SYSEN 5900

CUSD Sustainable Mobility - Garage

CORNELL UNIVERSITY SUSTAINABLE DESIGN

Cornell Engineering
Systems Engineering

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Best Regards,
CUSD – Sustainable Mobility Team - Garage

Preface

The Sustainable Mobility team is a part of Cornell University Sustainable Design (CUSD) and is dedicated to re-designing transportation in Tompkins County, New York. This interdisciplinary team is comprised of both undergraduate and graduate students from Cornell University, and is advised by Professors Sirietta Simonini and Wenqi Yi.

Sustainable Mobility as a subteam has many concurrent projects occurring at once. At the moment, there are four different sub teams within it. These are Shelter, Master Plan, Planning, and Garage. Although each of the sub teams interacts with the others in order to successfully complete a project, the division allows for more specialized analysis of each system.

The Garage subteam is now in its second semester of operation. This team is currently working with the City of Ithaca in order to analyze and optimize three public parking garages located at Green, Seneca, and Dryden Streets. Last semester, the team worked on figuring out what problems were contributing to the underutilization of the parking structures. After finding that navigation confusion contributed significantly to a negative overall user experience, this semester the project has evolved to focus on redesigning garage signs. This project is partially influenced by Sustainable Mobility's successful past work with Tompkins Consolidated Area Transit (TCAT) to implement new bus signs around Tompkins County.

This semester, the team has focused on using Systems Engineering and Design Thinking Process tools to understand how best to tackle the identified issues. This has included understanding various user needs, analyzing how users interact with the system, and figuring out appealing, cost efficient, and effective ways to communicate important information. The sub team has made great strides this semester that, once revised with feedback from the City of Ithaca, will allow for the Garage sub team to begin implementation and more involved user testing next semester.

Garage Team

Last semester, the CUSD Sustainable Mobility team was formed in order to identify and tackle issues the City of Ithaca was experiencing with their parking garage system. Last semester, this consisted of looking specifically at the Green, Seneca, and Dryden Street Garages. The City of Ithaca reached out to CUSD with this project after successful implementation of signage changes for the TCAT system.

The garage team has grown this semester to 13 members. Our team has a variety of backgrounds including Design and Environmental Analysis, Architecture, Electrical & Computer Engineering, Information Science, and Operations Research & Engineering. This year, our team has 8 M.Eng Systems Engineering students, one of whom is a distance learner based out of California.

Leor Alon: Leor is pursuing his Master's degree in Systems Engineering at Cornell as a Distance Learning student. He completed his undergraduate degree in Mechanical Engineering in 2018 at Cornell University. Currently, Leor is in California working on developing a new generation of autonomous vehicles at Zoox. He is passionate about solving problems with creative solutions, mobility, robotics, and wakeboarding.

Emma Boudreau: Emma is a Master of Architecture thesis student, focusing on architectural acoustics and musical performance spaces. She completed her undergraduate degree at Cornell in Mechanical Engineering from Cornell. She is from Cape Cod, MA and is interested in creative problem solving across disciplines. Outside of school, Emma loves to travel, play piano and watch stand- up comedy.

Alex Ciampaglia: Alex is an early admit Master of Engineering student studying systems engineering. While completing his undergraduate degree at Cornell, he has become heavily involved in the community doing teaching programs at several Ithaca elementary schools.

Mary Essex: Mary is a second semester Master of Engineering student at Cornell studying Systems Engineering specializing in Systems Design & Optimization as well as Logistics Engineering. She completed her undergraduate degree at Cornell in Operations Research & Engineering and is interested in quality and reliability engineering specifically within software and hardware. She is from Fairfield, CT, and enjoys skiing, baking, and playing golf.

Annie Fu: Annie is a junior studying Information Science and Architecture, concentrating in Data Science and User Experience Design. She's interested in sustainability and data-driven design through the lens of technology and front-end development. In her down time, she can be found writing or illustrating for Cornell's alternative opinion magazine, *kitsch,* or playing the grand piano in Anabel Taylor Hall.

Zeyu Hu: Zeyu is a Master of Engineering student at Cornell University studying Systems Engineering specializing in Sustainability, Energy & Environmental Systems. He completed his undergraduate degree at Cornell in Environmental and Sustainability Sciences with a focus in Environmental Economics. He is passionate about sustainability and this is his fourth year involved with Cornell University Sustainable Design. Outside of school, he spends her time playing violin in the Cornell Symphony Orchestra and was the former Editor-in-Chief of Guac Magazine, Cornell's first and only travel magazine.

Sohwi Jung: Sohwi Jung is a sophomore majoring in Information Science, Systems, and Technology in the College of Engineering. She is from the island of Guam and is currently most interested in data science and front-end development. She is passionate about finding efficient solutions to various problems that arise, both digitally and in the real-world. In her free time, Sohwi enjoys playing golf and taking pictures outdoors.

Jackson Kopitz: Jackson is a senior majoring in Electrical and Computer Engineering and will be pursuing a Master of Engineering in Systems Engineering from Cornell following his undergraduate degree. Jackson is most interested in robotics, sustainability, and autonomous systems. He is from Manhattan Beach, California and likes to play trombone, pet dogs, and be outside.

Hilary Paul: Hilary is a Master of Engineering Student at Cornell studying Systems Engineering, focusing on transportation and energy systems. She is passionate about sustainability and this is her third year involved with Cornell University Sustainable Design. Outside of school, she spends her time as a physical education instructor, teaching climbing, backpacking, and cross-country skiing.

Amrita Ramamurthy: Amrita is a second semester Master of Engineering student from Manhattan, New York, currently in the Systems Engineering program. She completed her undergraduate degree in Operations Research & Engineering and is interested in applying emerging technologies. She is a competitive long-distance runner and enjoys watching soccer.

Rowan Reddy: Rowan is a junior majoring in Operations Research and Information Engineering. He is from Westchester, NY, and is interested in consulting and finance. Being a fan of efficiency and problem solving, he hopes to apply his engineering skill set to a broad variety of real world problems. In his free time Rowan enjoys paintballing or skiing depending on the season and watching a movie with friends at night afterwards.

Elena Sabinson: Elena Sabinson is a PhD student in Human Behavior & Design within the department of Design + Environmental Analysis at Cornell University. Elena currently works in the Architectural Robotics Lab, where she studies human robot interaction. Prior to Cornell, Elena was an Assistant Teaching Professor at Drexel University, where she received an MS in Interior Architecture & Design. She has experience with environmental graphics, human-centered design, environmental psychology, digital fabrication, and computational design.

Jiyuan Xu: Jiyuan is a Master of Engineering student majoring in Systems Engineering at Cornell. He earned his bachelor's degree in Mechanical and Aeronautical Engineering from Rensselaer Polytechnic Institute. Jiyuan is passionate about civil aviation and hopes to apply his knowledge and engineering skills to aviation industries. Outside of class, he enjoys watching movies, hanging out with friends, hiking in nature, and trying out new things.

The Garages

The City of Ithaca currently houses four public parking garages; Green Street, Dryden, Seneca, and Cayuga. The Green Street, Seneca, and Cayuga garages are located in the Ithaca Commons, while the Dryden garage is located in Cornell University's Collegetown area. The Green, Seneca, and Dryden street garages are also managed by the city and are the focus of the Garage team's work, while the fourth on Cayuga street is managed by private company Allpro Parking. This garage served as an initial inspiration and starting point for team research. The three city-managed garages offer parking permits, so patrons can park year-round at a reduced rate, but also offer hourly rates that differ depending on season and duration of stay. Within all of the garages, certain day-to-day difficulties led the city of Ithaca to believe that there was potential for optimization of signage and operation.

Previous Work

In its first semester, the garage team began by researching the various geography, users, and stakeholders of each of the garages. Using ArcGIS and collected research, we identified geographically based factors of interest to focus on in the initial stages of the project. This information provided insight into what people were using each of the garages for, whether that be recreation, work, or other activities, as well as general garage activity throughout the day.

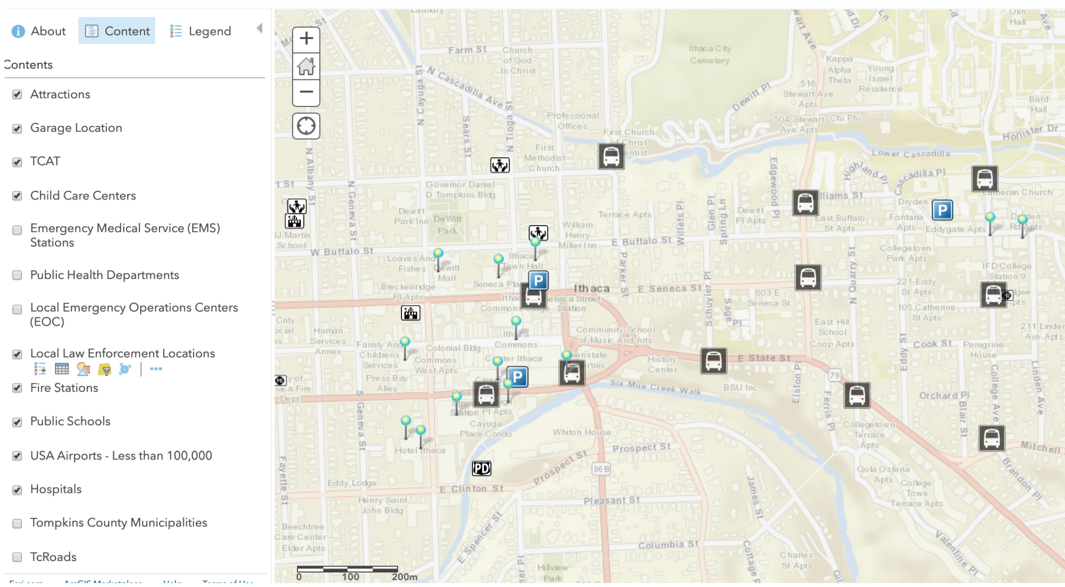


Figure 1: An ArcGIS map with the garage locations and major attractions.

Based on these geographical details from each of the garages, the team gathered a more detailed sense of what people were matriculating through each garage day to day. We established three main categories of garage users: the Ithaca Population, Cornell along with other educational institutions, and visitors.

Ithaca Population (Constant)

- Residents of Ithaca
- Residents of neighboring towns
- City employees, parking lot attendants

Cornell (Seasonal)

- Students
  - Cornell
  - Ithaca College
  - TC3
- Professors, faculty

Visitors (Seasonal)

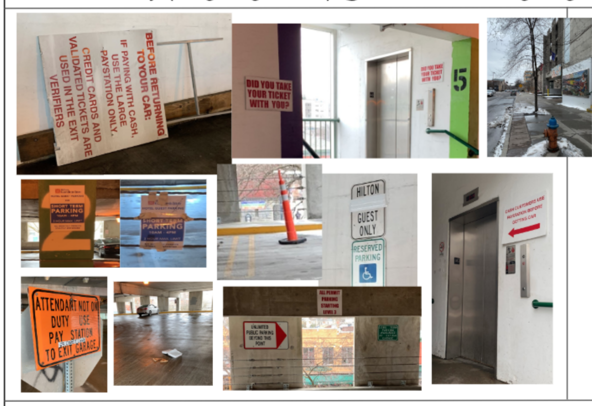
- Tourists/visitors to Ithaca
- Student families
- Hotel guests (Seneca Street lot)

Figure 2: Overarching Users in Action Diagram

These overarching categories were broken down to outline considerations unique to each group and began to better define the needs and uses of each garage. The team then proceeded to conduct empathy fieldwork for each of the garages, which involved Observation, Immersion, and Engagement. Each of these modes engaged with the garage in a different way, with Observation taking a third-person point of view, Immersion taking a first-person point of view, and Engagement directly interacting with users.

The collected insights from empathy fieldwork were then unpacked using a uniform chart structure. Each of the episode charts included the time, date, type of empathy fieldwork, images from the episode, thoughts or feelings the user had or may have had, etc. Figure 3 includes an example of such a chart. These charts then presented the needs, insights, and surprises of the user involved in each fieldwork episode. In total, the team compiled 40 different episodes for the 3 garages.

2-1-S Kelley (as garage user) @ Seneca Street garage - March 3rd 2019 WEEKEND Noon



- One sign is one the ground, okay, does that mean it isn't in use/ is not valid? A lot of words on one sign.
- These two signs are just redundant and they are both slightly different than other signs I saw, kind of confusing and like annoying almost.
- Random cones in spots? Why? Is this on purpose or was it an accident?
- Signs covering numbers, signs being taped badly to the wire. Shouldn't sign placement be more consistent? The tape is such a poor and short term solution.
- Duct tape over a sign. How am I supposed to know that this is legit? Sign supposed to be pointing to the paystation is pointing to the elevator. Do I need to take the elevator to get to the pay station? What does this mean? I can't find the pay station.
- Signs are conflicting and confusing: unlimited public parking beyond this point with all permit parking starting
- Pizza on the ground, ew gross
- Signs amended with tape, not professional.
- No way of knowing there is a side entrance here

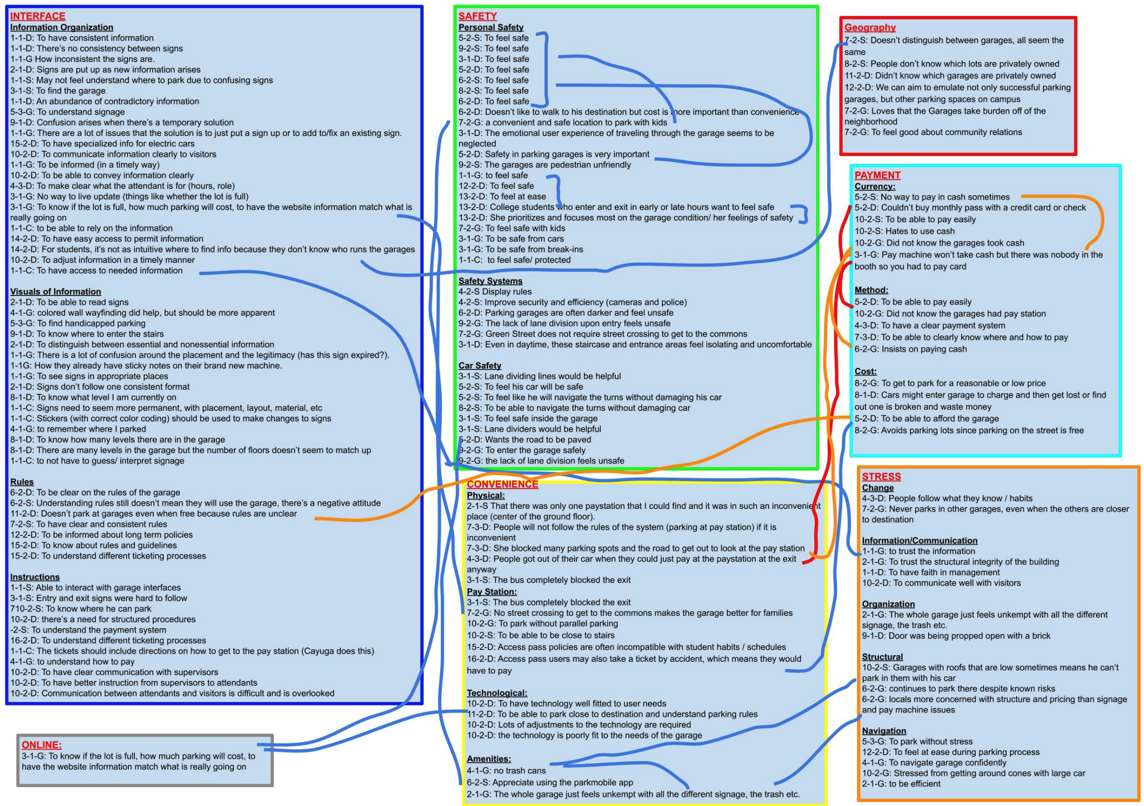
N To understand signage, to not have their time wasted/ to be efficient

I There are many different needs for signs, and sometimes signs need to be amended.

S That there was only one paystation that I could find and it was in such an inconvenient place (center of the ground floor).

Figure 3: An example of an unpacking chart for an immersion done in Seneca Garage.

Establishing the 40 standardized episode charts allowed the team to move forward into the modeling stage, in which connections between different insights were synthesized into new findings.



Connection Color	Meaning
Red	Tensions
Orange	Contradictions
Yellow	Hmmmm
Light Blue	Consistencies
Dark Blue	Synergies

Figure 4: Emotional Relationship Map

We represented our data using an Emotional Relationship Map as shown in Figure 4, among others, forming categories of needs related to Interface, Safety, Convenience, Stress, Payment, Geography, and Online. The users involved with each of these needs were represented in detail by a use case diagram, detailing who interacts with which parts of the garages. Later in the semester, these personas were further fleshed out in the form of personas, or specific fictional instances of each of the use case figures that helped emotionally connect the users to the systems process.

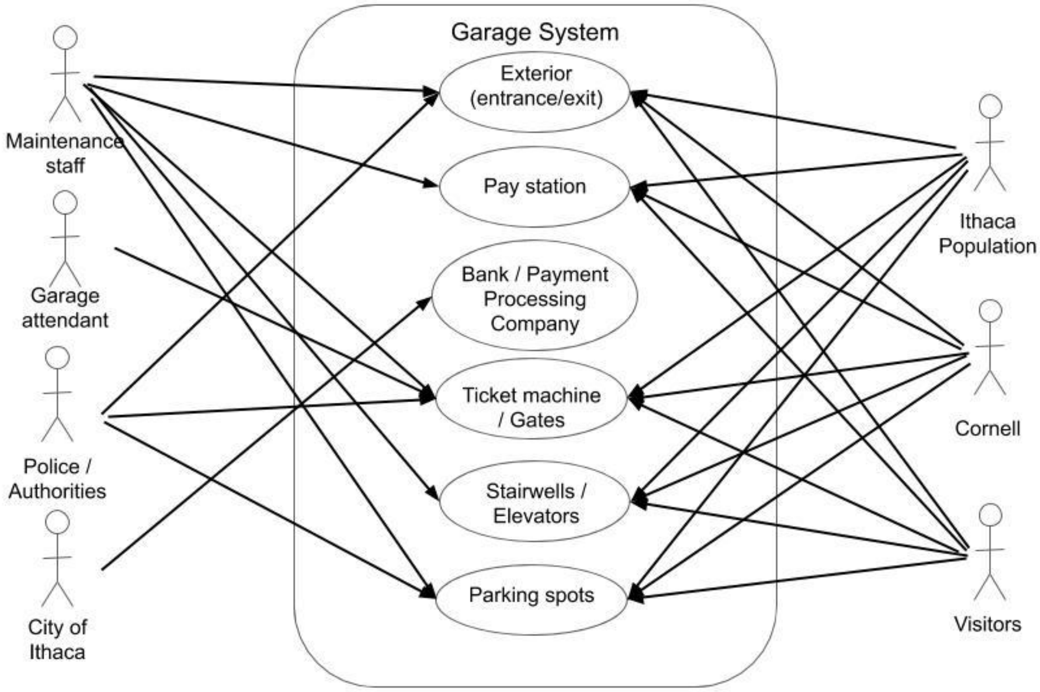


Figure 5: The Use Case Diagram

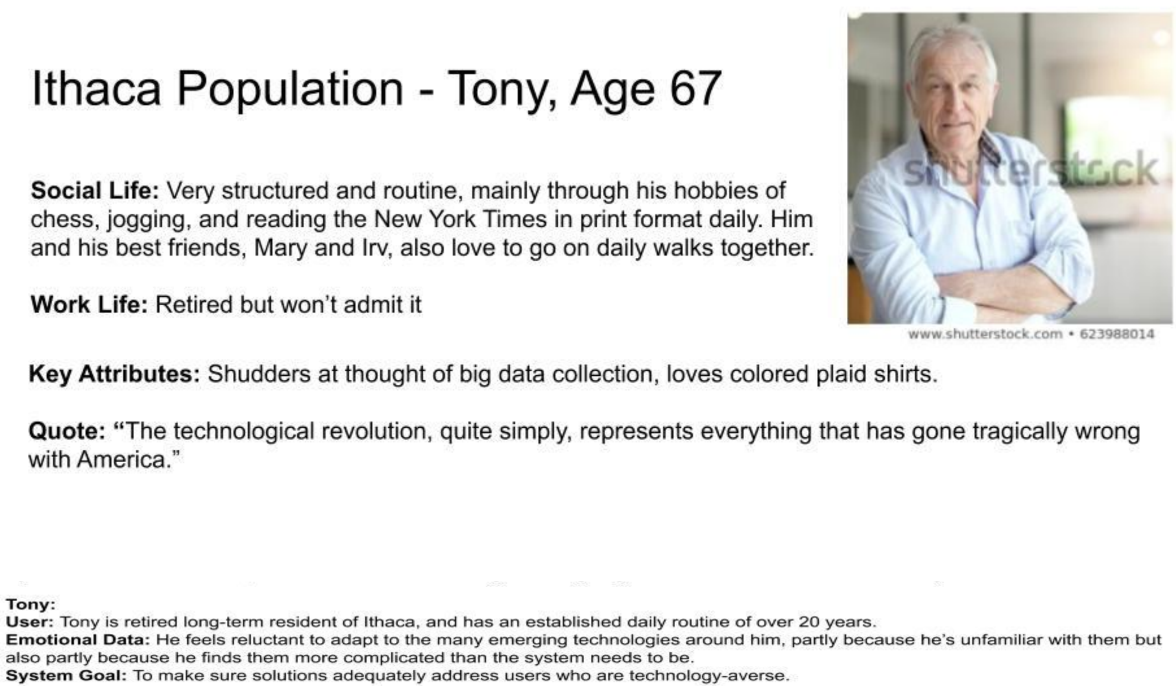


Figure 6: Persona of Tony, from the Ithaca Population, and his respective Emotional Data and System Goal

Having modeled and unpacked all the data into easily parsable representations, the garage team problem statement was reframed into an all-encompassing How-Might-We statement:

How might we design a parking garage system that, through efficient and pleasant parking experiences due to clear and informative signage, intuitive navigation, and seamless payment and exiting, inspires people to explore Ithaca?

