LA - EXP

QuickPark (Team 4)

Ronit Parekh
Henry Glover
Lilyana Orozco
Fin Prakittiphoom
Anushka Shah
Vineeth Rajesh

Dec 6, 2024

Table of Contents

Executive Summary

Our project aims to address the challenges faced in urban parking by creating a more efficient, technology-based solution. Our core feature is an app that simplifies the reservation process, automates payments, and provides real-time updates on available parking spaces. We offer options for both pay-per-use and a subscription model that guarantees parking spots.

Within the parking structure, we have integrated an automated vertical parking system that uses lifts to transport cars to available parking spaces. This is based on the vehicles specifications and the use case per each vehicle. For example, compact vehicles will be stored on designated floors to allow for the parking spaces to be optimized to fit more compacts. On another floor SUVs will be placed together to maximize the efficiency of fitting as many vehicles as possible on a particular floor. The customer will drive onto the lift platform and will be sent to a specific floor and spot. The platform can hold several cars at a time to maximize the efficiency of the process. This eliminates the need for consumers to drive around the structure looking for a spot, making the procedure more efficient and time-saving. The system also supports shared parking, allowing businesses to rotate the use of spots based on their operating hours, ensuring continuous use of the available spaces that are already available.

Additionally, for customers who prefer a more traditional experience, our app provides an easy way to locate available spaces without using the vertical lift parking system. This approach enhances efficiency further by minimizing congestion and wait times making the parking solution versatile and user friendly. For those who are not comfortable using the app, we have included a ticket machine, similar to what you would find in a standard parking garage. While the efficiencies of the app may be lost in this scenario, users still benefit from access to the vertical lifts, which help minimize wait times and reduce congestion. The standard ticket holders will be placed on their dedicated floor to keep app users away from that congestion. Overall, our structure remains faster and safer, ensuring a positive parking experience for all users.

Other key factors we have focused on are safety and convenience. Security guards will be stationed within the structures in case of an emergency, and cameras will be placed throughout. The parking facilities will be well-lit, clean, and equipped with fast elevators (to move people). Sustainability is also a key consideration, with EV charging stations and solar panels incorporated into the design. Emergency features, such as real-time alerts for issues like elevator malfunctions or parking depot openings will ensure a secure environment for users. We have carefully planned the location and layout of the parking structures to ensure that they meet customer needs and reduce the stress of finding parking in busy areas.

Product Planning

Team Composition

Ronit Parekh is a mechanical engineering student at the University of Southern California. He is experienced in additive manufacturing and product development. In this project, he focused on targets and requirements, embodiment design, product evaluation, detail design and worked on the conclusion.

Henry Glover is a senior mechanical engineering student at the University of Southern California who has experience in automotive design and data acquisition analytics. For this project, he focused on benchmarking the needs and metrics as well as supporting different areas of the document.

Lilyana Orozco is a senior mechanical engineering student at the University of Southern California and is experienced in parts manufacturing and engine repair in the aerospace field. Lilyana contributed to this project by collecting customer interviews and surveys and determining customer needs. She also partook in the FSD design and organized it based on the process that would take place when a customer uses the product being designed.

Fin Prakittiphoom is a mechanical engineering student at the University of Southern California who excels in mechanical design and systems integration. In this project, she utilized her skills to conduct detailed market analysis and create user-focused conceptual designs.

Anushka Shah is a Mechanical Engineering student at the University of Southern California, experienced in systems analysis. She analyzed the key interview findings and the empathy map to develop a list of primary and secondary needs, categorizing them according to their importance. She further reflected on the process to come up with the same.

Vineeth Rajesh is a mechanical engineering student at the University of Southern California. He has significant experience with CAD and product design. In this project, he focused on the metrics and needs-metric matrix, the layout drawings and the product evaluation.

Market Analysis

Design Problem:
Design a parking solution that optimizes existing spaces in congested urban areas, prioritizing convenience, affordability, and safety for drivers while maximizing occupancy and profitability for garage operators.

Stakeholders:
Drivers (end users): primary users of parking facilities, seeking convenient, safe, and affordable parking options that accommodate their daily commutes, shopping trips, or residential needs in congested urban areas.
Parking Garage Owners/Operators: manage the daily operations and maintenance of parking facilities, aiming to maximize occupancy and profitability while ensuring customer satisfaction and operational efficiency.
City Planners: responsible for the development and regulation of urban infrastructure, including parking systems, with a focus on improving traffic flow, reducing congestion, and enhancing the overall urban environment.
Technology Companies: develop and supply the equipment and systems necessary for modern parking solutions, such as automated parking systems, surveillance technologies, and payment platforms, driving innovation in the industry.
Property Managers: oversee the integration and operation of parking facilities within residential and commercial properties, balancing the needs of tenants, visitors, and operational demands.
Insurance Companies: offer coverage for vehicles and parking facilities, focusing on managing risks associated with vehicle damage, liability, and property loss within parking structures.
Local Businesses: depend on accessible and efficient parking to attract and retain customers, making parking availability a critical factor in their operations.
Construction and Engineering Firms: design, construct, and renovate parking facilities, ensuring that structures are safe, efficient, and capable of incorporating new technologies to optimize space usage.
Investors: provide the financial backing necessary for the development and deployment of innovative parking solutions, seeking profitable returns in a competitive market.

Competitor Overview:
Standard Parking Garages: Traditional parking structures that provide a cost-effective and widely-used solution for increasing parking space.
Automated Parking System Providers (Park Plus, Westfalia, Wohr): These companies offer high-tech parking solutions that maximize space but come with high installation and consumer costs. They are also slow and do not maximize efficient vehicle flow.

Parking Management Software (Wayleadr): Software solutions that optimize parking efficiency with features like online reservations, pay-at-station solutions, and dynamic pricing to reduce costs.

Customer Needs Identification

Approximately 62% of people spend 10-20 minutes looking for parking. The issue isn't about the physical parameters of a parking space but rather about making people aware of its availability, informing them of open spots and costs, placement of the parking structure or solution, and the features the structure has to offer (like safety or overnight parking) is what is most important. According to studies, available parking spots are everywhere, our solution tries to get the information out to potential customers, makes it easier to park, and provides efficient hardware to get cars parked quickly in parking structures reducing wait times and the stress of parking.

Key Interview Findings - Complied : (Friends, Family, Stranger)
Interviews were conducted with six long-term Los Angeles residents, and key themes were found regarding the challenges of parking in a condensed urban city. Residents cite high costs, avialaiblity, and safety as primary concerns. Where secondary concerns included, proximity, cleanliness, and accessibility. Most of the interview participants actually preferred street parking for its affordability and proximity, although it often lacked the availability and carries a higher risk of vehicle damage. Structured parking offers safety but is often too expensive and not easily acceptable. A big complaint was how far the structures where to the actual destination of the customer. Suggested improvements given in the interview suggested included to subsizdize parking from the state or federal government which would alleviate the cost of parking and improve customer satisfaction.

Interview # 1: Valarie

Valarie lived in Los Angeles for 25 years.

Q: What are the primary reasons for your commuting in Los Angeles?

A: “Mainly for work, school, and errands but I also go out to restaurants and shows”

Q: On a scale of 1-10 with 10 being the highest, how would you rate your stress when looking for parking in Los Angeles?

A: “8.1”

Q: Given the option of parking in a lot, structure, or on the street, which parking would you choose and why?

A: “Umm, I would probably prefer the street just because it’s more convenient, it’s closer and it’s not as expensive as other parking.”

Q: How often are you able to find street parking?

A: “50% of the time street parking is not available”

Q: Have you ever found damage to your vehicle after parking in Los Angeles?

A: “Yes! Someone sideswiped my car once and another time, someone broke into my car.”

Q: Where were you parked when your vehicle was hit?

A: “On the street.”

Q: Where were you parked when your vehicle was broken into?

A: “On the street.”

Q: What is your biggest inconvenience when looking for parking in Los Angeles?

A: “How expensive it is.”

Q: What’s the most you had to pay?

A: “Well look, I went to an interview that took maybe 15 to 25 minutes, but I had to pay $34 dollars!”

Q: What do you think is a reasonable price to pay for parking for lots and structures?

A: “Lots that charge a flat price should be no more than $25, but for street parking, no more than $1 per hour.”

Q: Do you ever worry about your personal or your vehicle’s safety parking in Los Angeles?

A: “Yes, there’s always creeps and weirdos hanging out near lots and structures. It’s scary, especially as a woman because you never know what can happen.”

The rest of the Interview are found in the Addendum (1)

Key Points from Customer Interviews

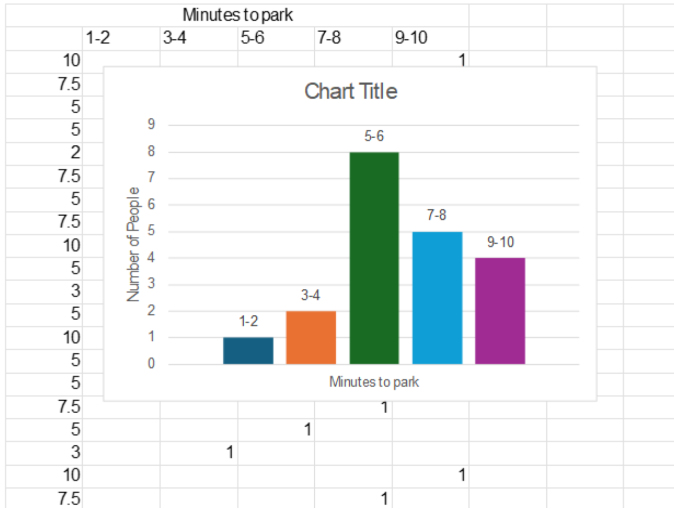


Figure 1: Bar chart results representing the amount of time people believe it should take to park with dark blue = 1-2 minutes, orange = 3-4 minutes, green = 5-6 minutes light blue = 7-8 minutes and purple = 9-10 minutes.

Top complaints for parking on the street:

1. Time limits
2. Never available
3. Parking tickets

- Some people mention that they avoid LA because of the stress of parking
- Street signs and permit parking instructions are unclear
- Streets are unsafe and sometimes blocked by homeless communities

Top complaints for parking in lots/structures:

1. Expensive
2. No elevators/ dirty elevators
3. Compact spaces

- Some people mention that prices fluctuate according to time, location, and events
- Structures are dangerous (bad lighting, inconvenient exits, no parking security

Some of the pros that people mentioned about parking in lots and structures are:

- Still safer than parking on the street
- Easier to park
- Parking is always available

Issues to consider:

1. Customers don't like to worry about the safety of their car or their own well-being.
2. Customers don't like having to try to figure out when parking is/is not permitted.
3. Customers don't like to have to look for parking for over 10 minutes.
4. Customers don't like having time limits for parking.
5. Customers don't like to pay lot/structure parking ~$10-20.
6. Customers don't like having to walk too far from their destination.
7. Customers don't like compact parking spaces.

Empathy Map:

An empathy map is a visual tool that helps us understand our user and empathize with them by putting ourselves in the customer's shoes. Ethnography helps us understand what the customer is actually feeling, saying, doing, and thinking during an encounter while trying to find parking. The scenario that we have used to create the empathy map is:

Jimmy and his wife who have a reservation for a restaurant in Los Angeles and are looking for a parking spot.

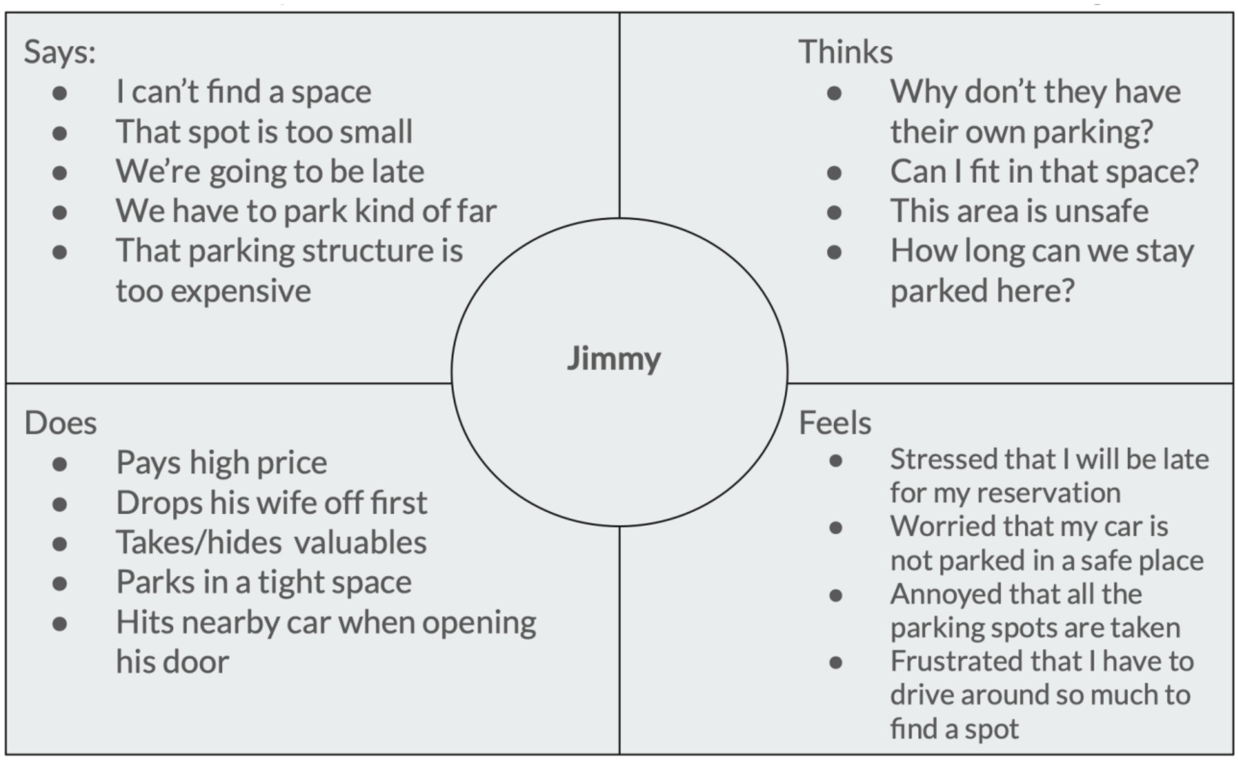


Figure 2: Empathy map using "Jimmy" in a scenario looking for parking.

Requirements Developments From Customer Needs

Primary Needs:

1. The ability to find parking in two to three minutes is the primary need.
2. Quick and effective parking search is essential for client comfort and stress reduction.
3. An app for smartphones that provides real-time, up-to-date information on parking availability and costs.
4. Detailed justification of price variations based on location, events, and time of day: clear pricing guarantees that consumers can avoid uncertainty and make educated judgments.
5. Easy and transparent payment procedures are essential for lowering friction and increasing client satisfaction.
6. The ability to book reservations in advance, which reduces the stress of having to rush to find a spot. Making a reservation in advance guarantees clients parking and lowers uncertainty.
7. Parking spaces designed to securely hold standard, larger cars without running the danger of damage. Parking spaces must be sufficiently roomy to avoid damaging vehicles and displeasing patrons.
8. The parking structure will store cars based on type, size, and weight. Larger vehicles will be on separate floors than compacts to optimize space efficiency.

Secondary Needs:

1. Clean, well-maintained accessible amenities and lifts are essential for parking buildings. While they enhance the whole parking experience, they are not as important as paying for a place.
2. Customer service is available for parking-related concerns at all times of the day. Although useful, having customer service available is more of a backup plan than a fundamental requirement.
3. Lifts in parking structures should operate as rapidly as feasible to cut down on wait times and ensure that levels may be reached quickly.
4. Emergency aid available in parking lots and buildings, including personnel or call boxes. A crucial safety component is emergency help, but only in certain circumstances.

