwilling to ride the bus.



Therefore, it is important to design a visual communication system that could convey important information or serve as a more human-like touchpoint with passengers to establish trust and comfort between riders and the shuttle.

There are three components to the pick-up phase

| Pre-Arrival | Approaching | Arrival |
| --- | --- | --- |
| This is the portion of the journey before the shuttle arrives. | This is the portion of the journey when the bus is approaching the stop. The bus should be visually seen from the riders. | The bus has physically arrived at the bus stop and is ready to pick-up/de-board |

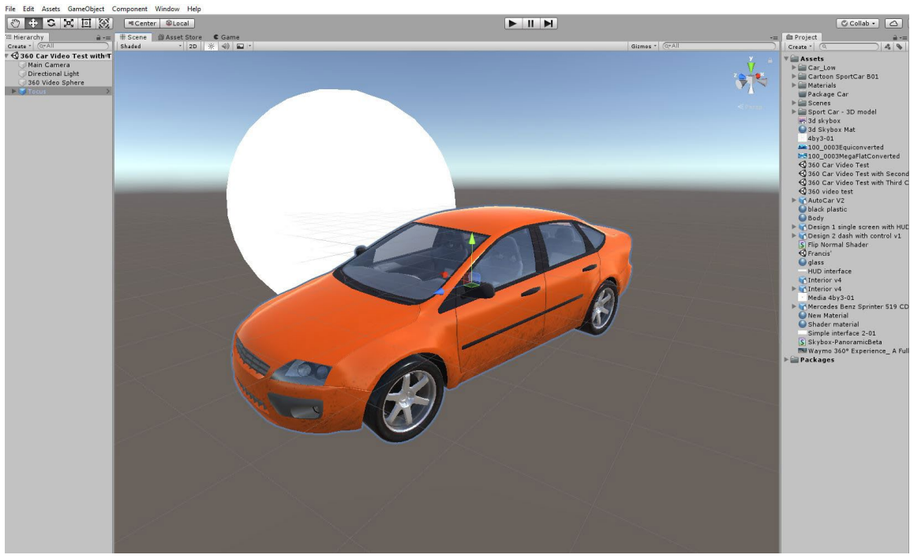
# 4. Study Preparations and Conduction

## 4.1.1 Prototype and Preparations

The first step in preparing to test out virtual reality is to define the scope of the virtual reality prototype. This means coming up with a set of parameters.

1. The V.R. prototype must be easy to use for novice V.R. users
2. Must be easy and relatively quick to produce
3. Can potentially be modular so more experienced users can take prototypes further
4. Prototype must be able to be viewed and experienced by a group of designers.
5. Must use Unity 3D software

Unity 3D is a game developing software that has the ability to import 360 degree videos. Unity 3D also has the potential to create interactive environments and import CAD models from the Unity asset store such as cars, buildings, people and more. The original scope of this project was to create a fully immersive and interactive model within a 360 degree video in Unity 3D. However this requires extensive knowledge of coding and computer logic. So the scope of the role virtual reality plays has been reduced to importing 360 degree videos and potentially inserting asset models into the 360 degree videos. The defining characteristic with this method is that these videos will be immersive and because they are high definition videos they are also high fidelity. Although these environments are not interactive, their immersive qualities are hypothesized to help designers see the design context from an immersive perspective to then identify novel problem spaces and design opportunites compared to traditional ID methods.




360 degree videos are easy to produce and allow users to experience an environment in an immersive way. However, there is only so much immersion that can happen in a 2-D screen. When combined with a V.R. headset, users can have a greater immersion experience. All one needs is a 360 camera to film.

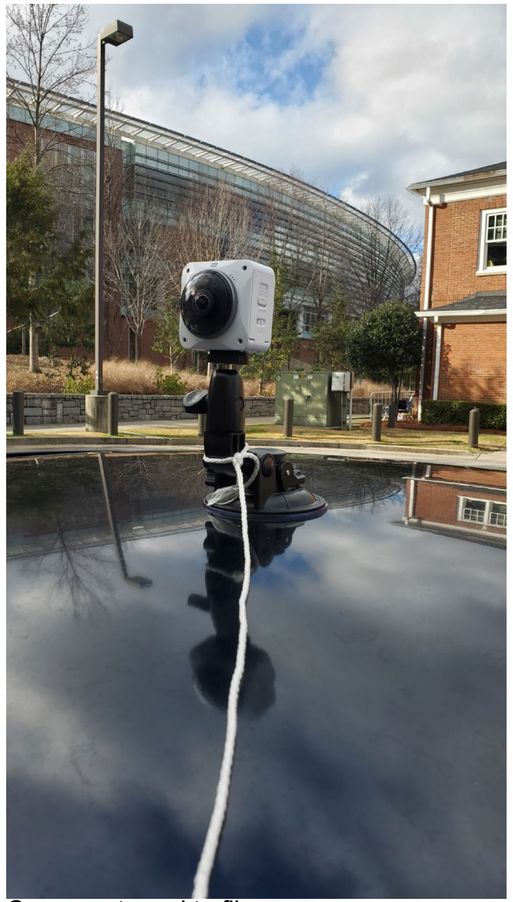
A Kodak PixPro Orbit 360 4k camera is used to produce the V.R. videos. This camera captures 360 degree videos and is inexpensive at 149.99$ according to amazon.com (as of 2019). With different attachment options it is an ideal camera to film 360 degree videos.



I used a Kodak PixPro Orbit 360 4k camera. This camera captures 360 degree videos and is inexpensive at 149.99$ according to amazon.com (as of 2019). With different attachment options it is an ideal camera to film 360 degree videos.

Because the context of the design relates to autonomous shuttles, the first prototype model will be filming a 360 degree video from the point of view of an autonomous shuttle. This will test out how 360 videos look in a virtual reality headset as well as how an imported asset model looks within a 360 degree video.

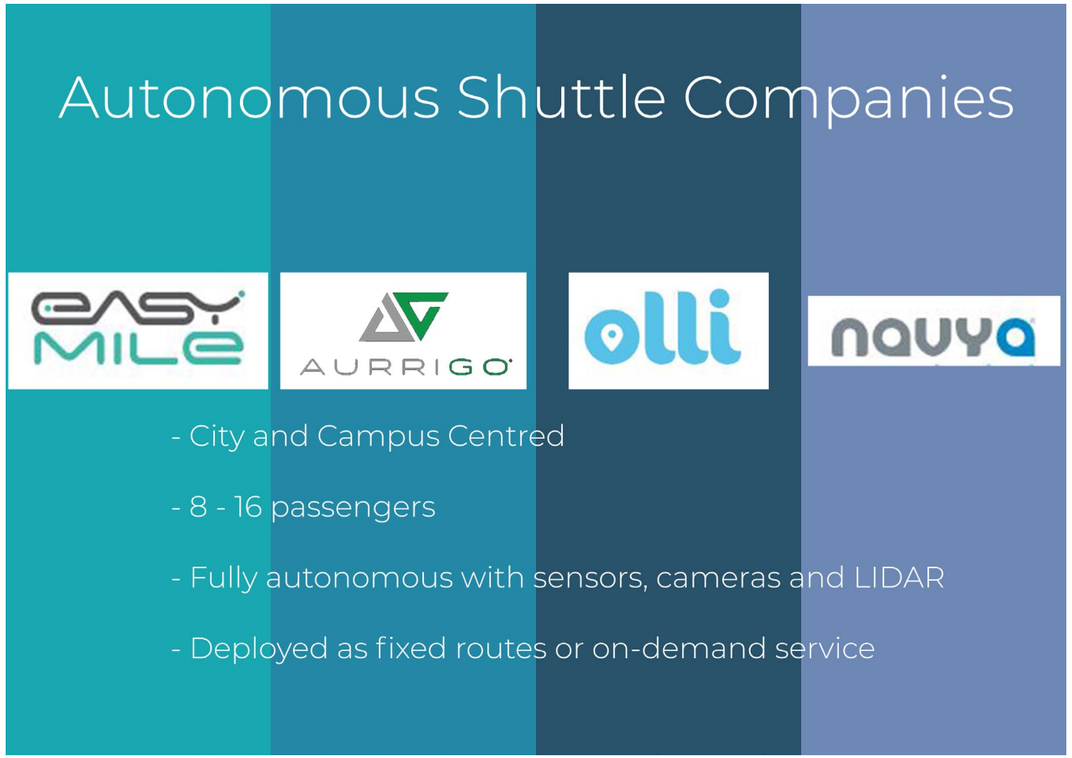

Kodak 4K PixPro camera used to film. *Image: Kodak*



Car mount used to film.

# 4.1.2 Current Technologies in Autonomous Shuttles

The design challenge has to be a challenge revolving around a future need. There is no question that autonomous service vehicles, such as a people mover or a shuttle, will be the future of mass transportation. In order for the design challenge to be engaging for participants, some research has to be made about where autonomous shuttles stand today. This will also help in figuring out what elements to focus on when filming 360 degree videos.

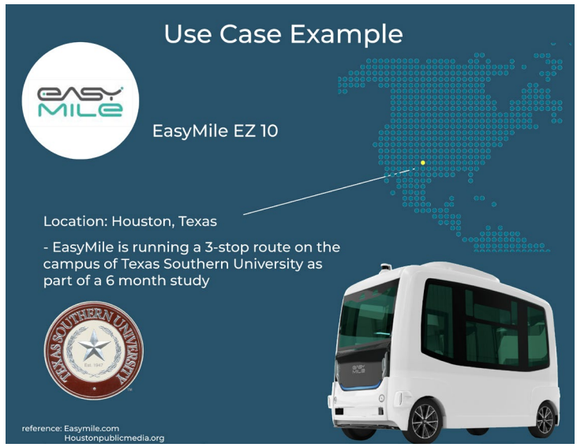


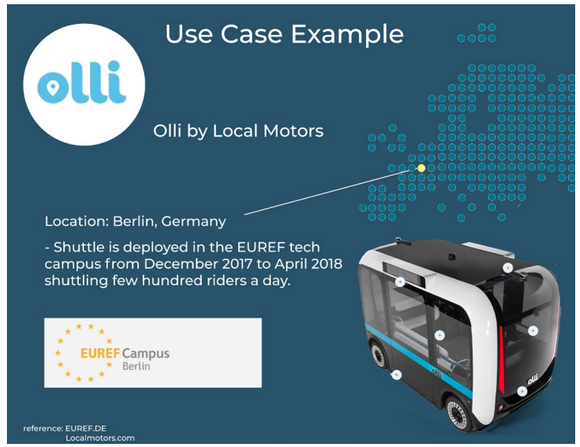

There are four major autonomous shuttle manufacturers that exist. Each manufacturer has different models that offer some variations among its competitors but for the most part they have four key similarities.

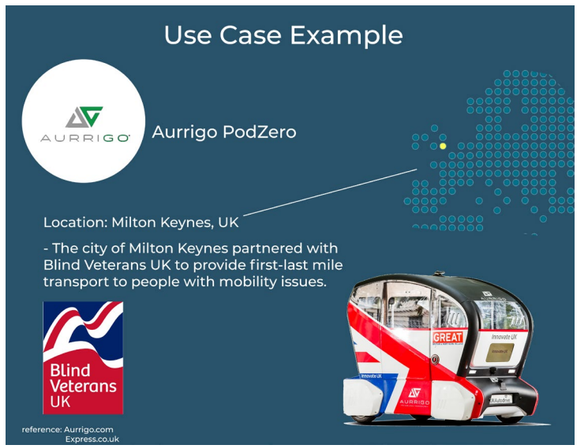


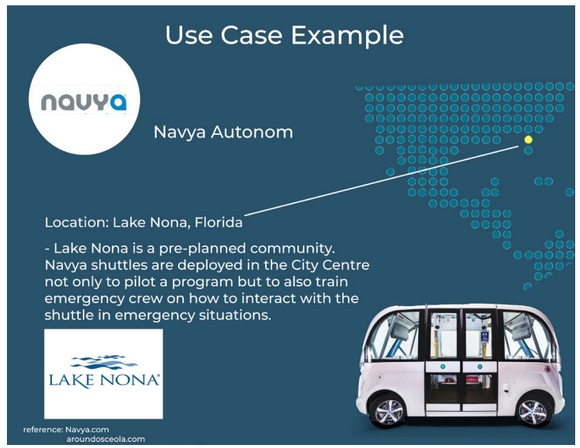
- They are primarily designed for city centers or college campuses
- They are small to medium sized offering space for 8-16 passengers
- They are fully autonomous with no driver or human touchpoint between the vehicle and passengers
- They work on either fixed routes with fixed stops like a traditional shuttle service or on a fixed route but hail-to-ride like a taxi.

There are several uses cases for each manufacturer that provide an insight as to possible stakeholders that may use the autonomous shuttle.



# 4.1.3 Persona and Journey Map Development

These autonomous shuttles operate in a similar scale of environment, typically city-centres, college campuses, and business campuses as a first-last mile transit. The design challenge will focus on college campuses because it is a familiar scenario to the design participants.

The premise of the design challenge is to ultimately test out design methods, persona development is not a crucial element but in any case should be realistic to give design participants a sense of realism to the design challenge and a resource to tap into during the design challenge.

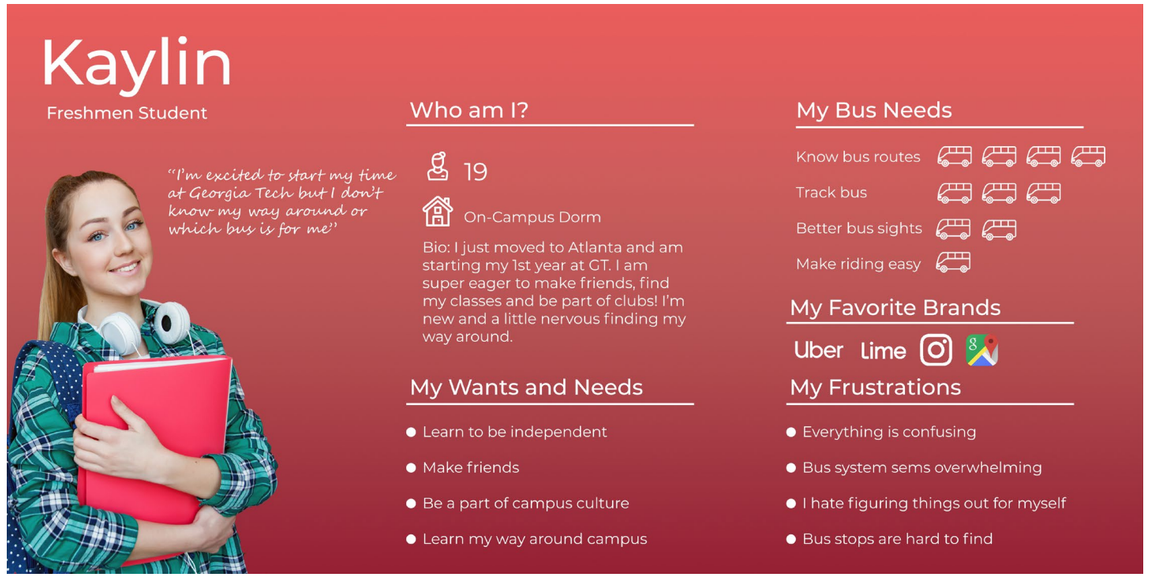
4 personas were created;

- Freshman Student
- Graduate Student
- Faculty Staff
- Out-of-Town Visitor

Each member represents a different sector of the Georgia Tech demographic. They represent their outlook on current college campus shuttle service, their current needs in relation to the current shuttle service and a small biography. Although the design challenge is based around a future autonomous shuttle service, no such service exists today at Georgia Tech. These profiles reflect current ridership behaviour.