The emerging Capabilities Diagram then explored sub-capabilities such as providing wayfinding, accessibility, is reliable, etc. These sub-capabilities fit into categories as either contributing to the system's efficiency or effectivity. In the Fall 2019 semester, the team used this capability diagram to refer back to when generating concept ideas, as this capability diagram captures the both the user's and the stakeholders' needs for the system.

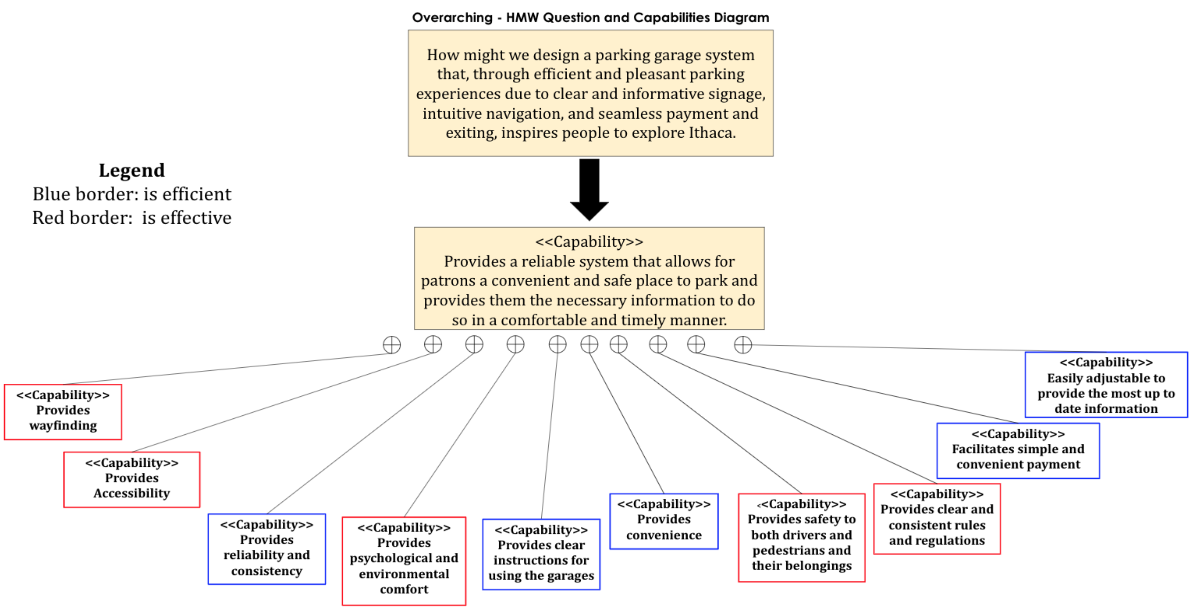


Figure 7: HMW Capabilities Diagram for the overall system

Establishing the last stage of system evaluation involved creating Behavioral Diagrams for a user's progression on foot through the garages, as well as the creation of a compiled Originating Requirements Table for the garages, to keep in mind moving forward to design.

The previous semester's work concluded with the beginning of a brainstorming stage, under the general concept phrase "Ithaca is Garages." Created by implementing the requirements and capabilities discovered throughout the user research work done in the team's beginning semester, this statement provided the starting point from which the Fall 2019 semester team began to investigate Ithaca's garages as a more cohesive component of the downtown experience.

Figure 8: Ithaca Garages, the portal to Ithaca City

Concept & Development

Stakeholders

In beginning to design the garage system's improvements, the first and most important step was to identify all of the stakeholders. Without this list, we would not be able to tailor the design to the appropriate users or use cases. The stakeholders we identified included entities such as the City of Ithaca as well as regular and non-regular users. Some users experience the garage from different viewpoints as well, such as when a driver leaves the vehicle and becomes a pedestrian, or vice versa. These transitions were captured as well, resulting in the following stakeholder list:

List of All Stakeholders:	**Related Persona**
City of Ithaca	
Regular Customers (drivers)	Mariah, Melissa, Pam, Tony
Regular Customers (pedestrians)	Mariah, Melissa, Pam, Tony
Attendants	Jim Sullivan/ Felipe Cooper
Passthrough Pedestrians	
Law enforcement	Arnold Smith

Seasonal Customers (drivers)	
Seasonal Customers (pedestrians)	
Pets	
State Legislators	
Building Codes office	
Visitors from outside of Ithaca	Jay Leung
University Students	Ryland Williams
Hotel Guests	Jay Leung
Children	Ramona
Emergency Responders	Arnold Smith

Table X: Stakeholders and associated personas

This list was then grouped into broader categories of stakeholders by those that shared similar interactions and used similar functions of the garage system. This allowed us to condense and organize all of the following work without leaving out any information. This can be seen in the context diagram in the next section. The broad stakeholder groups that we identified were:

Drivers (reg)	**Drivers (seasonal)**	**Operators**	**Legal**	**Pedestrians**	**Other**
Regular Customers (drivers)	Seasonal Customers (drivers)	Attendants	Building Codes office	Passthrough Pedestrians	Emergency Responders
University Students	Hotel Guests	City Of Ithaca	State Legislators /Laws	Regular Customers (pedestrians)	Children
				Seasonal Customers (pedestrians)	Law Enforcement
				Pets	

Table X: Stakeholder Groups

Context Diagram

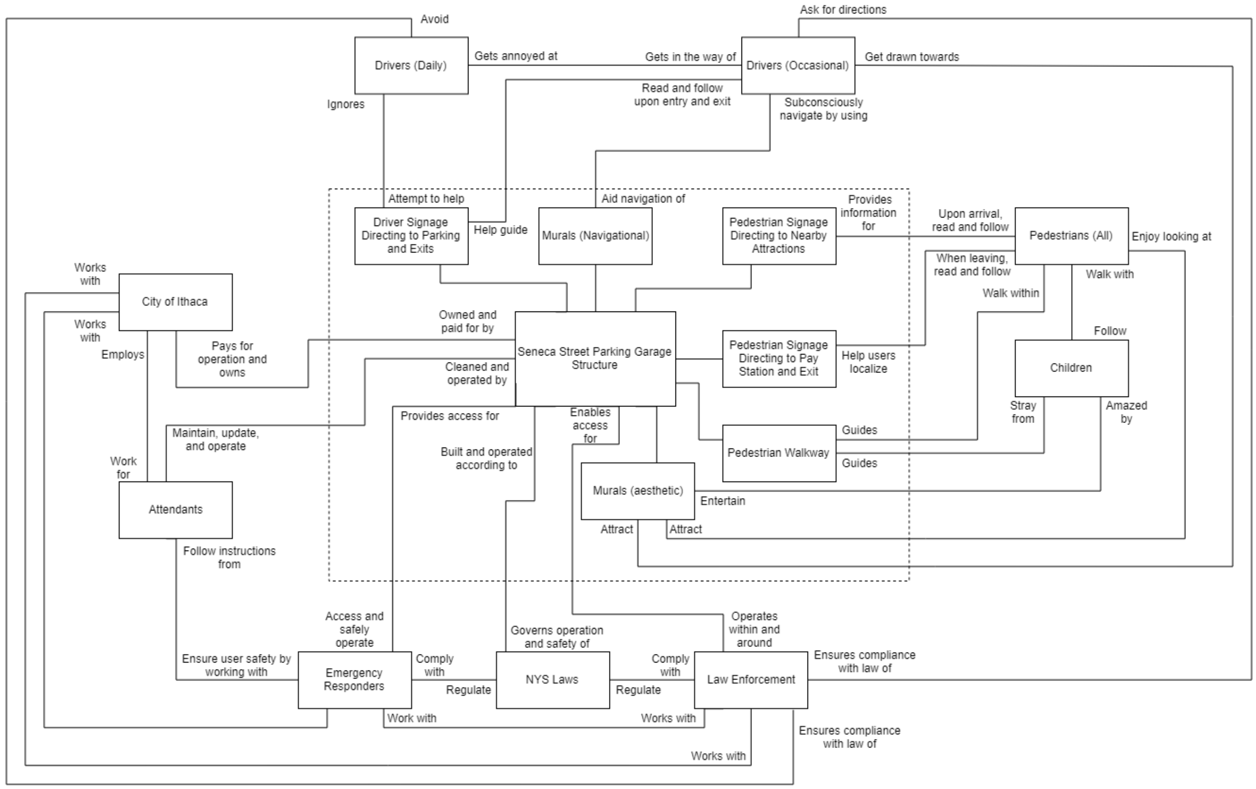


Figure 9: Context Diagram

The context diagram presented above defines exterior interactions with the Seneca Garage System, and the new subsystems that we are designing within it. In order to keep the diagram from becoming overly complex and unreadable, this high-level view groups together similar interactions from similar but different users or features. For example, all pedestrians were grouped into one block rather than displaying each individual agent, since all pedestrians will act very similarly with our system when located within the garage. Furthermore, on the system side, things like exit signage were not distinctly categorized into non-emergency versus emergency signage, since the general function of the signage and interactions with the user are similar and the diagram would become messy. This diagram can be used for the other Ithaca garage systems since the systems are identical from a functional perspective.

Personas

Personas are a systems design thinking tool used after emotional data has been collected and analyzed. Personas are generalized representations of the different types of garage users. Each persona represents a unique system goal to keep in mind when creating solutions. Last semester, 8 personas were created for the garages. These personas were used to model the users of the system.

This semester, after further analyzing the garage system, we added 2 new personas. The first is Ramona, a child from Ithaca. The second persona is Melissa, a disabled citizen of Ithaca. Our previous personas had not included these 2 demographics that were a critical perspective we had to include in the system design.

Child - Ramona, Age 6

Social Life: Niece of Mariah. She is currently in first grade and loves animals. Her favorite movie is the Bee Movie. She wants to be a marine biologist when she grows up. She enjoys accompanying her aunt running errands around downtown ithaca.

Work Life: A first grader at Bell Sherman Elementary School. She knows her animals, colors, and can read picture books on her own.

Key Attributes: Curious, fascinated with animals. Can read at a low level and likes pictures. She is a regular at the science center

Quote: Can we get hot chocolate then go to the science center?

Disabled User - Melissa, Age 31

Social Life: Melissa just got married and enjoys spending time with her husband Joe and all of her friends. She likes to be in nature and enjoys hosting board game and wine nights with her friends. She also loves to read mystery novels.

Work Life: Melissa is an accountant at a company in Ithaca. Mostly works alone.

Key Attributes: In a wheelchair but can drive herself & get around independently, loves to read, active person.

Quotes: “Parking in the garages is always a pain because there are handicapped spots where people pull in to temporarily park when they are paying for their ticket so I always have to wait before I can pull into one of them.”

Figure 11: New Personas added in Fall 2019. See Appendix for additional personas.

Personas Context Diagram

The Personas Context Diagram was created in order to help visualize how personas interact with one another to create a community. This helps us understand how different types of users' needs fit into the system. Each persona interacts with the garage in a distinct way, either for work, or general use, either temporarily or long term. By putting each of the users into context, we can more easily find different tensions, problems, and necessities that need to be addressed when we make adjustments to the system or consider implementing different solutions.

For example, Tony and Ryland regularly use the garage, and thus any changes to payment methods and how users can pay for their parking must not interfere with their different methods of paying. Furthermore, while people like Pam may not pay attention to the signage anymore, it is still necessary to make them clear and concise for users like Jay who must navigate the garages in real time. Thus, the context diagram presents ties between each of the personas needs and the capabilities diagram.

From last semester, we have added two new personas after integrating feedback from the City of Ithaca. These are described in more detail earlier in the report in the "Personas" section. We have integrated both of these in the diagram as well.

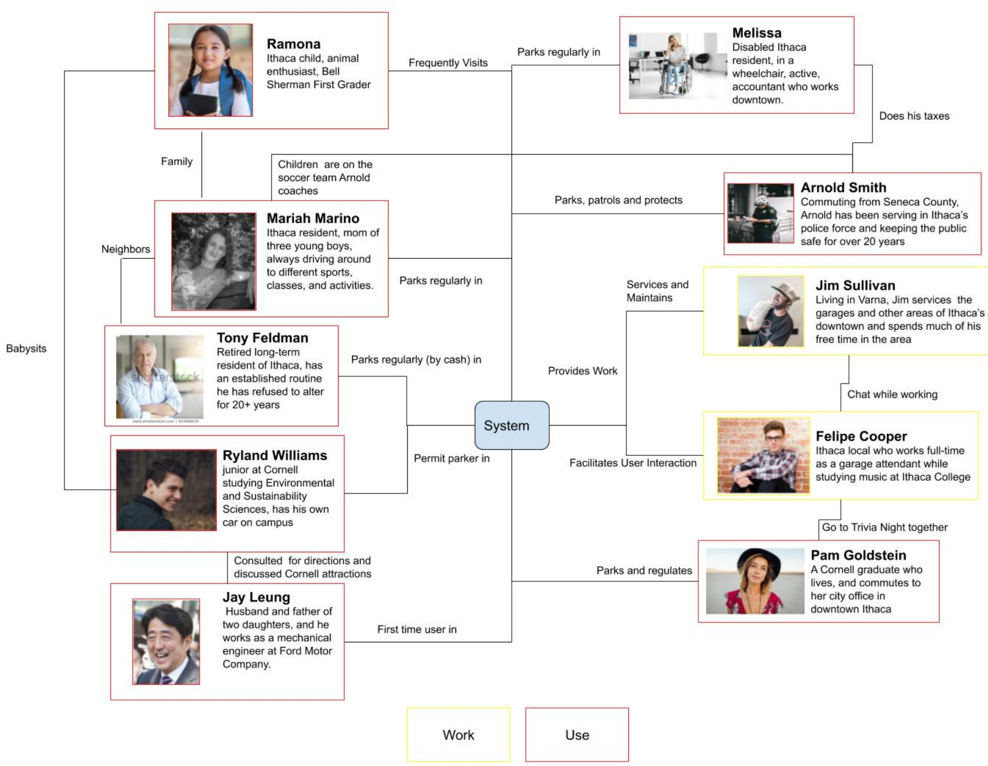


Figure 12: Personas Context Diagram.

Customer Affinity Process

To begin the design process and help the team understand customer needs, the garage team utilized customer affinity process to summarize user comments. It is useful for the team to grasp the operation condition of the current system, discover the downside of the system and eventually formulate design for improvements. The team reviewed interviews conducted in the spring semester in Cayuga, Dryden, Green and Seneca garages. Then the team selected 105 relevant comments regarding user experience, garage operation and desirable improvements, and categorized these comments into similar groups and finally into five ending groups. They are Parking Payment (30 comments), Safety (21 comments), Signage (21 comments), Garage Facilities (19 comments) and Functionality of Garage (14 comments). Out of the 105 comments, the top comments are “user desire cheaper parking fees” (11 comments), “user desire a safe pedestrian walkway” (5 comments), “user desire wider turns at corners” (4 comments), “user desire security cameras in the garage” (4 comments) and “user desire clear payment instructions” (4 comments).

Lvl 1 Group Title	# Comments in Each Lvl 1 Group	Lvl 1a Group Title (not all branches of the tree have to be of equal depth)	Sum # of Comments in Each Lvl 1a Group	Group Lvl 2 Titles	Sum # of Comments in Each Lvl 2 Group	Group Lvl 3 Titles (aka Area Titles since they are at the top level)	Sum # of Comments in Each Lvl 3 Group
Bright indoor lighting	2	Lighting	3	Elegent design	6	Garage Facilities	19
Bright outdoor lighting	1						
More art inside the garage	2	Elegant interior	3				
Welcoming environment	1						
Wider parking spots	1	Better driving facilities	13	Better driving facilities	13		
High ceiling	2						
Smooth road in and out garage	1						
Wider turns at corners	4						
Clear divider between lanes	3						
Better gate opening detection	2						

<table>
<tr><td>More spots in garage</td><td>2</td><td rowspan="3">capacity of garage</td><td rowspan="3">6</td><td rowspan="8">Functionality of garage</td><td rowspan="8">14</td><td rowspan="8">Functionality of garage</td><td rowspan="8">14</td></tr>
<tr><td>Even distribution of designated parking pots</td><td>3</td></tr>
<tr><td>Fexibility of parking</td><td>1</td></tr>
<tr><td>Convienent location of garage</td><td>3</td><td rowspan="4">Accessability of facilities</td><td rowspan="4">7</td></tr>
<tr><td>Short walking distance inside garage</td><td>1</td></tr>
<tr><td>Convenient location for stairs/elevators</td><td>1</td></tr>
<tr><td>Convenient location of paystation</td><td>2</td></tr>
<tr><td>Fexibility of parking</td><td>1</td><td>Fexibility of parking</td><td>1</td></tr>
<tr><td>Multiple paystations</td><td>3</td><td>Multiple paystations</td><td>3</td><td rowspan="7">Ease of payment</td><td rowspan="7">16</td><td rowspan="11">Parking Payment</td><td rowspan="11">30</td></tr>
<tr><td>Fast payment process</td><td>1</td><td>Fast payment process</td><td>1</td></tr>
<tr><td>Accept multiple payment methods</td><td>2</td><td rowspan="3">Multiple payment methods</td><td rowspan="3">6</td></tr>
<tr><td>Accept Apple Pay</td><td>1</td></tr>
<tr><td>Utilize mobile parking app</td><td>3</td></tr>
<tr><td>Functioning cedit card reader</td><td>3</td><td>Functioning cedit card reader</td><td>3</td></tr>
<tr><td>No cash Payment at exit</td><td>3</td><td>No cash Payment at exit</td><td>3</td></tr>
<tr><td>Easy process of getting a pass</td><td>1</td><td rowspan="2">Easy parking pass posession</td><td rowspan="2">2</td><td rowspan="2">Easy parking pass posession</td><td rowspan="2">2</td></tr>
<tr><td>Easy process of renewing the pass</td><td>1</td></tr>
<tr><td>Free short-term parking</td><td>1</td><td rowspan="2">Resonable price</td><td rowspan="2">12</td><td rowspan="2">Resonable price</td><td rowspan="2">12</td></tr>
<tr><td>Cheaper parking fees</td><td>11</td></tr>
</table>

Uniform rules for all garages	1	Uniform rules for all garages	1		1	Safety	21
Functioning gate	1	Functioning facilities	6	Regular maintenance needed	7		
Functioning elevator	2						
Functioning ticket reader	3						
Regular structual maintenance	1	Regular structual maintenance	1				
Regulations of Skateboarders	1	Regulations enforcement	2	Safety Assurance	13		
Regulations of illegal actions	1						
Install security cameras	4	Safety measures	11				
More enforcement staff	1						
Install staircase protection equipment	1						
Safe Pedestrian walkway	5						
Visible signs for motorists	1	Size and location of signs	5	Size, function and location of signs	21	Signage	21
Large signage size	3						
No misplaced sign	1						
Less redundent signs	2	Less redundent signs	2				
Clear handicap sign	1	Functional signs	3				
Clear "help" button sign	1						
Signs in elevator	1						
Signs showing free parking during normal time	3	Signs showing payment information	9				
Sign showing free holiday parking	2						
Clear payment instructions	4						
Clear direction to surrounding places	2	Directional signs	2				
	105		105		105		105

Table X: Customer Affinity Process Results

Requirements

The originating requirements are important in figuring out what an ideal solution is going to look like. Before we begin the process, in order to remain solution agnostic, having requirements for the final system allows us to work towards the end solution without being biased towards a particular path to reach it. This process can be done through originating requirements, in order to figure out what essential characteristics a system requires. The originating requirements should be representative of the overall objectives of a system, and from these more specific requirements called derived requirements can be created.

The originating requirements are meant to be specific enough that they can be applied to multiple solutions but work well to establish what a solution must have in order to be viable and effective. First, we created originating requirements for the garages, followed closely by originating requirements for the signage itself. Once we focused our project on the signage, we were able to make many derived requirements from the originating requirements. To make these requirements, we drew heavily upon our experiences conducting interviews and speaking with users of the garage.