#	NEEDS	Imp
1	Ability to locate parking within 2-3 minutes	3
2	A smartphone app that offers up-to-date information about parking costs and availability in real time	2
3	An affordable parking solution	3
4	Explicit explanation of changing prices according on location, events, and time of day	1
5	Convenient payment options, including mobile payments, without hidden fees	2
6	Parking buildings should provide clean, well-maintained accessible amenities and elevators	2
7	Possibility of making reservations ahead of time, which lessens the anxiety of rushing to find a spot	2
8	Availability of customer support for parking issues at any time of the day	3
9	Parking spots are made to safely accommodate larger and regular cars without posing a risk of damage	2
10	To reduce wait times, lifts need to be able to hold multiple cars as well as be fast.	3
11	Access to emergency assistance in parking lots and structures, such as call boxes or staff	3
12	Notify customers immediately through a mobile app alert about parking spaces, availability, and estimated wait times	3
13	Easy to locate structure or lot with visible signage and directions	2
14	Clear explanation of closing and opening times	3
15	Seamless exit and entry process	2
16	Accessible design for diverse needs of vehicles	2
17	Integration with public transportation	3

Los Angeles customers' parking needs are determined through a multi-step process that combines quantitative data and qualitative insights to produce workable, value-driven solutions. The first step in the process is identifying the main issues that customers have expressed, such as time constraints, safety concerns, confusing signage, and fluctuating costs. Quantitative information highlights how urgent it is to fix these inefficiencies. One notable statistic reveals that 62% of individuals spend 10-20 minutes searching for parking. The basic customer values of time, safety, and convenience are reflected in each pain point, which translates directly into particular needs such as quicker, more efficient parking options and safer, more convenient areas. We make sure the solutions stay current and useful by comparing our solutions to those of our competitors and iteratively improving them based on client feedback and continuous data collecting.

Metric List and Needs-Metrics Matrix:

Metric #	Need #s	Metric	Imp (1-3)	Units
1	1, 2	Average time to locate parking spot with real-time updates	3	minutes
2	3	Average parking cost per hour	3	$
3	4	Transparency score of pricing changes	2	scale
4	5	Payment methods available	2	count
5	6	Cleanliness and maintenance rating of amenities	1	scale
6	7	Reservation success rate	2	%
7	8	Availability of customer support channels	3	count
8	8	Response time for customer support queries	3	minutes
9	9	Safety compliance for accommodating large vehicles	2	scale
10	10	Elevator efficiency (number of cars moved per hour)	3	%
11	10	Elevator wait time during peak hours	2	minutes
12	11	Number of lifts available during peak times	2	count
13	12	Response time for emergency assistance	3	seconds
14	13	Signage and directions to, from, and within lot	2	scale
16	16	Clearance for vehicle to enter/exit and fit in parking spots.	12 xH 9 xW 18 xL	ft
17	17	Time to get to closest public transportation	8	minutes

The metrics for our parking system were developed based on the identified customer needs, ensuring that each need is addressed and satisfied. We measure how long it takes users to find a parking space, how clear and transparent the pricing adjustments are, and the availability of different payment options. We also track how clean and well-maintained the parking facilities are, the success rate of reservation attempts, and how quickly customer support responds to inquiries. Additionally, we monitor the speed of the lifts, wait times during busy periods, and ensure the structure can safely accommodate different types of vehicles. Response times for emergencies and how user-friendly the automated parking system is are also measured to ensure the overall experience is as smooth and secure as possible. These metrics will ensure that our system aligns with customer requirements and improve the overall parking experience.

Needs to Metrics List:

Metrics Needs	Average time to locate parking spot with real-time updates	Average parking cost per hour	Transparency score of pricing changes	Payment methods available	Cleanliness and maintenance rating of amenities	Reservation success rate	Availability of customer support channels	Response time for customer support queries	Safety compliance for accommodating large vehicles	Elevator speed	Elevator wait time during peak hours	Number of lifts available during peak times	Response time for emergency assistance	Ease of use for automated parking solutions	Alert notification time for lift malfunction	Time to park and exit structure based on signage	Fully explained and clear closing times
Ability to locate parking within 2-3 minutes	x																
An affordable parking solution		x															
A smartphone app that offers up-to-date information about parking costs and availability in real time	x																
Explicit explanation of changing prices according on location, events, and time of day			x														
Convenient payment options, including				x													

mobile payments, without hidden fees																	
Parking buildings should provide clean, well-maintained accessible amenities and elevators					x												
Possibility of making reservations ahead of time, which lessens the anxiety of rushing to find a spot						x											
Availability of customer support for parking issues at any time of the day							x	x									
Parking spots made to safely accommodate larger and regular cars without posing a risk of damage									x								
In parking structures, lifts should run as quickly as possible to reduce wait times and guarantee that levels may be										x	x						

accessed quickly.																	
To accommodate heavy traffic, larger parking structures should have many lifts available so that no one needs to wait for a lift for very long											x						
Access to emergency assistance in parking lots and structures, such as call boxes or staff												x					
Automated parking solutions that are simple to operate and comprehend and optimize both space and convenience													x				
Notify customers immediately through signage and a mobile app alert about the elevator's status and estimated repair time incase of malfunction														x			

Easy to locate structure or lot with visible signage																x	
Clear explanation of closing and opening times																x	x

Benchmark Against Metrics:
Known competitors in the space:

a. Park Plus, Westfalia, and Wohr - These companies install automated parking systems, parking lifts, multi-level car stackers, and custom garage solutions. The goal of these companies is to park more cars in less space. They are expensive to install and expensive for the consumer.
    i. Evaluation score: 2
b. Parking management (LAZ Parking) - Implementation of a management company that simplifies parking and can use space more efficiently and optimally. LAZ may also come with its own dedicated app depending on location.
    i. Evaluation score: 4
c. Standard parking garage - Probably the main competitor for a smart solution system that can increase the number of parking spaces while keeping costs low and convince high. They are typically dirty, overcrowded, and not efficient.
    i. Evaluation score: 2
d. Parking meter - Street parking is a common way for consumers to park. They are not secure and availability widely varies. You also have to be careful about parking tickets. One good thing about meters is typically their proximity to the consumer's destination.
    i. Evaluation Score: 2

Metric #	Need #s	Metric	Imp	Unit	Parking meter	Standard parking garage	Park Plus	Laz Parking
1	1, 2	Average time to locate parking spot	3	minutes	8-10	5-10	1-3	2-5
2	3	Transparency score of pricing changes	2	Scale (1-5)	4-5	2-3	4-5	4-5
3	4	Payment methods available	2	count	4	5	6	5
4	5	Cleanliness and maintenance rating of amenities	1	Scale (1-5)	1-2	2-4	5	4-5
5	6	Reservation success rate	2	%	0	60	100	80
6	7	Availability of customer support channels	3	count	3	5	5	5
7	8	Response time for customer support queries	3	minutes	5-IND	5-15	3-10	3-10
8	9,16	Safety compliance for accommodating large vehicles	2	scale	1	3	4	4
9	10	Elevator speed	3	m/s	NA	0.5-1	0.5-1.5	0.5-1
10	9	Elevator wait time during peak hours	2	minutes	NA	2-5	1-3	1-4
12	11	Response time for emergency assistance	3	seconds	NA	5-10	2-5	3-7
13	12	Ease of use for automated parking solutions	2	scale	NA	2	5	4
14	14	Fully explained and clear closing time	3	scale	2	3	5	3
15	15	Seamless exit and entry points	3	scale	5	4	3	3
16	17	Integration with public transportation	2	Minutes	5	8	15	10

Benchmark Against Needs

Need #	**NEEDS**	Imp	Parking meter	Standard parking garage	Park Plus	Laz Parking
1	Ability to locate parking within 2-3 minutes	3	*	***	*****	****
2	A smartphone app that offers up-to-date information about parking costs and availability in real time	2	*	**	***	**
3	Explicit explanation of changing prices according on location, events, and time of day	1	****	****	**	***
4	Convenient payment options, including mobile payments, without hidden fees	2	**	***	*****	***
5	Parking buildings should provide clean, well-maintained accessible amenities and elevators	2	*	**	*****	***
6	Possibility of making reservations ahead of time, which lessens the anxiety of rushing to find a spot	2	*	**	*****	***
7	Availability of customer support for parking issues at any time of the day	3	*	*	*****	**
8	Parking spots made to safely accommodate larger and regular cars without posing a risk of damage	2	*	**	**	**
9	In parking structures, lifts should run as quickly as possible to reduce wait times and guarantee that levels may be accessed quickly.	3	NA	*	*****	***
10	To accommodate heavy traffic, larger parking structures should fast lifts available so that no one needs to wait for a lift for very long	3	NA	**	*****	***
11	Access to emergency assistance in parking lots and structures, such as call boxes or staff	3	*	**	*****	***
12	Automated parking solutions that are simple to operate and comprehend and optimize both space and convenience	2	***	**	****	***
13	Notify customers immediately through signage and a mobile app alert about the elevator's status and estimated repair time incase of malfunction	3	*	*	*****	***
14	Time to reach a spot and time to exit/enter	3	***	**	****	**

15	Fully explained and clear closing time	3	*	**	***	**

After benchmarking against the needs and metrics, LAZ Parking and Park Plus won in efficiency scores, cleanliness scores, and optimization scores but lost in pricing scores. These options are too expensive for the average customer who typically spends less than 2 hours in a commercial parking structure. The benchmarks highlighted the different companies and their strategies. A parking meter is not secure, not always available, and not always clear in terms of parking signage but are quick to get in and out of. A standard parking structure is just not good enough for the consumer. They are dirty, poorly lit, not always secure, not clearly indicated, and not well staffed. LAZ offers a good combination of a normal parking structure and ParkPlus but their lack of a uniform app is disappointing. It is apparent that an app-centered parking structure with the ability to use a ticket machine for those who are tech “limited” is the proper way to go. Additionally, to keep costs down, it is important that the structure offers both a vertically integrated car lift system and a normal distribution of parking spots separated by car type (suv, compact, large). To be successful and efficient a reservation system with an estimation of availability is needed and can outweigh the consumers who refuse to use an app or refuse to use the lifts. Our consumer prioritizes efficiency, quickness, affordability, and space as their primary needs.

Targets and Requirements

Metric	**Units**	**Marginal Value (Target Value)**	**Ideal Value (Required value)**
Average time to locate parking spot	minutes	<3	<2
Payment methods available	count	>2	3
Response time for customer support queries	minutes	<5	<3
Transparency score of pricing changes	scale	>3	5
Cleanliness and maintenance rating	scale	>3	5
Reservation success rate	%	>80%	90%
Safety compliance for large vehicles	scale	>3	5
Elevator wait time during peak hours	minutes	<3	<2
Speed of lifts	m/s	2	0.1
Response time for emergency assistance	seconds	<60	<30
Alert notification time	seconds	<60	<30

for lift malfunction			
Parking space width	meters	2.4	2.5
Clear height for large vehicles	meters	2.1	2.3
Turning radius for vehicle entry/exit	meters	5.5	6

Functional Design

Problem Abstraction

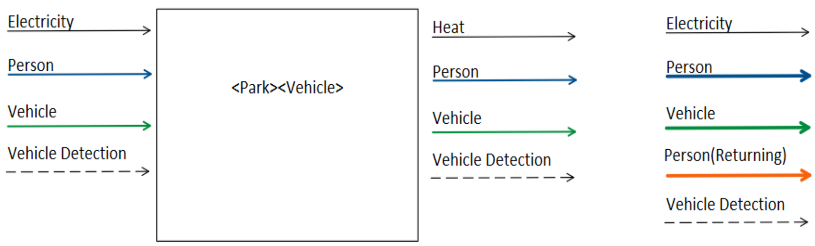
To address the most critical aspects of the problem, problem abstraction is employed to streamline the design process by eliminating unnecessary details. This approach enables designers to simplify, generalize, and prioritize the essential components of the problem. The EMS diagram aids in identifying the core functions of the solution and helps uncover the trends within the problem that can guide potential solutions. The benefits of this process include a clearer, more concise understanding of the problem in its most fundamental form. The EMS digram displays how energy, mass, and signal flow in our solution.

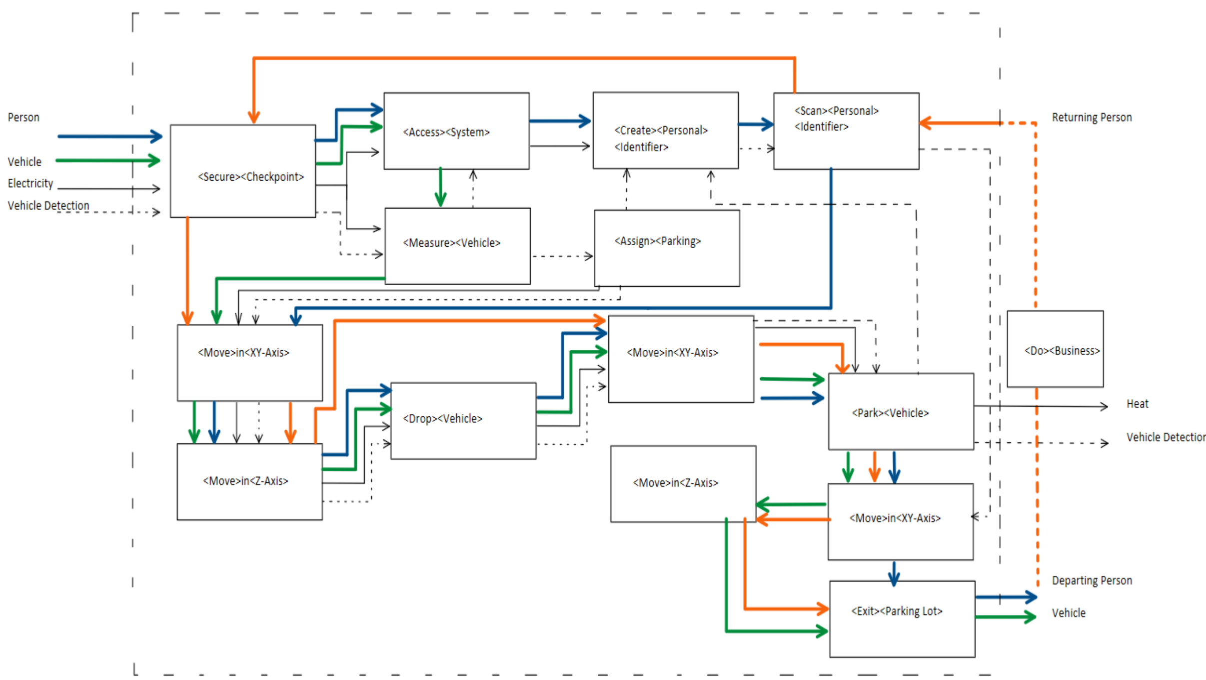
EMS

	Setup	Usage	Wrapping up
Energy	Store energy Convert energy Transfer energy Apply Energy	Electrical energy to cameras, lights, sensors - Secure checkpoint Mechanical Energy to motors, lift, gate Energy to scan vehicle and dimension it Energy to access system (app, pay booth)	Energy losses - Friction from lift - Losses from components (Heat) - Mechanical losses - Malfunction or misinput
Mass	Person Vehicle Lift	- Move person - Person exits vehicle and lot - Move vehicle through secure entry - Move vehicle to lift - Park vehicle Move entry lift	- Person returns to collect vehicle - Vehicle moves down exit lift - Move exit lift - Person exits structure with vehicle
Signal	Send parking location signal Send secure entry signal Send identification signal	Transmit data to/from cameras, sensors, and processors Process signals to generate output	Receive parking location signal on app Receive secure entry signal (allows you to enter) Receive identification data