These persona demographics were derived from a simple, informal survey conducted across the Georgia Tech Industrial Design community gauging simple pain/gain points of current G.T. shuttle/bus stop designs (see appendix for sample of survey). The main objective of this survey was to gauge the demographic who responds in order to develop persona profiles. The results from the pain/gain category were also used to inspire pain/gain points for each persona. Because the design context revolves around autonomous shuttles in the college campus setting, it would be appropriate to develop personas and journey maps based around relevant demographics such as students, faculty and visitors.






# Stephen

Visitor

*"I have friends here and I visit them every now and again. I mostly rely on Uber because I don't know how to use mass transit."*

## Who am I?

35

Not a native resident

Bio: I like to visit friends and I come here a lot. I work in a marketing agency back home and I try to immerse myself in the local culture everywhere I go. I usually rent a car or use Uber when I travel.

## My Bus Needs

- Easy to use
- Easy to understand
- Clearly marked
- Good signage

## My Favorite Brands

Uber The New York Times youtube

## My Wants and Needs

- Learn to make my way around
- Know what I like/don't like
- Be immersive in the city culture.
- Not to get lost/bug my friends for directions.

## My Frustrations

- Infomation hard to understand
- Local norms may be strange to me
- Don't know if I'm doing something right

# Rachel

Professor

*"I have a consistant routine everyday. I usually commute early in the morning and leave around 5 pm"*

## Who am I?

42

Lives in the suburbs

Bio: I've been teaching for about 4 years now at Georgia Tech and its been pretty consistant. However despite me being an employee of the campus we don't find out about the latest campus tech and services.

## My Bus Needs

- Easy to use
- Accurate service
- Knowledge of how crowded bus is
- Know about bus info

## My Favorite Brands

Pinterest The New York Times youtube

## My Wants and Needs

- Bus stops that are close by
- Have as much useful info as I can
- Check-In feature for pick up
- Less crowded experience

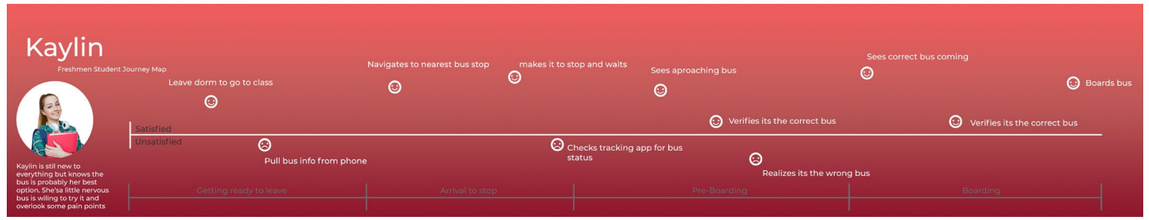
## My Frustrations

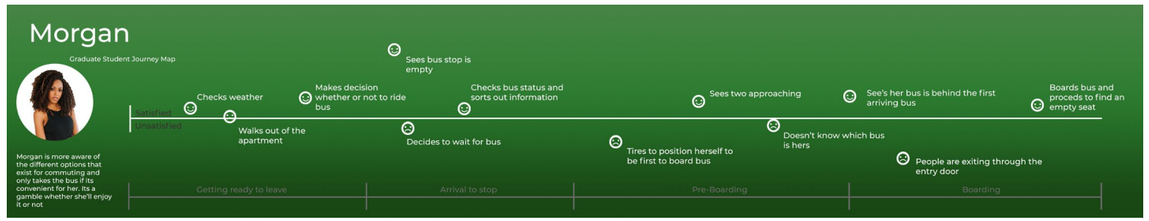
- Staff aren't told about new products
- Inaccurate or inconsistent service
- Bus stops are not convienent.

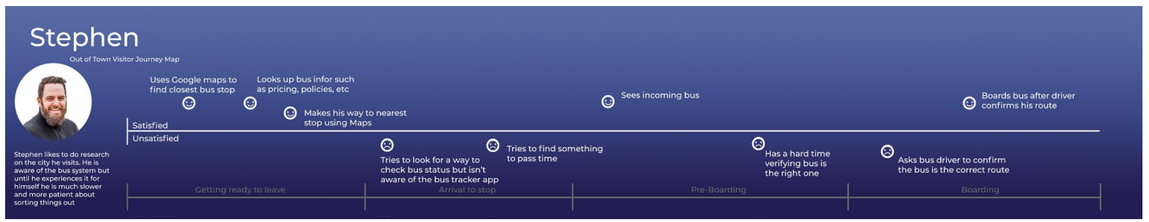


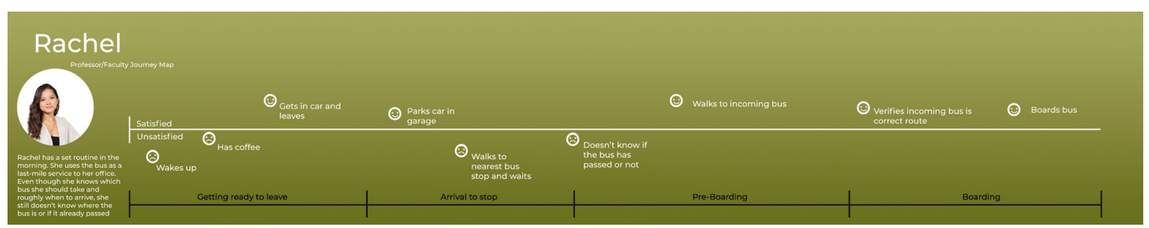
These persona profiles was given as a resource so that they can become better immersed into the design challenge. They give a better sense of the stakeholder's personalities and needs.

Journey maps try to model the bus riding behaviours of each persona. These again will serve as another source of resource for the participants.



# 4.1.4 Structure of Workshop

The design challenge will be divided into five phases and two post-challenge phases:

- Design Briefing

The design briefing section entails gathering the participants together in a brief ice-breaker game to loosen people up and get everyone familiar with each other. This is important so that participants can overcome any shyness and allow participants to be comfortable in brainstorming with each other.

The second part of the design briefing details what they will expect from the design challenge such as participant rights, the design challenge itself, and the itinerary for the workshop.

- Team Selection

Participants were recruited by a combination of simple advertisement, contacts with Professor Wei Wang, and traditional old fashioned cold calling recruitment. Recruitment is centered around the MID student body, more specifically with master students who completed prep year because of their experience in the industrial design process. Among the participants gathered for the design challenge they will be equally and randomly assigned to one of two teams. Team 1 will be the virtual reality team that relies on virtual reality to define design opportunities. Team 2 will be the traditional industrial design methods team that relies only on traditional design methods to do the same as team 1.

- Design Phase

Both teams will be given 40-45 minutes to design. The first 15-20 minutes teams are encouraged to work together with their individual teams to empathize with the design brief, brainstorm problem spaces and design opportunities. Once teams have design opportunities identified, each team member will design individually concepts based on those design opportunities. Individual design is done so that every team member participates and produces a design that can be used to evaluate later. This is also done to prevent one team member from carrying the design responsibility for team members who may be too shy to participate and designing for the whole team.



- Design Reflection

Once the design phase is over, teams will come together and share each of their concepts and have a small reflection period. The teammates will present their designs in a “show-and-tell” style format. Teams, however, will not be evaluating each other’s designs during this phase. The reason for this sharing of concepts phase is so observation can be made about the outcomes of the design challenge and corroborate them with any other observations made during the design phase of the workshop in a post-hoc analyzation period.

- Task Analysis

Lastly, teams will be asked to complete a TLX/SUS task analysis survey as soon as the reflection period is over. This task analysis is meant to gauge the usability of each design method (according to which team the participant was a part of) and the mental workload of the methods they used according to the team they were randomly assigned to be a part of. The survey will be conducted individually and each survey taker will code their answers according to which team they participated in (see appendix for sample of TLX/SUS survey).

**Post-Challenge Phases:**

- Post-Hoc Analyzation

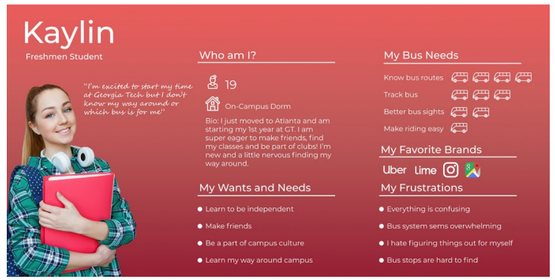
After the design challenge has concluded and the participants have been dismissed, observations, photos, videos, notes and designs from both teams are analyzed and correlated to find relationships and outcomes in relation to the design outcomes and in-design behaviours.

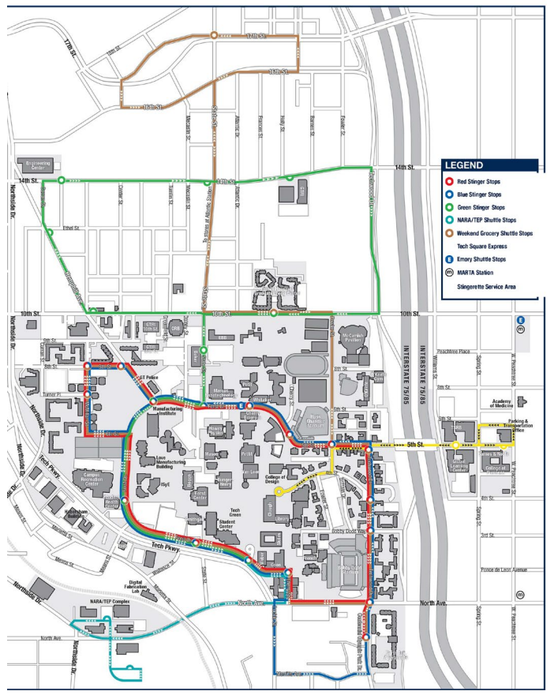
- Design Evaluation

About a week after the design-challenge, a design evaluation survey will be digitally publicated and distributed to 3 entities to take; participants of the design challenge where participants will cross evaluate the other teams designs, MID student body, and industry experts. It took about a week to code each design and produce a design evaluation survey (see appendix for sample of survey). 3 entities are recruited to evaluate in order to ensure objectivity and compare scores to gain accuracy of scores.

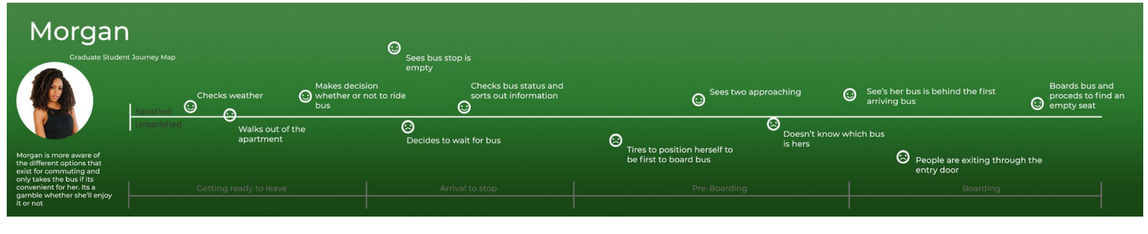
# 4.1.5 Tools + Definition of Workshop

Each team was given resources to work with during the design phase. It is important that the differentiating factor be virtual reality versus traditional industrial design methods. Therefore each team should receive the same supplemental resources. Those include:







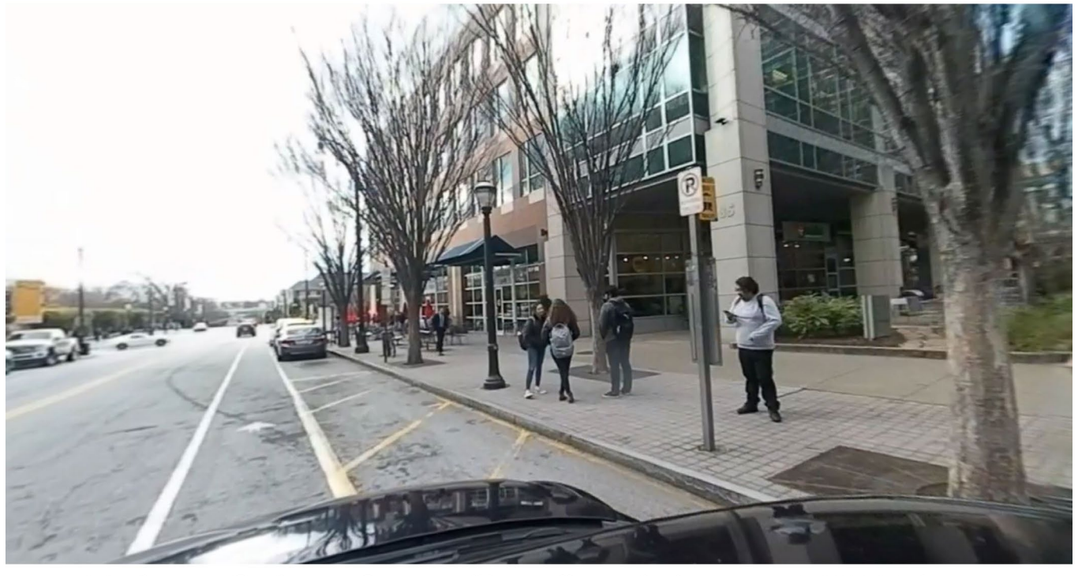

Personas | Journey Maps | Transportation Maps of Current GT Shuttle | Use Cases of Current Autonomous Shuttles | Pen, Paper and Sticky Notes



Where Team 1 and Team 2 will differ are in these tools:

- Team 1 will have access to the HTC Vive virtual reality headset along with 4 different 360 degree videos, or "scenes" as they are referred to each lasting around 2 minutes. The headset is hooked up to a computer that mirrors the image inside the V.R. headset onto a large screen TV so fellow Team 1 members may also participate in watching the V.R. feed. These videos are high fidelity, meaning they offer clear resolution and real world behaviors, but are low interactive because the videos themselves are not able to be interacted with, only viewed. Therefore Team 1 were encouraged during the design briefing to supplement their V.R. brainstorm session with "thinking out loud" techniques such as sketching to communicate ideas. Each participant viewed all 4 scenes and V.R. use lasted around 10 minutes. While instructions on how to use V.R. was purposefully kept vague in order not to influence any particular direction in their design process and ensure all design decisions were made without any external influence, encouragement on how to incorporate V.R. into group discussion was given in order to ensure V.R. is actually used by Team 1 and not become passive. Their behavior is documented later on in the observation portion.

## Scenes Used in V.R. Videos



Point of view from "bus" arriving at TSRB bus stop, 5 pm

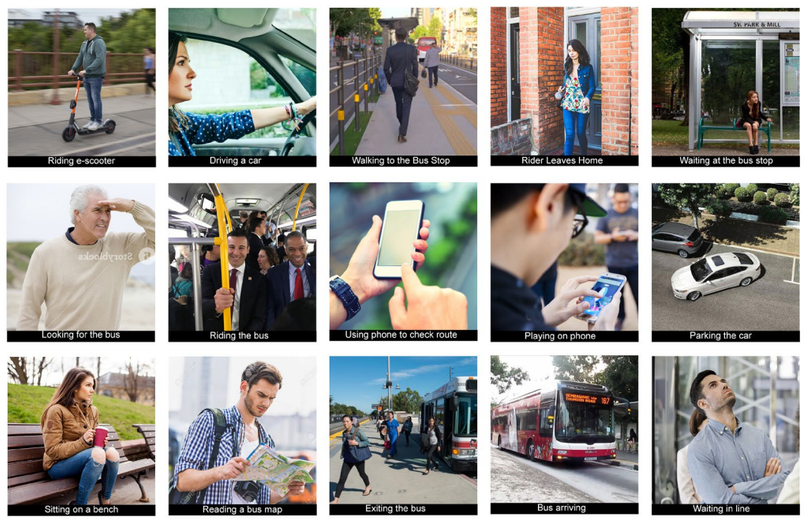
Student Centre Bus stop at 4 p.m.