The complete list of originating and derived requirements is included in the appendix.

System Analysis

Subsystem Matrix

The first tool we used in our system analysis was to the subsystems matrix. The subsystems matrix allows us to clearly determine our system's subsystems by grouping together related originating and derived requirements. We divided the garages into 10 main subsystems: Signage Design, General Signage, General Navigation Signage, Parking Signage, Entrance Signage, Exit Signage, Payment Signage, Electric Vehicle Signage, Security and Safety Signage, and Specialized Signage. Each subsystem has between 4 and 10 requirements. The matrix concisely displays all originating and derived requirements for each subsystem. From this diagram, we can clearly see exactly which subsystems meet which of the stakeholder's needs. In our subsystems matrix, the requirements across different subsystems are mostly unrelated to each other. Signage Design is the only subsystem that affects the other subsystems; however, the requirements in the Signage Design Subsystem explicitly state how the signage in the other subsystems must be designed so the crossover is clearly communicated.

Signage Design		General Navigation Signage		General Signage		Parking Signage	
Index	Requirement	Index	Requirement	Index	Requirement	Index	Requirement
DR.50.1	The system shall have distinct labeling for each floor.	DR.8.1	The system shall have signage directing pedestrians to the elevators on each level.	OR.51	The system shall make it clear the user must bring the ticket to the exit booth.	OR.29	The system shall have a method of notifying potential users when the system is at capacity.
DR.50.2	The system shall have brightly colored levels.	DR.8.2	The system shall have signage next to the buttons in the elevators that match the themes of each level.	OR.58	The system shall have updated and accurate information at all times.	DR.29.1	The system shall have a sign informing users that the garage is full.
DR.50.3	The system shall have a centralized theme that is related to the Ithaca community.	OR.17	The system shall direct users to parking spots.	OR.59	The system shall have protocol in place for replacing information that is outdated.	DR.17.2	The system shall have signage informing users which spots are for short term parking.
DR.50.4	The system shall use icons and images in addition to colors on each level to distinguish between levels.	DR.17.1	The system shall inform users what direction to drive within the garage.	OR.71	The system shall indicate vehicle height clearances	DR.29.2	The system shall have an easy way of displaying and hiding the capacity sign.
OR.60	The system shall have consistent signage styles throughout.	OR.61	The system shall have separate signage for pedestrians and drivers.	OR.82	The system shall contain signs that can be read from undetermined_distance	OR.63	The system shall display available spots.
OR.83	The system shall contain signs that utilize colors that contrast at a low light level.	DR.25.1	The system shall have signage directing pedestrians to pedestrian walkways.	OR.84	The system shall have signs that can be read from any car height.	DR.65.2	The system shall have signs indicating which parking spots are loading zones.
OR.85	The system shall incorporate nature and community in its design.	OR.66	The system shall display signs and directions to stairs / elevator.	OR.86	The system shall have signs that will be maintained cheaply.		
		DR.25.2	The system shall have outlined pedestrian walkways.	DR.65.1	The system shall have painted lines marking zones that are not for parking.		
				OR.65	The system shall restrict areas where vehicles may not travel.		

Table X: Subsystem Matrix for Signage Design, General Navigation Signage, General Signage, and Parking Signage

Electric Vehicle Signage		Security and Safety Signage		Specialized Signage	
Index	Requirement	Index	Requirement	Index	Requirement
DR.3.2	The system shall have signs with directions to the electric vehicle charging stations.	DR.7.1	The system shall have signage stating that the garage is under surveillance.	DR.5.1	The system shall have signage directing users to disabled parking spots.
DR.3.3	The system shall have signs that indicate number of electric vehicle charging stations.	OR.57	The system shall have signage displaying clear emergency exit procedures, protocols, and guidelines.	DR.5.2	The system shall have signage indicating which parking spots are for disabled parking.
DR.3.4	The system shall have signs indicating how to plug in an electricle vehicle.	DR.57.1	The system shall have signs marking emergency exits.	DR.56.1	The system shall have signs indicating where motorcycles should park.
DR.3.5	The system shall have signs indicating that only electric vehicles can park in the charging station spots.	OR.69	The system shall show direction to emergency exits.	OR.21	The system shall have signs indicating which spots are for the hotel.
DR.3.6	The system shall have signage indicating how long a vehicle can park in a charging station spot.			DR.21.1	The system shall have signage indicating penalty for non-hotel guests parking in hotel spots.

Table X: Subsystem Matrix for Electric Vehicle Signage, Security and Safety Signage, and Specialized Signage

Entrance Signage		Exit Signage		Payment Signage	
Index	Requirement	Index	Requirement	Index	Requirement
OR.40	The system shall inform users how to enter the system.	OR.4	The system shall inform users how to exit the system.	DR. 3.1	The system shall have signs with directions to the pay stations.
DR.40.2	The system shall inform a user how to get a ticket.	DR.4.1	The system shall have exit signs seen from every point in the garage.	OR.13	The system shall inform users parking prices before they enter the system.
DR.40.3	The system shall have signs differentiating the entrance from the exit of the system.	DR.4.2	The system shall have arrows on the floor to direct users to the exits.	DR.13.1	The system shall have signage outside the entrance with parking prices.
DR.40.4	The system shall have a sign informing users the process to get a ticket and enter the garage.	DR.4.3	The system shall have signage to direct pedestrians to pedestrian exits.	OR.15	The system shall inform users how to pay for parking.
OR.41	The system shall be easy to find from the road.	DR.4.4	The system shall have exit signage that is unique and easy to read.	DR.15.1	The system shall inform the user where to insert their ticket.
DR.41.1	The system shall have external wayfinding signage.	DR.27.1	The system shall have signs directing pedestrians to pedestrian exits.	DR.15.2	The system shall have signage indicating what payment methods are accepted.
DR.41.2	The system shall have large external signs indicating that it is a public parking garage.			DR.15.3	The system shall inform the user what to do if they have lost their ticket.
OR.80	The system shall have a marked pedestrian entrance			DR.15.4	The system shall direct the users to the payment machines.
				DR.15.5	The system shall have signage indicating where the pay stations are located.
				OR.72	The system shall have signage that point to the payment machines

Table X: Subsystem Matrix for Entrance Signage, Exit Signage, and Payment Signage

Decision Matrix

In order to figure out the ideal solutions for improving the garages, our team began by brainstorming a variety of ideas that would contribute to a better overall garage experience. Some of these were expanding upon existing ideas such as including more murals in the garage, and some were extremely complex like the development of a parking app. Since each possible feature for implementation has, for example, a different cost and effectiveness, we also developed criteria by which to rate them.

For this process, we used a decision matrix. We were then able to assign a rating to each of the different features, listed in the left column, based on each of the criteria we determined, listed in the first row of the matrix. A key to ratings can be found after the decision matrix. In order to complete the process with correctly weighted values for each of the features, we also determined weights for each of the criteria, listed in the bottom row. We wanted to ensure that safety and navigation were considered heavily, as they were the driving factors behind implementing new features, and elements such as how long they'd take to implement had less weight. Our final scores are shown in the right column.

Through use of the decision matrix, we determined that the best course of action for our team is to work on clarifying driver and pedestrian signage, installing navigational murals, creating pedestrian walkways, and improving lighting. Thus, our team has focused on design of signage, both through murals and signs, which are documented in the "Design" section of this report.

Features	**Implement Cost**	**Upkeep Cost**	**Implement Speed**	**Navigability**	**UX**	**Perceived Safety**	**Total**
Payment app	1 [1]	2 [5]	1	1	5	2	50
Addition of payment machines	2	5	3	1	4	1	63
New garage entrances	1	5	1	4	4	2	73
Clarify pedestrian signage	5	5	3	5	5	4	114
Clarify driver signage	5	5	3	5	5	3	109
Increased attendant presence	3 [2]	3 [6]	4	4	3	5	93
Improved Lighting	5	5	5	2	3	5	102
Pedestrian Walkway	5	5	3	5	4	5	115
Parking spot vacancy monitor	1	5	1	4	4	2	73
Murals (aesthetic)	4 [3]	5	2	1	5	5	92
Murals (navigational)	4 [4]	5	2	5	5	5	112
Weight (0-5 scale)	4	4	3	5	4	5	

Figure XX: Solution Decision Matrix

Notes:
1. Estimate based off of https://www.cleveroad.com/blog/how-much-does-it-cost-to-create-an-app
2. Attendant salary estimate based off of https://www.indeed.com/salaries/parking-attendant-Salaries,-New-York-NY
3. Mural estimate based off of https://www.fixr.com/costs/paint-wall-mural
4. Mural estimate based off of https://www.fixr.com/costs/paint-wall-mural
5. App upkeep estimate based off of https://www.fiercewireless.com/developer/maintaining-app-critical-to-its-overall-success
6. Attendant salary estimate based off of https://www.indeed.com/salaries/parking-attendant-Salaries,-New-York-NY

Implementation Cost	
1	> $40k
2	< $40k
3	< $30k
4	< $20k
5	< $10k

Navigability	
1	Offers no benefit to navigability
2	Offers little benefit to navigability
3	Allows only for basic navigation
4	Contributes significantly to ease of navigation
5	Is primary method of navigation for all users

Upkeep Cost	
1	> $4k/month
2	< $4k/month
3	< $3k/month
4	< $2k/month
5	< $1k/month

UX (User Experience)	
1	Customer will never want to return
2	Customer had a hard time with all systems in the garage and is likely to avoid garage in the future
3	Customer managed to use the garage but wouldn't immediately return on future visits to the area
4	Customer will remember this garage and likely return to park in it next time they visit the area
5	Customer will navigate directly to the garage in the future

Implementation Speed	
1	> 1 year
2	< 1 year
3	< 6 months
4	< 3 months
5	< 1 month

Perceived Safety	
1	Has no effect on safety of garage
2	Has an indirect effect on perception of safety in garages
3	Has a small effect on perception of safety in garages
4	Provides a significant improvement to safety in garages
5	Allows users to feel safe both and welcome in the garages

Table X: Decision Matrix Criteria Ratings

Goal Question Metric

Our team created a list of goals for our design, such as "Make the signage easy to read". We did this so that while creating a design we could check to ensure that the design as a whole follows the goals of our team. We used a Goal Question Metric as a tool to do this. A Goal Question Metric (GQM) is a tool where a list of goals is compiled, and for each goal a subset of questions is created that are related to the goal and help us determine if the goal is being met. For each question, there is an idea metric used for ultimately determining the answer to the question, and an approximate method which can be used with a thorough analysis or if we have a design that is just a mockup and has not been fully implemented. The last column in the GQM shown below is the data collection method, which details how the question will be answered, whether it is analyzing the blueprints of the garages or by analyzing and counting items within our own design.

Goal	Questions	Ideal Metric	Approximate Metric	Data Collection Method
Make the signage easy to read.				
	What size are the signs?	Area in square inches		Analysis of the design
	What size text is being used in the signs?	Font size	n/a	Analysis of the design
	What color are the signs?	Hex codes	General color names	Analysis of the design
	What color is the text on the signs?	Hex codes	General color names	Analysis of the design
Make the garage have distinct level designs.				
	How many levels are there?	Number of levels	n/a	Blueprint of the garages
	What colors are being used on each level?	Hex codes	General color names	Analysis of design
Make the garage incorporate the local community.				
	How many community connections are in each garage?	Number of connections	Number of connections	Counting from design
Make the garage incorporate nature.				
	How many plant images or items are included in the garage design?	Number per garage	Number per garage	Counting from design
	How many animal images are included in the design?	Number per garage	Number per garage	Counting from design
Make the garage have consistent signage.				
	How many signs have the same format?	Total number of signs	Estimate of number of signs	Analysis of total garage design

Table X: Goal Question Matrix

Analytical Hierarchy Process

The Analytical Hierarchy Process is a tool that is built off the goals created in the Goal Question Metric. This tool allows us to determine which goals are the most important based on the importance we determine for the larger overarching goals shown in the top row. The overarching goals for the signage system are listed in row 1, and right below each goal are the determined importance of that goal, a score given out of 1. Within each overarching goal are at least one of the goals from the GQM. Some of them have been grouped into larger and more general goals. Below each subset of goals, which have been colored, there is a further breakdown of weighting and importance within that category if there is more than one goal in the category. At the bottom of the chart is the calculated weights for each goal. This determines which individual goal is most important.

1	**Make the garage signage accessible.**	**Make the garage have distinct level designs.**	**Make the garage design incorporate the surrounding environment.**		**Make the garage have consistent signage.**
	0.35	0.3	0.15		0.2
2	Make the signage easy to read.	Make the garage have distinct level designs.	Make the garage incorporate the local community.	Make the garage incorporate nature.	Make the garage have consistent signage.
3	**1**				
4		**1**			
5			**0.5**	**0.5**	
6					**1**
7	**0.35**	**0.3**	**0.075**	**0.075**	**0.2**

Table X: Analytical Hierarchy Process

From this Analytical Hierarchy Process, we can see that the goal of “Make the signage easy to read” is the goal with the highest priority. It has a calculated weight of 0.35 out of 1. Next is “make the garage have distinct level designs”, then “make the garage have consistent signage”. Finally, while the last 2 goals are assigned a weight of 0.075, they are still important to consider when creating a design for the garages.

Personas Use Case Diagram

The Personas Use Case Diagram shows how different users might interact with the system. A use case diagram is a systems engineering tool that shows the different types of users and how the different uses of the systems relate to each other. The personas are used to represent the different types of users that interact with the systems and how those interactions are related. Identifying the different types of users and use cases is important for designing a system that meets the needs of different use cases. Each use case in the Personas Use Case Diagram is expanded with more description in the Emotional Activity Diagrams, located in the next section of the report.

In our project, the personas for Jay, Melissa, and Ramona were used to show use cases of an Ithaca Parking Garage. Jay is an out of town visitor on a college visit who is parking downtown to visit the Ithaca Commons and does not use the parking garage regularly. On a trip to the garage, he parks his car and exits the garage as a pedestrian. An extension of this use case is parking on a busy weekend, which is a slightly different use of the parking garage system. Melissa is a working professional in downtown Ithaca who parks in a reserved parking space for people with disabilities and exits the garage via the pedestrian pathway. Upon returning to the garage, both Jay and Melissa find their parked car and exit the garage, which is a process that includes paying at the pay station. Ramona is a first grader accompanying her aunt running errands downtown who engages with the wildlife graphic in the garage.

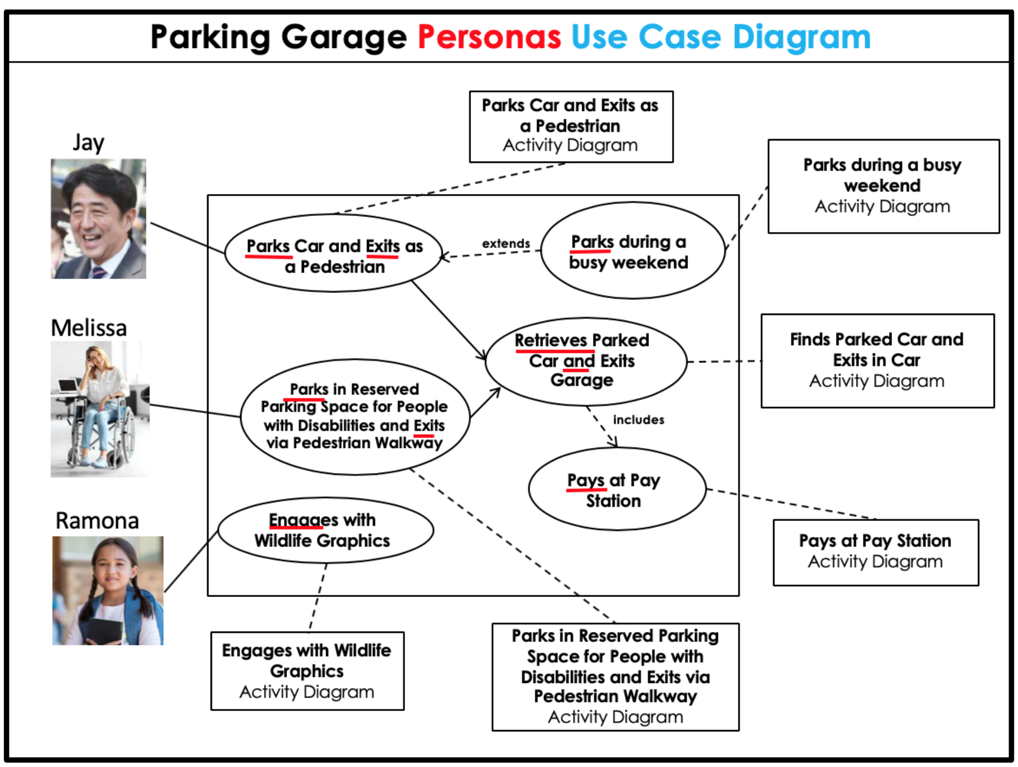


Figure XX: Personas Use Case Diagram

Emotional Activity Diagram

The emotional activity diagram depicts how the user interacts with the system and the user's emotional response throughout their use of the system. An activity diagram shows a progression of the user's actions and how the system shall respond to those actions. The emotional activity diagram builds upon a traditional activity diagram by including the emotions that a user will experience during their actions. The emotions are displayed using emojis, which are explained with a key that describes what each emoji means. Emotional Activity Diagrams are helpful to design a system that provides a positive user experience that meets the system requirements created in the concept phase.

The emotional activity diagrams break down the use cases outlined in the personas use case diagram. The specific user actions, emotions, and systems requirements are shown and described in the emotional activity diagrams below.

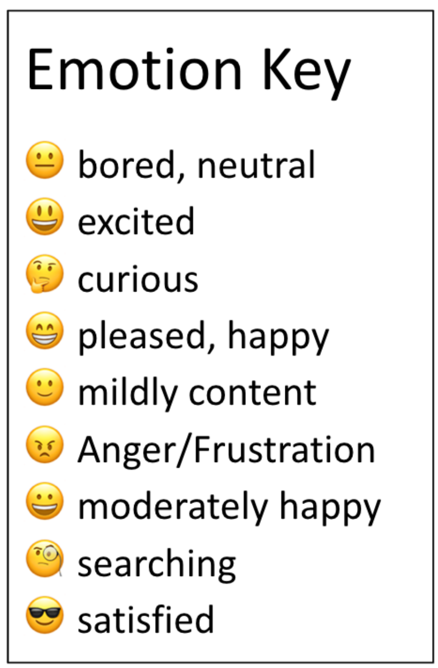


Figure XX: Emojis are used to represent user emotions. The key is used to label the emoji to the emotion that it represents.

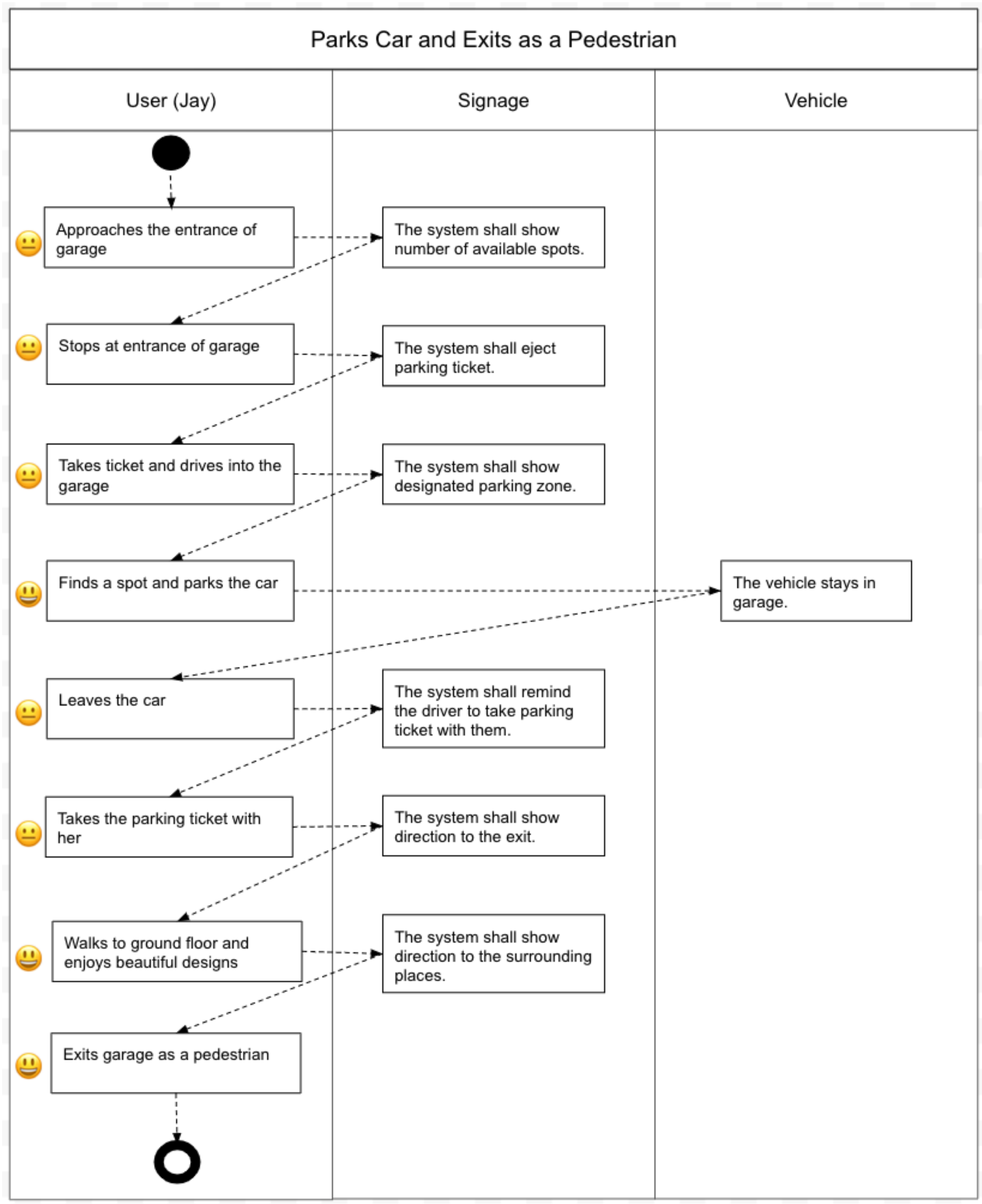


Figure XX: A user parks car and exits as a pedestrian. This diagram shows that the system must be able to show the number of available parking spots, eject the ticket, show the designated parking zone, remind the driver to take the parking ticket with them, show the user the direction to exit and show the direction to the surrounding places. The user begins the interaction feeling neutral/ bored and ends it feeling excited.