	Send “space occupied” signal		

Function Structure Diagram





Conceptual Design

Concept Combination Table

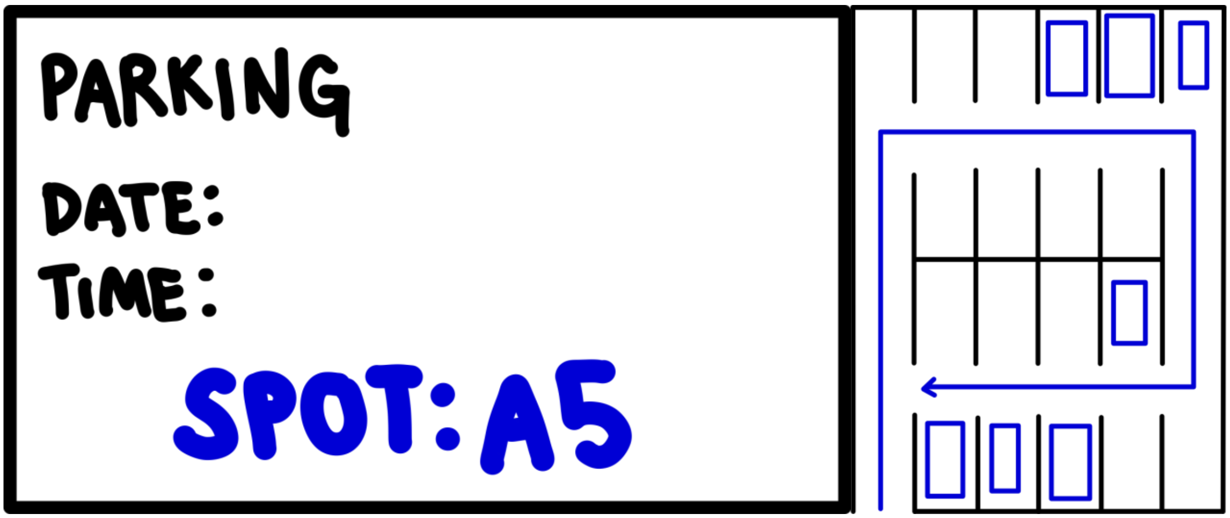
Functions	Option 1	Option 2	Option 3
Secure Checkpoint	Security Guards (3) (5)	CCTV (2) (4)	Emergency Stations (1)

Access System	App (2) (4)	Security Booth (1) (3)	RFID Card (5)
Create Personal Identifier	QR Code (2) (4)	Ticket (1) (3)	NFC Tag (5)
Scan Personal Identifier	QR Code Scanner (2) (4)	Manual Input (1) (3)	RFID Scanner (5)
Measure Vehicle	Sensors (3)	Camera (2) (4)	Manual Input (1) (5)
Assign Parking	Security Computer (1) (3)	App (2) (5)	AI System (4)
Move Vehicle (X-Y)	Wheels (1) (3) (5)	Conveyor System (2) (4)	
Move Vehicle (Z)	Lift (2) (4) (5)	Ramp (1) (3)	
Drop Vehicle	Valet (3)	Self (1) (5)	Automated (2) (4)
Move Vehicle (X-Y)	Wheels (1) (3) (5)	Conveyor System (2) (4)	
Park Vehicle	Valet (3)	Self (1) (5)	Automated (2) (4)
Move Vehicle (X-Y)	Wheels (1) (3) (5)	Conveyor System (2) (4)	
Move Vehicle (Z)	Lift (2) (4) (5)	Ramp (1) (3)	
Exit Parking Lot	Valet (3)	Self (1) (5)	Automated (2) (4)
To Business	Elevator (2) (5)	Escalator (3) (4)	Stairs (1)

Design Variants Generation

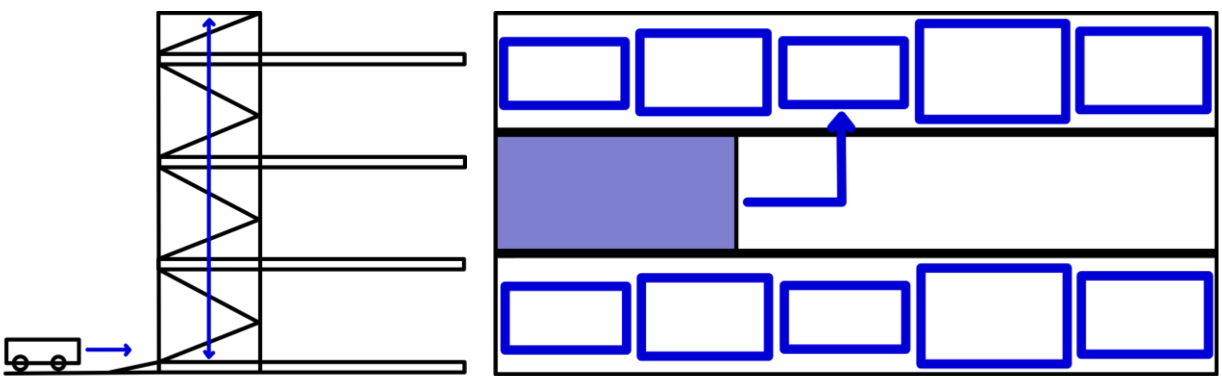
Design 1: Low-Cost Option

This design emphasizes simplicity and cost-effectiveness, utilizing basic manual systems such as security booths, tickets, and manual input for scanning, alongside self parking and no automation.



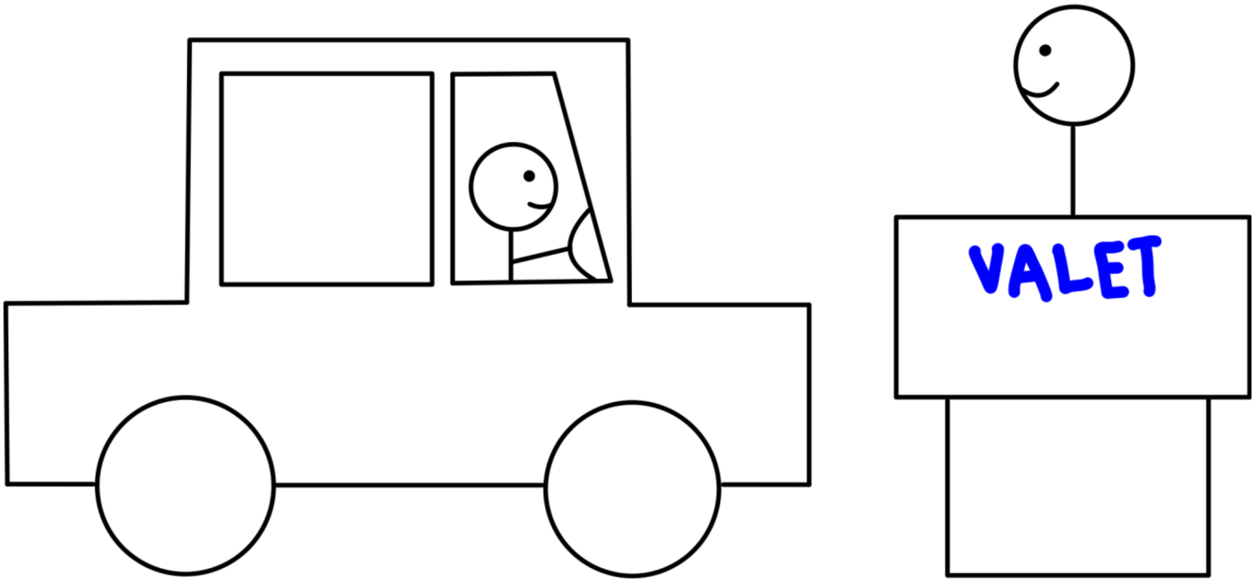
Design 2: Fully-Automated Option

This design is tailored for complete automation. It leverages cameras, apps, QR codes, algorithms, and conveyor belts, with fully automated parking and retrieval processes, minimizing human interaction.



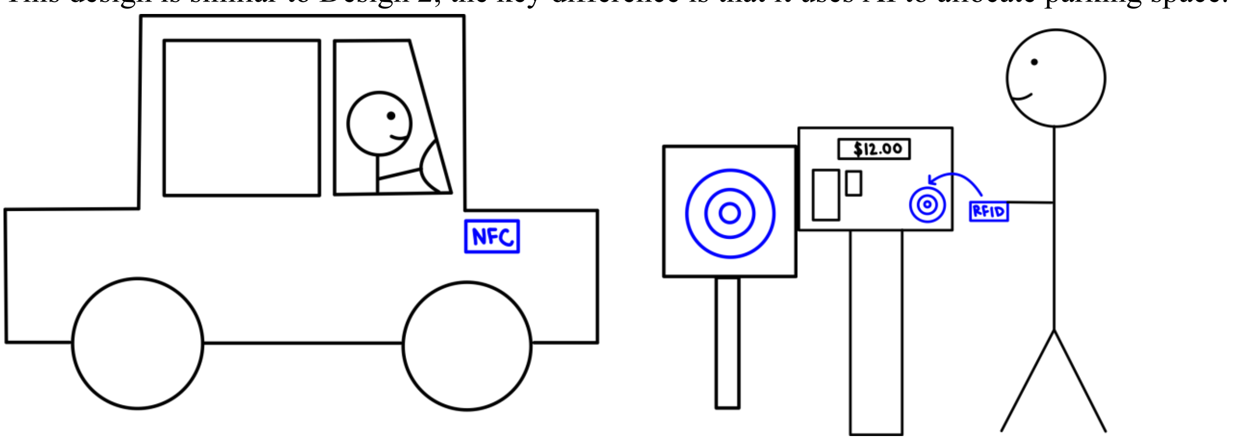
Design 3: Labor Intensive Option

This design prioritizes service-driven features with security guards, security booths, and valet services. It caters to a user-friendly but labor-intensive experience.



Design 4: AI Powered Autonomous Option

This design is similar to Design 2, the key difference is that it uses AI to allocate parking space.



Design 5: Long Term Use Option

This design focuses on durability, targeted for repeated long-term uses, such as in an apartment complex. It incorporates security guards, RFID cards, and lifts, ensuring ease of use and scalability over extended periods, suitable for sustained operation.

Concept Evaluation

Feasibility and TRL

Design	Name	TRL	Feasibility
1	Low-Cost	9	High. Minimal infrastructure, manual management of parking, and low technological reliance make it cost-efficient and simple. Fully operational in existing low-tech environments with no development needed.
2	Fully Automated	6	Moderate. Requires advanced conveyor/lift systems and integration of cameras or sensors for automation. Proven in pilot deployments but needs broader operational validation.
3	Labor Intensive	9	High, as it depends on readily available labor and basic tools for valet services. However, labor cost and reliability may vary by region.
4	Fully Automated + AI	5	Moderate, as AI integration with automation is cutting-edge but still evolving. High cost and the complexity of implementation might limit feasibility.
5	Long-Term	8	High. Employs NFC/RFID-based access and payment systems for seamless operations over time.

Evaluation of Variants

Concept Screening Matrix

Selection Criteria	Design					
	REF	1	2	3	4	5
Average time to locate parking spot with real-time updates	0	-1	1	0	1	0
Average parking cost per hour	0	1	-1	0	-1	0
Transparency of pricing changes	0	0	1	0	1	0
Availability of multiple payment methods	0	-1	1	0	1	1
Cleanliness and maintenance of amenities	0	0	1	1	1	1
Reservation success rate	0	0	1	0	1	1
Availability and response time of customer support	0	0	0	1	0	1
Safety compliance for accommodating larger vehicles	0	0	1	0	1	1
Speed and wait time during peak hours	0	1	1	-1	1	1
Response time for emergency assistance	0	0	0	1	0	1
Ease of use	0	0	1	-1	1	0

Alert notification time for malfunction	0	0	1	-1	1	1
Time to reach a spot and exit structure efficiently	0	0	1	0	1	0
Clear explanation of closing times	0	1	1	1	1	1
Net	-	1	10	1	10	9
Rank	-	4	1	5	1	3

Based on the concept scoring matrix, Designs 2 and 4 performed equally best, while Design 5 may outperform Design 4 in terms of "average time to locate parking spot with *real-time updates*, *speed and wait time during peak hours*, and *time to reach a spot and exit structure efficiently* by very slight margins, the additional cost is not worth the potential benefits. Thus, moving forward to the concept scoring matrix, Designs 2 and 5 will be evaluated, in addition to a Design which combines aspects of Design 1 and 2, combining cost-saving aspects of Design 1 with certain automation and technology features of Design 2.

Concept Scoring Matrix

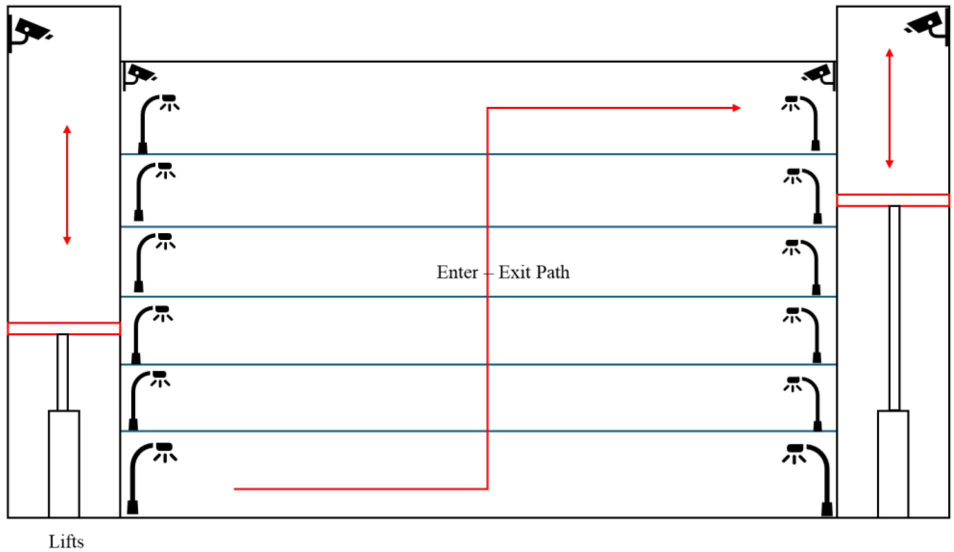
Selection Criteria	**Weight**	**Design**		
		2	**5**	**1+2**
Average time to locate parking spot with real-time updates	0.1	5	3	5
Average parking cost per hour	0.1	1	3	3
Transparency of pricing changes	0.05	5	3	5
Availability of multiple payment methods	0.06	5	5	5
Cleanliness and maintenance of amenities	0.04	5	5	5
Reservation success rate	0.08	5	5	5
Availability and response time of customer support	0.06	3	5	5
Safety compliance for accommodating larger vehicles	0.05	5	5	5
Speed and wait time during peak hours	0.1	5	5	5
Response time for emergency assistance	0.07	3	5	3
Ease of use	0.09	5	3	5
Alert notification time for malfunction	0.07	5	5	5
Time to reach a spot and exit structure efficiently	0.08	5	3	5
Clear explanation of closing times	0.05	5	5	5
Total Score		4.34	4.16	4.66

Selection Criteria	Weight	Design		
		2	**5**	**1+2**
Average time to locate parking spot with real-time updates	0.1	5	3	5
Average parking cost per hour	0.1	1	3	3
Transparency of pricing changes	0.05	5	3	5
Availability of multiple payment methods	0.06	5	5	5
Cleanliness and maintenance of amenities	0.04	5	5	5
Reservation success rate	0.08	5	5	5
Availability and response time of customer support	0.06	3	5	5
Safety compliance for accommodating larger vehicles	0.05	5	5	5
Speed and wait time during peak hours	0.1	5	5	5
Response time for emergency assistance	0.07	3	5	3
Ease of use	0.09	5	3	5
Alert notification time for malfunction	0.07	5	5	5
Time to reach a spot and exit structure efficiently	0.08	5	3	5
Clear explanation of closing times	0.05	5	5	5
Rank		2	3	1

Selected Variant

Design 1 + 2

- Security Guards + CCTV
- App/Printed Ticket
- QR Code Scanner
- Camera + Sensors
- App Algorithm Allocation
- Self-Driving/Drop/Park/Exit
- Lifts
- Elevators + Stairs



Embodiment Design

Rules and Principles
Clarity of Function:

- Ensure that the design fulfills its intended function effectively.
- Define the function requirements clearly and assess them against the final product.