Bus departing from CRC bus stop at 3 pm



Passenger talking to Bus driver

Team 2, in addition to screenshots from the V.R. scenes Team 1 has, had what is called a “deck of cards” which are small playing cards depicting different actions associated with the shuttle riding experience. These playing cards can be used to construct a story line or explain possible actions or construct a possible scenario that could help designers better empathize with the design brief.



Team 2 will also have Lego bricks and Matchbox cars to construct scenarios and interact with possible storyline actions in an interactive 3D space. While both teams were given many of the same resources to ensure parity, Team 2 was given Legos, cars, and a deck of cards in order to have a bank of resources to use. They were explained that while they are encouraged to explore all their resources (just like Team 1 were encouraged to "think-out-loud" their discussions) they did not have to use all of them, just the ones they felt most comfortable with.

V.R. and the Legos, cars and deck of cards are the differentiating factors between both teams. All other resources are the same. This is to ensure that the evaluation scores are reflective of what methods both teams had. Besides the resources themselves, another differentiating factor that will be examined by the evaluation scores is V.R.'s "low-interaction/high-fidelity" component vs. traditional desktop research tool's "low fidelity/high-interaction".

# 4.2 Study Conduction

## 4.2.1 Workshop Preparation

First order of business is to film the different scenes that will be used for the 360 degree videos. This was done over the course of several days during the week of February 3rd 2020. Criteria for determining what should be filmed for the scenes were focus on popular stops offered by Georgia Tech shuttles. Those were Tech Square (Tech Express route), Clough building, the Student Centre, and the Campus Recreation Centre. Another component focused was behaviours associated with riding shuttles including the bus stop, interacting with bus drivers, shuttle interaction with traffic and lastly a point of view from a shuttle.  In total there were four scenes.

Each team will receive persona profiles, journey maps, transportation maps, and autonomous shuttle use cases. Resources are the same and ensure that each team are on parity level, meaning both teams have the sufficient tools to do the job without feeling one team has too much advantage. As mentioned the defining factors between both teams are virtual reality and the desktop research tools such as legos, cars and deck of cards.



To ensure there is no overlap of ideas or information (I.E. Team 2 members don't look over at the big T.V. screen that shows the V.R. feed and get ideas from that) the two teams will work separate areas of Lab 150 separated by a whiteboard which faces Team 2's work area so that they may also use it during their brainstorm session. Ideally, teams would be observed separately on seperate days but due to conflicting schedules of the participants, a single day and time was selected to kick-off the design challenge. Precautions were taken to ensure cross influence from both teams was not a possibility. In addition to a whiteboard, a giant screen typically used for one of the car rigs to test out A.R. concepts by Prof. Wayne separated both teams in addition to several feet of buffer space and a bookcase. During the design phase, while making observations it was found that there was absolutely no cross influence.

Team 2's table with all of their supplies layed out.

# 4.2.2 Design Brief

The following are slides that accompanied the design briefing for the 8 participants that were recruited. As mentioned the goal was 12 but only 8 were recruited which is enough. These design brief slides were explained more in detail to the participants. As mentioned before, participants will be randomly assigned to one of two teams. The briefing also explained the design context, design rules, itinerary and other instructions related to the design challenge.

## Itinerary for Today

- Ice-Breaker Game : 5 mins
- Design Briefing : 10-15 mins
- Team Selection : 1-3 mins
- Begin Designing: 40-45 mins
- Design Presentation/Reflection: 10 mins
- Design Method Evaluation: 5 mins
- End of Workshop : approx. 1 hour and 30 mins

## What are we doing?

You will tasked with designing an visual exterior communication system for a self driving shuttle centred around the pick up phase of a ride using 1 of 2 design methods



## Team Selections

**Time to split into 2 teams! One team will be V.R. and the other Traditional ID**

## Deliverables

What you'll need to have at the end:

- A list of problem spaces/design opportunities discovered during the group collaboration phase.
- Each team member present at least one design/concept (can be sketches, storyboarding, sticky note mind mapping, narration using V.R. videos, etc)
- Completion of Task Analysis evaluation (will be given at the end).

## Design Rules

Here are a couple of rules to follow:

- You have 40-45 mins to design.
- The first 15-20 mins should be devoted to group discussion/collaboration
  - You are encouraged to engage in the "thinking out loud" method. Talk about your observations, design issues, storyboarding, etc
- By the end of the group discussion/collaboration each team should have one, or several, **clear defined design issue(s)** identified to address.
- Each team member choses one issue to design (multiple designers can work on the same issue but individually)

- Each team member should produce at least 1 idea individually
  - You are free to collaborate and share ideas but in the end each team member should each have at least 1 idea.

# 4.2.3 Observations

The design challenge took place on February 28th 2020 in the Special Projects & Thesis Studio (room 150) in the architecture west building. 8 participants signed up to partake in the challenge. After participants signed release forms and went through the design brief, teams were randomly selected to join one of the two teams. They are reminded that their design phase is divided into two more phases; a group brainstorming phase and an individual design phase. The design briefing was clearly explained such as the design context, deliverables, division of teams, the methods both teams are assigned to and the resources at both teams disposal. However, certain elements such as expectations on how methods should be used, examples of ways methods should be used, examples of what kind of concepts are expected were left vague. This is to ensure that no outside influence affects the design output of both teams. Any design decision in relation to how the methods are used should be made by the teams by their own volition.



- Team 1

Team 1 is the virtual reality team. The team had 4 full time members, two male and two female. As mentioned before the resources they have at their disposal includes V.R. headset with four 360 degree, persona profiles, journey maps, transportation maps and case studies of current autonomous shuttles.

Team 1 underway in the Design Challenge

Group Brainstorming Phase

- As expected, group members were a little slow in familiarizing themselves with both each other and the V.R. system.
- The V.R. headset was not used until after 7 minutes
- V.R. was used by team members for a total of 10 minutes. They adhered to the direction encouragement given of using V.R. to use “think-out-loud” discussion.
- 3 of the 4 scenes were viewed with 3 minutes being the most time spent on a scene.
- A team member made a comment that one of the videos was ‘uninteresting”.
- V.R. was used to get a discussion started about the problem space but V.R. was not revisited after the first use.
- V.R. didn’t seem to influence the group discussion. The supplementary resources seemed more useful. Discussion space revolved around scenes rather than using the scenes to think beyond the box.

Individual Design Phase

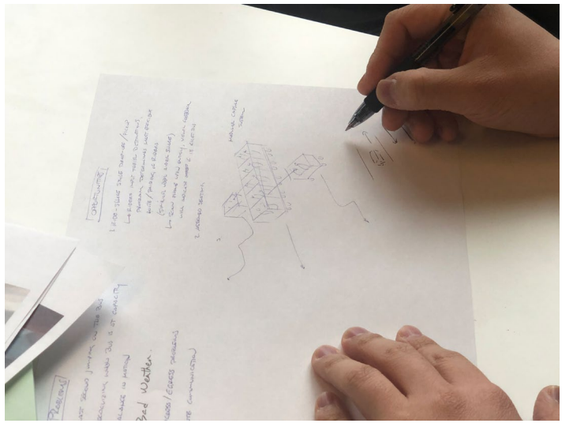
- Designing didn’t start until after minute 27
- While the V.R. scenes did help spark discussion, it mainly revolved around their own personal experiences of riding shuttles rather than using the scenes to think ahead.
- Participants went directly from discussion to sketching. Other design methods to supplement the V.R. wasn’t used.

Team 1 finished sooner than team 2

Team 2

Team 2 had two full-time members and two part-time members. One of the two part-time participants joined at the beginning of the workshop and left early and the second arrived later on during the workshop and replaced the first participant that left early. In addition to the supplemental resources given to Team 1, Team 2 is also given Legos, matchbox cars, a “deck of cards” storyboard kit, post-it notes, colour pencils, and snapshots of different shuttle stops.






Group Brainstorming Phase

- Team 2 initially was one member less than Team 1
- They took a significantly less time in initiating a discussion that Team 1
- Team 2 were more active and involved with their resources than Team 1 with theirs
- Participants followed instructions by documenting their discovery of problem spaces and design opportunities.
- While Team 1 primarily stayed within the confines of the scenes, Team 2 used the deck of cards, matchbox cars and sketching to go beyond the context of the design challenge to think outside the box.

Individual Design Phase

- Design phase was straightforward and started sooner than Team 1.
- Team 2 explored more design areas than Team 1 in their design concepts
- Although their design phase was more open ended, Team 2 did establish a structure and logic by writing down problem spaces discovered and fleshed out ideas using the tools and resources given. Team 1, however, did not write down their problem spaces or design opportinities discovered. They went from group discussion to designing straight away.

When interviewing Team 1 after they have just finished their design phase important points were revealed:

1. While V.R. did play a role in initiating discussion, they mainly relied on past experience with the public transportation. They traded stories and their own observations. Because teams were at liberty with their methods, there was no required amount of time Team 1 had to dedicate to V.R.
2. Team 1 believes that V.R. could be extremely useful in contexts that are not common, for example if the design brief was focused around designing a football helmet with improved visibility because not everyone has experience playing football let alone wearing a football helmet. Riding a shuttle, whether manned or autonomous, is a familiar experience they can tap into without the need of V.R. to help them better understand the context.

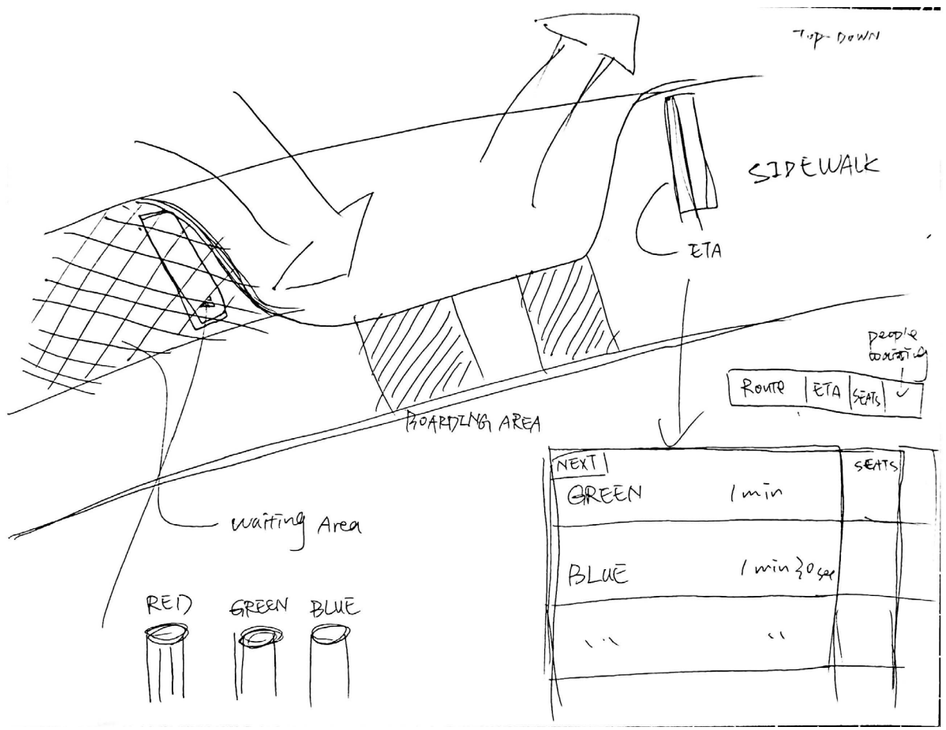


Discussion over whether or not to require Team 1 to use V.R. for a required amount of time has been mulled when developing the design challenge. However concerns over whether or not genuine design decisions would be affected by setting a required time of usage. This project aimed to observe Team 1's usage of V.R. with total design liberty and few guidelines such as the ones given during the brief. For that reason Team 1 was left to their own devices when determining how long to use V.R. to empathize.

## 4.2.4 Designs from Teams

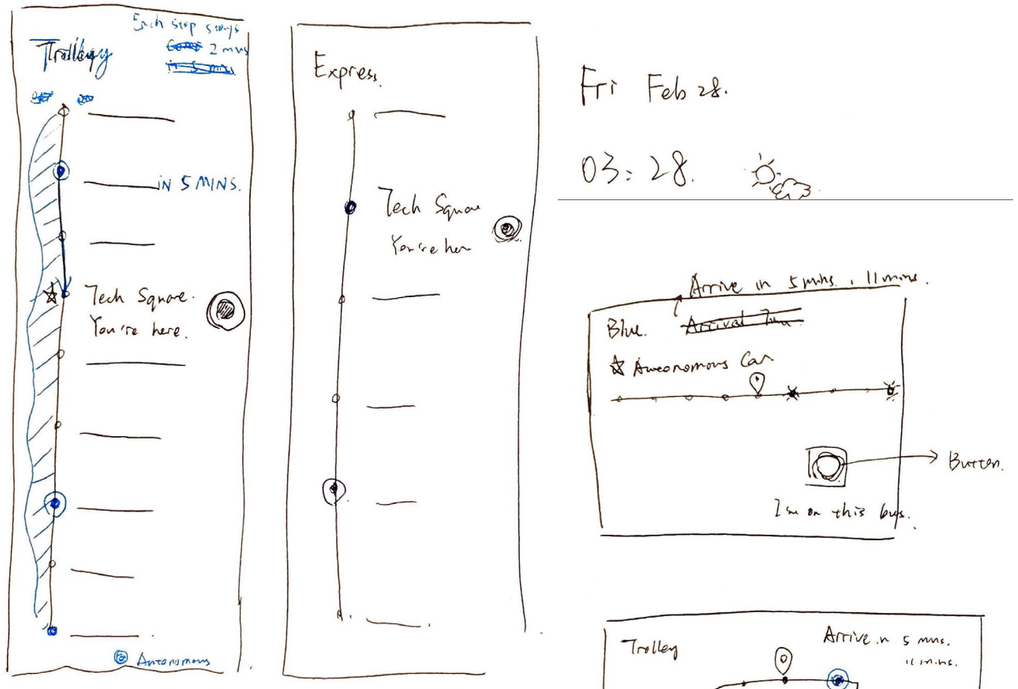
### Team 1

### Design 1




Design 1 from Team 1. This concept envisions a "smart bus stop". This design is similar to a subway display sign in that it displays incoming buses, their ETAs, their route info and also an estimated number of open seats on each bus so that passengers can get a better sense of which bus is more empty. Lastly, the smart bus stop also features a "traffic light" style indicator that lets passengers know when its safe to board the bus

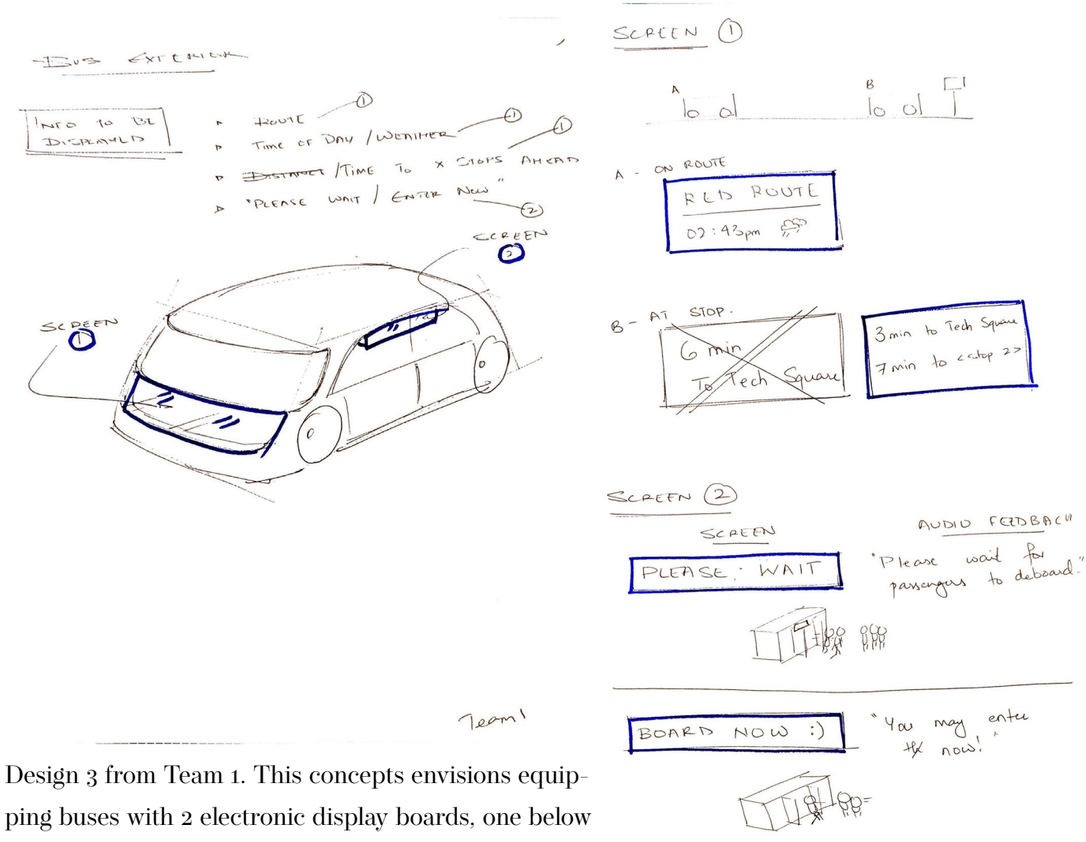
# Design 2




Design 2 from Team 1. This concept is another smart bus stop albeit a little more simpler. The smart bus stop breaks down route stops in a linear form and displays ETAs for each stop as well as give a weather report.