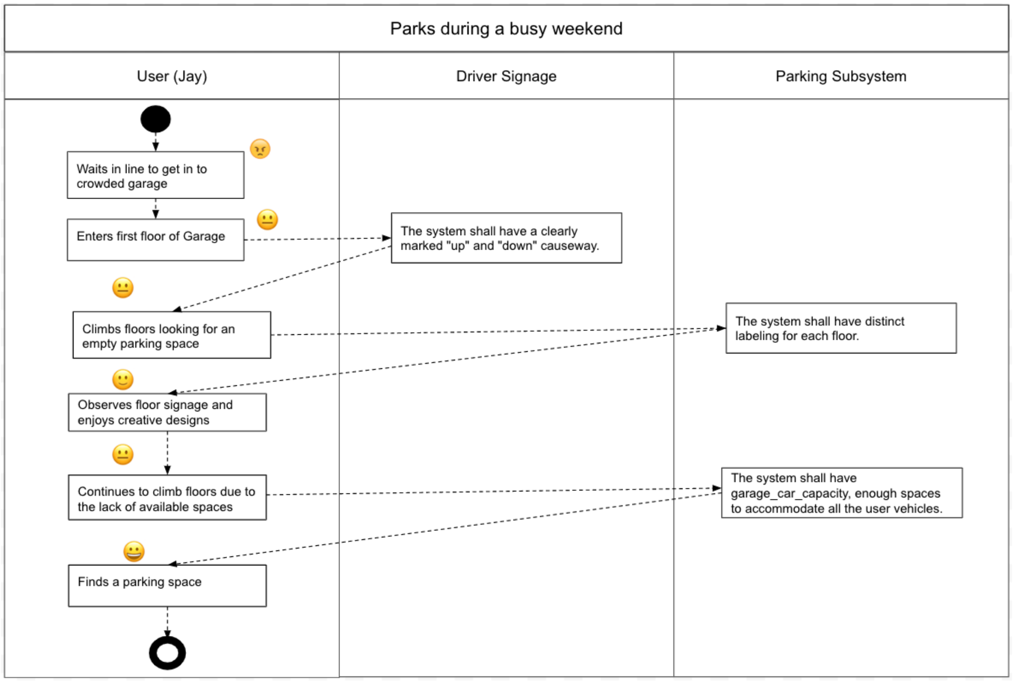


Figure XX: User parks in the garage during a busy weekend. The diagram shows that the system must have clearly marked "up" and "down" causeway, distinct labeling for each floor, and enough capacity for user vehicles. The user begins the experience feeling angry and ends feeling moderately happy.

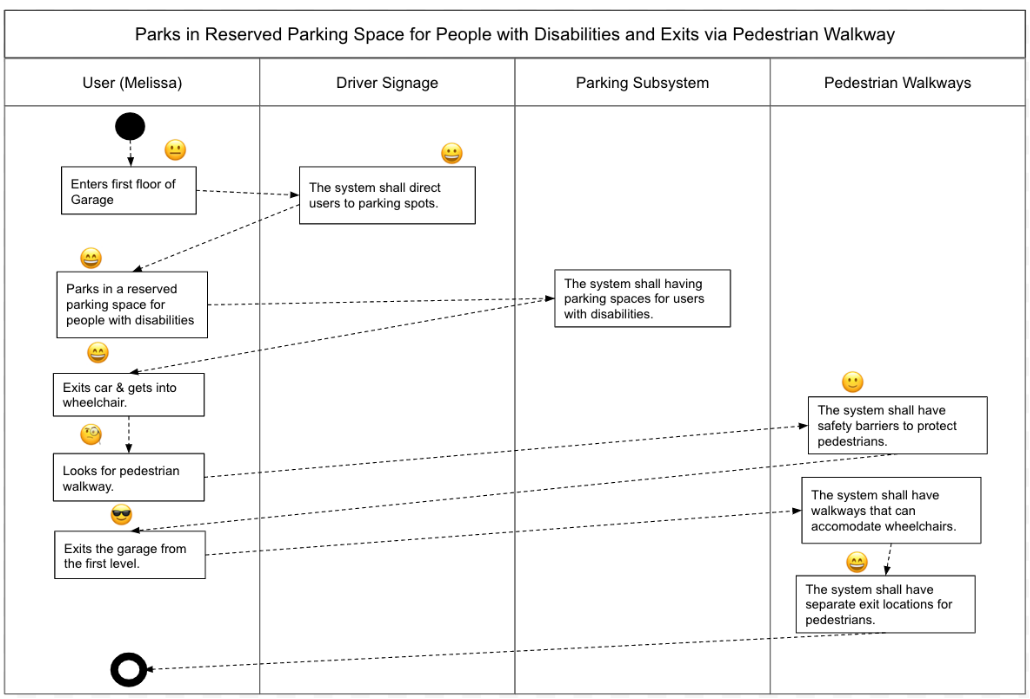


Figure XX: A user parks in a disability parking spot and exits the garage via pedestrian walkway. This diagram shows that the system must direct users to the reserved parking spaces for people with disabilities, have parking spaces for users with disabilities, have walkways that can accommodate wheelchairs, and have separate exit locations for pedestrians. The user begins the interaction feeling neutral and ends it feeling happy.

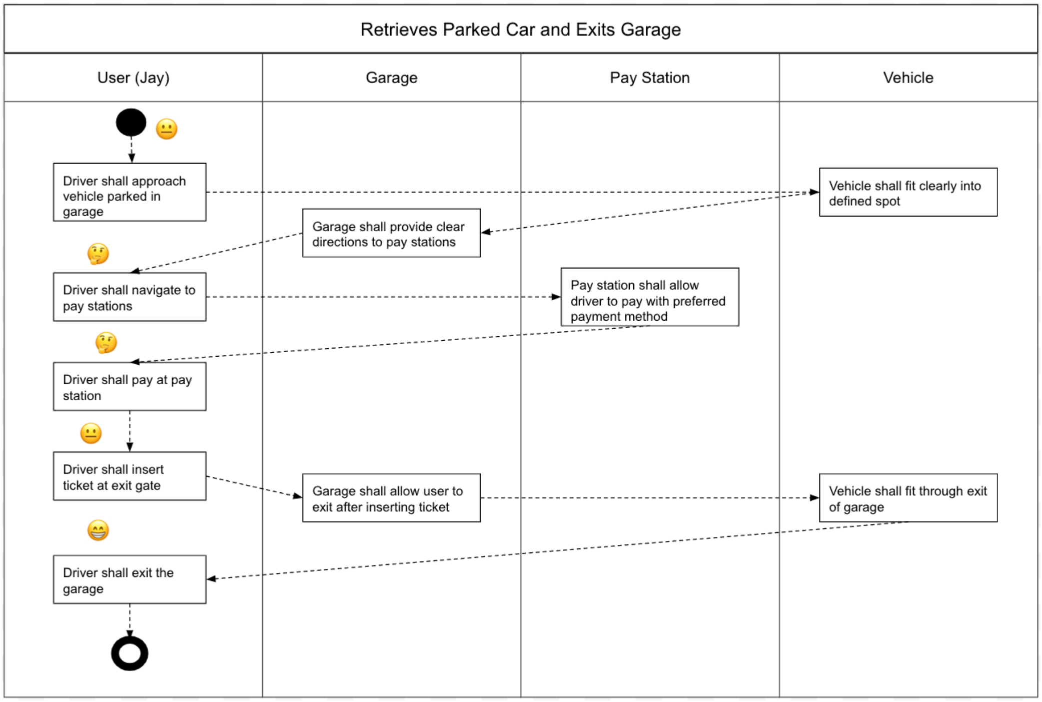


Figure XX: A user retrieves a parked car and exits the garage. This diagram shows that the system must provide clear directions for the pay station, allow the user to pay with their preferred payment method, and allow the user to exit after inserting their ticket. The user begins this interaction feeling neutral and ends feeling happy.

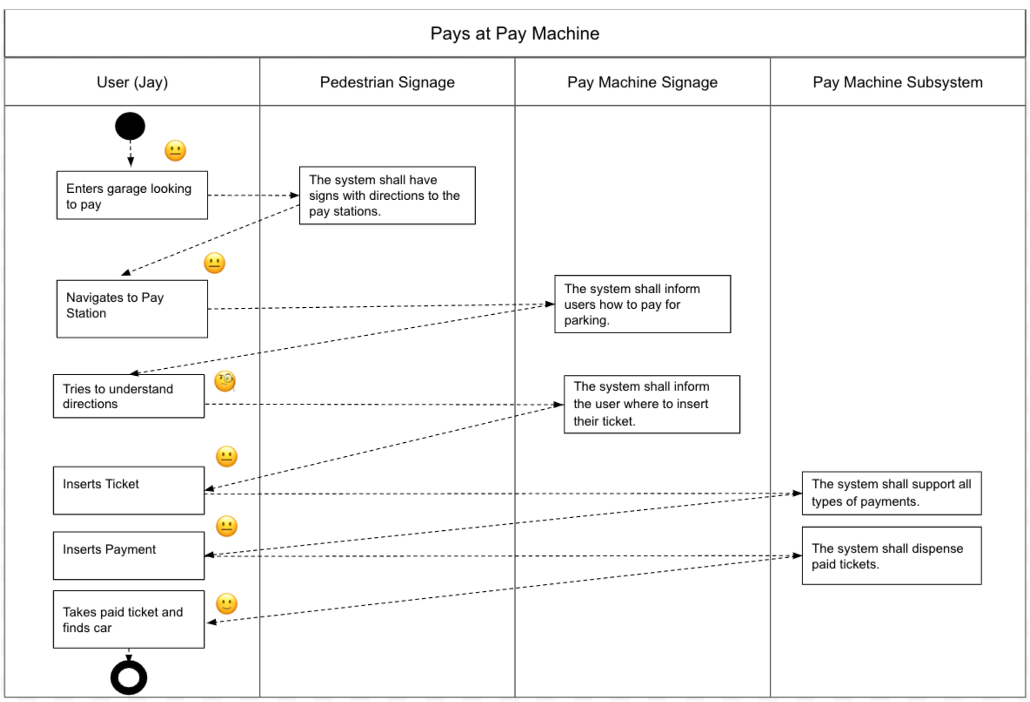


Figure XX: A user pays at the pay machine. The diagram shows that the system must have directions to the pay station, inform the user how to pay for parking, inform the user where to insert the ticket, support all types of payments, and dispense paid tickets. The user begins the interaction feeling neutral and ends feeling mildly content.

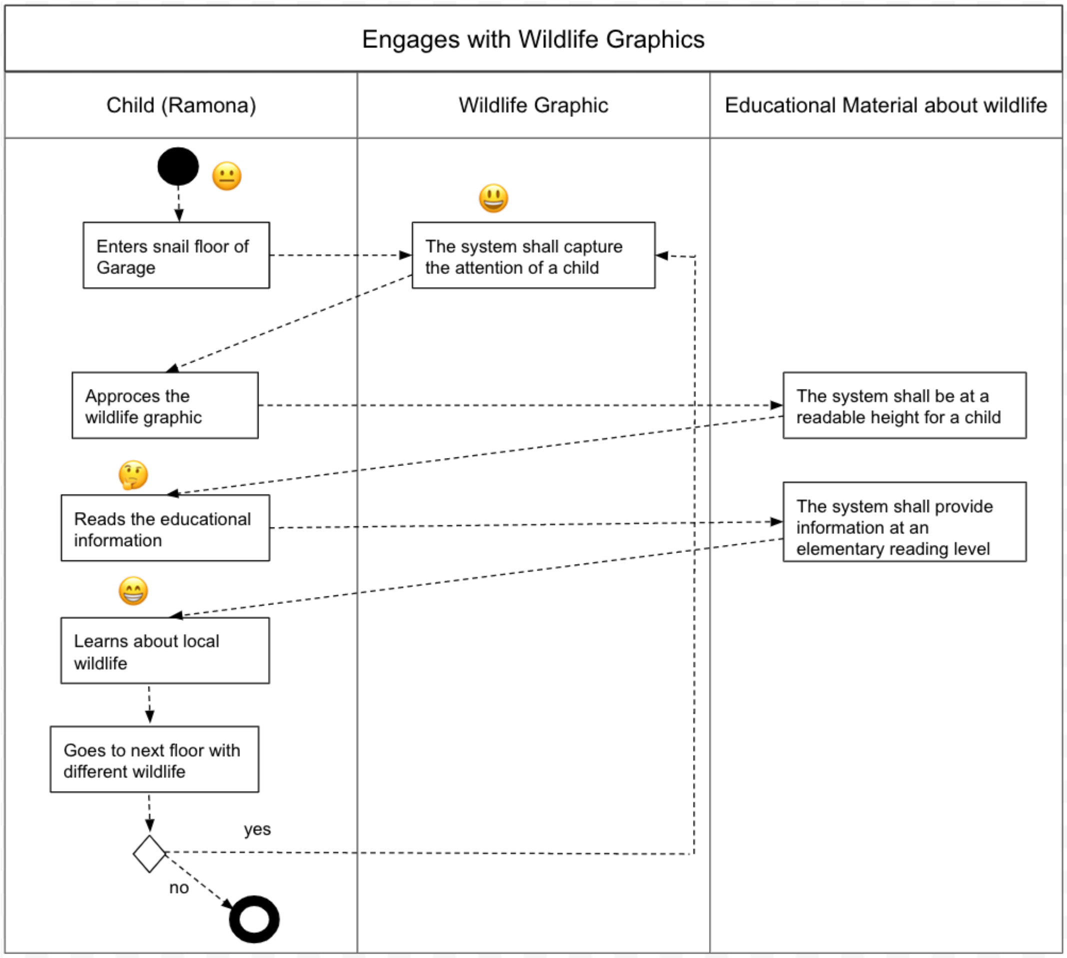


Figure XX: The user engages with the wildlife graphics. This interaction shows that the wildlife graphic must be able to capture the attention of the child and the educational material must be displayed at a readable height for the child and provide the information at an elementary reading level. The user begins the interaction feeling neutral and ends it feeling excited.

FMEA

We created the Failure Mode and Effect Analysis diagram in order to effectively break down which failures were possible in our design and the potential risks and causes associated with them. Each failure mode identified is grouped into a Function and its effects are described in column 4. The effects can be in the scope of: only that item, the entire system, and the mission itself. We have made an educated guess at a potential cause of the specific failure mode and then brainstormed potential solutions that would prevent this failure from happening in the first place.

The FMEA contains a ratings system to provide a sense of significance amongst the failures. Each failure mode has a Severity and Occurrence Likelihood index associated with it. The Severity index is the degree of the effects of the potential failure while the Occurrence Likelihood denotes how frequent this failure will occur. The Risk Priority Number is the product of these indices.

This FMEA was constructed specifically for the updated signage system and specifically how users interact with the sign. We do not consider more structural failures such as degradation or fire and instead focus on informational failures; whether or not the signs do their job.

Failure Mode Number	Identification or Item of Function	Failure Mode	Failure Effects (a. Local b. System c. Mission)	Possible Cause	Corrective Action a. design, b. manufacturing process, c. opertion	Failure Effects Severity (1=least, 5=most)	Occurrence Likelihood (1= least, 10=most)	Risk Priority Number=severity*occurrence	Critically (Corrective Action Priority)
F.1	Navigation Misdirection	Signs direct commuter away from up/down ramp	c) Commuter becomes lost inside the garage. Garage is no longer a positive place to park	Lack of clarity in signage wording and visibility	Select better spots for signage and redo the information on the signs	1	5	5	Low
F.2		Signs direct exiting commuter into oncoming traffic	b) System becomes damage or blocked by the accident c) Critical mission failure, garage is no longer safe nor positive	Signage was not clear or loud enough of the potentially dangerous move	Clearly mark which way traffic is flowing and use large sign designs to ensure drivers know of this safety risk	5	3	15	Medium
F.3		Signs direct EV commuter away from EV parking	c) Elecric Vehicle commuter spends more time finding the parking spot and becomes disenthused with garage functionality.	Lack of clarity in signage wording and visibility	Place signage further ahead of the Electric Vehicle parking spots to alert drivers earlier.	1	6	6	Low
F.4	Sign Visibility	Hanging signs cannot be read from vehicle	b) Information is not conveyed within the system. c) commuter misses vital garage information, failing the mission of the garage	All vehicle types were not considered in sign design	Length of signposts should be re-assessed	2	4	8	Medium Low
F.5		Sign cannot be read at night	b) Information is not conveyed within the system. c) commuter misses vital garage information	The correct contrasting colors were not selected for night visibility	Color scheme of signs should be reassessed	3	2	6	Low
F.6	Sign Information	User misunderstands payment sign information	b) Pay system will not process user's ticket c) User cannot pay for parking, may not be able to exit	Inconsistent/unclear information on pay machine signage	Consider entire payment process, redisgn sign infromation to include easy to follow instructions. Test on new users.	3	5	15	Medium
F.7		User parks in hotel parking spaces due to lack of sign clarity	b) System contains cars in the wrong locations c) Damages relationship with hotel and causes confusion	Information about hotel parking was not conveyed early enough	Insert signage at entrance to inform users of which floors are hotel guests only	2	6	12	Medium Low
F.8	Pedestrian Signage	Pedestrian cannot find staircase	c) Pedestrians have difficulty exiting system, garage is not positively viewed	Not enough pedestrian signage is on each floor	Implement more visible signs and have them occur at a higher frequency.	1	4	4	Very Low
F.9		Pedestrian cannot remember which floor they parked on	c) Pedestrians have a difficult time returning to their parked car. May become panicked.	Lack of differentiation between garage floors	Implement a system to give each floor uniqueness	2	3	6	Low

Table X: FMEA. For a larger version of the FMEA please see the Appendix

Design

Signage Background Research

When moving into the design stage of the project, focusing on the stakeholders' original concerns regarding signage remained a priority, as reinforced by our empathy fieldwork. We conducted various forms of research and found that garage needs separated into different categories, including pedestrian and car traffic wayfinding signs, payment information signs, and the inclusion of aesthetic design to enhance each of these respective areas. As found in our work last semester, the existing state of the garages creates confusion surrounding which signs are addressed to which users as well as the accuracy of signage information. Inspiration research helped narrow down how other garages around the world chose to address these difficulties. Combined with legal research on mandatory signage to include, we began to explore the scope of our potential design space.