Modularity:

- Break the design into distinct subsystems or chunks that can be independently developed and evaluated.
- Ensure modularity to facilitate repairs, upgrades, and scalability.

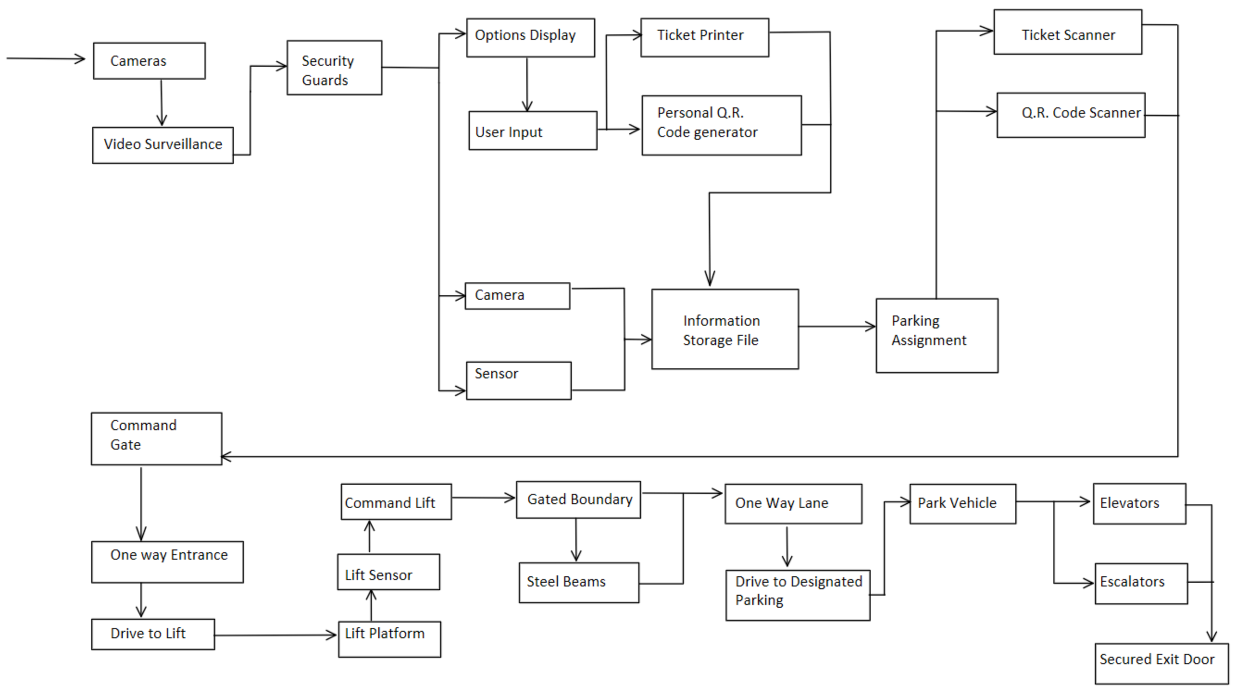
Consideration of Robustness:

- Account for noise factors such as environmental conditions, material variability, and aging effects.
- Design to ensure consistent performance under varying real-world conditions.

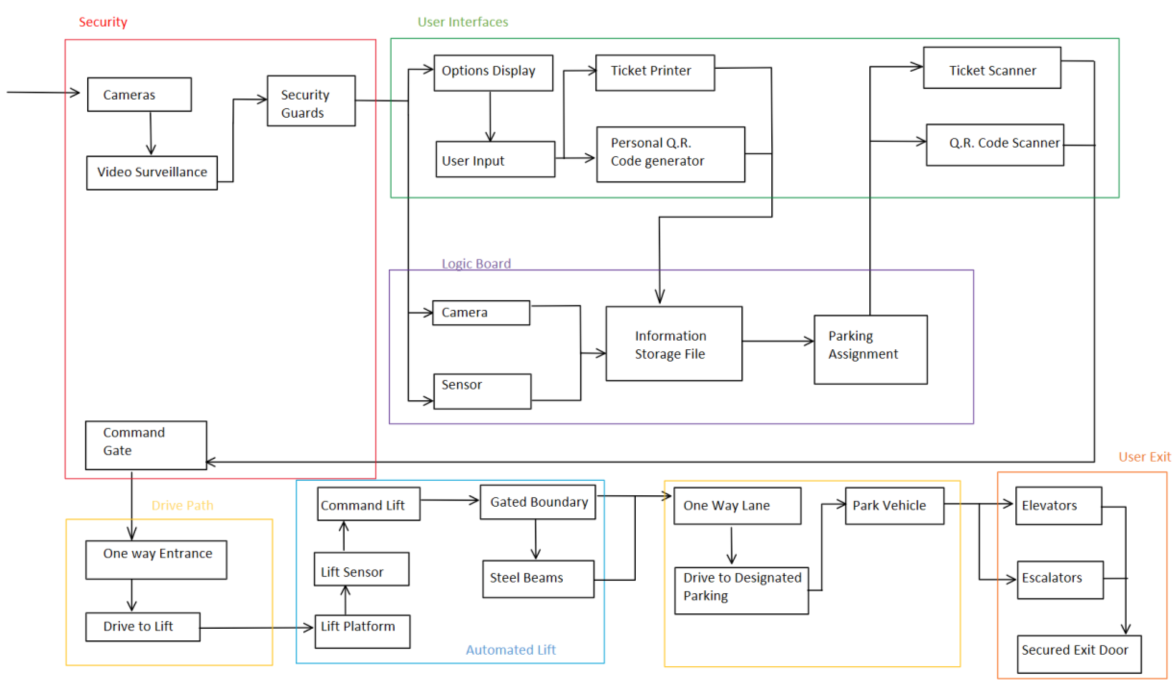
Cost Effectiveness:

- Evaluate the cost of materials, production, and labor early in the design process.
- Balance between high-quality outputs and affordable production processes.

Schematic



Clusters



Major Interfaces Among Chunks

Security Chunk

Subsystem	Interaction
Cameras	Placed in strategic locations to capture drivers, passengers and vehicle characteristics with included time and date stamp, this subsystem will send captured recordings to the information system with correspondence to the user's updated personal identifier.
Video Surveillance	Recordings captured by cameras will be live streamed to a security room where they will be monitored 24/7.
Security Guards	In addition to video surveillance, security guards will be present to uphold safety rules and regulations to protect all persons and property within the structure.
Gate	During entry, upon completion of necessary operations (measurements, captures, and tickets/QR codes), the ISF will send a signal to open the gate to allow a vehicle to pass.

User Interfaces Chunk

Subsystem	Interaction
Options Display	Prior to entry, the user console provided for customers will offer the options for parking at a flat rate for 8+ hours or an hourly rate. Information will then be uploaded to the Information Storage File (ISF)
User input	Allows the user to confirm their vehicle's license plate number and input a phone number for communications via text messaging. User inputs will be recorded and stored in ISF
Ticket printer	Prints personal identifier ticket for users who prefer not to use a cell phone.

Personal Q.R. code Generator	Creates a Q.R. code that can be scanned using a camera phone. Once scanned, information is uploaded to the user's preferred method of app or web page.
Ticket scanner	Users will be required to scan tickets for entrance and for lift operation. Ticket scans for reentry will be recorded within ISF.
Q.R. Code Scanner	Users will be required to scan QR code for entrance and for lift operations. QR scans for reentry will be recorded within ISF.

Logic Chunk

Subsystem	Interaction
Cameras	Cameras placed in locations for capturing license plate numbers and will be sent to the information system with correspondence to user's personal identification.
Sensors	Sensors will obtain the measurements of the vehicle and send results to the ISF.
Information Storage File	Electronic file storage that will contain all vehicle and user information, as well as assigned parking location, dates and times, total parking time, and pricing. Information Storage File is only available to be accessed by the appropriate staff.
Parking Assignment	Upon completion of measurements, the ISF will then use a logic system to determine which is the most efficient parking location. This information will then be displayed to the user during their ticket/QR code generation.

Drive Path Chunk

Subsystem	Interaction
One-way entrance and lanes	All drive paths will only allow movement in one direction to prevent confusion and congestion within structure.

Drive to lift	Following the drive path will lead user to the lift
Drive to designated parking	Parking spaces will be identifiable via space numbers
Park Vehicle	Once parked, the system will note that the space has been filled and remove it from the system to prevent double bookings.

Automated Lift Chunk

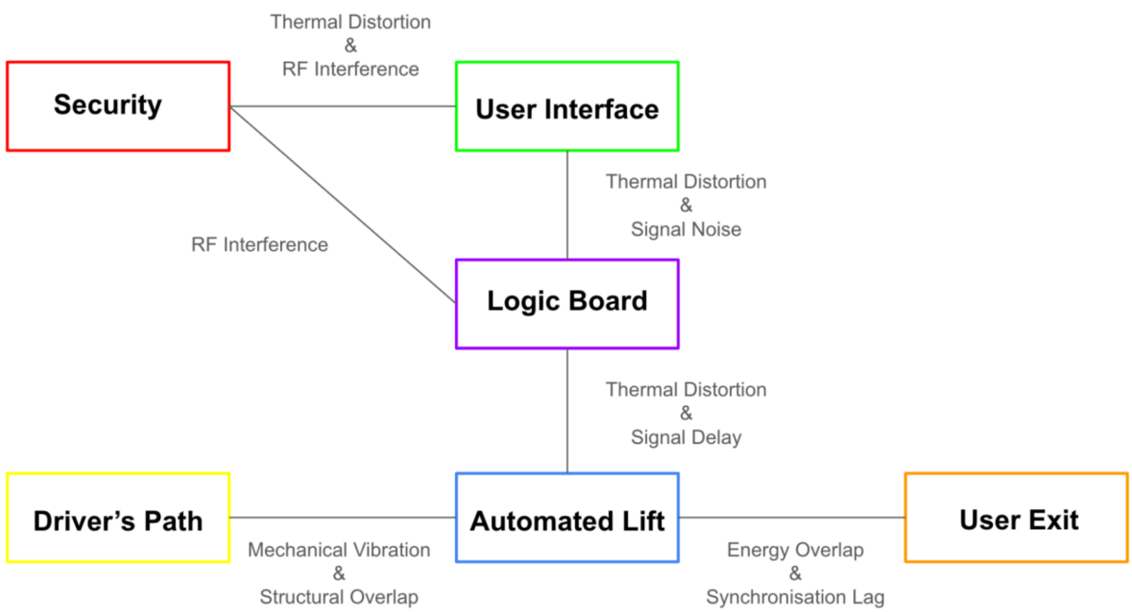
Subsystem	Interaction
Lift Platform	Platform where the user’s vehicle will be lifted to the appropriate parking level
Lift Sensor	Sensor which displays to the user whether their vehicle is correctly parked on platform or if it requires adjustments. Sends a signal to the lift to stop/start operations.
Command lift	Receives signal from the lift sensor and starts/stops accordingly
Gated boundary	Receives signal from the lift sensor to raise/lower gated boundary to prevent or allow movement.
Steel beams	Receives no signal but provides 4 pillars of support to the lift.

User Exit Chunk

Subsystem	Interaction
Elevators	Receives user input to raise/lower elevator to user’s desired level.
Escalators	Escalators going up and down.
Secured Exit Door	Doors locked at all times allowing exit, but no reentry until a ticket or QR code is scanned.

Interfaces and Interactions

Incidental Interaction



There are incidental interactions between the Security Cluster and the User Interfaces Cluster, such as RF interference, where wireless signals from security cameras can interfere with sensitive components like ticket scanners or QR code readers, and thermal impact, where extended camera operation generates heat that may affect nearby displays or printers; signal lag from delayed video data can interfere with real-time processing, and cross-talk from camera data wires introduces electrical interference; and interactions between the User Interfaces Cluster and the Logic Board Cluster, such as thermal overlap, where heat from scanners and printers raises the operating temperature of the logic board, and signal noise, where simultaneous inputs result in processing errors.

Challenges for the Drive Path Cluster and Automated Lift Cluster include structural overlap that can cause misalignment because of shared dependencies and mechanical vibrations from vehicle movement that reduce lift stability. Vehicle location is impacted by lift sensor communication delays between the Automated Lift Cluster and the Logic Board Cluster, and the logic board's functionality may be impacted by lift heat thermal distortion. Finally, the User Exit Cluster and Automated Lift Cluster cope with energy overlap, where excessive energy consumption slows lift performance, and synchronization lag, where delays in coordination disturb vehicle retrieval, potentially irritating users.

All Interfaces Among Chunks

A. Security

1. Power to cameras, monitors, and guard shack
   - Energy Flow: Energy derived from solar panels and the city energy grid.
     i. Geometric Constraints: Cameras position must be in an area without blind spots, they must be secure to a wall and must have power going to it at all time
2. Cameras to monitors
   - Signal Flow: Live stream video uploaded to guard shack monitors.
   - Signal Flow: Recordings stored in Information Storage File.
   - Geometric Constraints: The camera-to-monitor connection should be stable, have a good internet/system connection, and have minimal obstructions to get good surveillance
3. Information Storage File to gate
   - Signal Flow: Signal received from ISF to gate when required information has been gathered and stored.
   - Geometric Constraints: Storage file and gate communication systems need to be close together to minimize network or system latency. Constrained by bit rate and system connection

B. User Interfaces

1. Power supply to user console
   - Energy Flow: Energy derived from solar panels and city energy grid to console.
   - Geometric Constraints: Energy is constrained by the amount allotted, how much can be stored locally, and how efficiently it can transfer to the other systems
2. User to Information Storage File
   - Signal Flow: Options displayed and selected by user are sent to and stored in ISF.
   - Signal Flow: ISF information sent to user console.
   - Geometric Constraints: Latency and connection derive how fast the user can see the information. Optimal latency is within a few seconds of an open spot, reservation request, or open lift spot
3. Ticket Printer/QR code generator
   - Energy Flow: Energy derived from solar panels and city energy grid to printer/console.
   - Signal Flow: Information signal received from ISF to printer/QR code generator.
   - Mass Flow: Print ticket/generate QR code with all relevant information.
   - Geometric Constraints: Printers must be installed within arm's reach of the user and must be durable. QR codes are constrained by power and system latency to display the information to the user within seconds

C. Logic Board

1. Power supply to cameras, sensors, and ISF database
    - Energy Flow: Energy derived from solar panels and city energy grid.
    - Geometric Constraints: Logic boards should be located next to the system hub, power output to cameras, and energy constraints from the grid
2. Cameras and sensors to ISF
    - Signal Flow: Images of captured license plate to ISF.
    - Signal Flow: Measurements taken of vehicle to ISF.
    - Geometric Constraints: Sensors must be installed at entry points, and within the lot with unobstructed views of the vehicle to read dimensions and license plates
3. ISF to parking assignment
    - Energy Flow: Energy derived from solar panels and city energy grid.
    - Signal Flow: Measurements processed and sent to parking assignment system.
    - Signal Flow: Parking assignment signal returned to ISF.
    - Geometric Constraints: The ISF system need to process data fast and efficiently, they are constrained by latency and computer processing power
4. ISF to lift system
    - Signal Flow: Signal sent to lift system allowing it to rise to the appropriate level.
    - Geometric Constraints: Lift system and ISF must maintain a direct line of communication, with low latency, high sampling rate, and accurate inputs
5. ISF to user console
    - Signal Flow: Parking assignment signal sent to user console.
    - Geometric Constraints: Broadband connectivity constraint, the user needs to be able to quickly know where they have to park

D. Drive Path

1. One-way lanes and entrance
    - Mass Flow: User drives vehicle to lifts or parking spaces.
    - Geometric Constraints: Physical constraints, lanes must be wide and accommodate standard and larger vehicles, traffic needs to flow continuously, and user needs to see/know where they are going (signage, lights)

E. Automated Lift

1. Lift sensors
    - Energy Flow: Energy derived from solar panels and city energy grid to lift.
    - Signal Flow: Signal sent to user console for parking corrections.
    - Signal Flow: Signal sent to motor, gated boundaries, and lift system to begin operations.