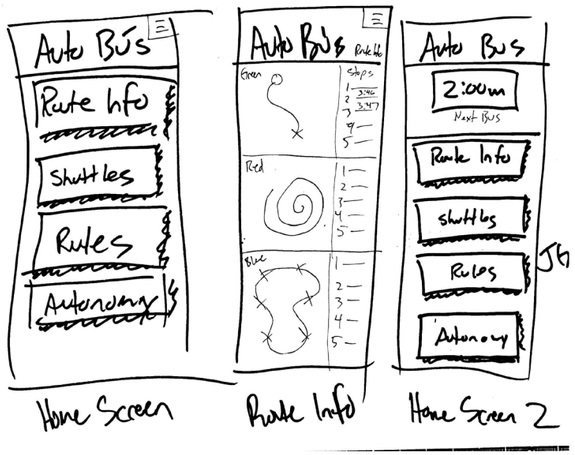


# Design 3

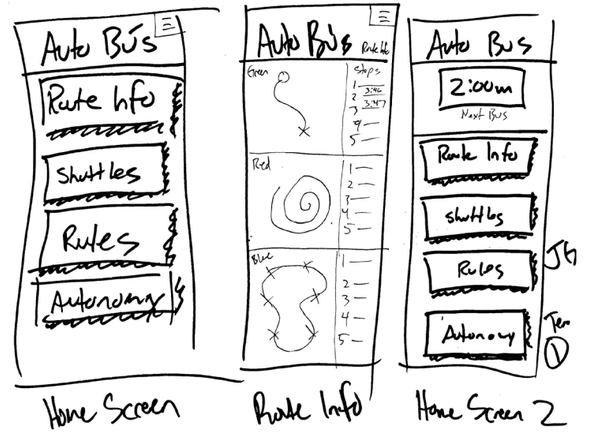


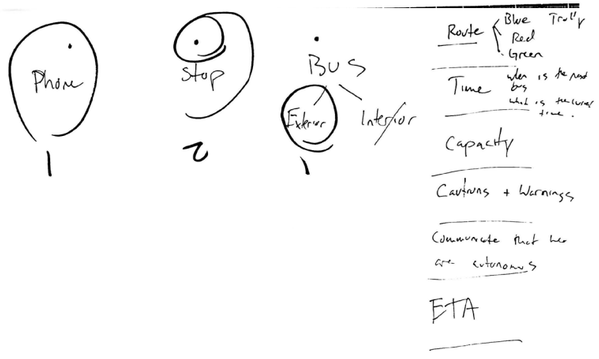

Design 3 from Team 1. This concepts envisions equipping buses with 2 electronic display boards, one below the front windshield and the other on the boarding side each displaying different information. The front screen displays route information and ETAs to each stop. The side screen displays boarding instructions to passengers

# Design 4







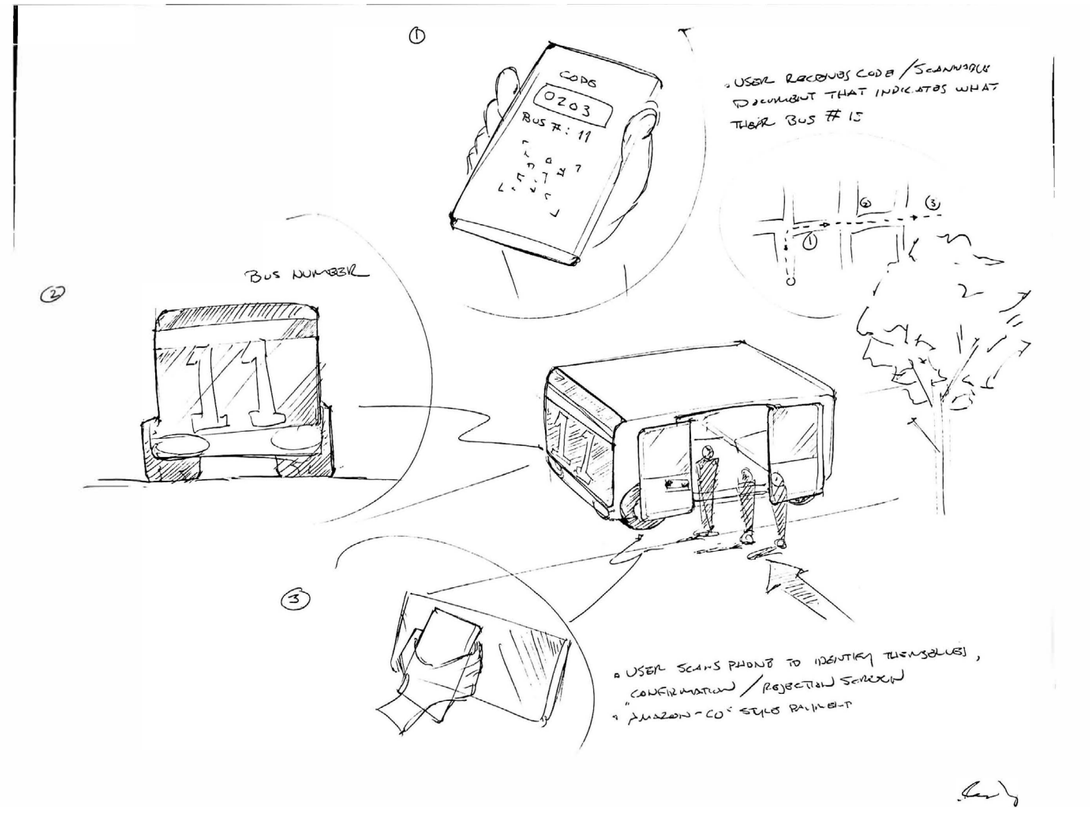




Lastly, Design 4 from Team 1. This concept is an all inclusive app that aims to calm fears of passengers and establish trust as well as be informative. In addition to displaying typical bus rider information such as route information, ETAs and shuttle information, the app uses friendly images and UI as well as display autonomous shuttle statistics and educational information to help establish trust between the rider and the autonomous shuttle.



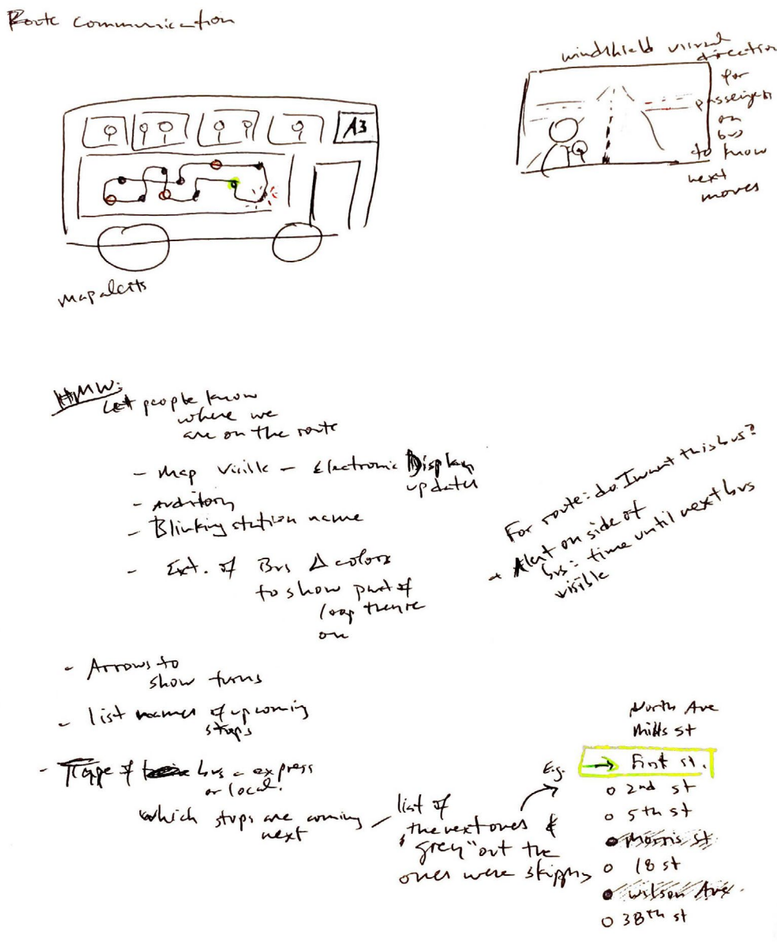
# Team 2

## Design 1




Design 1 from Team 2: This concept envisions an environment where there are numerous smaller buses in service as opposed to fewer bigger buses, passengers input their destination into the bus app where the bus takes the information from several nearby passengers and gives the passengers the optimal pick-up and drop-off locations. Once the bus arrives, passengers can then scan a code on the bus door to confirm their ridership and the passenger can then board the bus

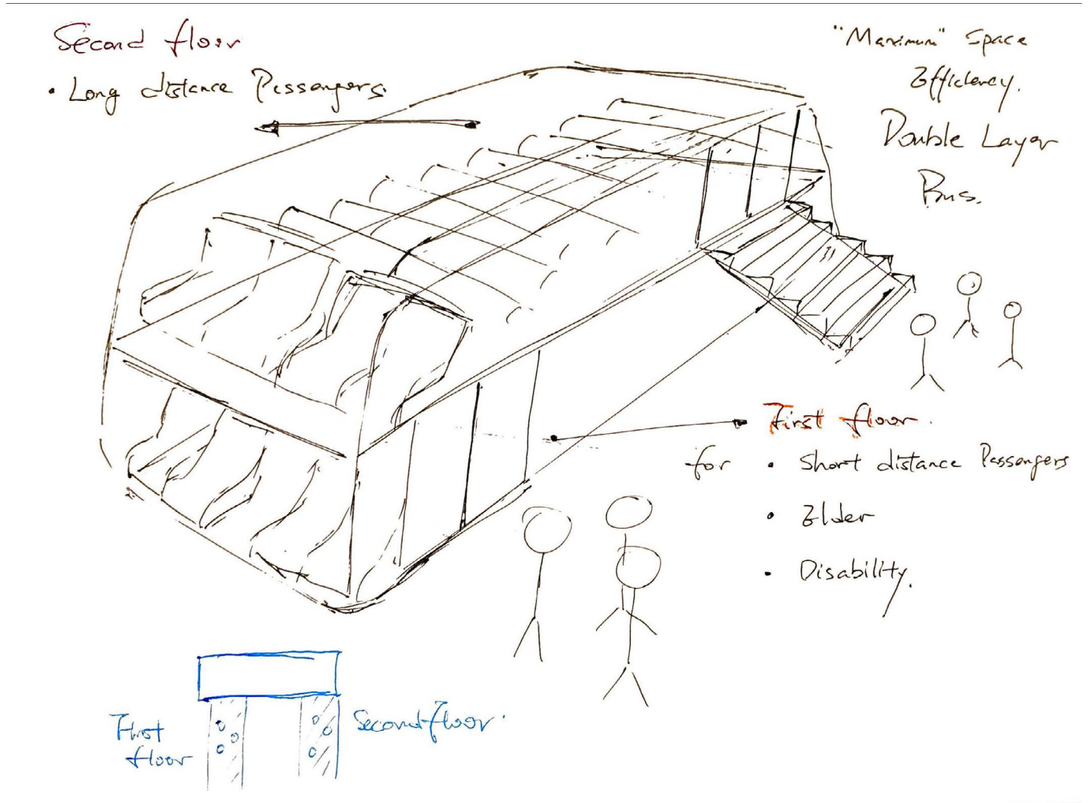
# Design 2




Design 2 from Team 2. This concept envisions the bus combining a side display panel with an AR overlay on the interior windshield. The side display panel shows the bus route in relation to the bus location on that route. It would also the bus stops as a list in case people wanted that information as a list rather than in relation to geography. The AR windshield would show passengers the directions its about to take to give passengers a better ideas as to where the bus will be going, stopping, and give passengers a better sense of directions especially out-of-town visitors

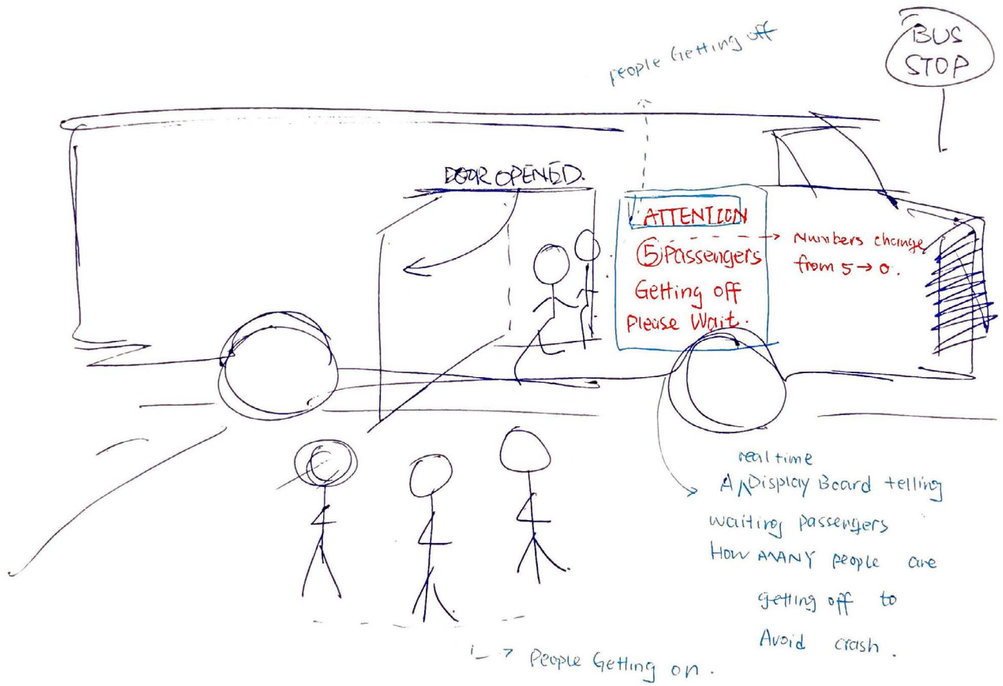


# Design 3




Design 3 from Team 2 is fairly straightforward. This concept envisions a 2 story shuttle. The first story is designated for easier entry/exit of the shuttle for short-distance passenger, elderly and disabled passengers. The second story is designated for long-distance passengers. The theory is that this will allow quicker and more efficient passenger flow according to the distance needs of each passenger.