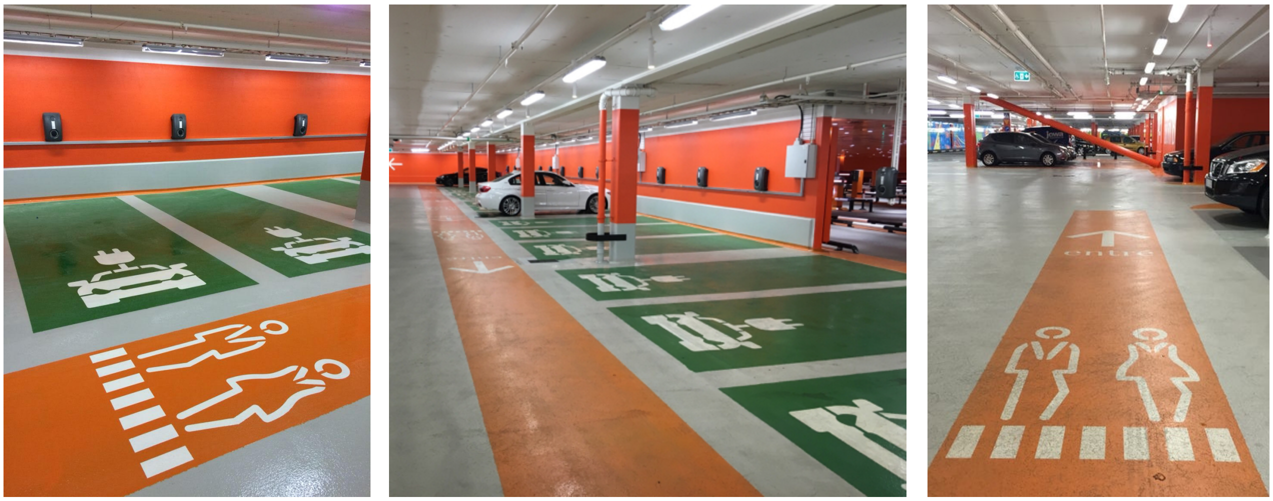
Inspirations

Research into existing parking garages was performed to identify other successful parking garage designs. These visual inspirations provide valuable insights for the development of a new graphic identity for the Ithaca parking garages. These inspirations help to refine the design concept prior to the ideation process, so that team members can discuss the advantages of different signage types and graphic elements.

Designed at 360 Architecture with Studio Tilt | Client: Copaken, White & Blitt
(https://www.behance.net/gallery/1870693/Town-Pavilion-Parking-Garage-Wayfinding)

Advantages:

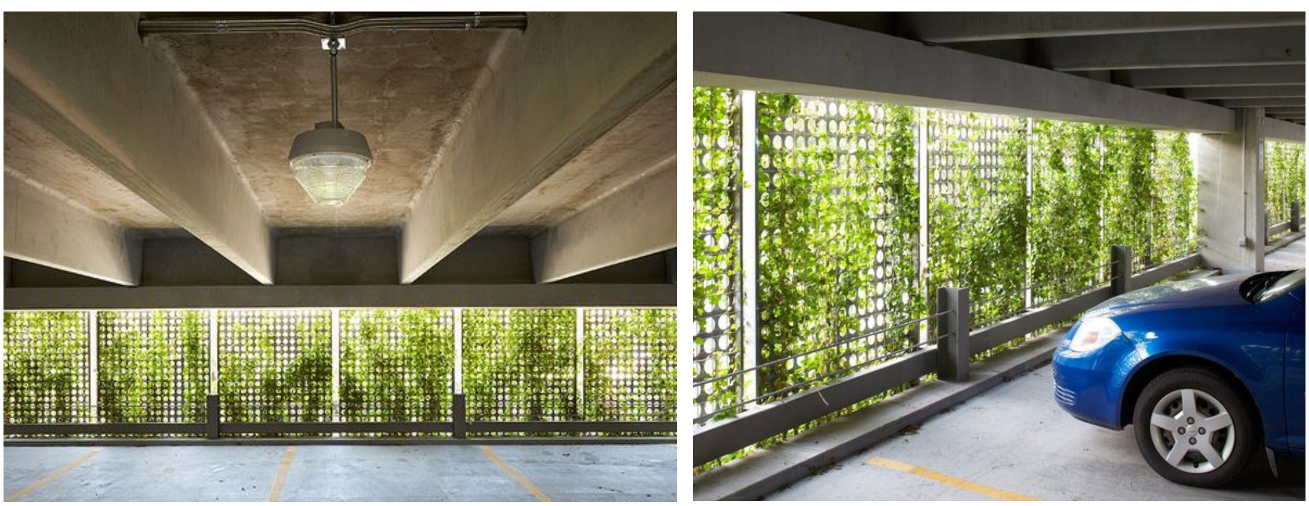
- Uses distinct themes and colors to differentiate between levels and assist with recall
- Large numbers are easy to read from a distance or while in a moving vehicle
- Uses biophilic imagery to bring nature indoors



Mall of Scandinavia Parking Garage
(https://www.pinterest.com/pin/346073552596633559/)

Advantages:

- Signage directs users towards parking spots designated for electric vehicles
- Considers pedestrians and clearly designates a path for walking
- Maximizes design through graphics as floor treatment



North Parking Garage and Retail for Rockhurst University | BNIM
(https://www.bnim.com/project/north-parking-garage-and-retail)

Advantages:

- Vertical garden incorporated into a parking garage, LEED Silver
- Biophilic design (natural elements) provides a sense of wellbeing and restoration

Cinema City Jerusalem | SAZ Design

Advantages:

- Easily recognizable icons and colors to designate floor levels
- Graphic identity visually reinforces the building's use
- Architectural features (i.e. structural columns) are utilized for graphic interventions

Legal Requirements

Because we were unable to find specific regulations for garages in Ithaca, NY, the information below was taken from an accumulation of the regulations in different parts of NY, including but not limited to New York City, Syracuse, Rochester, and Buffalo.

The legal requirements for garages in NY state include:

1. Valid garage license
2. Easy-visible DCA's combined license and complaint sign
3. Printed items given to customers must have the license number and the license number must be identified as a DCA license number
4. Clear entrance and exit signs
5. Each entrance must include
    a. Business name
    b. Business address
    c. DCA license number

    d. Vehicle capacity as shown on the DCA license
    e. Minimum number of bicycle parking spaces required by law (if vehicle capacity is more than 50 cars)
    f. Business hours
    g. Rate, where the sign needs to abide by the following:
        i. Black letters on a white background.
            1. Day rate sign must have black letters on a white background.
            2. Night rate sign must have white letters on a black background.
        ii. Capital letters that are 3 inches high/
        iii. Lowercase letters that are 2 inches high.
        iv. All letters must be the same font.
        v. All letters and numbers must be proportionally spaced.
        vi. Each type of rate must be listed on a separate line.
        vii. No line can exceed 40 inches in width.
        viii. Lines must be spaced 1 and 1.5 inches apart as measured between capital letters.
6. Copy of the rate signs at payment area
7. Additional signs as long as the letters and numbers in signs are the same
8. Sign stating “Capacity Full” in 6-inch-high letters at each public entrance if garage is full
9. Garages with a capacity greater than 51 must provide parking spaces for bicycles, each at least two feet away from a car.
10. Must provide claim checks to all customers that include:
    a. The date the vehicle was accepted for parking
    b. Business name
    c. DCA license number

Signage Content

Before reconstructing how the garage communicated information to its patrons, it was essential to document what signs are currently on display, and legally essential. The garage team conducted research into the state requirements that would need to be incorporated into the new set of signage, which included essentials like signs illuminating exits, fire extinguishers, and maximum capacities. Next, after visiting the garages and recording the information and location of every currently existing sign, the team was able to extract the vital messages that must be apparent in the redesign, as well as address how to make them more visible and easier to read for the public. This will become the foundations of the next phase of the project, as the team tests how different presentations of the information will streamline the user’s garage experience, and their portal into Ithaca.

Design Charette

A charrette is a concentrated workshop, where designers work together to develop solutions for a specific project or community issue. The garage team conducted a design charrette to develop a holistic graphic identity for two of the Ithaca Parking Garages. Two subteams were formed to address the Seneca and Dryden garages. The charrette provided the opportunity for team members with backgrounds in systems engineering, architecture, and design to collaborate and draw on their diverse areas of expertise. Both subteams worked independently to come up with an initial design concept and discuss how the previous research should be utilized to guide design interventions to improve the space. Main areas of focus included: wayfinding, graphic identity, ergonomics/human factors, and user experience.

Seneca Garage Team

The Seneca Team compiled a list of goals that would improve the space, while balancing a consideration for final installation costs and overall feasibility. The team began the ideation process with a discussion of potential graphic themes that would be appropriate to the geographic location and local users. The team felt it was important to choose a theme that was easily recognizable, cheerful, and would engage a broad audience of users. The group came to a consensus based on a few initial options and selected a wildlife theme and overall color scheme.

To further develop the graphic identity for the garage, the team assessed the current signage and discussed problematic areas. A major issue that emerged through the discussion was the existing system used to designate different levels within the garage. The Seneca garage currently identifies nine distinct levels in the garage, with each half level designated as a separate number. The nine-level designation is confusing to garage customers, especially when using the elevator, which only has five buttons for major levels. Through wayfinding research, the team decided that each major level would be assigned a different color to assist in recognition. The major level would then be broken into an A and B levels to distinguish between half levels (i.e. Level 1A & 1B). Each major level was assigned a hue (e.g. green); sublevels were assigned colors of different values within that hue (e.g. light green/dark green). The dark tone /light tone color coding system was used to identify Levels 1-4; the Ground Level and Level 5 were assigned one color. The revised level designation system is comprised of five major levels and a ground level (Figure xx).

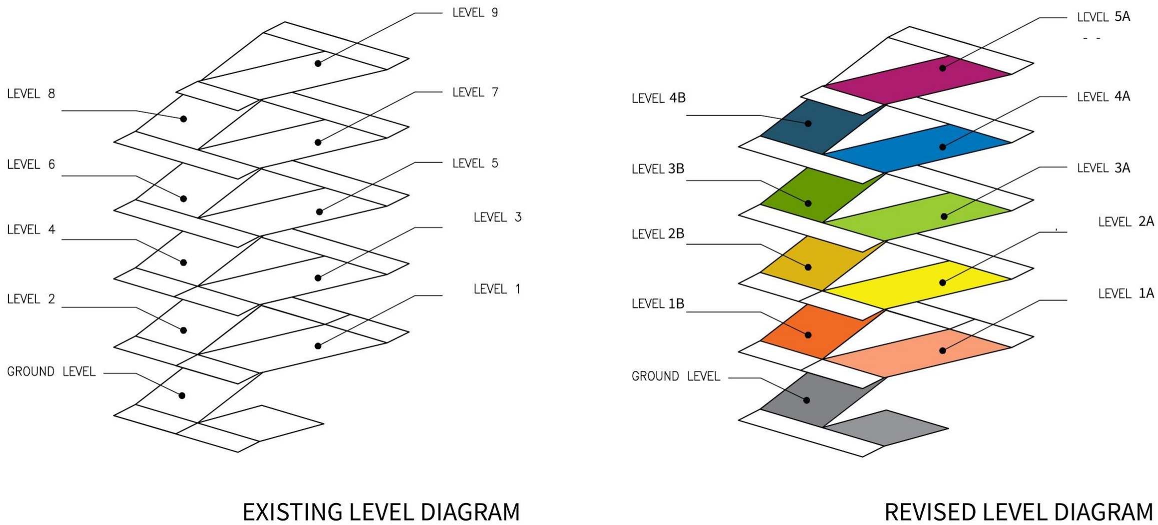


Figure XX: Existing and revised level diagrams

Next, the Seneca team split into smaller groups to work on different tasks, one group researched design guidelines for parking garage signage, while the other group started to develop icons for the wildlife theme. The design guideline group compiled information regarding wayfinding standards such as text size, color/contrast, the correct height for sign installation, and government mandated signage. The graphic development group selected icons from the Noun Project (https://thenounproject.com/) for visual inspiration. A set of ten animal icons were chosen and assigned to different levels in the Seneca garage (Figure yy). These icons were used as temporary placeholders for the graphic identity and provided a resource for quick ideation and visualization of the final design intent.

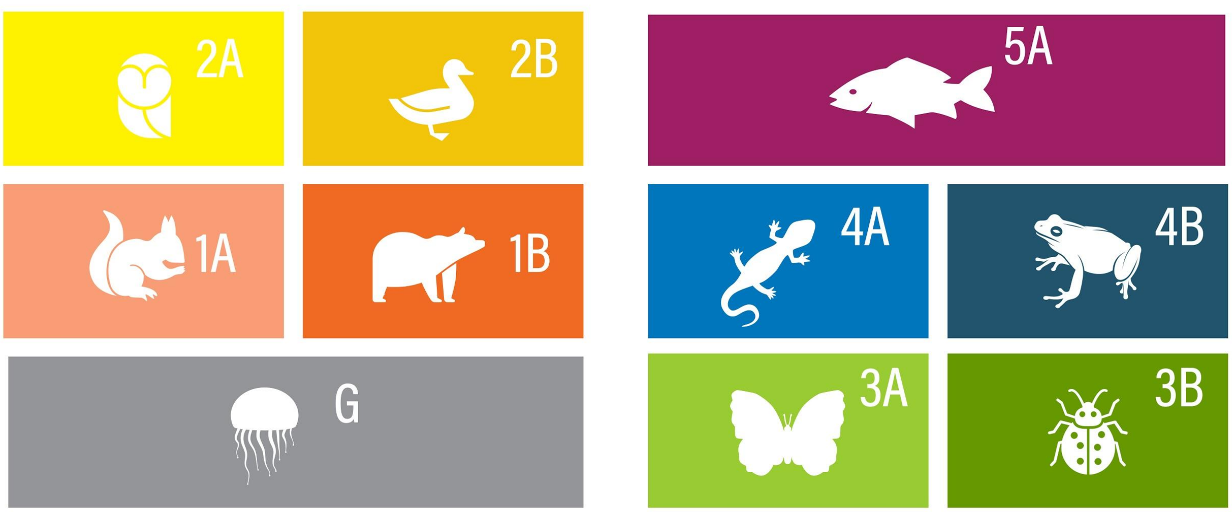


Figure YY: Initial design scheme of the wildlife theme for Seneca garage

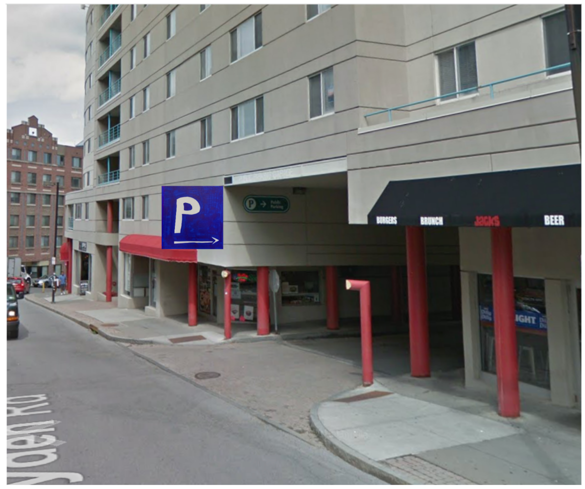
The animal icons are designed to serve several important wayfinding functions. Identifiable symbols are an important element of feature recognition; the use of recognizable imagery can increase recall memory and can assist users that are trying to remember where they parked their car. The animal icons also help to present a unified identity for the space, which can build a sense of community. Parking garages are often decorated sparsely. The architectural typologies of parking garages, tall ceilings, undefined pathways and industrial materials, can overwhelm users who do not know where to focus their attention. Icons can be used to help to define areas and guide people throughout the space. The use of repeated icons can reinforce the organization of the garage to the user in multiple locations such as elevator button markers, stairwells, and identification signage on each level. Imagery also enlivens a space and helps to create a cheerful atmosphere that positively affects the user experience.

At the end of the charrete, the Seneca team regrouped to discuss plans moving forward; a few key goals for further development were identified. First, to create defined pedestrian pathways to increase safety. This goal was developed in response to parking garage customer feedback, and other secondary research that states the need for clear pathways for both vehicles and pedestrians. These pathways help to organize the flow of traffic and steer pedestrians away from moving vehicles. A marked pathway also increases the awareness of drivers towards the presence of pedestrian traffic. Another goal is to create new informational signage for the garage to improve legibility and clarity; the current signage has confusing text and in some instances is very difficult to comprehend. Overall, the charrette was a valuable part of the design process and helped to define the scope of the design and establish clear goals for further development of the graphic identity for the Seneca garage.

Dryden Garage Team

The Dryden team began by identifying the signage issues, both external and internal, that are particular to this parking garage. Among the items discussed were its visibility as a public garage from Dryden Road, the challenges of distinguishing the pedestrian and vehicular entrances, and most significantly, the garage's confusing floor-level structure, which currently descends from a roof-level vehicle entrance. This last issue became a design opportunity for the garage's new internal signage and overall graphic identity to incorporate an intuitive wayfinding strategy.

Brainstorming solutions for the external visibility issues culminated in improved and additional signage proposals. At the current vehicular entrance (Figure X), the team suggested replacing the existing parking lot indicator sign, which is mounted under the entrance to private parking for an apartment building and is difficult to spot from Dryden Road. The new sign would mount perpendicular to the apartment building facade (Figure Y) to improve visibility from the road and would be of the same standard public parking 'P' used in the garages downtown.



Figures X and Y: Current sign under apartment building; Proposed perpendicular sign

At the pedestrian entrance from Dryden Road at the base of the hill, the team recommended adding an additional sign to the exterior of the garage so that drivers approaching from downhill know there is parking up ahead. As shown in Figure X, this idea revealed the need to communicate clearly that the vehicular entrance is further up the hill without confusing pedestrians who can enter at that level. The team did not fully resolve implementation for this sign during the charrette and brought it to the rest of the team for discussion.

Figure X: Proposed location for exterior garage identification sign, highlighting potential confusion with pedestrian entrance

The bulk of the development for Dryden Garage's new graphic identity proposal stemmed from the wayfinding challenges within the garage. Because vehicles enter on the roof level, numbering the garage floors proved confusing. The team discussed a variety of options - roof at Level 0 with negative level numbers below, roof at level 4 counting down to 1, or popular convention for basement level numbering (B1, B2, etc.) below the roof level. Ultimately the basement level numbering was selected because numerous precedents suggested many users would be familiar with this scheme (Figure X).

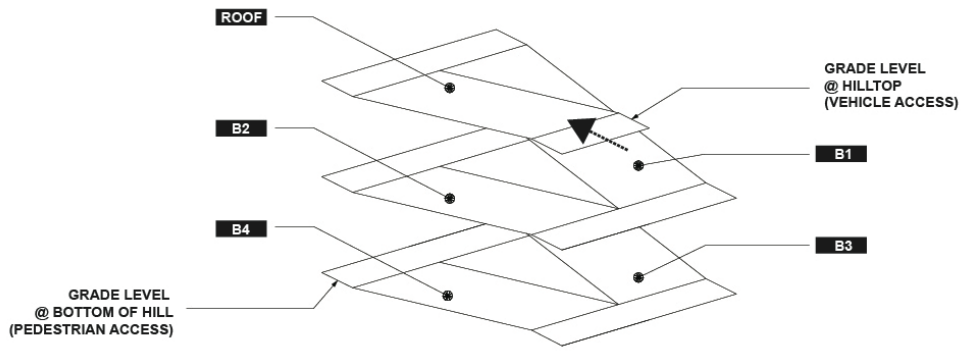


Figure X: Basement level numbering system in Dryden Garage

Recognizing that the numbering system alone may not be clear and memorable enough to many users, the team proposed a series of environmental murals to intuitively communicate the garage's descending traffic pattern so that garage users are less reliant on the confusing floor level numbering system to remember where they parked (Figure X).

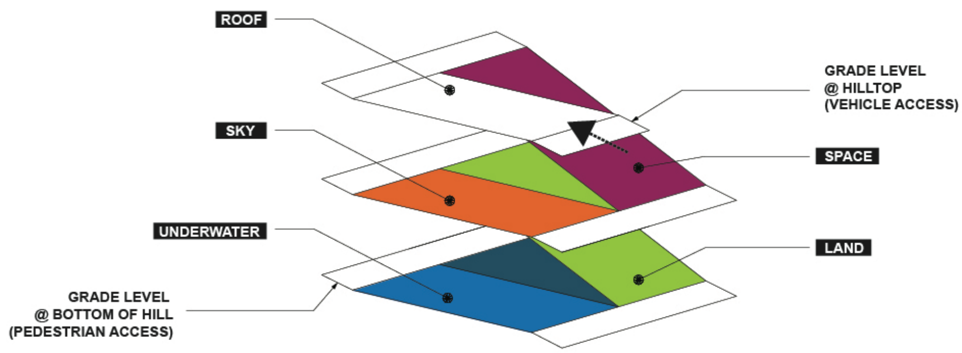


Figure X: Environmental mural themes in levels

This idea engages with an existing culture of murals within the Dryden Garage. As seen in Figure X, many of the walls inside the garage are painted by local artists, and most are in need of revitalization.