- Geometric Constraints: Sensors need to be placed where they can visually see the car at all times, constrained by allotted energy from the city, latency of the camera system, and the resolution of the camera (how far can it see)

2. Lift system
    - Energy Flow: Energy derived from solar panels and city energy grid to lift system.
    - Energy Flow: Returns the lift to the ground floor.
    - Mass Flow: Transfers user and vehicle to designated parking level/exit.
    - Geometric Constraints: Physical constraints, lifts should be able to accommodate different heights and widths of vehicles, account for energy losses from the transferring of energy to separate systems, and need to account for the amount of time it takes to lift a vehicle

3. Gated Boundary
    - Signal Flow: Receives signal from lift sensors to raise/lower gated boundary.
    - Mass Flow: Gates rise to prevent vehicle operation while lift is in motion.
    - Mass Flow: Gates lower to allow vehicle to proceed.
    - Geometric Constraints: Physical gate dimensions, speed of the gate lowering and rising, durability of the gate, placement of where the gate goes is also a constraint
4. Steel Beams
    - Mass Flow: Provides support to lift as it moves up/down.
    - Geometric Constraints: Beams must maintain a specification to handle the added weight of lifts, solar panels, and more cars than standard parking garages

F. User Exit

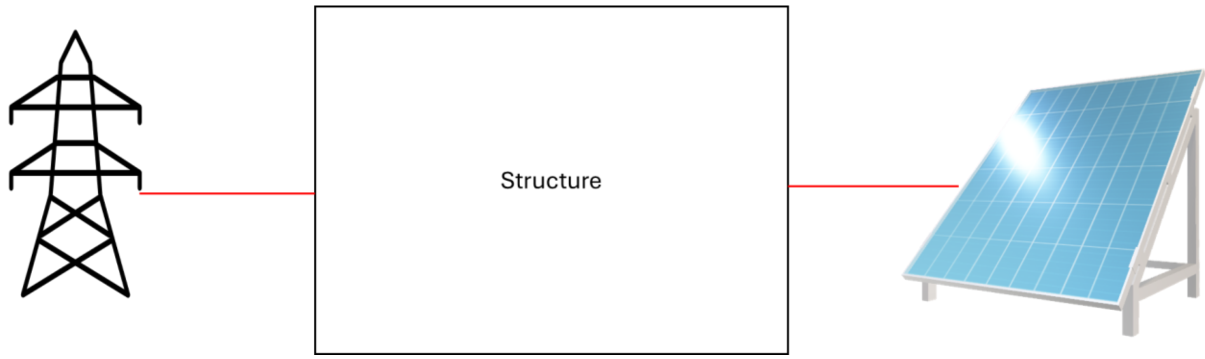
1. Elevators
    - Energy Flow: Energy derived from solar panels and city energy grid.
    - Signal Flow: Receives user input and rises/lowers to desired floor.
    - Mass Flow: Lifts/lowers persons to desired floor.
    - Geometric Constraints: Elevators need to be accommodating, constrained by speed and placement, elevators need special reinforcement materials to propagate and function, energy to the building is a constraint
2. Escalators
    - Energy Flow: Energy derived from solar panels and city energy grid.
    - Geometric Constraints: Escalators must be durable, constrained to certain parts of the structure, and have a power limit/constrain
3. Secured Exit Door
    - Energy Flow: Energy derived from solar panels and city energy grid.

- Signal Flow: Upon receiving a valid signal from ticket/QR scan, door unlocks to allow entry.
- Geometric Constraints: Doors need to be reinforced and secured, only accessible using a ticket or QR code

Major Interfaces Between System and its Environment

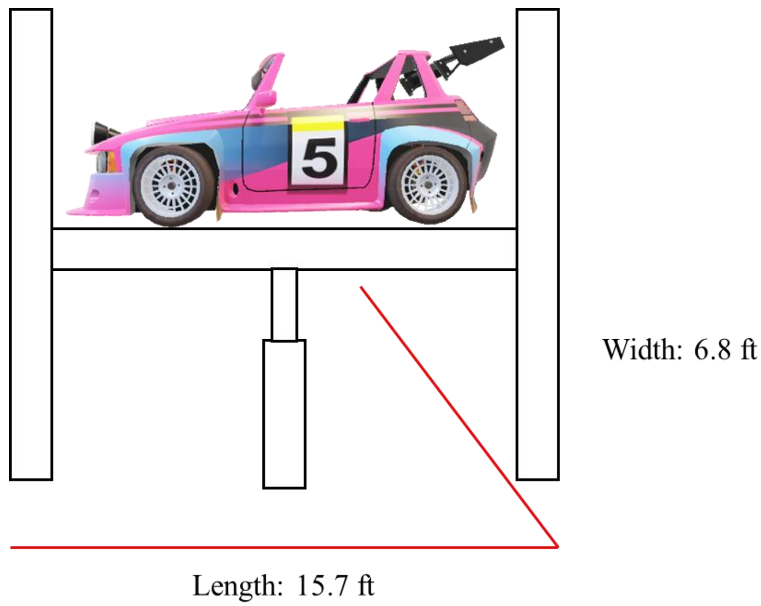
- User to parking structure
  1. Mass flow
  2. The user needs to successfully enter the parking structure and the system will proceed as normal if all boundaries are met (physical boundaries and payment)
  3. The user also interacts with the layout of the structure (how to reach the elevators, where the stairs are located, where the desk attendants are, etc…)
- User to park vehicle
  1. Mass flow
  2. The user directly enters/exits the vehicle and drives to the lift system
- User to App
  1. Mass flow (user input and interface to work)
  2. The app provides hourly rates and pricing information and is a direct interface between the system and the environment (the user)
  3. The user provides payment info through the app and receives the entry/exit tickets. The app is the way to enter or leave the parking structure system
- User to lift
  1. Mass flow
  2. The user drives onto the lift and interacts with the constraints of the lift plate
- Power grid to structure
  1. Energy flow
  2. Interface: the parking structure relies on external power to operate the lifts, cameras, lights, sensors, and data acquisition systems
  3. Interface: solar power and structure rely on each other to get extra energy to run all the electronic components
- External communication
  1. Signal flow
  2. Data exchange with external networks for monitoring, payments, and real-time updates
- Traffic management
  1. Signal flow
  2. Internal data exchange to optimize the system and parking efficiency within the structure

Sketch of Each Chunk

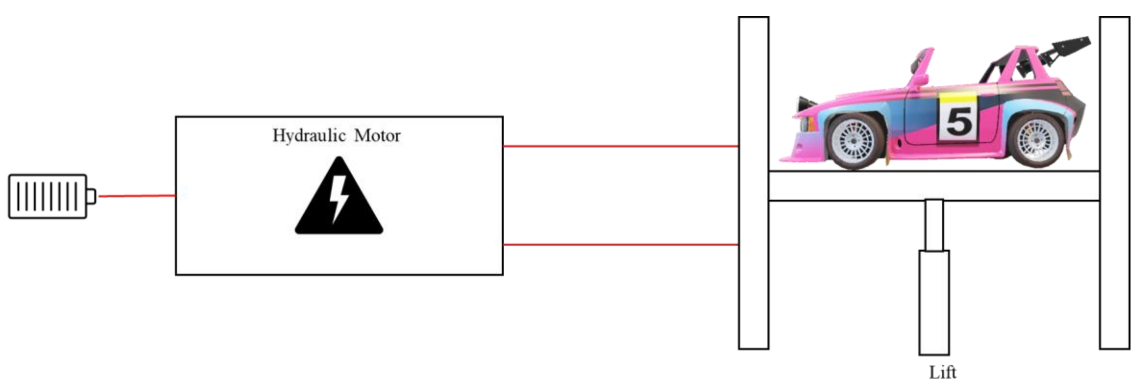


The structure needs to be properly powered. For instance, a 10,000-square-foot structure needs around 720 Kw per structure for lighting, ventilation, and security systems. Lifts consume roughly 96 Kw per day. Assuming the structure contains 2 heavy-duty lifts we need an additional 200 Kw per day. The solar panel array looks to reduce the energy consumption provided by the city and balance out the cost of operation.

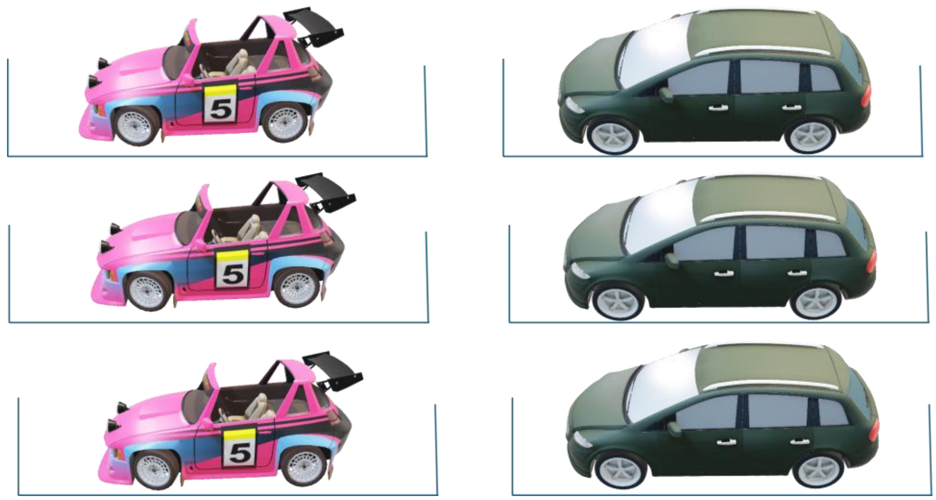
Vehicle registration is managed by a series of license plate reader cameras, along with surveillance cameras that can transmit data such as vehicle type, model, and color. This allows the system to efficiently sort and store vehicles based on their type, maximizing parking efficiency. The registration system is also synced with the app, providing users with concise information, including entry and exit tickets.



The lift system is located on the outside of the structure and will handle the majority of the work. The average vehicle weight is 4,904 lbs, and the lift will be rated to 7000 lbs to accommodate large vehicles and trucks. Additionally, the average vehicle length is 14.7 ft with a width of 6.8 ft. The lift is designed with an extra foot of space to accommodate larger vehicles. It is hydraulically powered for efficient operation.

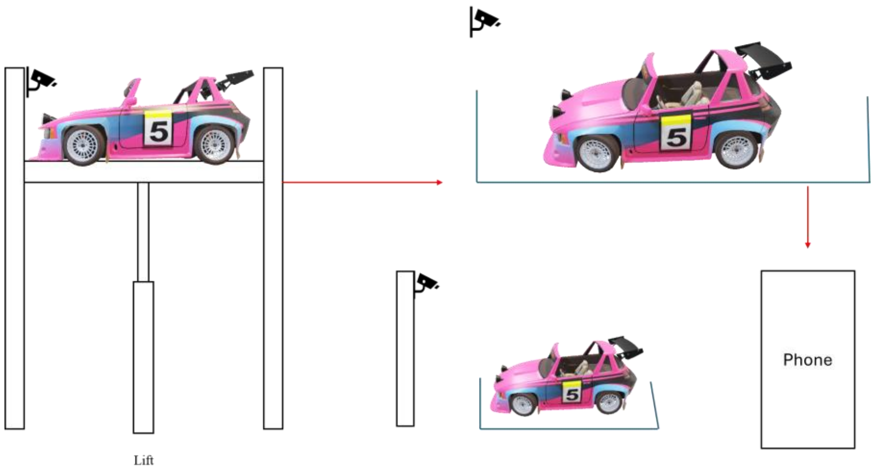


The hydraulic lift system is powered by motors integrated into the structure. Each lift has an estimated energy consumption of 100 kW per day. Currently, the design includes two main lifts to facilitate vehicle movement within the structure. The motors rely on a stable and reliable power source. These hydraulic motors are chosen for their reliability, energy efficiency, and ability to handle heavy loads. This is essential for a high-capacity parking system.

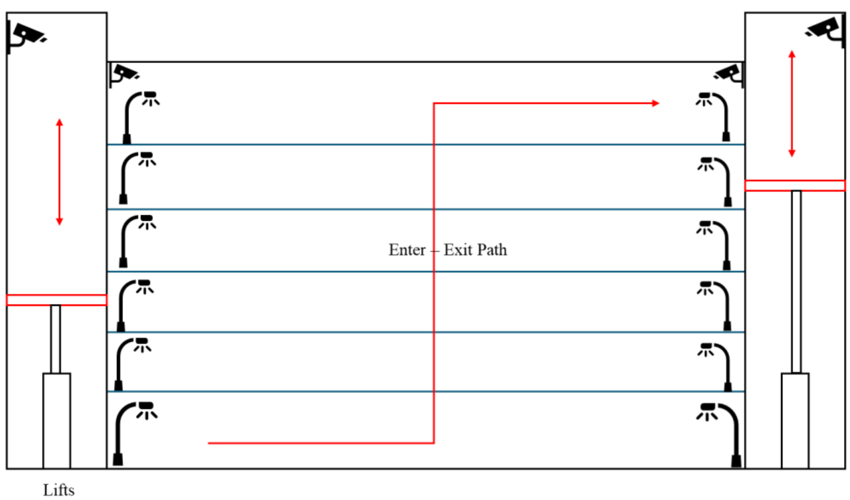


Within the parking structure, car storage is organized efficiently based on the size of the vehicle and the duration of the customer's stay. Vehicles that remain for longer durations will be placed further from exits or may even be double-parked, while vehicles parked for shorter durations will be closer to exits and not double-parked. Additionally, vehicles will be grouped by size, with boundary lines drawn to maximize space. By grouping SUVs and larger vehicles in one area and compact cars in another, potentially separated by floor, the overall capacity of the structure can increase by up to 20-25%, depending on layout and utilization.

The vehicle tracking system is a fully automated solution that provides vehicle registration, security, and real-time updates on the location of your car, all accessible via the app. The system addresses a key customer need: safety. To ensure vehicles are secure, multiple cameras are strategically placed throughout the structure, continuously monitoring and updating customers on the status of their vehicle. For efficiency, customers can pay and receive entry/exit tickets directly



on their phones. Accurate tracking and categorization of each vehicle are essential to ensure that ticket information and payment details are precise for every car.