## Design 4



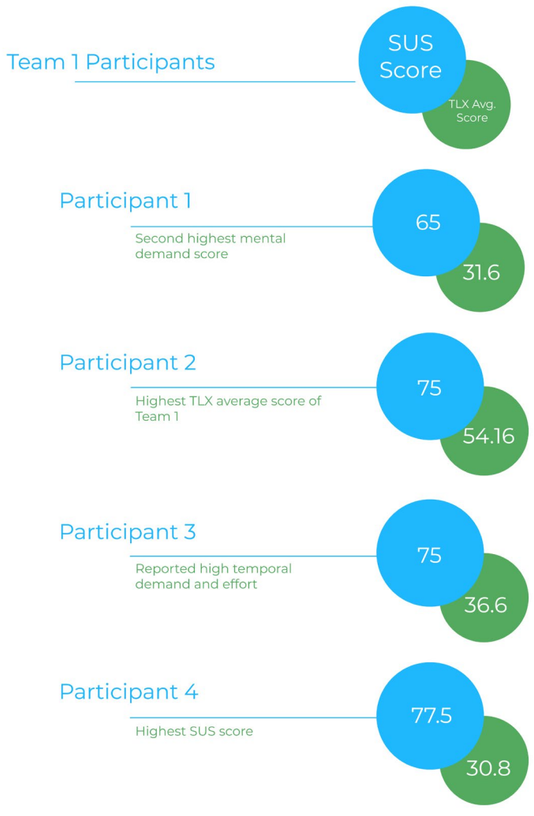

Design 4 from Team 2. This concept is also fairly straightforward. This concepts envisions a real-time display board that gives entry/exit instructions to passengers. It will display information like how many people will be disboarding so incoming passengers can know to wait and allow passengers to deboard in order to reduce bottlenecking

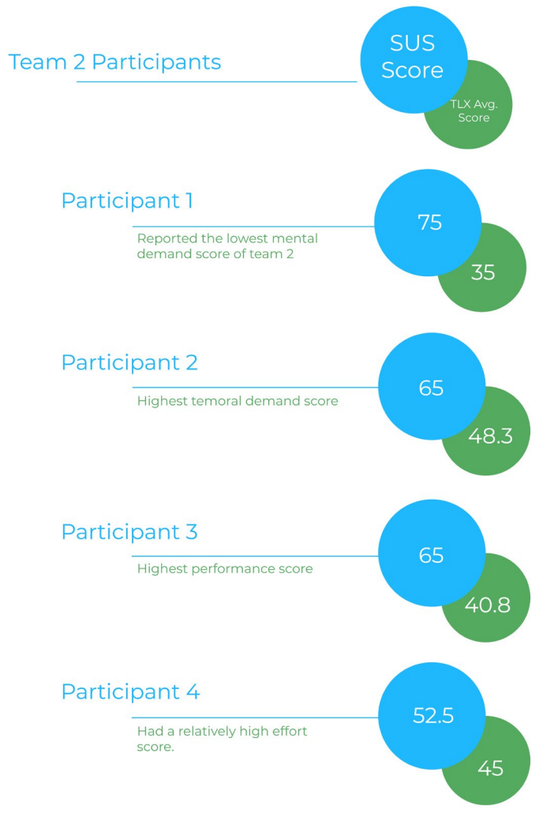


# 5. Result Analysis

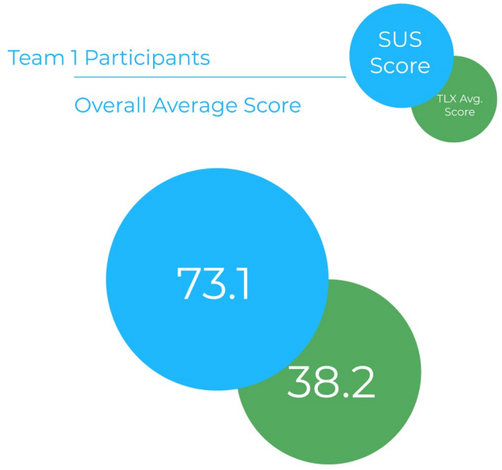
# 5.1 Data Breakdown

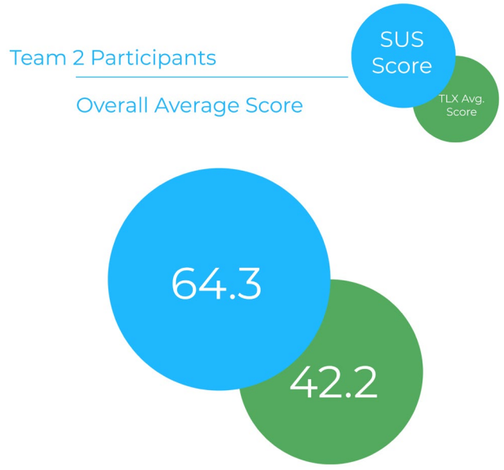
Participants were given the NASA TLX task assessment and a System Usability Scale immediately after the design phase. TLX stands for Tasks Load Index and measures the perceived workload from the task. (Jeff Sauro, NASA TLX). A System Usability Scale is a quick and easy way to measure the usability of a system or process with a good amount of precision (Usability Geek). The tasks both survey's measured was the design challenge in relation to the design tools used by both teams. Each participant was asked to rate system usability scores on a Likert scale for how they felt using 1 of 2 methods (V.R. to empathize or traditional I.D. tools to empathize). For the TLX survey, participants were asked to rate the mental workload and comfort levels of using each design tool to empathize. Each participant evaluated their own experience and design.





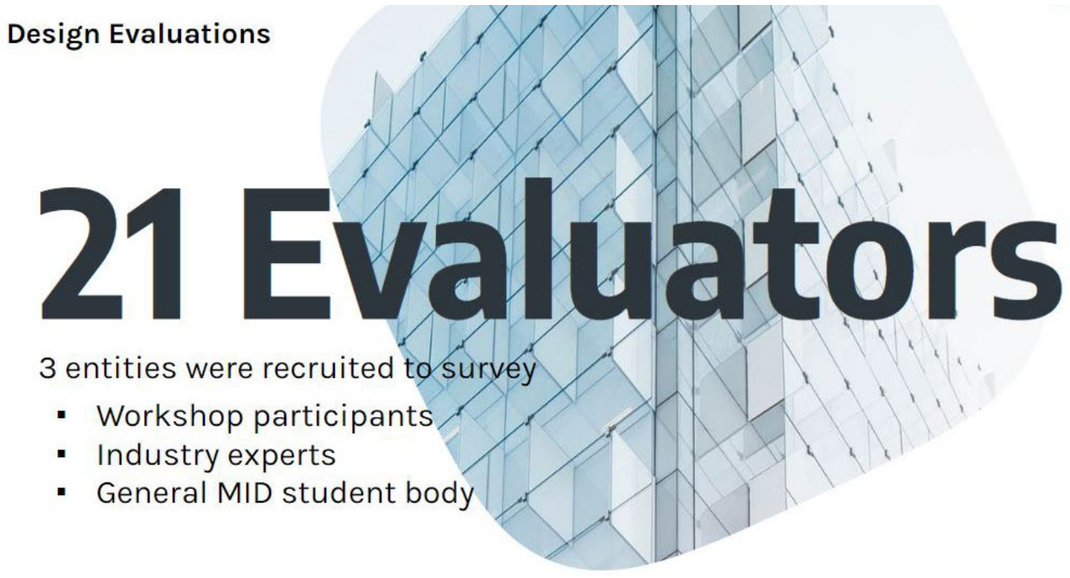



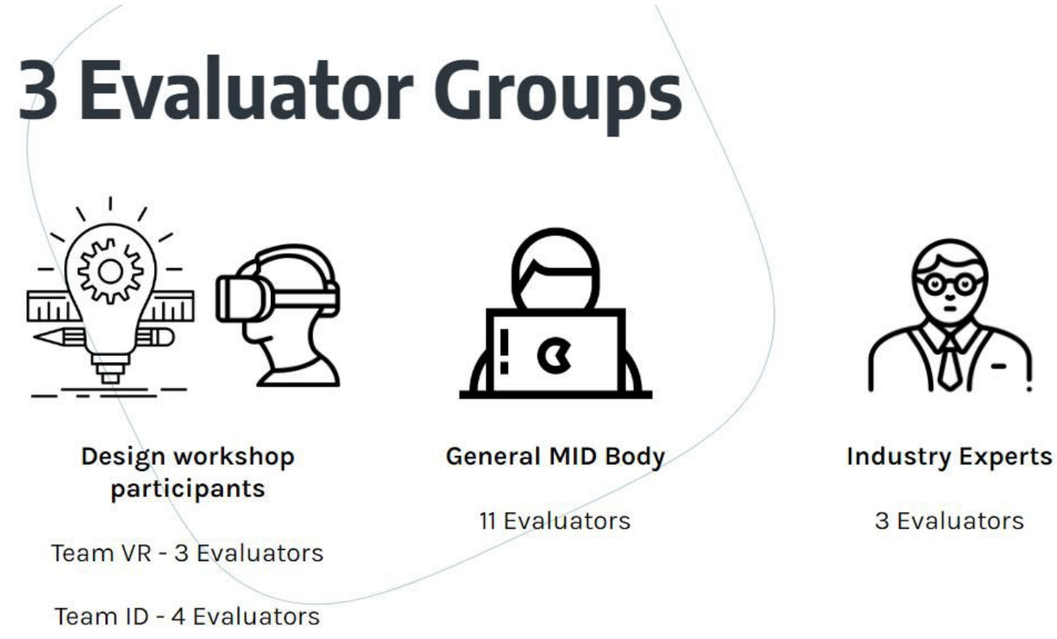

In comparing the numbers, no one team dominated both the TLX and SUS assessments. Team 1 had three participants report higher SUS scores than Team 2 who only had one participant report a higher SUS score while Team 2 had three participants report a higher TLX average score to Team 1's one. While ideally more participants would mean a more accurate outlook (only 8 participants in total took part in the design challenge), if anything can be extracted from this is that virtual reality scored higher from a system usability standpoint than traditional industrial design methods while traditional industrial design methods was a better task to undertake than virtual reality.

When the overall average score was taken for both SUS and TLX scores from both teams, it further points to both teams performance in both categories with Team 1 having an overall average score in the SUS category higher than Team 2 while in the TLX category Team 2 has a higher overall average score than Team 1

This could be explain because team 1 participants indicated that while virtual reality did serve a purpose and was easy to use (the usability factor) they reverted back to simple group discussion and "thinking out loud" methods because they weren't sure how to further integrate virtual reality into their problem identification phase (the task analysis factor).

For Team 2's part their SUS scores were not terribly far off from Team 1's and as far as the task analysis factor, traditional industrial design methods of empathizing are familiar and they knew how to harness it for the design challenge which could explain the higher TLX scores.




A graphical breakdown of the types of evaluators recruited for the design evaluation.

## Why These Groups?


- Provides 3 distinct points of view
- Allows for comparison of scores to gauge bias
- Points of view offered for objectiveness;
  - Participants with experience in design context and methods tested
  - Experienced MID students with no knowledge of workshop
  - Experienced industry experts with knowledge in real world design

Design evaluations paint a different picture, however. Before going any further how these data numbers were arrived at should be explained. Four evaluations were given out; one evaluation was given to the design challenge participants where two surveys are given to members of each team to evaluate the other teams designs. In other words, participants would cross-evaluate designs. A third to industry experts with knowledge in the autonomous vehicle area and the fourth given out to the general masters of industrial design body. Each evaluator was asked three questions per design;

- Is the design innovative? Innovation definition was left to the evaluator's opinion.
- Did the design solve the issue successfully?
- Is the design clear to understand?

In total 21 people were able to partake in the design evaluations as these were voluntary. The reason being these evaluations were put out a week after the design challenge to sort of "reset" the minds of the participants and not allow their participation to influence the evaluations.

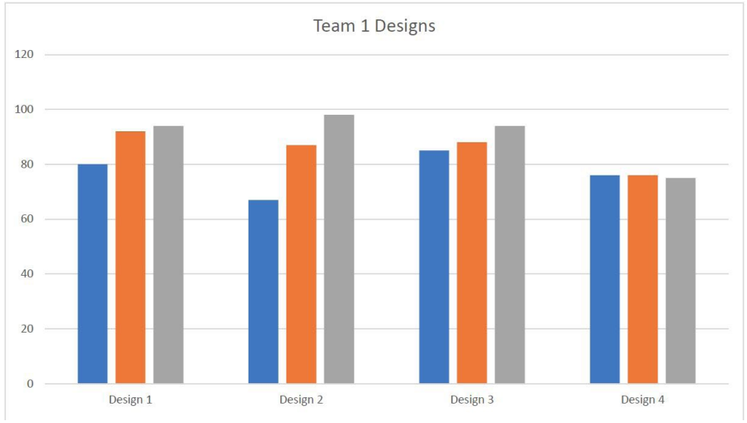
It was also important to ask evaluations from different groups (participants, MID body and industry experts) in order to compare objectivity among scores as well gauge differentiation between each score to gain an accurate measurement.

The questions were kept concise and only 3 were asked in order to retain participation rates.

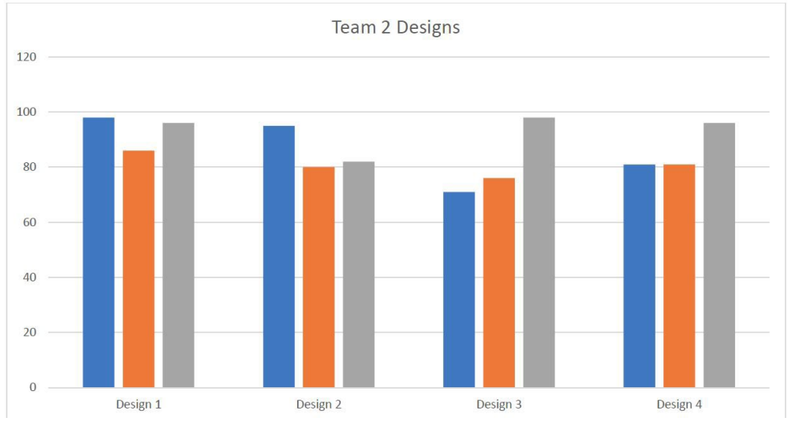
The values were separated by both the evaluator and the scores associated with team 1 and team 2 and applied an additive formula as shown here to come up with the overall evaluation score per design. Then the average was calculated per category to come up with the final values per category per team.

$$(a1+a2+a3+.....)+(b1+b2+b3+.....)+(c1+c2+c3+.....)+(d1+d2+d3+.....)= \text{Overall Score}$$

Team 1's evaluation | Team 2's evaluation | Expert's evaluation | General MID




| | Design is innovative | Design solves the issue successfully | This Idea is Clear to Understand |
|---|---|---|---|
| Design 1 | 80 | 92 | 94 |
| Design 2 | 67 | 87 | 98 |
| Design 3 | 85 | 88 | 94 |
| Design 4 | 76 | 76 | 75 |




| | Design is Innovative 1 | This Design Solves the Issue Successf | This Idea is Clear to Understand |
|---|---|---|---|
| Design 1 | 98 | 86 | 96 |
| Design 2 | 95 | 80 | 82 |
| Design 3 | 71 | 76 | 98 |
| Design 4 | 81 | 81 | 96 |






| | Innovation | Successful Design | Clarity |
|---|---|---|---|
| 1 | 98 | 92 | 98 |
| 2 | 95 | 88 | 98 |
| 3 | 85 | 87 | 96 |
| 4 | 81 | 86 | 96 |
| 5 | 80 | 81 | 94 |
| 6 | 76 | 80 | 94 |
| 7 | 71 | 76 | 82 |
| 8 | 67 | 76 | 75 |

Team 1
Team 2

Ranking of evaluation scores derived by formula and separated by category.