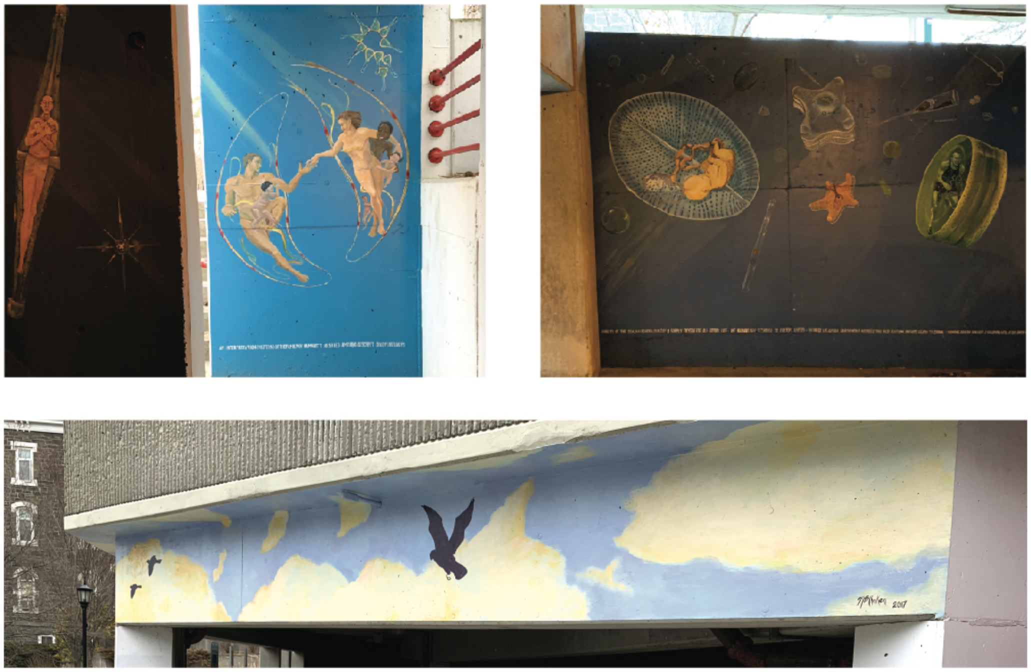


Figure X: Existing mural examples in Dryden Garage

The proposed murals depicted a gradient of environmental scenes, descending from outer space, to the sky, then land and lastly under the sea (Figure X). The intent was to incorporate local environmental conditions in the mural images to convey a sense of place identity within the garage, and this was developed further and with more graphic clarity following team feedback after the charrette.

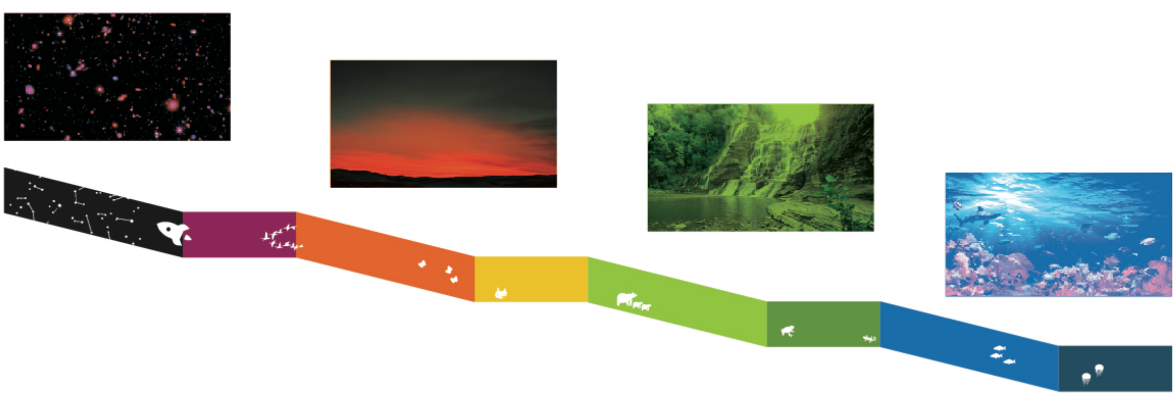


Figure X: Diagram of proposed gradient of environmental murals

Connections to Ithaca & the Environment

A focus of the garage team has been to transform the garage system in Ithaca as merely a place to park into a portal into Ithaca. Currently, Ithaca houses many valuable recreational and navigational features that make exploring the downtown area enjoyable and is known for its natural beauty within its many gorges and state parks. One of the main goals of our design process was to expand upon these landmarks or mimic them. Through the various elements of nature and landmarks that distinguish the levels of the garages, the team hopes to acclimate patrons into the hallmarks of the Ithaca region, transforming the garages into a gateway into the tourist experience. One garage, inspired by the Downtown Animal Print Walk, includes fun facts about animals that are tailored for kids in order to engage youth while their parents can seamlessly navigate to and from their car to their desired location. The bright colors and easily recognizable symbols aim to transform patrons' attitudes from neutral like the current grey look, into a more dynamic feel, thus charging up visitors for the great experience they will soon have. The other garage design expands upon the famous Carl Sagan Planet Walk, incorporating different terrestrial and extraterrestrial layers of the atmosphere into different themes of each level, and similarly incorporating flora and fauna characteristic of each. As users leave each of the newly renovated garages, they confirm that their first impression was correct of Ithaca as an emerging center for commerce, convenience, and comfort.

By redesigning the murals and themes of each of the garages, we hope to better incorporate parking into the experience of visiting Ithaca, while addressing previous stakeholder concerns of safety, family-friendliness, and ease of navigation.

Design Revisions

Seneca Garage Team

The initial design outcomes produced during the charrette were shared with all members of the garage team to receive feedback. New design iterations were developed to respond to specific issues identified for refinement. One area of concern was the color/icon system used to designate between levels. In the initial design proposal, the Ground Level and Level 5 were assigned one color per level, while Levels 1-4 were assigned sublevels with a light tone/dark tone designation (Figure xx--level diagrams from charrette section). In order to maintain a consistent approach for identification, the Ground Level and Level 5 were also split into sublevels. For the sake of clarity, the Ground Level was not assigned a letter (i.e. A/B) to denote the sublevels. Both Ground Level sublevels will be labelled "G" however, the color system (dark tone/light tone) is used to distinguish between them. Level 5 was split into sublevels 5A and 5B and follows the dark tone/light tone color coding system.

The stairwell was identified as a key zone in need of design intervention. Level recognition strategies to increase memory recall should be utilized every time a user needs to make a wayfinding decision. Stairwells are therefore an important place for wayfinding and environmental graphics. Additionally, according to the the WELL Building Standard, which provides design guidelines for the built environment that support human wellbeing, a celebrated stairwell can promote activity and increase sustainability. “Use attractive features like natural light, art and music to create a more appealing stairwell that incentivizes people to take the stairs rather than the elevator” (Donner, 2017). Responding to this research, the team decided to treat the stairwell as a focal point for the garage graphics.

Three wall treatment options for the stairwell design were produced (Figure zz). The orientation of the icons is used to help organize traffic flow within the stairwell. Each side of the stairwell was designated as ascending or descending; animal icons facing forward in an upward direction guide pedestrians to walk in the same direction. All three wall treatment options use paint for the background graphics, with wall mounted animal cutouts. These dimensional animal graphics are designed to be a relatively uniform size, therefore, the cutouts show animals at a larger or smaller scale than real life, depending on the species. This decision not only makes the fabrication process more consistent, and therefore efficient, but also creates a whimsical atmosphere that sparks imagination. The animal cutouts, while viewable from multiple eye heights, will be mounted at child scale to encourage interaction with youth community members and foster a sense of excitement during stair use.

A concept diagram of the route for pedestrian pathways was also created. The design of the pedestrian pathways was informed by the overall wildlife theme, the team selected animal footprint symbols that would guide users towards the safest path to walk through the garage. Two pathways were designated: an ascending route and a descending route. In order to keep an uninterrupted pathway from the Ground Level up to Level 5, two sets of animal footprints were chosen from the total set of animal icons (Figure ww). This makes it easier for users to navigate the garage, without unnecessary confusion caused by a variety of different footprint types to track through the space. The best placement for the pedestrian pathways was between the vehicle parking spots and road for vehicular traffic. While this location does not completely separate pedestrians from moving cars, the markers on the floor will increase visibility of the pathways and encourage pedestrians to walk in an organized manner.

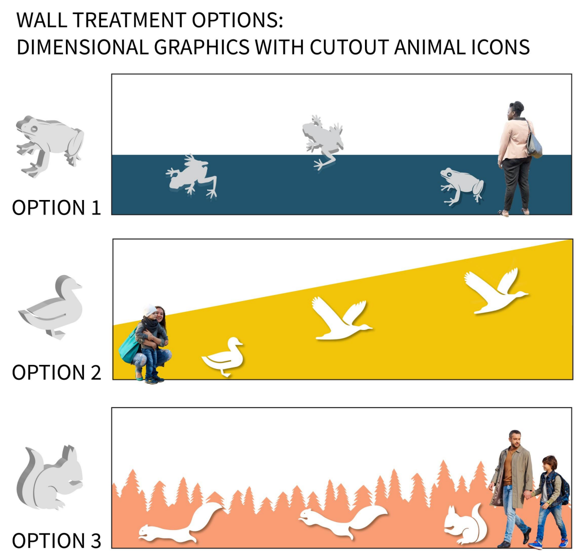


Figure ZZ: Wall Treatment Options

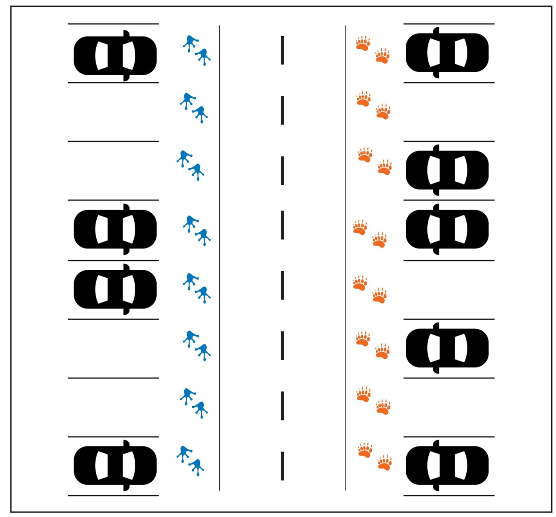


Figure WW: Pedestrian Pathways

The garage team determined a set of future goals and objectives for the final design. Based on feedback, a few key areas for revision were identified. First, the animal icons from the Noun Project needed to be redesigned with custom graphics made specifically for the Seneca garage. The icons also needed to be simplified, so that each icon is defined by a single profile line with not cuts made to the interior of the shape. Additionally, the animal icons were revised to represent only local wildlife, that would be most appropriate for the garage location and the Ithaca community. The team decided to move forward with the Option 3 wall treatment (Figure zz). The current iteration of Option 3 depicts a simple outline of trees. This approach guided the development of several additional graphic "environments" used as the background wall treatment for the final design. The graphic environments are designed to relate to the different animal types and their corresponding natural habitats. Additional wayfinding markers and signage also needed to be developed to visualize how the overall design scheme would be deployed throughout the space.

Dryden Garage Team

Following the charrette, the proposals were shared with the rest of the team for feedback, and the designs were clarified and refined in the next iterations. One of the most significant concerns from this round of feedback was for a sense of graphic continuity between the two garage designs. The team discussed the importance of sharing graphic styles without overlapping or conflicting themes in the designs. The team agreed that Dryden Garage should have its own clear graphic identity that relates to Seneca without confusing users between the two.

For this reason, the revised iterations for the murals incorporated the same colors as the animal environments proposed for Seneca but refrained from using Seneca's animal icons too heavily in the environmental scenes. In order to further this related-but-differentiated graphic identity, the proposed mural wall treatments in Dryden use color in the inverse to the graphics at Seneca. In this way the Dryden murals highlight the environments rather than the creatures living within them.

The rest of the team supported using local scenery to inspire the images, so silhouettes of the local skyline, gorges and underwater life were added into the mural designs. The silhouettes were simplified to match the style of the simple animal icons used in Seneca. The current iterations of the murals offer 2 style options for the background to the silhouettes, shown in Figures X - X. The first option takes the murals as an opportunity for a more realistic depiction of the Ithaca environments, though still somewhat abstracted and simplified to fit the Seneca color scheme. The second option uses simple color gradients, which relate more closely to the Seneca-style wall treatment proposals.

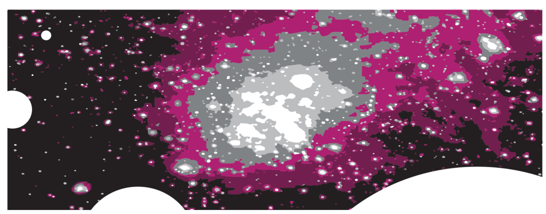


Figure X: Graphic Option 1 - Outer Space Mural

Figure X: Graphic Option 1 - Skyline Mural Color Tests

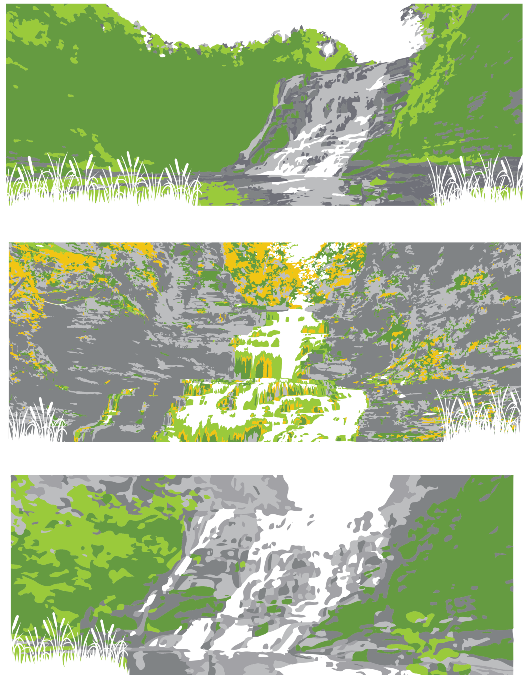


Figure X: Graphic Option 1 - Gorge Mural Scene Tests

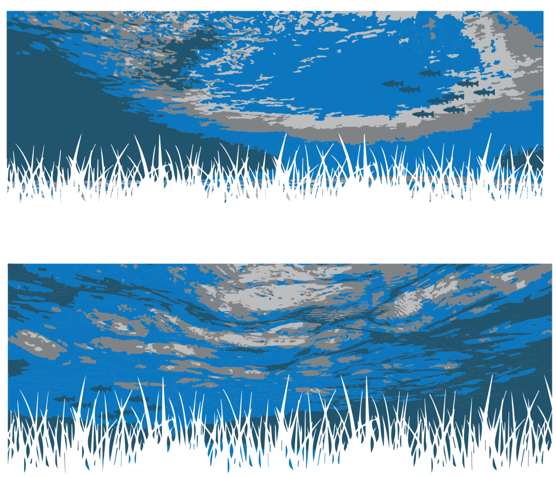


Figure X: Graphic Option 1 - Underwater Mural Scene Tests

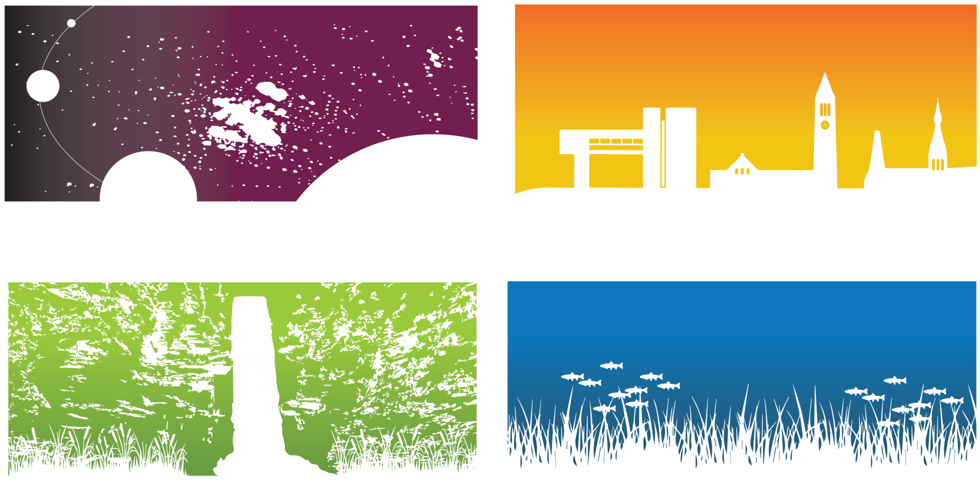


Figure X: Graphic Option 2 - Simple color gradients

Finalized Design

Seneca Garage Team

Through an iterative design process, informed by research and transdisciplinary collaboration, a final design scheme was developed for the Seneca garage. The Ithaca Wildlife theme is a core feature of the graphic identity and supports several important design concepts used to improve the space. One strength of the Ithaca wildlife theme is that it incorporates biophilic design principles through natural imagery and representations of patterns of nature. This is achieved through the use of animal icons and graphic environmental wall treatments. Biophilic design is theorized to be an innate attraction and attachment to nature; it has been shown to provide restoration and improve well-being for humans in the built-environment (Kellert & Wilson, 1993). Additionally, imagery of animals has the ability to actively engage children and adults, who find the symbols easily recognizable and relatable. Humans are intrinsically attracted to expressive figures, the graphic theme capitalizes on this instinct in order to draw attention to the animal symbols that relay important wayfinding and feature recognition cues. The design scheme could easily incorporate additional education signage that gives facts and information about the different animal species depicted.

Throughout the process, the team attempted to connect the design to the surrounding environment. This is accomplished by focusing on local wildlife and attention to other design features that currently exist in the Ithaca community, which helps to develop a sense of place identity. After the initial pedestrian pathways were designed, it was brought to our attention that there are a set of pre-existing animal footprints embedded in the flooring at the Ithaca Commons. Due to the proximity of the Seneca garage to the Commons, we viewed this connection positively, as the experience within the garage will resonate with the Ithaca community, and spark a sense of familiarity and comfort. It was important that our design solutions enhance the many unique characteristics of the Ithaca community, and do not clash with them or create distractions. The final design scheme carefully considered the needs of local residents, but the design is also approachable and recognizable to visitors. In this way, it not only improves the functionality of the space, but also creates a cheerful atmosphere that can be appreciated by all.

Figure XX: Final animal icons/colors

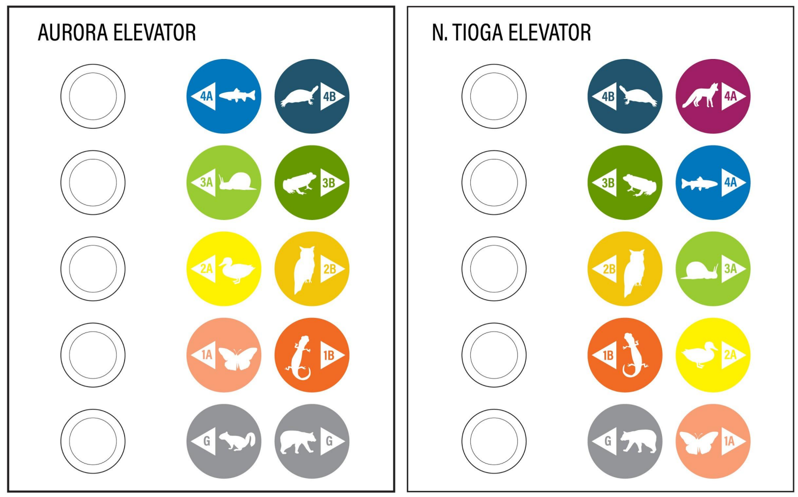


Figure XX: Elevator Button Labels

The Seneca garage has two elevators that stop at different floor levels (Figure xxx). Signage for the elevator button control panel for both elevators was designed with level markers that use color, animal icons, and directional arrows to assist in wayfinding upon exiting the elevator. The wall treatment for each level has been designed with the designated animal icon in multiple poses mounted on the wall. They are placed in front of a background with a custom 2D graphic environment in the corresponding color (Figure xxx). Each animal has several different postures to simulate motion, in order to direct the user to follow the animal "guide" up or down the stairs. The beams and walls in the main parking levels will be painted with the designated color, stencils will be used to paint 2D versions of the animal icons. A conceptual rendering of the space visualizes two sublevels of the parking garage with the new design elements incorporated (Figure XXX). The columns will have signage that displays the floor level (e.g. 4B), the color (e.g. dark blue) and animal icon (e.g. turtle), to inform customers where they are located in the garage. All of these elements contributed to the final design proposal that present a unified approach for the redesign of the Seneca garage. Additional design drawings and diagrams can be found in the Appendix.