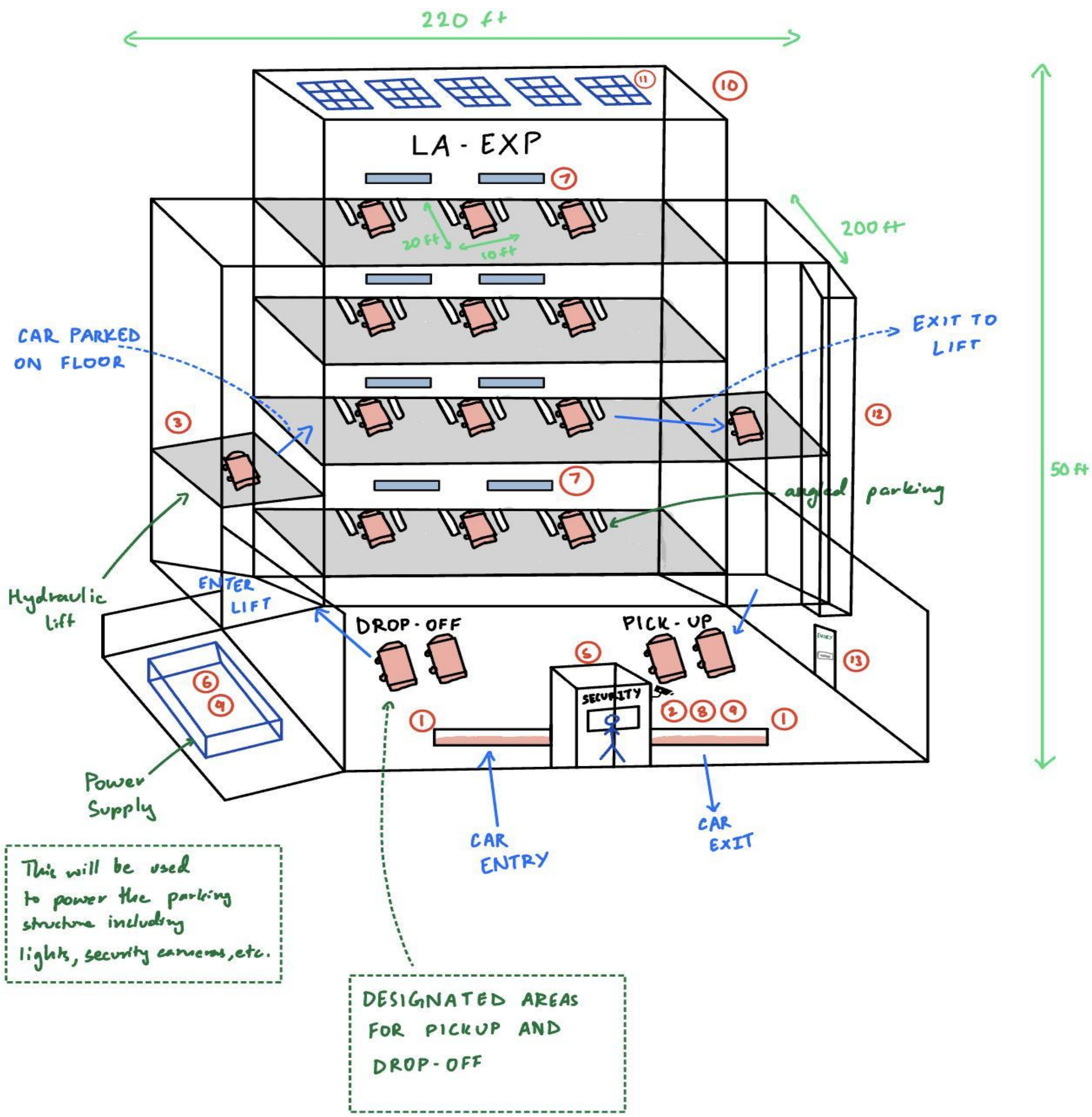
The parking structure is equipped with two hydraulic lift systems, efficient entry and exit paths, comprehensive lighting, surveillance cameras, elevators, stairways, and attendants. The design prioritizes efficiency, safety, and ease of navigation, with large signs and clear distinctions throughout the facility. These elements work together to ensure smooth vehicle movement, enhanced security, and convenient pedestrian access. The lifts optimize space and traffic flow, while cameras monitor and track vehicles, providing safety for both cars and customers. Lighting improves visibility and helps deter crime, and elevators offer easy access across the structure.

Layout Drawing

Based on the variant chosen, a detailed layout drawing was designed as shown in the figure below. As it can be seen in the figure, the car initially stops at the security booth where the vehicle is scanned and their personal identifier is checked. If the user has the app, they will scan their QR code, or a physical ticket is issued to them at the booth. In addition, they are assigned a parking spot based on the vehicle dimensions. The user then enters the parking lot into the "Drop-Off" zone where they wait for the hydraulic lift to take them to their designated floor and they can then park their car. Once their car is parked, they can leave the parking lot through elevators on the side and they can reenter the parking lot to retrieve their car using their personal identifier code.

The parking structure has dimensions of 220 ft x 50 ft and solar panels will be installed on the roof to supply power to the structure.

Parking Structure



Personal Identifier (App)

The image below shows how the personal identifier QR code will look like on the app along with all the details of the user.

Bill of Materials

Component	Unit Cost ($)	Quantity	Total Cost ($)
Entrance/Exit Gate	1500	2	3000
Vehicle Registration Camera	800	2	1600
Hydraulic Lift	5000	1	5000
User Interface (App Development)	20000	1	20000
Pay Booth	3000	3	9000
Generator	4000	1	4000
Parking Structure (Concrete)	100000	1	100000
Safe Park System	15000	1	15000
Power Supply (Solar Panel)	10000	1	10000
LED Tube Light	50	15	750
Electric Motor	1200	1	1200

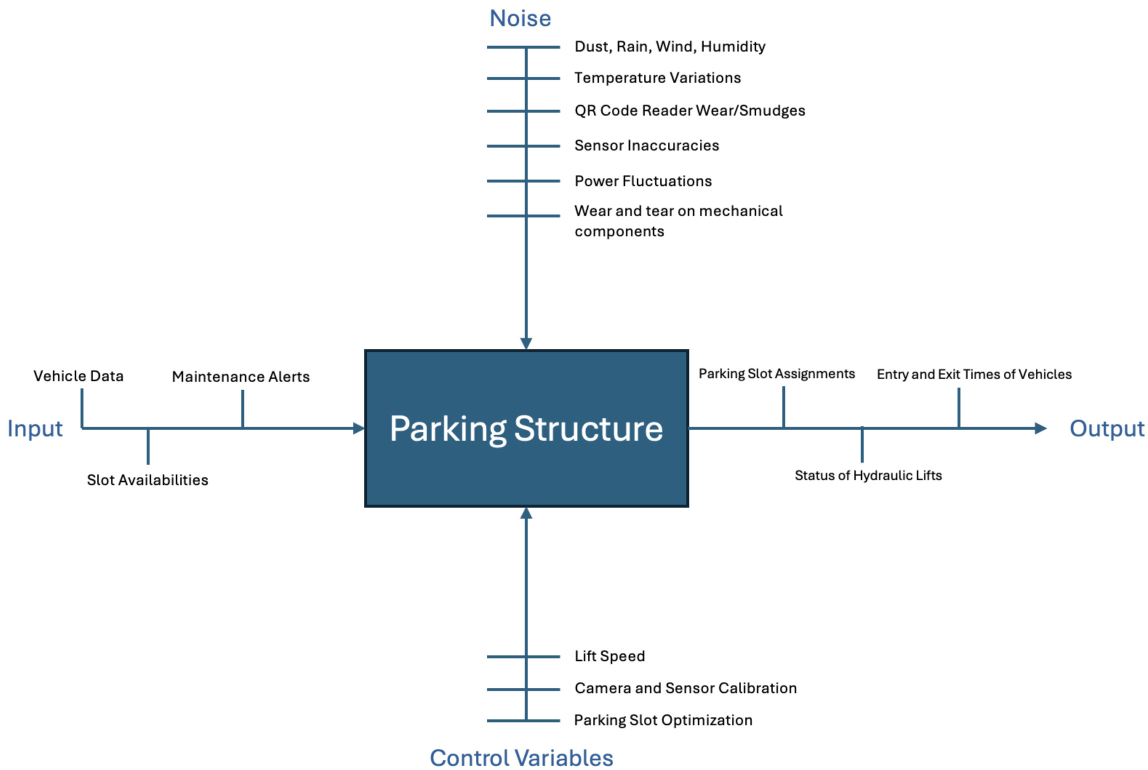
Product Evaluation

P-Diagrams of Major Subsystems

The P-diagram helps visualize the inputs, outputs, noise factors, and control variables associated with a product or process. For this project, two P-diagrams have been created: one for the parking structure and another for the user parking the vehicle.

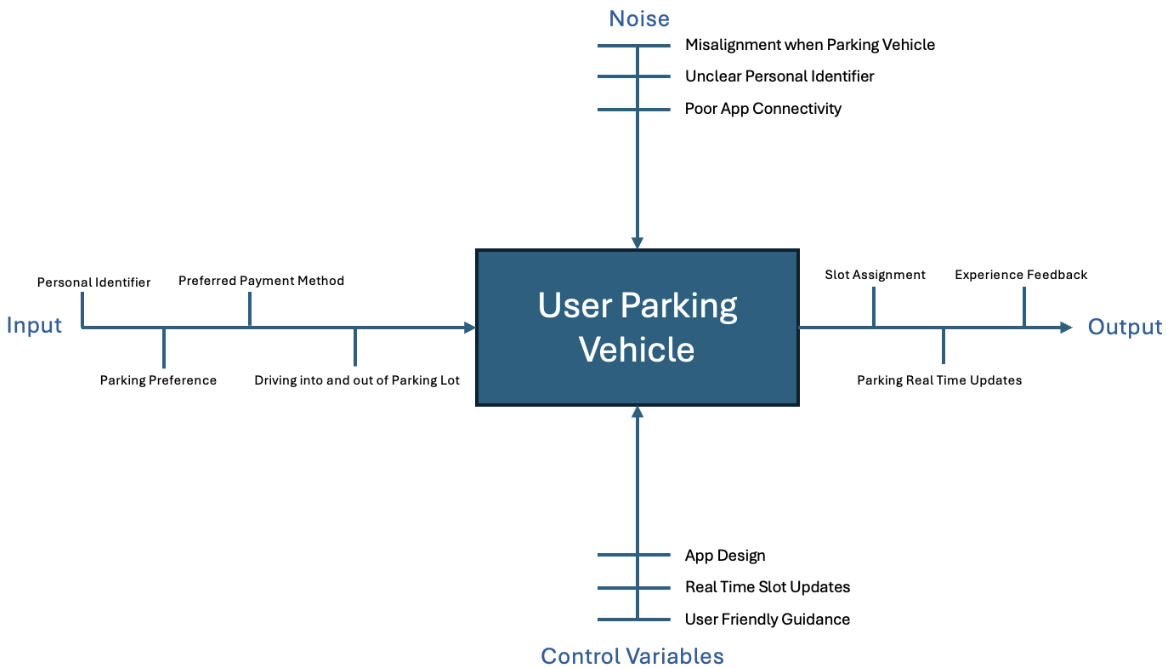
P-Diagram for Parking structure

For the parking structure, the security booth is where the significant amount of processing occurs. It receives the vehicle data and slot availabilities and assigns a parking slot to each new vehicle based upon its dimensions. It also keeps track of any maintenance requests and status of mechanical components such as the hydraulic lifts. Some of the noises that can be encountered include environmental conditions such as dust and rain, any inaccuracies with sensors, and power fluctuations within the structure. The variables that can be controlled within the structure include the lift speed, calibration of sensors, and optimization of parking slot availabilities.



P-diagram for the user parking the vehicle

The p-diagram for the user works hand-in-hand with that of the parking structure where the inputs include the user's personal identifier code, their preferred payment method, and their parking preference. They are then assigned a spot by the parking structure and they are allowed to drive to their parking spot. Some of the noises that can be encountered include misalignment when parking the vehicle, having an unclear personal identifier and poor app connectivity within the structure which can hinder the parking process. Some of the control variables include the app design to make it easier for the user to navigate, providing real time parking updates and providing user friendly guidance.



Performance Modeling/Simulation

Functional Evaluation

- **Secure Checkpoint**: Cameras and security guards meet safety and monitoring needs
- **Access System**: App and booths allow flexible access for users.
- **Personal Identifier Creation and Scanning**: QR code-based system ensures quick identification
- **Vehicle Measurement and Assignment**: Automated with cameras and sensors for precision.
- **Movement Mechanisms**: Drive and lift systems enable efficient vehicle handling.

Robustness and Reliability

- **Robustness**:
  - Cameras and sensors designed to work in various lighting and weather conditions.
  - QR scanners resistant to minor wear or smudges.
- **Reliability**:
  - Lift mechanisms require regular maintenance for consistent operation.
  - Elevators have redundancy measures to ensure user safety.

Detail Design

Use of Design for X

Design for Manufacturing (DFM)

Material Selection: The primary construction material for the parking structure will be concrete, selected for its high durability, strength, and cost-effectiveness in large-scale infrastructure projects. To align with modern sustainability goals, auxiliary components such as solar panels, LED lights, and other fixtures will be fabricated using eco-friendly and recyclable materials. These materials ensure long-term resilience, reduce environmental impact, and optimize the structure's lifecycle performance. Prefabricated modules for certain components will also be considered to streamline production and reduce waste.

Design for Assembly (DFA)

Ease of Installation: Components such as elevators, LED tube lights, and QR scanners will be engineered for rapid assembly using standardized fittings and fixtures. This approach minimizes on-site installation time and reduces labor costs. Modular designs for critical systems will enable easy integration into the structure, reducing the complexity of assembly processes.

Accessibility: Frequent maintenance items, such as vehicle registration cameras, parking sensors, and ticketing systems, will be strategically placed in easily accessible locations. This ensures that maintenance tasks can be performed quickly and efficiently, minimizing disruptions to operations and extending the lifespan of these components.

Design for Cost (DFC)

Optimize Costs: A cost-efficient balance will be maintained between the initial investment and operational expenditures. High-cost components such as hydraulic lifts and app development for smart parking will be justified by their long-term benefits, including enhanced user experience and increased parking capacity. Operational costs will be minimized by integrating renewable energy sources, such as solar panels, which will significantly lower energy consumption and reduce utility bills over time.

Design for Reliability (DFR)

Robust Design: The structure will incorporate treated steel reinforcements for added durability and weather-resistant coatings to prevent corrosion and withstand extreme temperatures. These features will ensure the parking structure remains reliable under varying environmental conditions, reducing maintenance requirements and extending its service life.

Backup Systems: Systems such as backup generators and power supplies, will be installed to guarantee uninterrupted operation of critical services, including lighting, elevators, and app-based systems. These backups will enhance reliability and user trust by minimizing the risk of system failures.

Design for Environment (DFE)

Sustainability: Solar panels will be integrated into the design, significantly reducing the parking facility's carbon footprint. LED lights will be used throughout the structure due to their energy efficiency and long lifespan. These measures not only promote sustainability but also contribute to long-term cost savings.

Recyclable Materials: Wherever feasible, recyclable or reusable materials will be prioritized. For instance, certain structural elements can be fabricated using recycled steel or composite materials, reducing resource consumption and aligning with global environmental standards.

Design for Ergonomics

User-Friendly Interface: The app interface will be designed with simplicity and usability in mind, ensuring a seamless parking management experience. It will feature intuitive navigation, real-time parking availability updates, contactless payment options, and QR code scanning capabilities. The app will also accommodate accessibility needs by including voice commands and large, easy-to-read fonts for users with visual impairments.

Physical Comfort: Elevators and staircases will be designed to ensure comfort and accessibility for all users. Wide elevators will allow for smooth and easy movement of individuals, including those using mobility aids. Staircases will have evenly spaced steps, anti-slip surfaces, and sturdy handrails for safety. Proper lighting and clear signage will further enhance the ease of use and navigation within the parking structure.

Description of Final Product

The **Smart Automated Parking Structure** is a cutting-edge solution to urban parking challenges, combining advanced technology, sustainability, and user convenience. Built with reinforced concrete and treated steel for durability, the structure spans **220 ft x 50 ft**, featuring rooftop solar panels and LED lighting to reduce energy consumption. Multiple levels are designated for specific vehicle types, optimizing space by up to **25%**.