The numbers are interesting. In the first category of innovation, Team 1 only had one design that ranked in the top 50% of innovative designs (placed #3). Of the top 4, or top 50%, team 2 placed designs in places 1,2, and 4. Team 1 had designs ranked in places 5,6, and 8. From these numbers it is clear that Team 2 had outpaced Team 1 in the innovation category.

In the second category of successfulness, the numbers are flipped. Team 1 had their designs place top 3 while Team 2 had their designs place 4th, 5th and 6th with 7th and 8th positions being tied by both Team 1 and Team 2. So while evaluators thought Team 2 had more innovative designs, Team 1 had designs that addressed the issue of communicating with passengers in the pick up phase more successfully.

The tie breaker came with the third category of clarity of design. While first place was tied between the top designs from Team 1 and 2, the next two top performing designs in this category belonged to Team 2 and 5th, 6th and 8th place were held by Team 1 designs.

While the last category can serve as a tie breaker and that I tried my best to clearly explain the core idea of each design to the evaluators as true to their essence as possible in order for the scores to reflect the ideas themselves, evaluators may still be influenced to rate each design in terms of clarity by the drawing/sketching skills of each designer which isn't a factor I want to measure.

By the numbers, the third category indicates that Team 2 performed better than Team 1. However the numbers from from 1st to 6th were very close with a difference of 4 points between 1st and 6th place. However it is still worthy to note that clarity leads to better iterations of a concept later on in the design process.

Another interesting data comparison to look at is the evaluation score discrepancies between the cross evaluations between the teams themselves and 3rd party evaluators like the experts and the general MID body. This will give an indication on team bias/confidence in comparison to that of the 3rd party evaluators. Because 3rd party evaluators have no attachment or connection to the designs themselves, they offer the most unbiased score possible. If the evaluation scores from the teams themselves are close to that of the evaluators from experts and the MID body, then that could offer a good indication on team performance/confidence in their designs. The overall average score for each category of Team 1 evaluations from their cohorts is subtracted by the overall average score from each category from the 3rd party evaluators combined. The number will always be negative because there were more 3rd party evaluators than workshop participant evaluators. However the lower the negative number, the higher the confidence factor for that particular team. I decided not to include the scores from the third category because those score may be indicative of the clarity of the designer's drawing and that factor is not as important as the innovative and successfulness factors.

Measuring bias discrepancy can indicate how close workshop participant scores are to non-biased MID and industry expert scores.



(Workshop Participant score) - ([Industry Expert score]+[MID Body score])= -| Final Score |

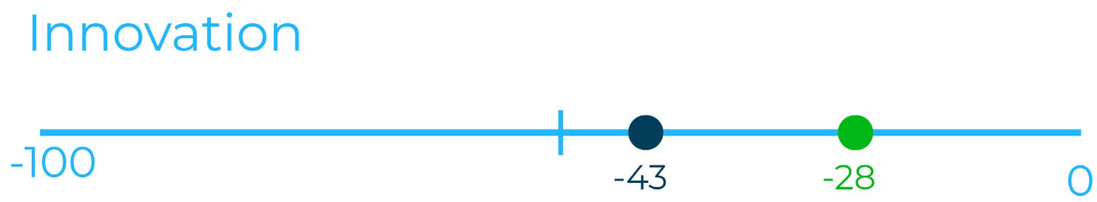
Each group score is a combined score from each category. I.E. all workshop participant score for the innovation category for each team are combined to give an overall score

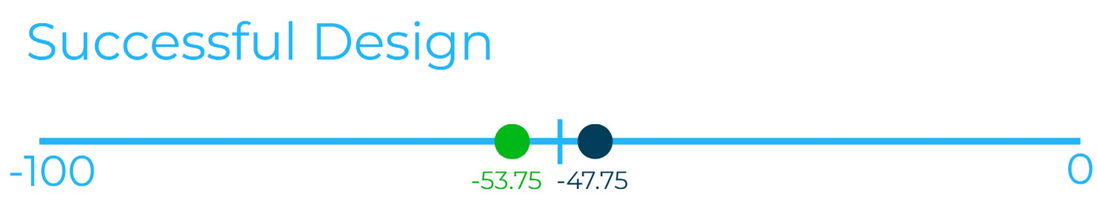
Team 1

Team 2

Overall Evaluation Average Discrepancy

The lower the negative value, the stronger the confidence factor among teams.




There is a higher confidence value in Team 2 than in Team 1 with respect to the innovation category. This reflects that Team 1 had a narrower design focus than Team 2. Team 2 had more confidence in this area because they were able to explore more design areas from boarding experience to ridership experience and service experience.

Success category reflects that Team 1 has slightly more confidcence in this area than Team 2. This is an indicator that Team 1 conducted more group discussion more in coordination than Team 2 who were more hands on with resources however spent less time in group discussion. Group discussion is key because teammates are able to bounce ideas off each other and validate one another.

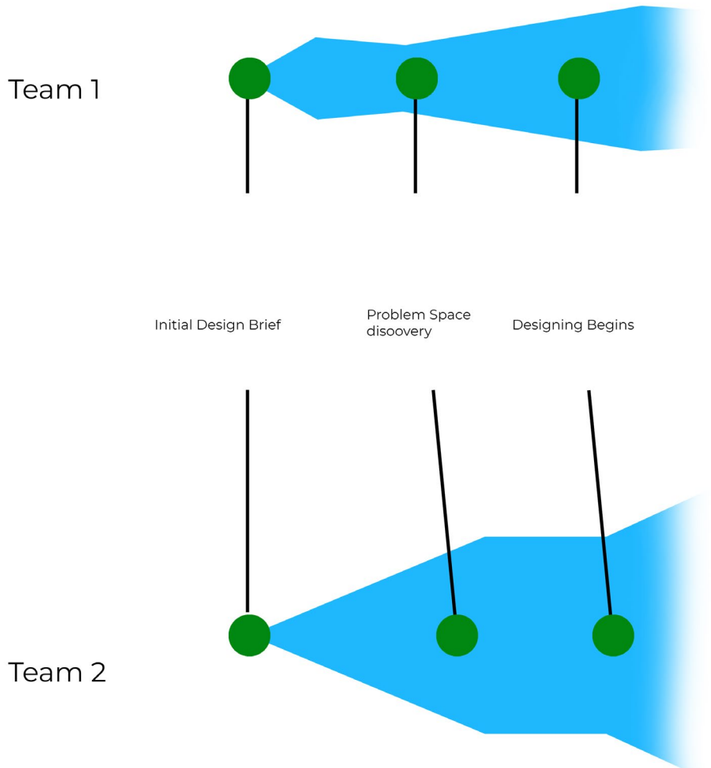
Overall discrepancy scores can indicate how far off teams evaluations are from non-biased evaluator groups. This is important because this shows how true team evaluators feelings and viewpoints are to the industry experts and MID body who are able to see each designs objectively.

# 6. Discussion

# 6.1 Analysis of Hypothesis

To recap, the hypothesis was that virtual reality could help designers in the early design stage become empathetic to the design brief better than traditional industrial design methods in order to come up with innovative concepts that can be further refined in the later parts of the design process for example in a double diamond method. The project started off as an examination of whether or not virtual reality can be an outright superior method than through traditional methods. However it became apparent after the design challenge that while virtual reality has its benefits over traditional methods, in relation to the hypothesis it is neither true nor false that V.R. is hand over fist better than traditional ID methods.

# 6.2 Observations of Findings




Scope of cognitive thinking of each team based on the post-hoc analysis of observations made after the workshop. Team 1 stayed mainly in oral group discussion while Team 2 engaged more with the tools to broaden their scope of empathy




**Design Evaluation**

- VR designs stayed in a similar design space
- Innovation scores reflect narrower design focus
- VR use helped kick off close, active oral discussion and group think
- Success scores reflects good understanding of context and confidence in ideas.


**SUS/TLX analysis**

- SUS scores show that the method was usable and correlates to Team 1 using VR to kick off discussions
- TLX scores reflects Team 1's initial confusion and reluctance to use VR and later resorted to pure group discussion

## Traditional ID tools

**Design Evaluation**

- Participants were more hands on and active with all resources available and active with each other
- Innovation scores reflect broader scope of exploration of design space
- Compared to Team 1, Team 2 spent more time reviewing resources than group discussions of design spaces
- Success scores could indicate less confidence in that area than team 1.

## Traditional ID tools

**SUS/TLX analysis**

- SUS scores reflect that team 2 used all resources but may have found that some tools were not as useful in this design context
- TLX scores reflect that ID tools were familiar to participants and were comfortable and not that much effort to use than V.R.



Both teams displayed their own trajectory of the early design phase in the double diamond method timeline. Team 1 had a narrower focus and arrived at different stages of early design quicker than Team 2. However, Team 2 had a much broader focus and explored more cognitive areas to arrive at their designs than Team 1. This can be explained because Team 2 were using more interactive "hands-on" methods, particularly the deck of cards and matchbox cars to recreate scenarios or explore possible solutions. Whereas Team 1 relied almost exclusively on oral dialogue and discussion.

The trajectory of their early design phase correlates with the performance in the innovative category of the design evaluations. Since Team 2 outperformed Team 1 in that category, that is reflected on the early design phase trajectory where Team 2 was more open and explored beyond the context of the design brief than Team 1 who primarily stayed within the bounds of the design brief. Virtual reality might have even had a negative impact on the design exploration of Team 1 because they used the scenes as a launch point for discussion and stayed only within that context as opposed to using virtual reality to explore beyond the context to develop innovative ideas.

## 6.3 Where V.R. Stands in Early Design Phase

More design challenge workshops involving different scenarios to truly determine virtual reality's validity in the early design phase. However this project gives a good insight into where V.R. stands now. Through the observations of this project, we can see that V.R. doesn't fall behind traditional industrial design methods. Team 1 members were able to complete the design challenge using virtual reality. Team 1 reported virtual reality as a usable system in design.

However, we can also see that in some design cases virtual reality is overkill at least in the early design phase. As reported by one Team 1 member,

“I think a simple 2D video would have been enough. I mainly relied on my own experience in riding a bus and my own imagination. I think virtual reality would be much more useful in, say, if I was designing a football helmet or equipment. I would love to be able to see what a football player sees because I never played football and in those cases I’d rely more on virtual reality than in others.”

Virtual reality can be more useful in design contexts, such as sports design, design taking place in a far away place, certain environments such as classrooms or work sites where behaviours and elements may not always be easily replicated, and others where an average person may not necessarily have experienced it first hand.

One topic that can be researched in the future is the correlation between suitability of virtual reality in the early design stage and the complexity/size of the design context. This project examined V.R. in the context of designing a visual communication system for an autonomous bus which is a big scale context and a fairly complex. V.R. could serve useful in small scale applications. A use case scenario example could be designing a more efficent HDMI port locations for wall mounted TVs or small kitchen appliances such as a rice cooker or blender. V,R, could be used to examine a model in a group setting to identify areas of improvement in a group context as opposed to having designers examine a low fidelity model in person one by one. V.R. can especially have a bigger impact if an interactive component is added. However, for quick and dirty design challenges, V.R. might not be as effective as physical paper model making or other ID tools for the simple reason that time and effort is required to prepare a V.R. resource.

Virtual reality, especially as they become more accessible over time, will be increasingly easier to use. The applications V.R. will have will grow. In this project, recording, producing and viewing 360 degree was fairly simple and didn’t not require a substantial learning curve. However, the application use for 360 degree videos are farily limited. Creating fully immersive, interactive digital worlds requires a good amount of knowledge such as coding, game theory/design, knowledge in software such as Unity 3D. Learning these skills to fully untap the potential of virtual reality.



Software like Unity 3D is ideal for creating interactive digital worlds like a video game but it requires time and knowledge. Software like Sketchbox 3D, however, is much easier to use and is highly interactive albeit much lower fidelity.

Cost of V.R. headsets should also be taken into account. According to HTC Vive’s website, the cheapest V.R. headset they offer is 549$ such as the one used for this project (HTC VIVE). Although financial accesibility of V.R. headsets have come a long way (I.E. have become cheaper) it is still a substantial investment to make.

Still, even in a design context such as the one used for this design challenge workshop, virtual reality can still serve as a supplemental tool to be used alongside traditional ones like storyboarding, sketching and role playing as opposed to outright replacing them or using virtual reality more than other tools. V.R. can also be useful in design education, where professors can use V.R. to teach design skills, theories and processes in a more immersive and engaging way that simple lectures.

## 6.4 Impact

As design prompts and contexts changes, so should methods of empathy and brainstorming in the early design phase. There are many tried and true tools of design that are simple, easy and effective in this stage of design. However, new tools and methods should be explored and adopted that could progress the way designers go about designing.

As virtual reality headsets become cheaper and more accessible, and forms of recording immersive videos becomes easier, virtual reality has the potential to be a powerful tool in the early design stages. This project aims to lay the groundwork for future consideration of research and development into virtual reality being used as an empathy tool and not just an entertainment device or a design tool to be used in much later stages of design.

# 7. Summary

This project aimed at making observation on V.R. in early design phase in a design setting that allowed designers freedom to make design decisions. V.R. was used and allowed designers to kick start discussion points during the empathy phase. Evaluation scores showed V.R.'s performance was on par with traditional industrial design tools and methods. Participants interviewed acknowledged V.R.'s role in early design and commented on its potential valuable role in design contexts that are unfamiliar to designers. Preparing V.R. resources such as 360 degree videos, filming techniques and use of headset was simple, straightforward and easy and required no prior knowledge of use. There was little to no hiccups in terms of producing V.R. content and resources. All together V.R. is a viable tool to use in the early design stage.

Through this project, new questions and potential research areas on the use of V.R. in early design phase arise:

- What would V.R. look like in the early design phase of small scale design opportunites such as appliances, human interactions, gadgets?
- What could V.R.'s role is in the realm of design education?
- What would V.R. use look like in novel design contexts such as sports design, service design, extreme scenarios such as envisioning a lunar colony or dealing with extreme situations like a design solution for pandemics where desktop research or field research is limited?
- How would early design phase change of V.R. had an interactive component where real time live design is possible in a group setting?

This project is a small scale introduction to the discussion of the future of design, particularly in the early design phase, using virtual reality to help convey ideas, observation, discovery of problems/opportunities in a new way that could potentially unlock new potential for more people across varying design experiences and gaps. Traditional I.D. tools and methods requires some level of design education and experience to use in a helpful manner in early design. But as shown by the "Gaming the Tibby" use case where ordinary people were given an immersive tool to empathize with the design context and communicate ideas. V.R. has the potential of giving more people design power to envision problems better and ideate opportunites to solve those problems.

# 7.1 Summary

This project aimed at examining virtual reality as an empathizing tool for the early ideation stage of design. Through creating virtual reality scenes with a 360 degree camera and Unity 3D and launching a design challenge workshop, we observed the design behaviours of two teams; one team using virtual reality to empathize and another team using traditional industrial design methods. From the design challenge workshop came design and task analysis which showed that evaluators thought that virtual reality performed better in the system usability category while traditional industrial design methods performed better when it comes to task performance. We also saw that the team that used virtual reality created designs that people thought solved the design task more successfully than the other team but that the team with industrial design methods produced more innovative designs.

What we can gather however is that virtual reality may not be useful in design scenarios that are familiar to most people, it does have a role to play in future design scenarios that involve empathizing with situations or problem spaces that is a unique use case scenario.