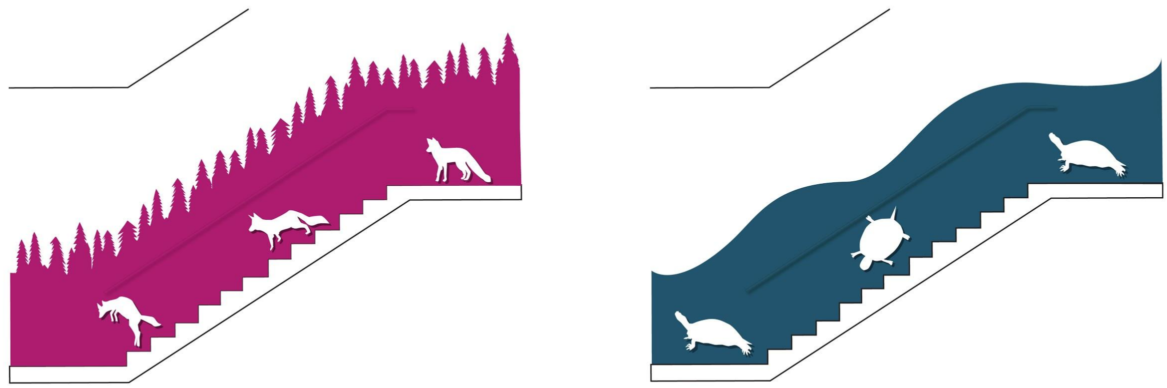


Figure XX: Final stairwell design wall treatment

Figure XX: Concept rendering of Seneca Parking Garage

Next Steps

Test Plans

Good practice in systems engineering and design calls for testing of the designed product as early and as often as possible. This is to ensure that maximum testing and feedback can be obtained before the design is finalized.

Test plans are split into two sections - behavioral and non-behavioral test plans. Behavioral test plans are developed to test the functional requirements of the system. Three behavioral tests were developed to test the main functions of the signage system. The first is whether the user can navigate through the system without the external aid. The second is if the user can relocate their parked vehicle after re-entering the garage, again without external help. The test facility is a list of materials, equipment, or personnel that is needed for the test to occur. The entry condition is where the system develop has to be before this test could be conducted. The exit condition is the requirement to dictate the test was a success.

The behavioral test plans are listed below.

Test #	Test Method	Test Facilities	Entry Condition	Exit Condition
TP.1	Test Procedure: User navigates the garage	User, garage, vehicle	Complete signage prototype installed	User is able to navigate the garage without external aid
TP.2	Test Procedure: User locates vehicle	User, garage, vehicle	Complete signage prototype installed, user parked vehicle in garage	User is able to relocate their vehicle after re-entering the garage on foot without external aid

Table XX: The behavioral test plans

Non-behavioral test plans are designed to test structural requirements and often times the reliability and safety of the system. These test plans are derived from the originating requirements to ensure that the requirements are met. Similar to the behavioral test plans, test facilities, entry and exit conditions are also included. These non-behavioral test plans are categorized into four major test methods which are inspection, analysis, demonstration, and test. These test methods are summarized in the table below.

Test Method	Definition
Inspection	Inspection is an element of verification that involves a visual examination of the item/system, reviewing descriptive documentation, gauging or measurement, and comparing the characteristics with a predetermined standard to determine conformance to requirements without the use of special laboratory equipment or procedures.
Analysis	Analysis is an element of verification that uses established technical or mathematical models or simulations, algorithms, charts, graphs, circuit diagrams, data, or other scientific principles and procedures to provide evidence that stated requirements were met.
Demonstration	Demonstration is an element of verification that involves the actual operation of an item. Operation or performance is verified through action and observation of responses with no specific analysis, instrumentation or quantitative data collection. Demonstration is used when quantitative assurance is not required for verification of requirements. Used for verification of requirements that have an On-Off/Yes-No response.
Test	Test is an element of verification designed to provide data on functional features, performance or equipment operation under fully controlled and traceable conditions. The data is used to evaluate quantitative characteristics. Operation or performance is verified through action with specific instrumentation or data collection. Implicitly requires analysis.

Table XX: Definition table of methods of testing

Below is the non-behavioral test plan.

Req. #	Requirement	Abstract Name	Test #	Test Method	Verification on Method	Test Facilities	Entry Condition	Exit Condition
OR.11	The system shall have signs indicating each level of parking.	Indicate levels	**TP.3**	Identifying visual cues in system	Inspection	Signage system designs	Signage system complete	Each floor of system has different visual cues
OR.83	The system shall contain signs that utilize colors that contrast at a low light level.	Sign Contrast	**TP.4**	Record how many of 50 drivers can read the signage system at night	Test	Garage with signage, 50 users of varying vision capacity	Signage system complete	All 50 users can read signage at night. Give ratings of 4 or 5 on a 5-point scale

OR.86	The system shall have signs that will be maintained cheaply.	Sign Cost	**TP.5**	Research different materials/painting techniques. Calculate average lifetime/ maintenance periods for each signage type	Analysis	Signage system designs	Different proposals for types of signage have been acquired	Signage System would have a maintenance cost under the city's approved budget.
DR 3.2	The system shall have signs with directions to the electric vehicle charging stations.	EV Charging Signs	**TP.6**	Record how many of 50 EV drivers correctly navigate to the EV charging station on their first try	Test	Garage with signage, 50 users EV users	Signage system complete	90% of EV drivers finds EV charging station on first attempt
OR.21	The system shall have signs indicating which spots are for the hotel.	Indicate hotel spots	**TP.7**	Question hotel guests whom require parking whether parking could easily be found	Test	Garage signage, 50 hotel guests who uses parking facilities	Signage system complete	90% of users found parking

Table XX: The non-behavioral test plans

Through these various testing procedures, we are able to determine whether the designs are able to direct users to their intended locations. Further test cases can be developed to better reflect the needs of the updated designs.

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Appendix

Personas

Ithaca Population - Mariah, Age 42

Social Life: She lives on Cook St, a quiet, residential area where she has copiou space. Her family loves to spend evenings and weekends outside, and she often calls over her friends to spend time outside while their kids play together, playing sports and ride their bikes. "Yeah, we have a lot of fun. Especially on ice cream truck days!"

Work Life: Mariah works mostly from home for the Ithaca Tompkins Library, managing their catalogs and databases. She loves her job, since it's flexible but also allows her to contribute to the community daily.

Key Attributes: Extremely busy, has a Mercedes minivan but wishes she had a Range Rover

Quote: "Of all the things I have to do in a day, the last thing I want to be stuck on is driving in circles around a parking garage! I'm a busy woman, yes I am!"

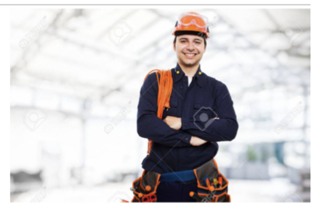
Visitors- Jay, 50

His social life is his work life: He's a big family man, and works hard at his job as a mechanical engineer Ford Motor Company every day to make sure his family is well supported. When he's not working, he's DIY fixing various things that his daughters broke (iPhone screens, lacrosse sticks, changing engine oil). Free time makes him very nervous. There's no such thing. There's always something to do. As a result, when he does eventually go on vacation (he loves camping), he loves to get up at 5 AM to watch and photograph the sunrise.

Key Attributes: Not completely fluent in English, unfamiliar with the area, has a huge photography hobby, wishes his daughter would have more affinity for CS ("Information Science is fine"), dislikes being wrong

Quote: "Comment? I have no comment for the garages. They're ok. We're here visiting colleges."

Maintenance Staff - Jim



Jim is a man from Varna who services various aspects of the garage system, who does not enjoy the constant problems he has to face in the garages

Age: 35

Social Life: Has a close-knit group of friends who enjoy spending their nights going downtown and their weekends on excursions to the local area. Likes spending time outdoors as he is insight for much of the day

Work Life: Usually works alone on tasks that need to be routinely done. Does not interact with many people while on the job

Attributes: Does not like the color orange, creative, persistent, likes puns, quick learner

Quote: "There's no problem that can't be fixed with enough time and effort"

Garage Attendant - Felipe

Felipe is an Ithacan local who has lived here his entire life, working full-time while studying classical music at Ithaca College

Age: 28

Social Life: Has many different friend circles who all do their own unique things. Always willing to go to a concert or music festival, including Coachella

Work Life: Social, friendly, and eager to help patrons who use the garage system. Concerned about some of the safety features of his workplace

Attributes: Avid singer and songwriter, patient, wants a corgi when he gets his own place

Quote: “Sometimes, the best music is heard where and when you least expect it”

Police/Authorities - Arnold

Arnold is a man from Seneca County who has been a friendly but strict member of the police force for over 20 years, and shows no signs of stopping soon

Age: 42

Social Life: Preferring to relax after stressful shifts, Arnold likes to hang out with his dogs, watch movies, or read a book on his patio. His friends in the force and outside are always eager to see him when he does head downtown.

Work Life: Having seen it all, Arnold has no problem dealing with a variety of situations, and is an inspiration to the younger officers in the force

Attributes: Composed while under stress, empathetic, likes Criminal Minds

Quote: “Safety is my number one priority”

City of Ithaca - Pam

Pam is woman from NYC who recently graduated from Cornell and is now working and living in downtown Ithaca

Age: 24

Social Life: Pam loves to meet new people, and has no problem navigating social spaces. Although doing so burns her out and you can also see reading a book with a glass of wine some weekend afternoons.

Work Life: Graduating with a degree in engineering and a minor in business, Pam excels at finding clever solutions to the cities endless problems

Attributes: Highly motivated, interesting to talk to, and has no problem working all night

Quote: “If you like your job you will never work a day in your life”

Requirements

OR represents an originating requirement, while DR represents a derived requirement.

OR Index	**DR Index**	**Originating Requirements**	**Abstract Function Name**
OR.1		The system shall record the date and time that a vehicle enters the system.	Record
	DR 1.1	The system shall recognize when a vehicle has entered the garage.	Recognize vehicle
OR.2		The system shall be completely operational in all weather conditions.	Weather independent
OR.3		The system shall have electric_vehicle_chargers charging stations for electric vehicles.	Electric Vehicle Chargers
	DR 3.1	The system shall have signs with directions to the pay stations.	Direct to pay station
	DR 3.2	The system shall have signs with directions to the electric vehicle charging stations.	EV charging signs
OR.4		The system shall inform users how to exit the system.	Inform to exit
OR.5		The system shall have parking spaces for disabled users.	Disability-friendly
OR.6		The system shall have a fire alarm system according to city regulations.	Fire regulation compliant

OR.7		The system shall have noticeable security cameras.	Monitor
OR.8		The system shall have an elevator next to each set of stairs.	Have elevator
OR.9		The system shall be operational with and without a parking attendant.	Operational
OR.10		The system shall allow traffic in 2 directions.	Allow 2-way traffic
OR.11		The system shall show the user what level they are on.	Indicate levels
OR.12		The system shall have drains for water runoff from storms.	Drain water
OR.13		The system shall inform users parking prices before they enter the system.	Inform prices
OR.14		The system shall be able to handle the structural load when filled.	Handle load
OR.15		The system shall inform users how to pay for parking.	Inform how to pay
	DR 15.1	The system shall inform the user where to insert their ticket.	Inform ticket insertion location
OR.16		The system shall support all types of payments.	Support payment methods
OR.17		The system shall direct users to parking spots.	Contain directions
	DR 17.1	The system shall inform users what direction to drive within the garage.	Inform direction to drive
OR.18		The system shall allow all types of passenger cars to enter the system.	Allow to enter
OR.19		The system shall have garage_car_capacity, enough spaces to accommodate all the stakeholders.	Accommodate with spaces
	DR 19.1	The system shall accommodate all passenger vehicles to enter.	Accommodate
OR.20		The system shall be patrolled daily by the police.	Patrolled
OR.21		The system shall have signs indicating which spots are for the hotel.	Indicate hotel spots
OR.22		The system shall be accessible to emergency vehicles.	Emergency vehicle accessible
OR.23		The system shall have trash cans available to users.	Contain trash cans
OR.24		The system shall be well-ventilated.	Ventilated
OR.25		The system shall have safety barriers to protect pedestrians.	Protect pedestrians
OR.26		The system shall have space to allow a car to turn around.	Have enough space
OR.27		The system shall have separate exit locations for pedestrians.	Have pedestrian exits
OR.28		The system shall have a lifespan of over 50 years.	Last long
OR.29		The system shall have a method of notifying potential users when the system is at capacity.	Notify of capacity
OR.30		The system shall have standard-sized parking spots of	Have standard

		standard_parking_spot_width.	spots
	DR 30.1	The system shall have parking spots which are the standard width to accommodate the vehicle.	Have standard size spots
OR.31		The system shall have number_of_paystations pay stations.	Have paystations
OR.39		The system shall allow all types of passenger cars to exit the system.	Allow to exit
OR.40		The system shall inform users how to enter the system.	Inform to enter
	DR.40 .1	The system shall prevent users without a ticket from entering.	Prevent from entering
	DR 40.2	The system shall inform a user how to get a ticket.	Inform to get ticket
	DR 40.3	The system shall lift the entrance gate arm 90 degrees after receiving the signal that the user has taken a ticket.	Lift gate 90 degrees
OR.41		The system shall be easy to find from the road	Road Navigate
	DR 41.1	The system shall have external wayfinding signage	External Signage
OR.42		The system shall be large enough for a Max_Size vehicle to fit through	Entrance height
OR.43		The system shall be able to print a ticket for the customer	Print ticket
OR.44		The system shall provide a ticket within reach of the customer	Ticket reachable
OR.45		They system shall read the ticket to verify that payment has been made	Ticket read
OR.46		The system shall remain up long enough for the car to exit	Exit gate duration
OR.47		They system shall make the user feel safe	feel safe
OR.48		The system should minimize user's time to park	min park time
OR.49		The system should minimize user's time to pay	min pay time
OR.50		The system shall make it easy for the user to find the location of their parked car	car find
	DR 50.1	The system shall have distinct labeling for each floor	Floor ID
OR.51		The system shall make it clear the user must bring the ticket to the exit booth	Bring ticket instruction
OR.52		The system shall be open and functional for operating_hours	Operating hours
OR.53		The system shall have overhead and natural lighting on every floor	Lighting
OR.54		The system shall be kept in clean condition	Cleaning
OR.55		The system shall have clear protocol for if a user loses their ticket	Lost ticket
OR.56		The system shall have designated spots for number_of_motorcycle_spots motorcycles	Motorcycles
OR.57		The system shall have clear emergency exit procedures, protocols, and	Emergencies

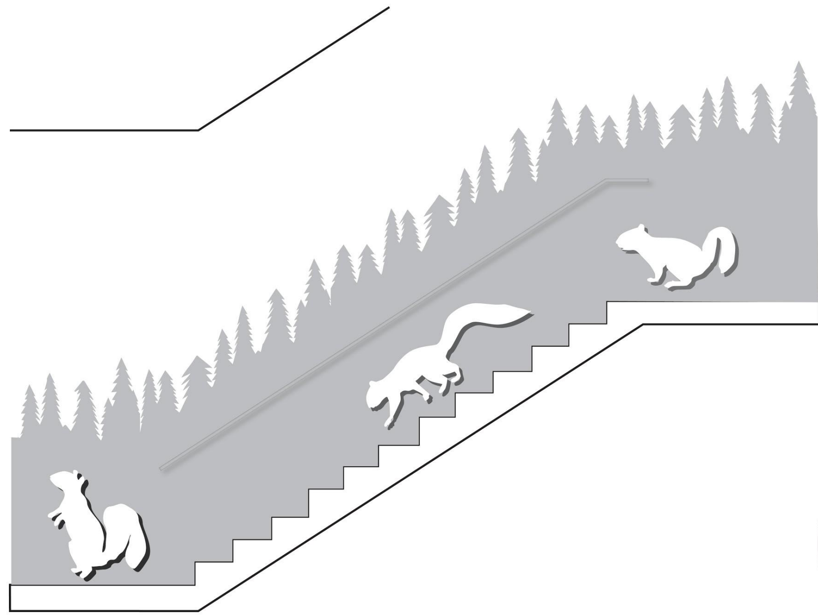
		guidelines	
OR.58		The system shall have updated and accurate information at all times	Prodividing accurate info
OR.59		The system shall have protocol in place for replacing information that is outdated	Replacing info
OR.60		The system shall have consistent signage styles throughout	Consistent style
OR.61		The system shall have separate signage for pedestrians and drivers	Driver vs Pedestrian signage
OR.62		The system shall signal driver when they enter the system.	Signal
OR.63		The system shall display available spots.	Display
OR.64		The system shall close the gate after the car enters.	Gate Movement
OR.65		The system shall restrict areas where vehicles may not travel	Zone Restrictions
OR.66		The system shall display signs and directions to stairs / elevator.	Information & Signage
OR.67		The system shall close the exit after vehicle leaves.	Detect & Close
OR.68		The system shall update number of available parking spots after vehicle leaves the garage.	Update
OR.69		The system shall show direction to emergency exits.	Emergency Signage
OR.70		The system shall open entrance and exit gates during emergency.	Emergency Gate Movement
OR.71		The system shall indicate vehicle height clearances	Vehicle Clearance
	DR.71.1	The system shall alert a user if their vehicle does not meet the clearance requirement.	Clearance Alert
OR.72		The system shall have signage that point to the payment machines	Payment Navigation
OR.73		The system shall provide a receipt for the service	Receipt
OR.74		The system shall be properly linked with local public transit	Public Transit
OR.75		The system shall area for vehicles to conduct a 3-point turn	Turn-around Space
OR.76		The system shall provide access to support for payment issues	Payment support
OR.77		The system shall have prominent security cameras at the payment machine	Security
OR.78		The system shall have walkways that can accommodate for disabled users	ADA Compliance
OR.79		The system shall have a clearly marked "up" and "down" causeway	Change Floors
OR.80		The system shall have a marked pedestrian entrance	Walking Entrance
OR.81		The system shall be considered safe by a sample of the community	Is Safe

OR.82		The system shall contain signs that can be read from undetermined_distance	Sign Lettering
OR.83		The system shall contain signs that utilize colors that contrast at a low light level.	Sign Contrast
OR.84		The system shall have signs that can be read from any car height.	Sign View Height
OR.85		The system shall incorporate nature and community in its design.	Natural
OR.86		The system shall have signs that will be maintained cheaply.	Sign Cost
OR.87		The system shall have parking space clearances large enough for the user to exit their vehicle	Vehicle Ingress/Egress
OR.88		The system shall aid the user to safely walk to their parked vehicle	Pedestrian Access
OR.89		The system shall minimize vehicle idle time	Efficiency

FMEA

Failure Mode Number	Identification or Item of Function	Failure Mode	Failure Effects (a. Local b. System c. Mission)	Possible Cause	Corrective Action a. design, b. manufacturing process, c. opertion	Failure Effects Severity (1=least, 5=most)	Occurrence Likelihood (1= least, 10=most)	Risk Priority Number=severity*occurrence	Critically (Corrective Action Priority)
F.1	Navigation Misdirection	Signs direct commuter away from up/down ramp	c) Commuter becomes lost inside the garage. Garage is no longer a positive place to park	Lack of clarity in signage wording and visibility	Select better spots for signage and redo the information on the signs	1	5	5	Low
F.2		Signs direct exiting commuter into oncoming traffic	b) System becomes damage or blocked by the accident c) Critical mission failure, garage is no longer safe nor positive	Signage was not clear or loud enough of the potentially dangerous move	Clearly mark which way traffic is flowing and use large sign designs to ensure drivers know of this safety risk	5	3	15	Medium
F.3		Signs direct EV commuter away from EV parking	c) Elecric Vehicle commuter spends more time finding the parking spot and becomes disenthused with garage functionality.	Lack of clarity in signage wording and visibility	Place signage further ahead of the Electric Vehicle parking spots to alert drivers earlier.	1	6	6	Low
F.4	Sign Visibility	Hanging signs cannot be read from vehicle	b) Information is not conveyed within the system. c) commuter misses vital garage information, failing the mission of the garage	All vehicle types were not considered in sign design	Length of signposts should be re-assessed	2	4	8	Medium Low
F.5		Sign cannot be read at night	b) Information is not conveyed within the system. c) commuter misses vital garage information	The correct contrasting colors were not selected for night visibility	Color scheme of signs should be reassessed	3	2	6	Low
F.6	Sign Information	User misunderstands payment sign information	b) Pay system will not process user's ticket c) User cannot pay for parking, may not be able to exit	Inconsistent/unclear information on pay machine signage	Consider entire payment process, redisgn sign infromation to include easy to follow instructions. Test on new users.	3	5	15	Medium
F.7		User parks in hotel parking spaces due to lack of sign clarity	b) System contains cars in the wrong locations c) Damages relationship with hotel and causes confusion	Information about hotel parking was not conveyed early enough	Insert signage at entrance to inform users of which floors are hotel guests only	2	6	12	Medium Low
F.8	Pedestrian Signage	Pedestrian cannot find staircase	c) Pedestrians have difficulty exiting system, garage is not positively viewed	Not enough pedestrian signage is on each floor	Implement more visible signs and have them occur at a higher frequency.	1	4	4	Very Low
F.9		Pedestrian cannot remember which floor they parked on	c) Pedestrians have a difficult time returning to their parked car. May become panicked.	Lack of differentiation between garage floors	Implement a system to give each floor uniqueness	2	3	6	Low