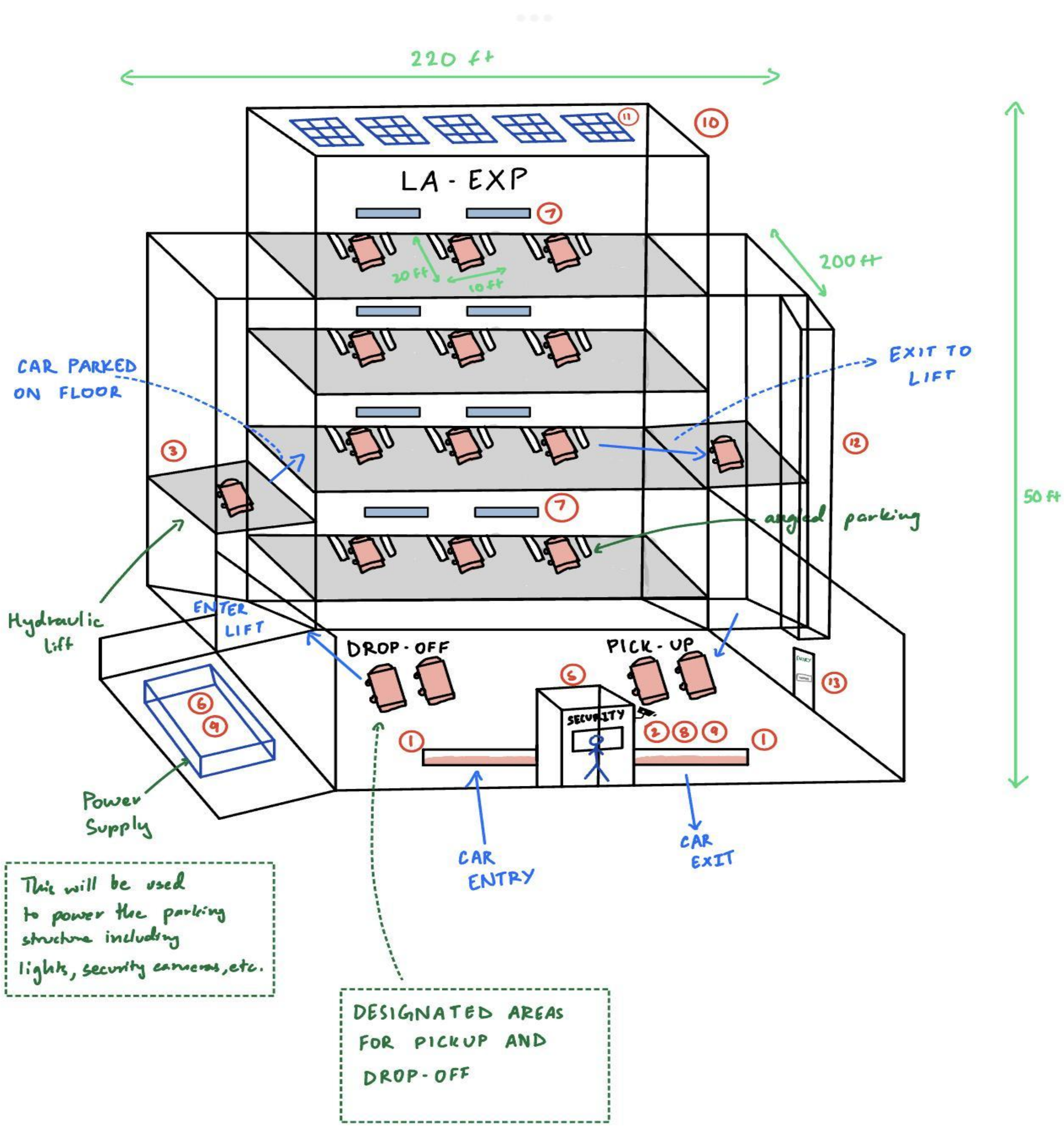
Key features include hydraulic lifts capable of transporting **7000 lbs**, ensuring quick and precise vehicle handling. Vehicles are assigned spots based on size and duration of stay, with long-term parkers placed further from exits. A mobile app offers real-time updates, QR code-based entry and payment, reservations, and accessibility options. For non-app users, kiosks issue printed tickets for seamless integration.

Sustainability is integral, with renewable energy from solar panels, EV charging stations, and recyclable materials incorporated into the design. Security is ensured through 24/7 surveillance, emergency call boxes, and on-site guards, supported by backup generators for uninterrupted operation. Ergonomic features, such as wide elevators, anti-slip staircases, and clear signage, enhance user comfort and accessibility.

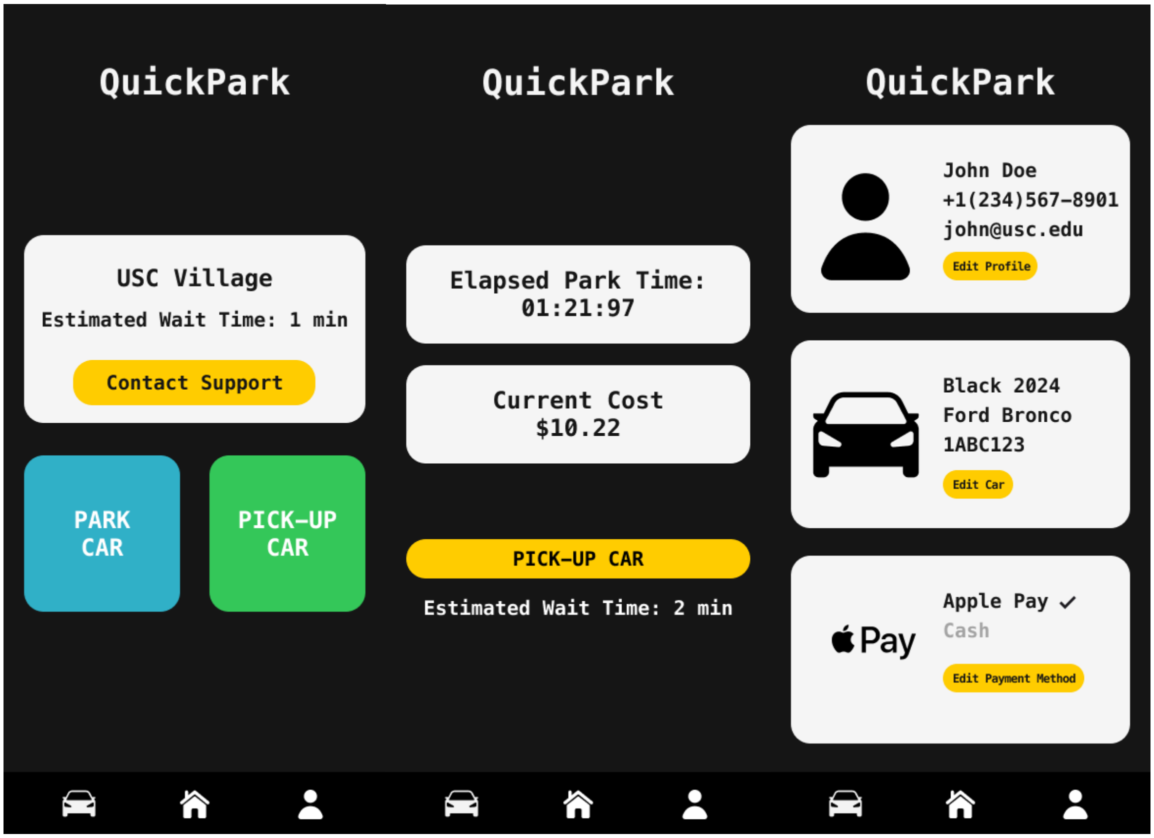
The streamlined parking process reduces time to under **3 minutes**, with users scanning their identifiers at entry, using hydraulic lifts to park, and retrieving vehicles with ease. This innovative structure meets modern demands for efficiency, safety, and sustainability, improving urban mobility and reducing congestion.

Final Layout Drawing and Supporting Drawings

The final layout drawings have been shown in the images below. After refinement of the design, it was decided that the final product would involve the user parking the vehicle themselves with the use of the hydraulic lift to take them to their designated parking floor. The user would then be able to exit and enter the building using personal elevators and their personal identifier code.



220 ft
LA - EXP
200 ft
20 ft
10 ft
50 ft
CAR PARKED ON FLOOR
EXIT TO LIFT
angled parking
Hydraulic lift
ENTER LIFT
DROP - OFF
PICK - UP
SECURITY
Power Supply
CAR ENTRY
CAR EXIT
This will be used to power the parking structure including lights, security cameras, etc.
DESIGNATED AREAS FOR PICKUP AND DROP-OFF


QuickPark
USC Village
Estimated Wait Time: 1 min
Contact Support
PARK CAR
PICK-UP CAR
QuickPark
Elapsed Park Time: 01:21:97
Current Cost $10.22
PICK-UP CAR
Estimated Wait Time: 2 min
QuickPark
John Doe
+1(234)567-8901
john@usc.edu
Edit Profile
Black 2024
Ford Bronco
1ABC123
Edit Car
Pay
Apple Pay ✓
Cash
Edit Payment Method


QuickPark
Personal Identifier Code
JD
John Doe
BMW 5 Series
Parking Spot
Level 3 - C6
Use this QR Code when returning to the parking site to pick up your vehicle
QR

Final Bill of Materials

Item	Component	Unit Cost ($)	Quantity	Total Cost ($)
1	Entrance/Exit Gate	1500	2	3000
2	Vehicle Registration Camera	800	2	1600
3	Hydraulic Lift	5000	2	10000
4	User Interface (App Development)	20000	1	20000
5	Pay Booth	3000	3	9000
6	Generator	4000	1	4000
7	Parking Structure (Concrete)	100000	1	100000
8	Power Supply (Solar Panel)	10000	1	10000
9	LED Tube Light	50	15	750
10	QR code scanner	50	12	600
11	Car measurement sensor	25	8	200
12	Elevator	10000	3	30000
13	Door	450	4	1800

Design Portfolio Entry

Redefining the Problem

The problem that we aim to address is the difficulty of finding parking in Los Angeles. Issues such as limited parking spaces, unsafe locations, and expensive options make it difficult for people to find a suitable parking location in a short amount of time. Our goal is to develop a safe, affordable, and fully automated parking system that eliminates the stress of parking, allowing users to focus on enjoying their day with peace of mind.

Customer Needs:

#	NEEDS	Imp
1	Ability to locate parking within 2-3 minutes	3
2	A smartphone app that offers up-to-date information about parking costs and availability in real time	2
3	An affordable parking solution	3
4	Explicit explanation of changing prices according on location, events, and time of day	1
5	Convenient payment options, including mobile payments, without hidden fees	2
6	Parking buildings should provide clean, well-maintained accessible amenities and elevators	2

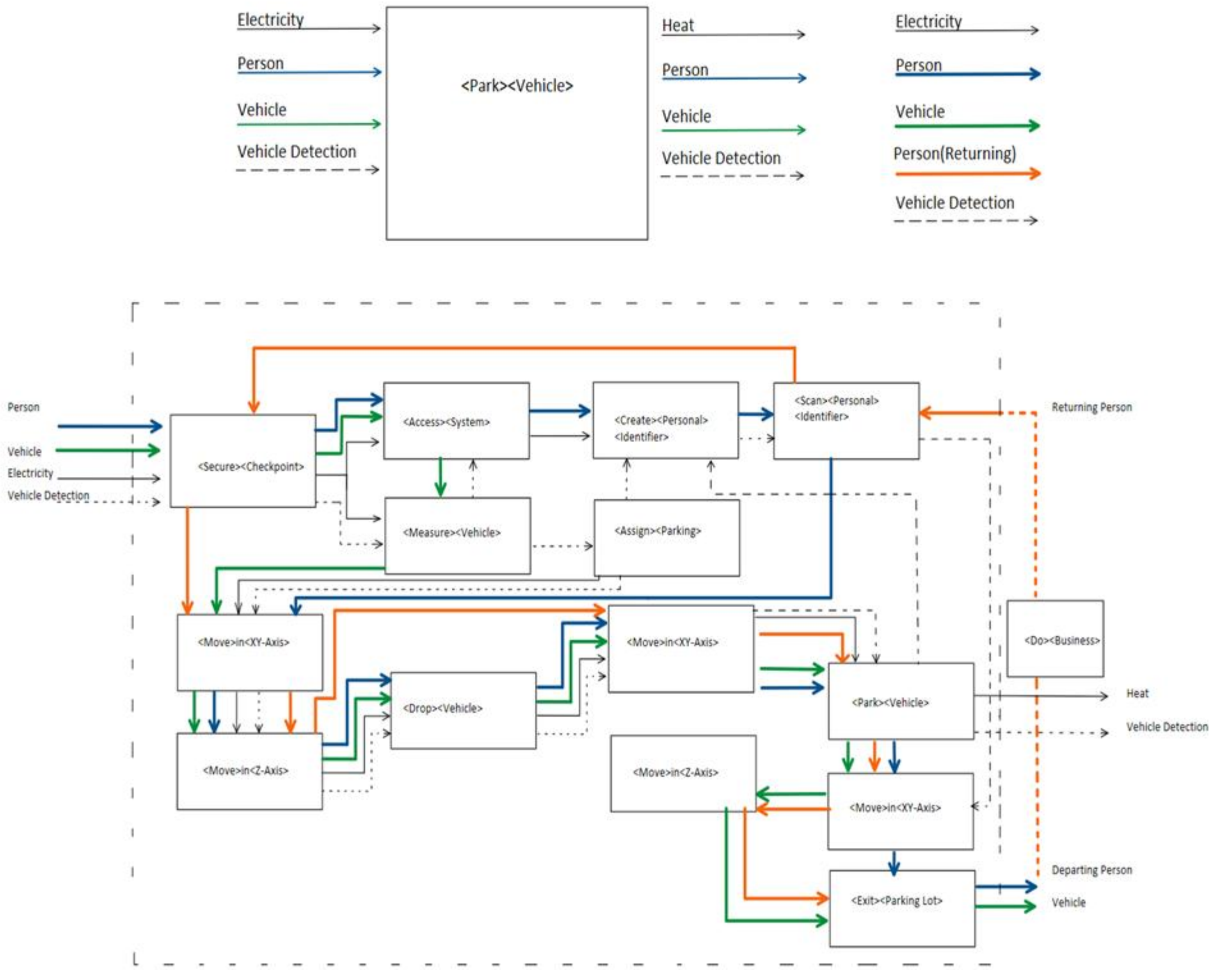
7	Possibility of making reservations ahead of time, which lessens the anxiety of rushing to find a spot	2
8	Availability of customer support for parking issues at any time of the day	3
9	Parking spots are made to safely accommodate larger and regular cars without posing a risk of damage	2
10	To reduce wait times, lifts need to be able to hold multiple cars as well as be fast.	3
11	Access to emergency assistance in parking lots and structures, such as call boxes or staff	3
12	Notify customers immediately through a mobile app alert about parking spaces, availability, and estimated wait times	3
13	Easy to locate structure or lot with visible signage and directions	2
14	Clear explanation of closing and opening times	3
15	Seamless exit and entry process	2
16	Accessible design for diverse needs of vehicles	2
17	Integration with public transportation	3

Engineering Requirements

Metric	Units	Marginal Value (Target Value)	Ideal Value (Required value)
Average time to locate parking spot	minutes	<3	<2
Payment methods available	count	>2	3
Response time for customer support queries	minutes	<5	<3
Transparency score of pricing changes	scale	>3	5
Cleanliness and maintenance rating	scale	>3	5
Reservation success rate	%	>80%	90%
Safety compliance for large vehicles	scale	>3	5
Elevator wait time during peak hours	minutes	<3	<2
Speed of lifts	m/s	2	0.1

Response time for emergency assistance	seconds	<60	<30
Alert notification time for lift malfunction	seconds	<60	<30
Parking space width	meters	2.4	2.5
Clear height for large vehicles	meters	2.1	2.3
Turning radius for vehicle entry/exit	meters	5.5	6