# 7.2 Call for Future Research

As mentioned before, future research on a much larger scale would need to be conducted in order to truly determine V.R's usefulness in early design. More participants and more novel design challenges can shed better insight as to V.R. validity. However, this project focuses on virtual reality primarily in a passive sense, meaning virtual reality was used only to view an environment, not interact. But what if an interactive component was added to the 360 degree videos?

It is clear that the interactive component to Team 2's methods, such as role playing and storyboarding using props like Legos and matchbox cars, helped broaden their exploration space and develop concepts that were evaluated to be more innovative than Team 1's. By making design engaging and cooperative, a larger creativity pool among designers can be unleashed and thus lead to more innovative ideas.



Current V.R. software, such as SketchBox, exists that allows for easy creation and manipulation of environments. However it is very basic and importing 360 degree videos is difficult and clumsy. Developing an interactive component to virtual reality and 360 degree videos that is easy to use and immersive can take virtual reality to the next level. This should be the next step in virtual reality research and testing.

# Acknowledgemnt

Even before my undergrad journey in architecture I have always wanted to be an industrial designer. I would have never imagined that I would be completing my industrial design degree at a prestigious institution like Georgia Tech. 2 years ago I started this journey and I wasn't even sure I'd be good enough to complete it. I am very proud of how far I've come and the people that have helped me along this journey.

I would like to thank my God for guiding me through the ups and downs of life. I would also like to thank and acknowledge my adviser Professor Wei Wang for believing in me and helping me push this project along.

I'd like to recognize my first professors of industrial design and my committee members Dr. Roger Ball and Dr. Young-Mi Choi for their guidance, support, and care for me, my well being and progress as a student.

Lastly, to my friends and family who have kept me going during my time at Georgia tech. I couldn't have done it without any of you.

I am a Florida Gator at heart, but now I can proudly say I am also a proud Yellow Jacket. The blue and gold will always be with me.

# Reference


1. Babich, Nick. “A Comprehensive Guide To Product Design.” Smashing Magazine, Vitaly Friedman, Sven Lennartz, 31 Jan. 2018, www.smashingmagazine.com/2018/01/comprehensive-guide-product-design/.
2. Bell, Jackie. “Gaming the Tibby: Virtual Reality Design for Community.” Green Places 71 (2011): 31-33. Web.
3. Beltz, Brian. “What Is the ‘First Mile, Last Mile’ Problem?” Something About Orange, SAO, 27 Sept. 2019, somethingaboutorange.com/first-mile-last-mile-problem/.
4. Berg, L.P., Vance, J.M. Industry use of virtual reality in product design and manufacturing: a survey. Virtual Reality 21, 1–17 (2017). https://doi.org/10.1007/s10055-016-0293-
5. Bharadwaj, Himanshu. “New Realities: VR, AR, MR, and the Future of Design.” Toptal Design Blog, Toptal, 2 Nov. 2017, www.toptal.com/designers/product-design/vr-ar-mr-the-future-of-design.
6. Brooks, Fredrick. What’s Real About Virtual Reality? University of North Carolina at Chapel Hill, 1997, www.cs.unc.edu/~brooks/WhatsReal.pdf.
7. Chang, Shao-Chen, et al. “Integration of the Peer Assessment Approach with a Virtual Reality Design System for Learning Earth Science.” Computers & Education, vol. 146, 16 Nov. 2019. Elsevier, doi:https://doi.org/10.1016/j.compedu.2019.103758.
8. Design Council . “What Is the Framework for Innovation? Design Council’s Evolved Double Diamond.” Design Council, Design Council, 10 Sept. 2019, www.designcouncil.org.uk/news-opinion/what-framework-innovation-design-councils-evolved-double-diamond.
9. Digital Native, director. Gaming the Tibby. Vimeo, Digital Native, 16 Aug. 2010, https://vimeo.com/14181584.
10. Ellis, Matt. “How to Design for Virtual Reality: Basics and Best Practices for VR Design.” 99designs, 99designs, 1 Mar. 2019, 99designs.com/blog/trends/virtual-reality-design/.
11. Ingrassia, T., Cappello, F. VirDe: a new virtual reality design approach. Int J Interact Des Manuf 3, 1–11 (2009). https://doi.org/10.1007/s12008-008-0056-2
12. Interaction Design Foundation. “What Is Design Thinking?” The Interaction Design Foundation, The Interaction Design Foundation, 2019, www.interaction-design.org/literature/topics/design-thinking.
13. Liedtka, Jeanne M., and Timothy Ogilvie. “10 Design Thinking Tools: Turn Creativity and Data Into Growth.” Darden Ideas to Action, University of Virginia, 15 Dec. 2018, ideas.darden.virginia.edu/10-design-thinking-tools-turn-creativity-and-data-into-growth.
14. Lindsay, Calum. “Volta VR Tool ‘Will Make Producing Audio More Expressive.’” Dezeen, Dezeen, 15 July 2019, www.dezeen.com/2019/07/15/volta-virtual-reality-alex-kane-royal-college-of-art-video/.
14. LTD, TMD Studios. “Virtual Reality Uses in Architecture and Design.” TMD STUDIO’s Insights, Medium, 27 Jan. 2017, medium.com/studiotmd/virtual-reality-uses-in-architecture-and-design-c5d54b7c1e89.
15. Murray, Tom. “How VR Is Changing the Game for Product Designers.” Core77, Core77 Inc., 16 July 2018, www.core77.com/posts/78681/How-VR-Is-Changing-the-Game-for-Product-Designers.
16. Sauro, Jeff. “10 Things to Know about the NASA TLX.” MeasuringU, MeasuringU, 27 Aug. 2019, measuringu.com/nasa-tlx/.
17. Slenske, Michael. “Will Virtual Reality Change the Design World?” Architectural Digest, Conde Nast, 12 July 2018, www.architecturaldigest.com/story/virtual-reality-augmented-reality-apps-oculus-vr-design-world.
18. Thomas, Nathan. “How To Use The System Usability Scale (SUS) To Evaluate The Usability Of Your Website.” Usability Geek , Usability Geek, Mar. 2020, usabilitygeek.com/how-to-use-the-system-usability-scale-sus-to-evaluate-the-usability-of-your-website/.

19. “Virtual reality.” Merriam-Webster.com Dictionary, Merriam-Webster, https://www.merriam-webster.com/dictionary/virtual%20reality. Accessed 14 Apr. 2020

20. VRS. “History Of Virtual Reality.” Virtual Reality Society, Virtual Reality Society, 2017, www.vrs.org.uk/virtual-reality/history.html.
21. Warren, Tom. “Google Maps Now Lets You Tour Street View in Virtual Reality.” The Verge, Vox Media, 18 Dec. 2014, www.theverge.com/2014/12/18/7414451/google-maps-street-view-virtual-reality.
22. Wilson, Mark. “Why Virtual Reality Will Change Design Forever.” Fast Company, Fast Company, 11 Apr. 2016, www.fastcompany.com/3058756/why-virtual-reality-will-change-design-forever.
23. Woodruff Health Sciences Centre. “Virtual Reality Exposure Therapy Reduces PTSD Symptoms.” Emory University | Atlanta, GA, Emory, 21 Apr. 2014, news.emory.edu/stories/2014/04/virtual_reality_exposure_reduces_PTSD/campus.html.

# Image Reference


1. Design thinking photo by fabian wiktor
   https://www.pexels.com/photo/person-writing-on-white-paper-3471423/
2. Virtual photo 1 by Harsch Shivam
   https://www.pexels.com/photo/person-wearing-vr-goggles-2007647/
3. St. Peters basilica by James Finch
   https://www.pexels.com/photo/the-tribunal-of-the-king-3684345/
4. John Deere VR
   https://johndeerejournal.com/2019/04/using-virtual-reality-to-build-the-next-generation-tractor/
5. Cadillac VR
   https://www.autonews.com/article/20180511/RETAIL01/180519916/cadillac-s-virtual-reality-project-has-no-limits-innovation-head-says
6. GM logo
   https://media.gm.com/media/us/en/gm/photos.detail.html/content/Pages/galleries/us/en/logos.html
7. Ford logo
   https://corporate.ford.com/homepage.html?gnav=footer-aboutford
8. Lockheed martin logo
   https://www.lockheedmartin.com/en-us/index.html
9. John Deere logo
   https://www.deere.com/en/our-company/history/trademarks/
10. Idaho national labs
    https://inl.gov/
11. VR photo by eugene capon
    https://www.pexels.com/photo/photo-of-man-using-virtual-reality-headset-1261822/
12. OLLI shuttle
    https://wamu.org/story/19/02/13/toaster-shaped-autonomous-shuttle-is-first-to-test-on-public-roads-in-maryland/




## Sample of Task Analysis, SUS, and Design Evaluations

Georgia Tech

### SUS/TLX Evaluation

Which Design method did your team use?

Virtual Reality

Traditional industrial design methods

Usability of This Design Method

| | Strongly Disagree | Somewhat Disagree | Neutral | Somewhat Agree | Strongly Agree |
|---|---|---|---|---|---|
| I think that I would use this method frequently | ○ | ○ | ○ | ○ | ○ |
| I found this system unnecessarily complex | ○ | ○ | ○ | ○ | ○ |
| I thought this system was easy to use | ○ | ○ | ○ | ○ | ○ |
| I think that I would need support of a technical person to be able to use this method | ○ | ○ | ○ | ○ | ○ |
| I imagine that people will learn to use this method very quickly | ○ | ○ | ○ | ○ | ○ |
| I found the various functions of this method is well integrated | ○ | ○ | ○ | ○ | ○ |
| I thought there was too much inconsistency with this method | ○ | ○ | ○ | ○ | ○ |
| I found this method was very cumbersome to use | ○ | ○ | ○ | ○ | ○ |
| I felt very confident in using (and designing with) this method | ○ | ○ | ○ | ○ | ○ |
| I needed to learn a lot of things before I could get going with this method | ○ | ○ | ○ | ○ | ○ |

# Workload Evaluation

Mental Demand — How mentally demanding was the task?

Very Low — Very High

Physical Demand — How physically demanding was the task?

Very Low — Very High

Temporal Demand — How hurried or rushed was the pace of the task?

Very Low — Very High

Performance — How successful were you in accomplishing what you were asked to do?

Perfect — Failure

Effort — How hard did you have to work to accomplish your level of performance?

Very Low — Very High

Frustration — How insecure, discouraged, irritated, stressed, and annoyed wereyou?

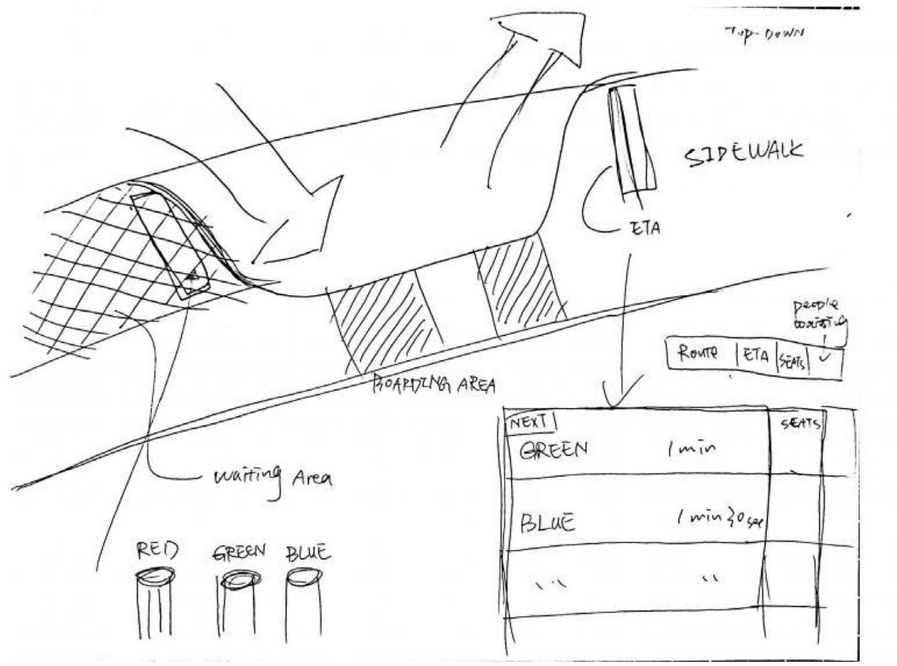
Very Low — Very High



## Design Evaluation for Team 1 Designs

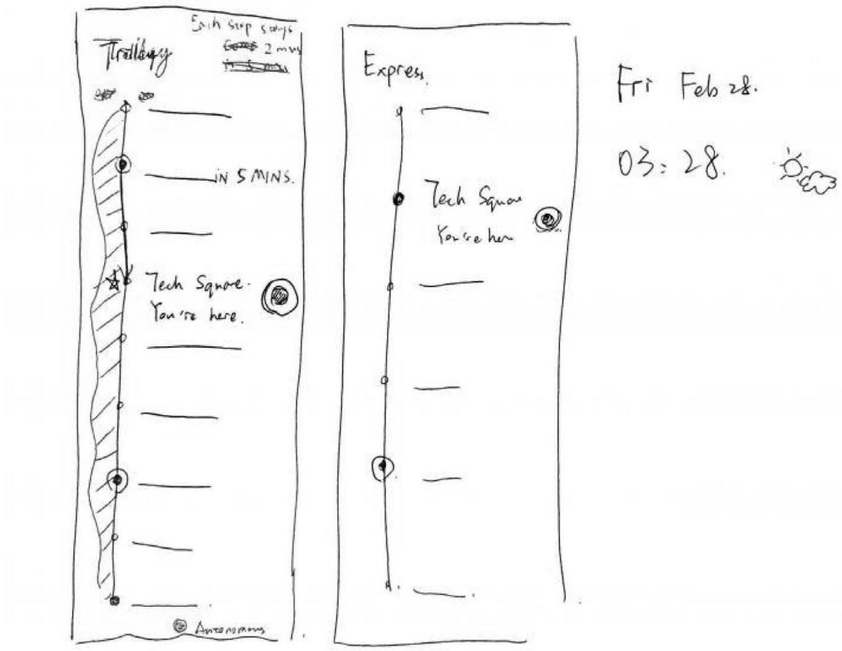
**Default Question Block**

You as a member of Team 2 will now evaluate the designs of Team 1. I'll give a brief description of each design in case you forgot and you will evaluate each design on a simple likert scale.. Should take you no more than 2 mins to complete.