Finalized Design



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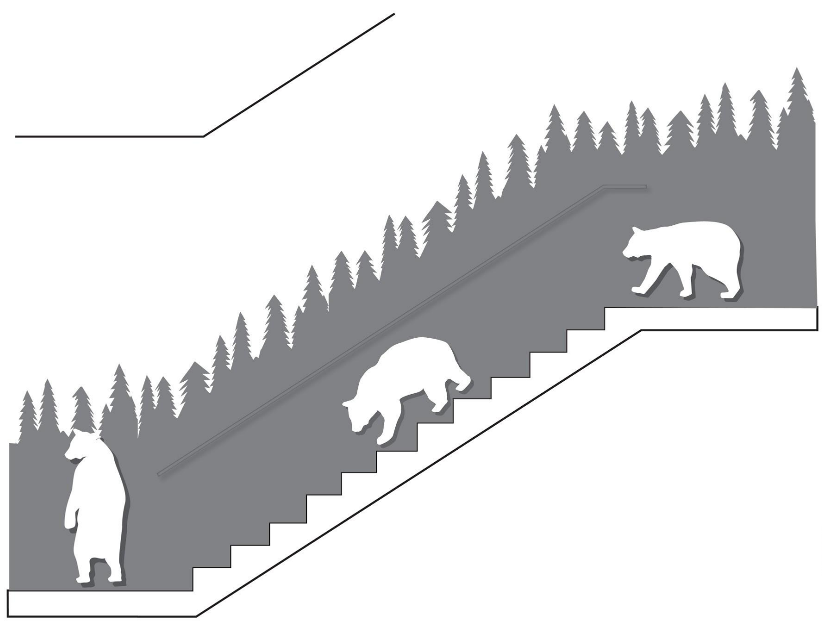

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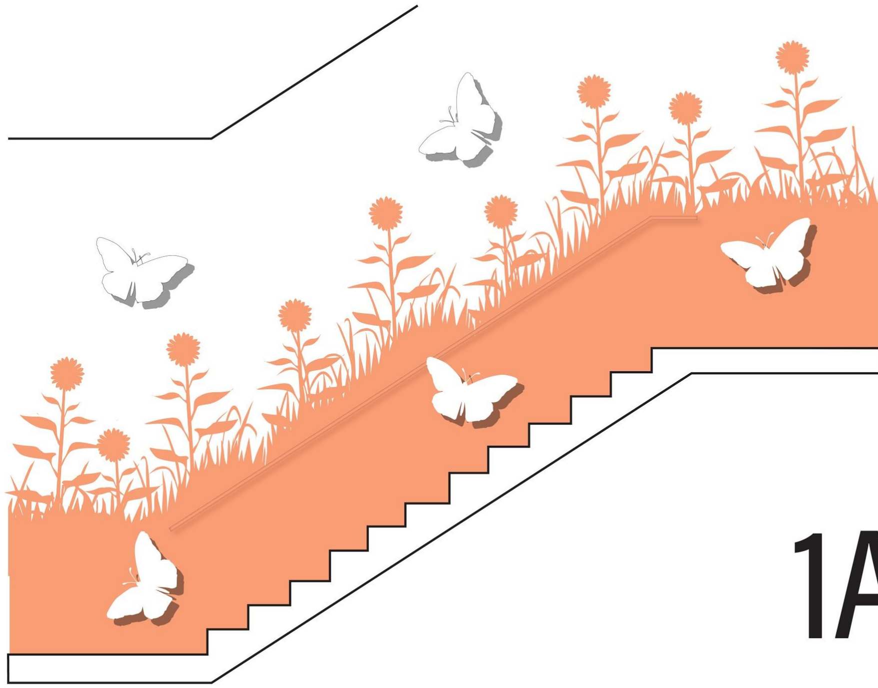

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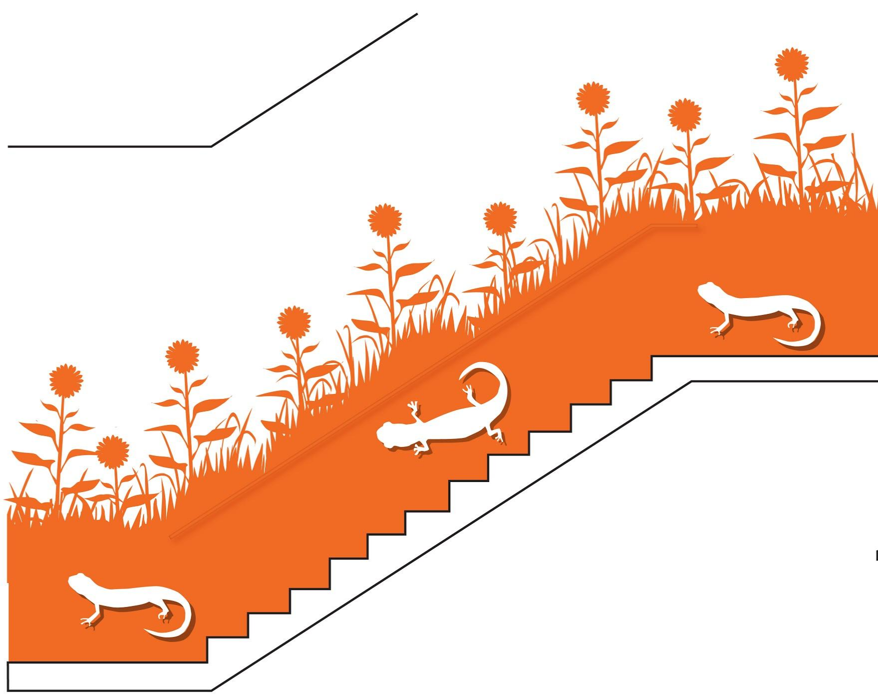

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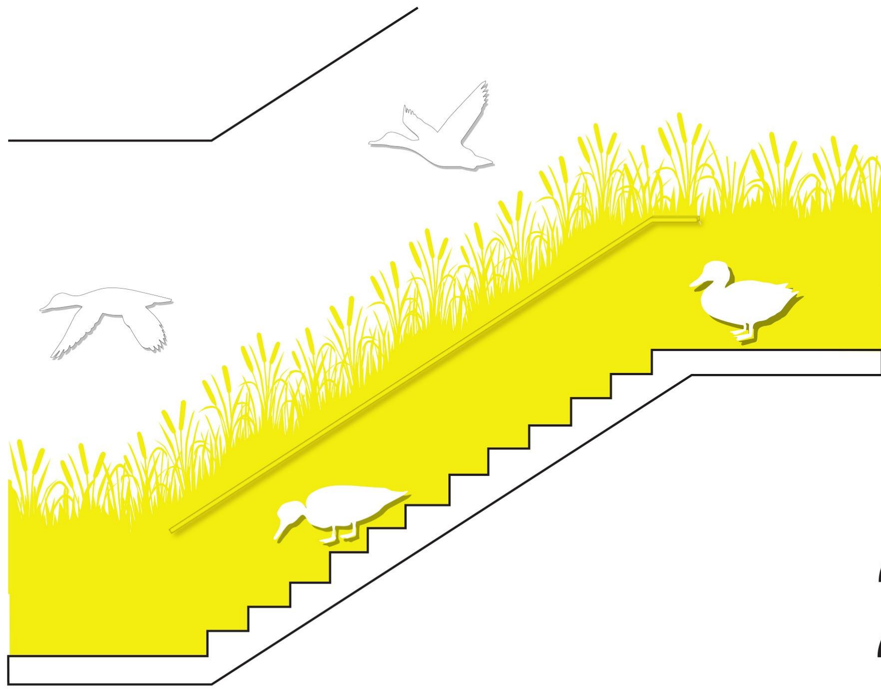

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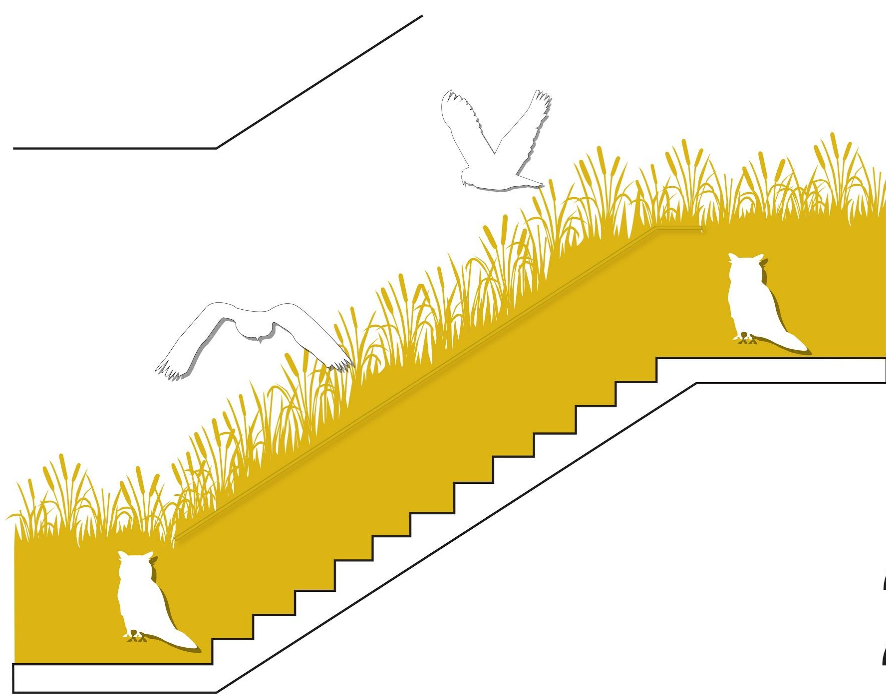

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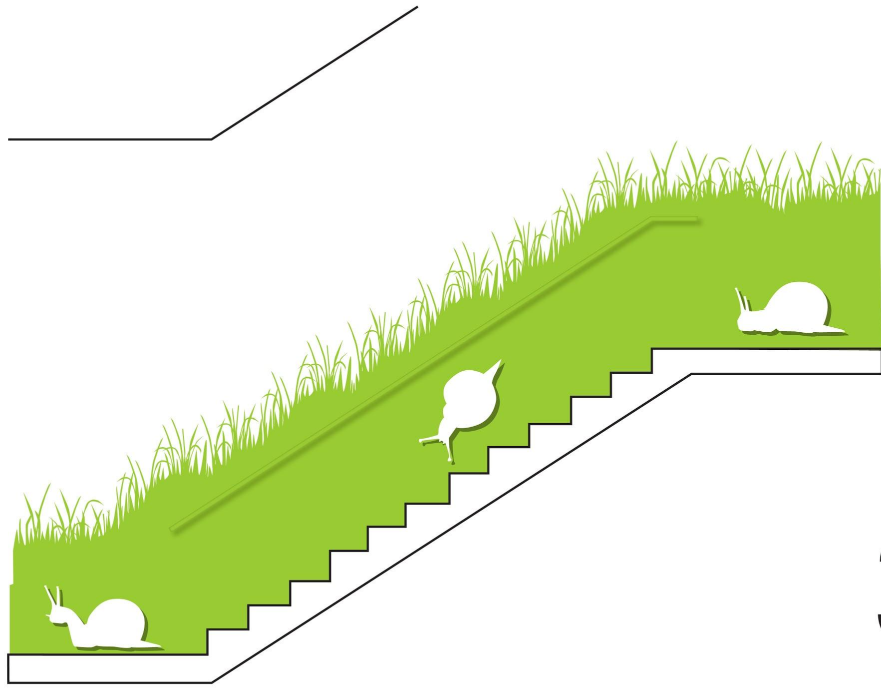

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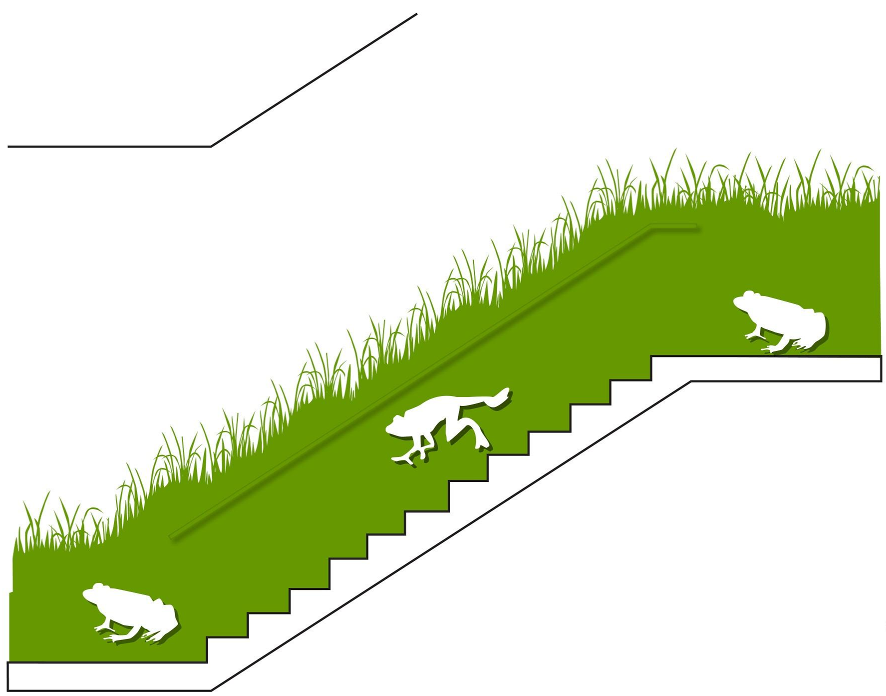

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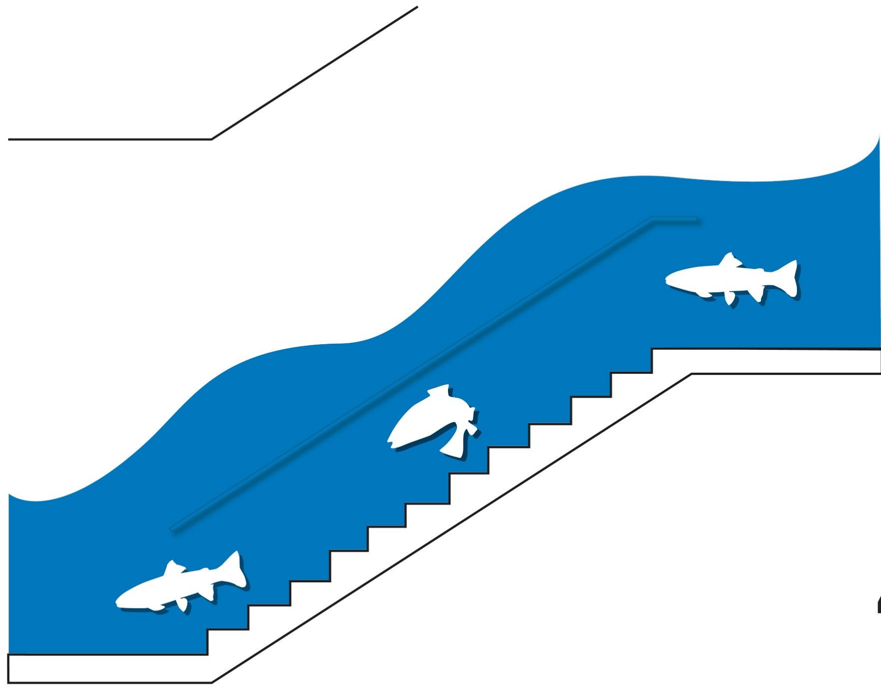

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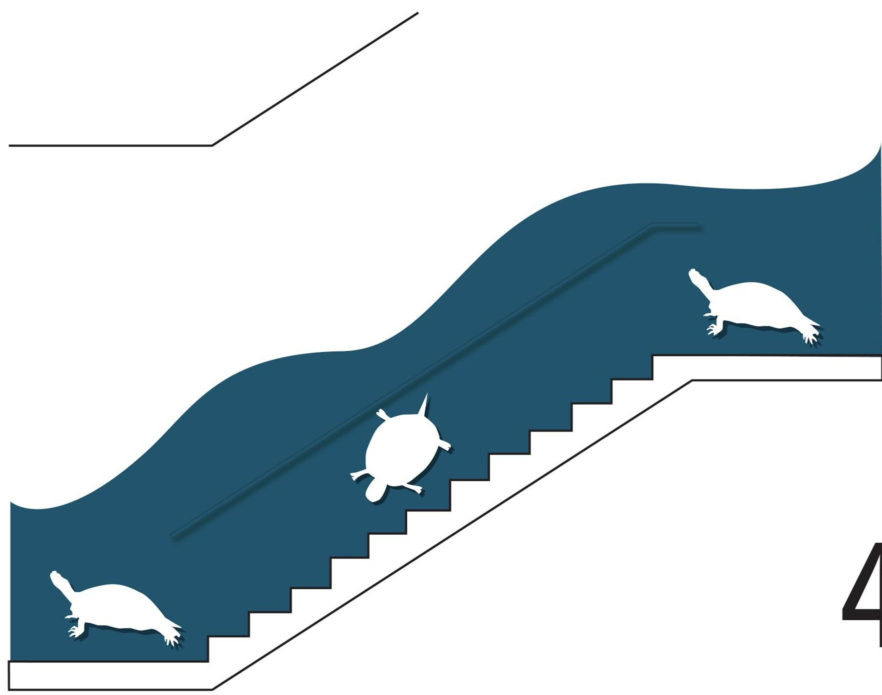

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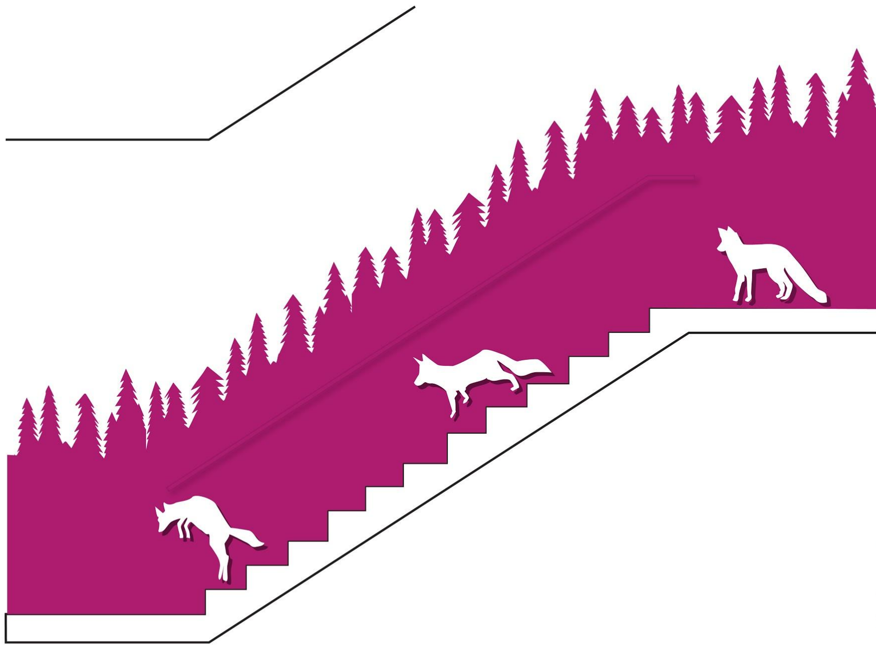

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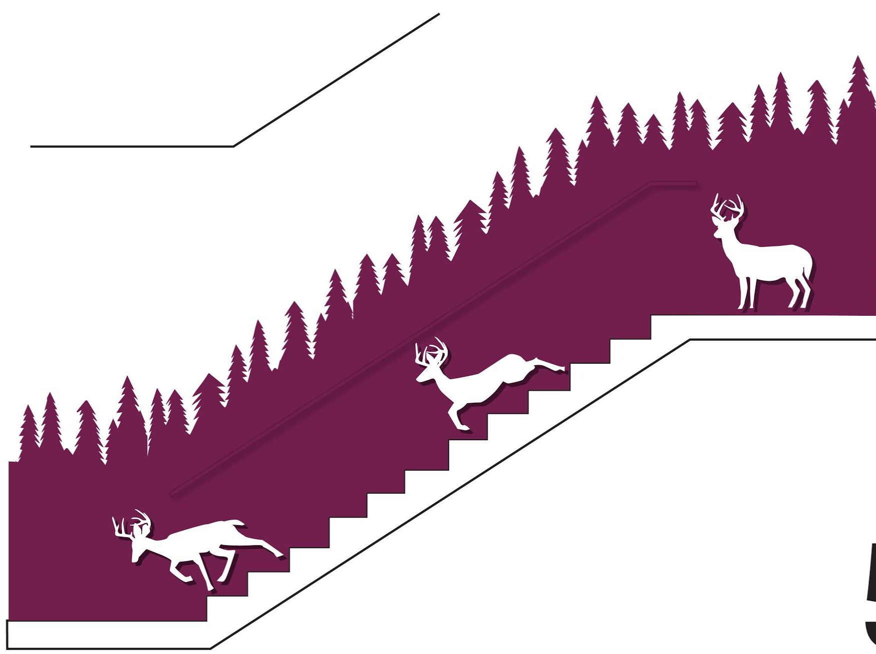

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