Design 1 from Team 1. This concept envisions a "smart bus stop". This design is similar to a subway display sign in that it displays incoming buses, their ETAs, their route info and also an estimated number of open seats on each bus so that passengers can get a

| | Strongly Disagree | Disagree | Somewhat disagree | Neither agree nor disagree | Somewhat agree | Agree | Strongly agree |
|---|---|---|---|---|---|---|---|
| This design is innovative | ○ | ○ | ○ | ○ | ○ | ○ | ○ |
| This design solves the issue successfully | ○ | ○ | ○ | ○ | ○ | ○ | ○ |
| The idea is clear to understand | ○ | ○ | ○ | ○ | ○ | ○ | ○ |



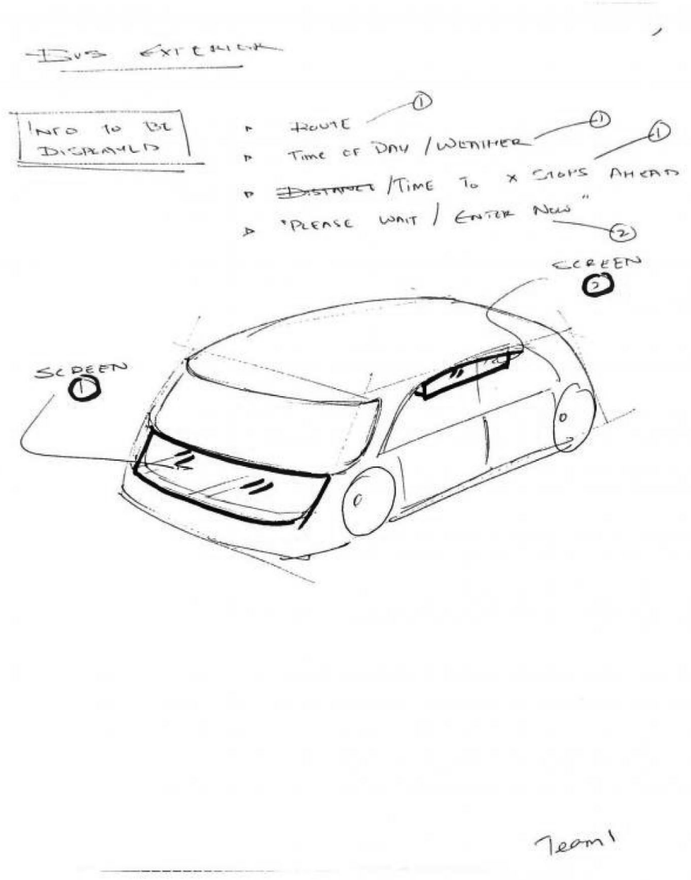

Fri Feb 28.

03:28.

Design 2 from Team 1. This concept is another smart bus stop albeit a little more simpler. The smart bus stop breaks down route stops in a linear form and displays ETAs for each stop as well as give a weather report.

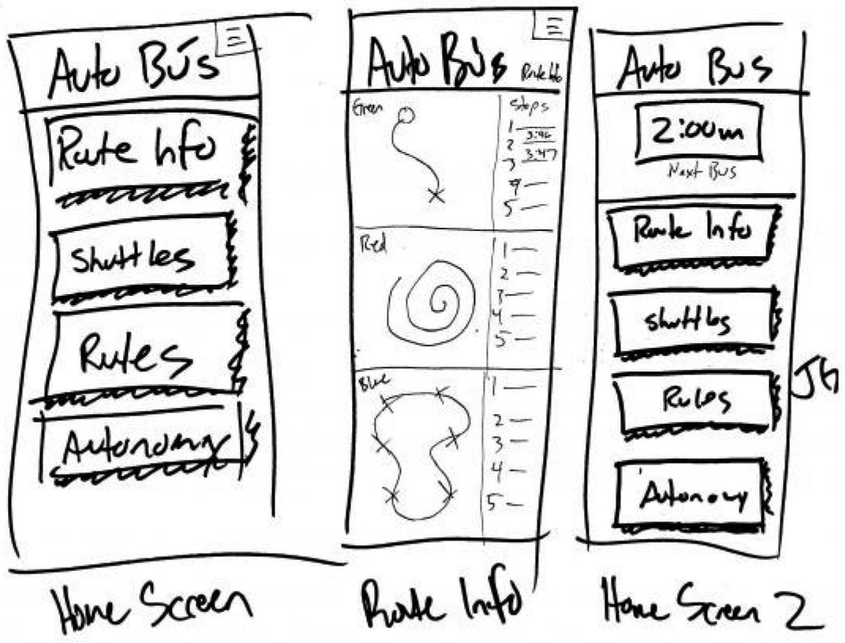
| | Strongly Disagree | Disagree | Somewhat disagree | Neither agree nor disagree | Somewhat agree | Agree | Strongly agree |
|---|---|---|---|---|---|---|---|
| This design is innovative | ○ | ○ | ○ | ○ | ○ | ○ | ○ |
| This design solves the issue successfully | ○ | ○ | ○ | ○ | ○ | ○ | ○ |
| The idea is clear to understand | ○ | ○ | ○ | ○ | ○ | ○ | ○ |






Design 3 from Team 1. This concepts envisions equipping buses with 2 electronic display boards, one below the front windshield and the other on the boarding side each displaying different information. The front screen displays route information and ETAs to each stop. The side screen displays boarding instructions to passengers

| | Strongly Disagree | Disagree | Somewhat disagree | Neither agree nor disagree | Somewhat agree | Agree | Strongly agree |
|---|---|---|---|---|---|---|---|
| This design is innovative | ○ | ○ | ○ | ○ | ○ | ○ | ○ |
| This design solves the issue successfully | ○ | ○ | ○ | ○ | ○ | ○ | ○ |
| The idea is clear to understand | ○ | ○ | ○ | ○ | ○ | ○ | ○ |




Lastly, Design 4 from Team 1. This concept is an all inclusive app that aims to calm fears of passengers and establish trust as well as be informative. In addition to displaying typical bus rider information such as route information, ETAs and shuttle information, the app uses friendly images and UI as well as display autonomous shuttle statistics and educational information to help establish trust between the rider and the autonomous shuttle.

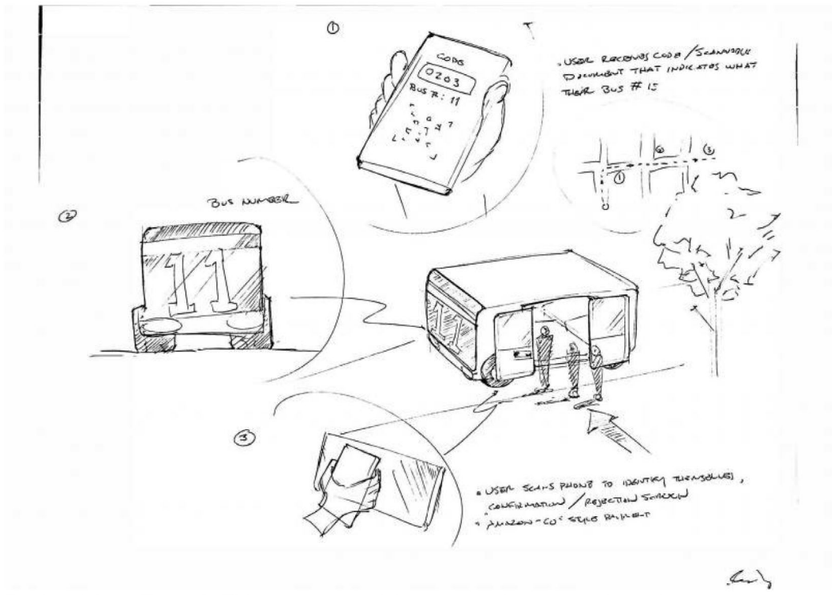
| | Strongly Disagree | Disagree | Somewhat disagree | Neither agree nor disagree | Somewhat agree | Agree | Strongly agree |
|---|---|---|---|---|---|---|---|
| This design is innovative | O | O | O | O | O | O | O |
| This design solves the issue successfully | O | O | O | O | O | O | O |
| The idea is clear to understand | O | O | O | O | O | O | O |



# Design Evaluation for Team 2 Designs

**Default Question Block**

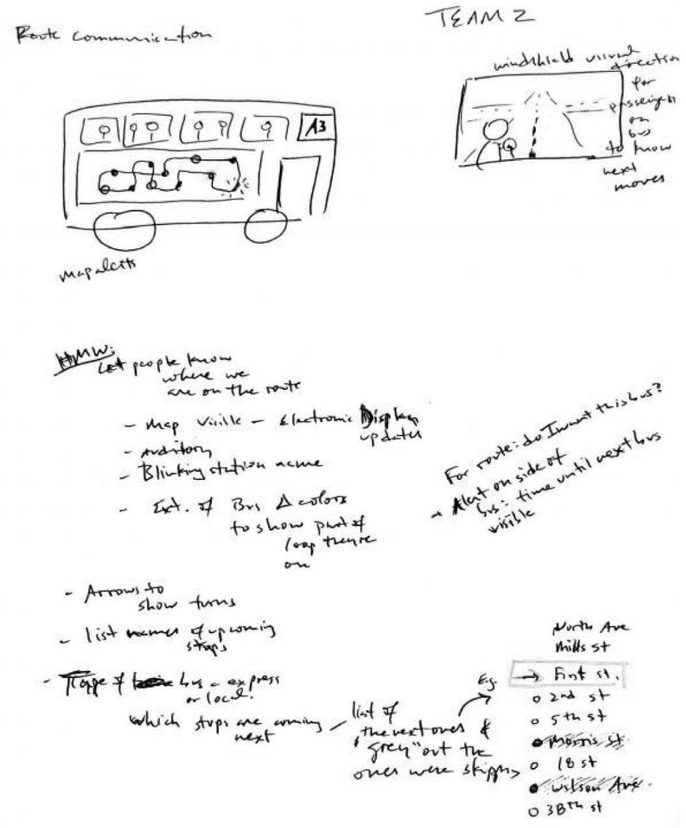
You as a member of Team 1 will now evaluate the designs of Team 2. I'll give a brief description of each design in case you forgot and you will evaluate each design on a simple likert scale.. Should take you no more than 2 mins to complete.




Design 1 from Team 2: This concept envisions an environment where there are numerous smaller buses in service as opposed to fewer bigger buses, passengers input their destination into the bus app where the bus takes the information from several nearby passengers and gives the passengers the optimal pick-up and drop-off locations.

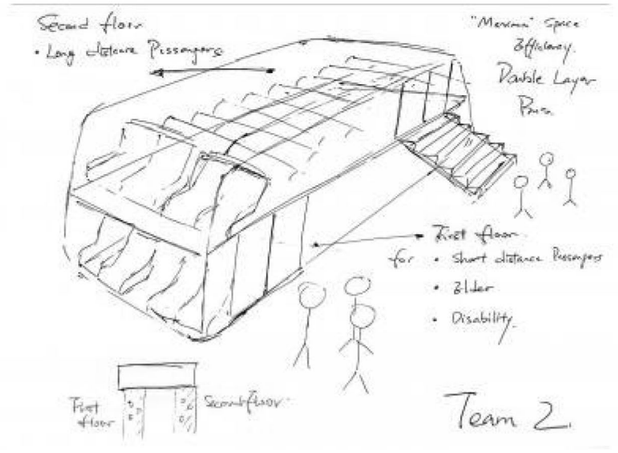
| | Strongly Disagree | Disagree | Somewhat disagree | Neither agree nor disagree | Somewhat agree | Agree | Strongly agree |
|---|---|---|---|---|---|---|---|
| This design is innovative | O | O | O | O | O | O | O |
| This design solves the issue successfully | O | O | O | O | O | O | O |
| The idea is clear to understand | O | O | O | O | O | O | O |

*Design 2 from Team 2. This concept envisions the bus combining a side display panel with an AR overlay on the interior windshield. The side display panel shows the bus route in relation to the bus location on that route. It would also the bus stops as a list in case people wanted that information as a list rather than in relation to geography. The AR windshield would show passengers the directions its about to take to give passengers a better ideas as to where the bus will be going, stopping, and give passengers a better*



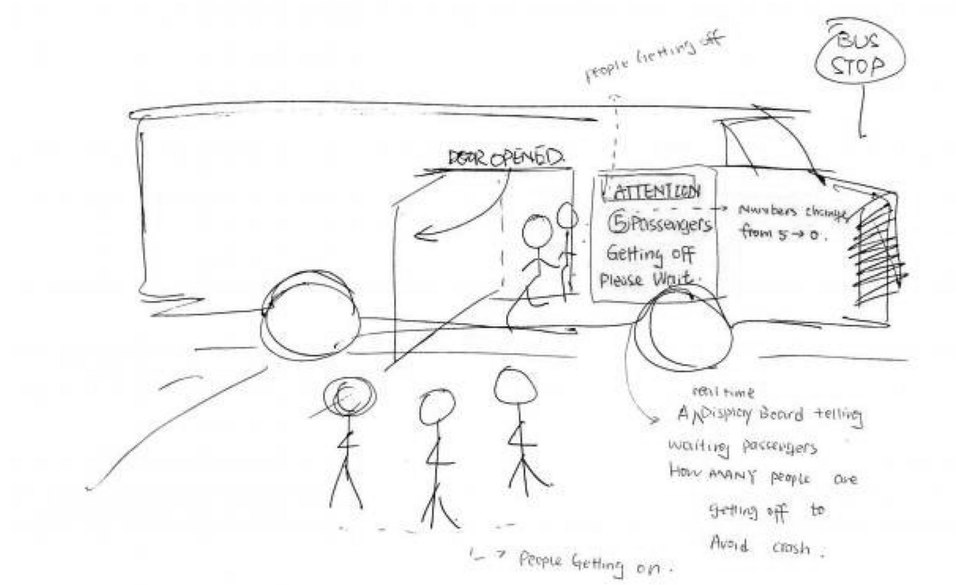

| | Strongly Disagree | Disagree | Somewhat disagree | Neither agree nor disagree | Somewhat agree | Agree | Strongly agree |
|---|---|---|---|---|---|---|---|
| This design is innovative | ○ | ○ | ○ | ○ | ○ | ○ | ○ |
| This design solves the issue successfully | ○ | ○ | ○ | ○ | ○ | ○ | ○ |
| The idea is clear to understand | ○ | ○ | ○ | ○ | ○ | ○ | ○ |






Design 3 from Team 2 is fairly straightforward. This concept envisions a 2 story shuttle. The first story is designated for easier entry/exit of the shuttle for short-distance passenger, elderly and disabled passengers. The second story is designated for long-distance passengers. The theory is that this will allow quicker and more efficient passenger flow according to the distance needs of each passenger.

| | Strongly Disagree | Disagree | Somewhat disagree | Neither agree nor disagree | Somewhat agree | Agree | Strongly agree |
|---|---|---|---|---|---|---|---|
| This design is innovative | ○ | ○ | ○ | ○ | ○ | ○ | ○ |
| This design solves the issue successfully | ○ | ○ | ○ | ○ | ○ | ○ | ○ |
| The idea is clear to understand | ○ | ○ | ○ | ○ | ○ | ○ | ○ |




Lastly,

Design 4 from Team 2. This concept is also fairly straightforward. This concepts envisions a real-time display board that gives entry/exit instructions to passengers. It will display information like how many people will be disboarding so incoming passengers can know to wait and allow passengers to deboard in order to reduce bottlenecking

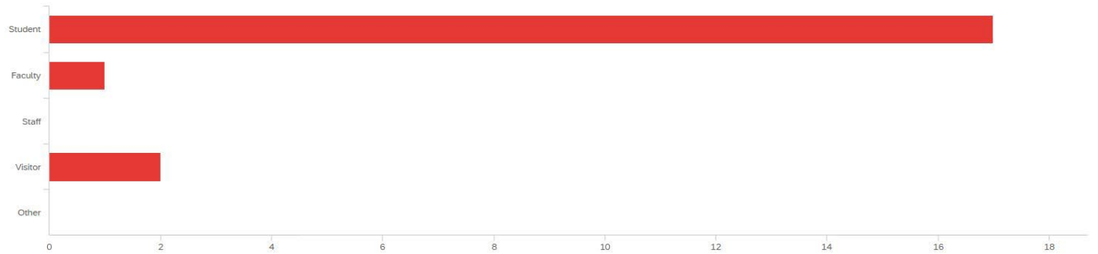
| | Strongly Disagree | Disagree | Somewhat disagree | Neither agree nor disagree | Somewhat agree | Agree | Strongly agree |
|---|---|---|---|---|---|---|---|
| This design is innovative | ○ | ○ | ○ | ○ | ○ | ○ | ○ |
| This design solves the issue successfully | ○ | ○ | ○ | ○ | ○ | ○ | ○ |
| The idea is clear to understand | ○ | ○ | ○ | ○ | ○ | ○ | ○ |

This concludes the survey. Again thank you very much for taking the time to complete this.



Q1 - Which one of these would describe you?

Page Options




Georgia Tech School of Industrial Design
College of Design