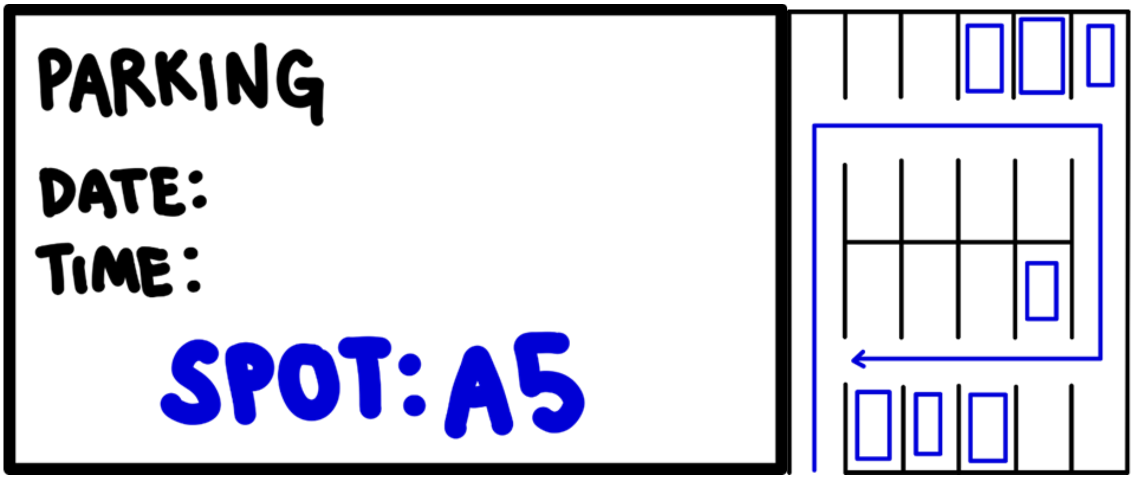
Function Structure Diagram (FSD)



Concepts

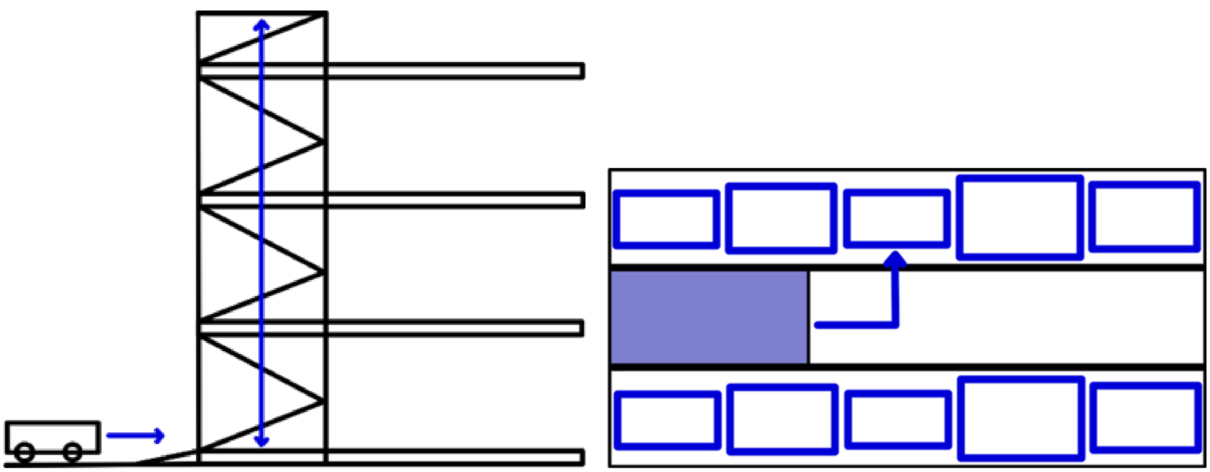
Design 1: Low-Cost Option

This design emphasizes simplicity and cost-effectiveness, utilizing basic manual systems such as security booths, tickets, and manual input for scanning, alongside self parking and no automation.



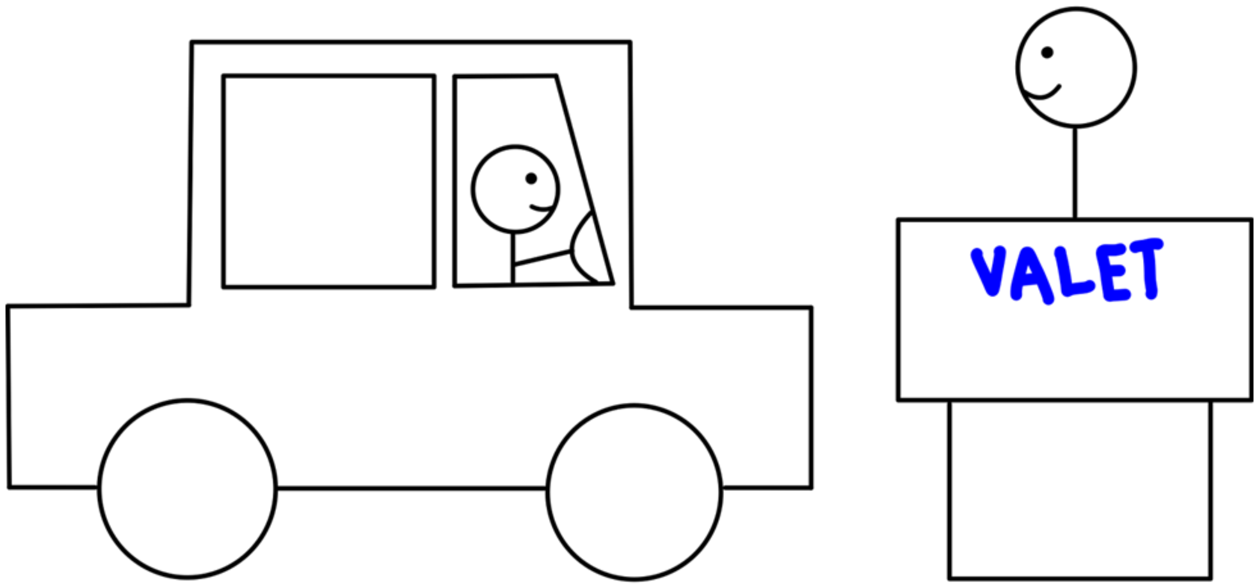
Design 2: Fully-Automated Option

This design is tailored for complete automation. It leverages cameras, apps, QR codes, algorithms, and conveyor belts, with fully automated parking and retrieval processes, minimizing human interaction.



Design 3: Labor Intensive Option

This design prioritizes service-driven features with security guards, security booths, and valet services. It caters to a user-friendly but labor-intensive experience.

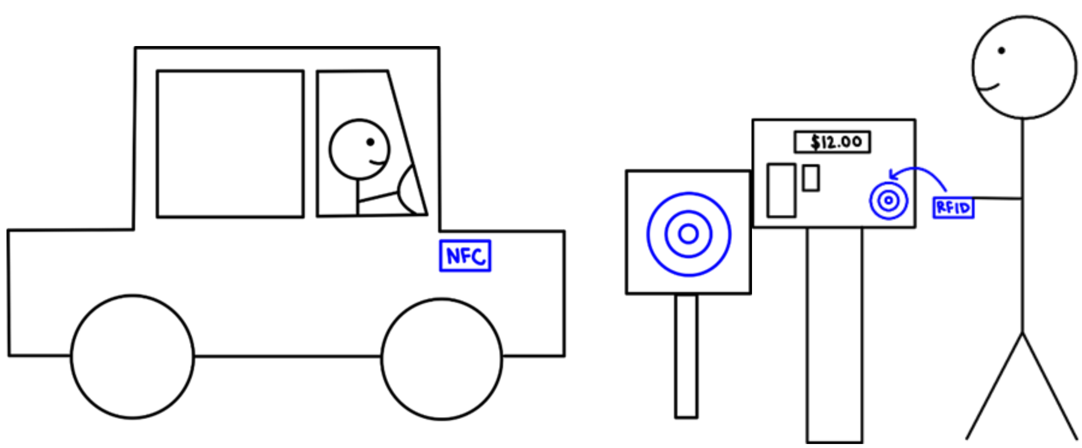


Design 4: AI Powered Autonomous Option

This design is similar to Design 2, the key difference is that it uses AI to allocate parking space.

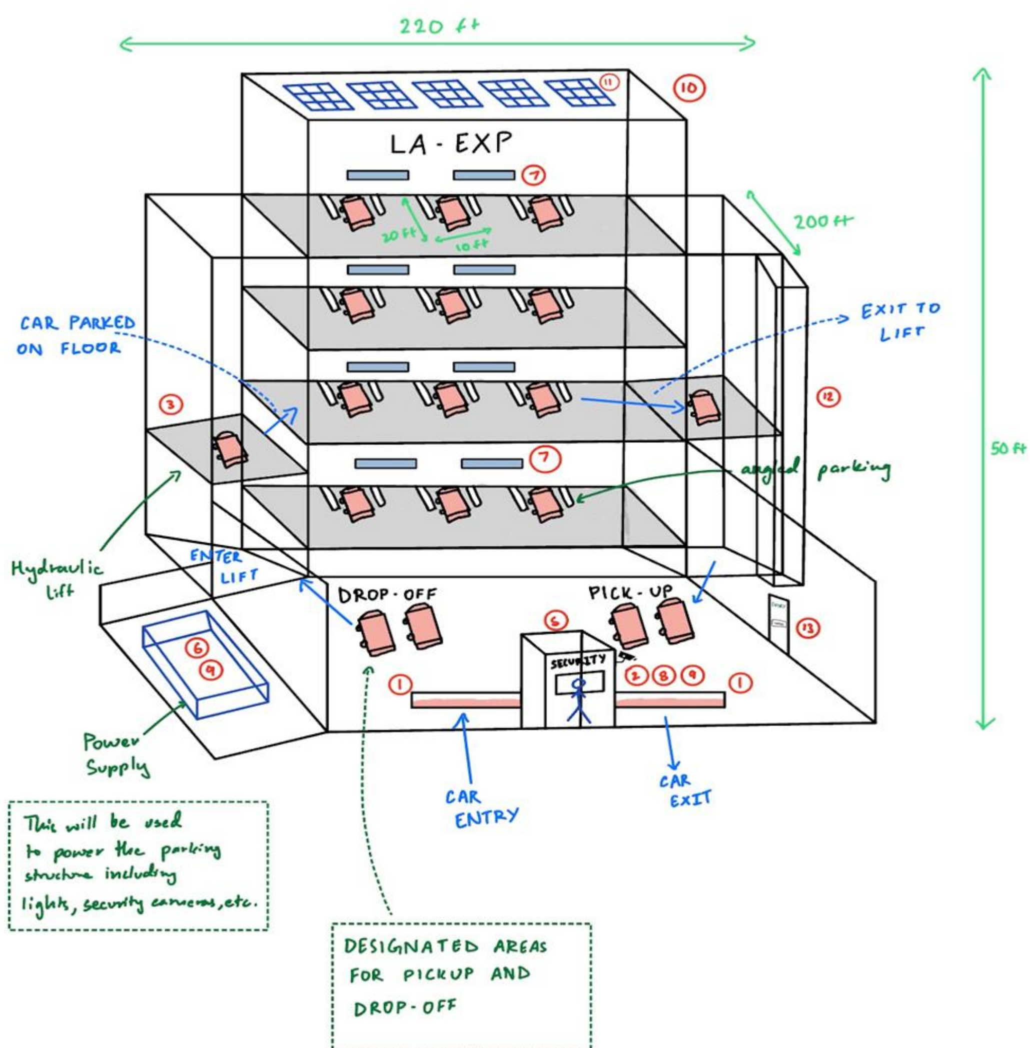
Design 5: Long Term Use Option

This design focuses on durability, targeted for repeated long-term uses, such as in an apartment complex. It incorporates security guards, RFID cards, and lifts, ensuring ease of use and scalability over extended periods, suitable for sustained operation.



Final Layout

The final layout features a parking structure with two vertical lifts strategically positions on either side, providing efficient flow for vehicles entering and exiting the system. The birds-eye view offers a clear visualization of the overall design, showcasing how the various components integrate into one. The system is complex and includes sensors, cameras, lifts, gates, actuators, and several other components. Givin the complexity of the system, with multiple interconnected moving parts, this layout serves as a critical tool to understand the operational aspect of the final solution.



Personal Identifier (App)

The image below shows how the personal identifier QR code will look like on the app along with all the details of the user. The app identifies your vehicle from the licence plate readers and cameras to determine the specifications of the vehicle and to determine the floor and spot the vehicle will be parked in.

Conclusion and Discussion

The "QuickPark" project provides a thorough examination of the creation of a hybrid parking solution that skilfully blends an automated vertical lift system with an app-based reservation system to improve space utilisation in urban environments. Significant progress was made by the team in designing a system that greatly streamlines the parking process by cutting down on time spent looking for a spot and streamlining payment procedures. The project's appeal is further enhanced by the incorporation of safety elements and environmental considerations like solar panels and EV charging stations. To increase accessibility and satisfaction, there is space for development, especially in the areas of helping non-app users and improving customer support.

According to a retrospective review, the strong use of design tools like function structure diagrams and the sympathetic approach to obtaining user insights were especially successful. On the other hand, more flexible approaches during the original design stage were advantageous in order to better react to future modifications in vehicle types and urban trends. The project demonstrates how academic theories may be applied practically in real-world situations by adhering to the AME 410 process, which emphasised on stakeholder feedback and iterative design.

The project's lessons highlight how crucial it is to include actual client feedback at the outset of the design process. Future initiatives might benefit greatly from a wider participation of stakeholder opinions at the outset, especially from non-technical users. Deeper understanding of system performance and user engagement may also be possible with improved prototype testing in a variety of urban environments.

In the future, the group could explore incorporating cutting-edge AI and machine learning technologies to enhance system responsiveness and better optimise parking logistics. Market appeal could be increased by extending the system's use to include a larger range of vehicle types, such as electric scooters and large cars. Moreover, boosting the integration of renewable energy sources and using more recycled materials could result in a more strict focus on sustainability. In addition to improving the existing project, these suggestions hope to establish a standard for upcoming developments in urban parking solutions, which could revolutionise municipal infrastructure through the use of intelligent, effective, and sustainable technologies.

Addendum

Inteviews 2-6 (1)

Interview #2: Elizabeth

Elizabeth is currently living in LA county

Q: What do you typically go to Los Angeles for? (work, school, events, recreation, visits, etc.)

A: Visits, events, dining

Q: On a scale of 1 to 10, 1 being the least and 10 being the most, how stressful do you find parking in Los Angeles?

A: 8 out of ten, if there's an event, maybe a 10

Q: What kind of parking do you prefer and why? (Street parking, lot parking, structure parking)

A: Street parking because it is cheaper and there is a chance you can get closer to the desired location or within proximity to the event, or restaurant.

Q: Have you ever found damage to your vehicle after parking in LA? (break-ins, accidents, scratches, etc.)

A: No, but I know of a lot of people who have.

Q: What is the biggest inconvenience to you when looking for parking in Los Angeles?

A: Availability, price, location

Q: What do you think is a reasonable price to pay for parking?

A: Parking meters are 1$ an hour, you can't beat it. But 5$ an hour is what I am willing to pay for parking. Most structures have the 2-hour free option which is completely preferable. There is also validation from business, there should be more service contracts with local vendors to do the validation method.

Q: Do you worry about your personal or your vehicle's safety parking in Los Angeles?

A: Yes, especially if I am alone, I worry about my vehicle too.

Q: What are your biggest complaints about parking structures?

A: They are hard to find and most of the time there isn't enough signage to direct me to the structure or inform me about price, and closure.

Q: What bothers you about standard parking structures now?

A: I never know if the structure is open 24 hours or when they close. The price clarity is sometimes misleading. Also, sometimes they are placed in areas that are hard to reach or are not clearly visible.

Q: Any suggestions to make the structure better?

A: Pricing is sometimes too high, if it can be subsidized by the city that would be nice. I would be okay with monthly subscriptions if that meant a lower overall cost. Restaurants, malls, and any adjoining businesses should make their customers aware of where to park and the location of structures.

Interview #3: Rita

Rita has lived in the Los Angeles area for 50 years.

Q: What do you typically go to Los Angeles for? (work, school, events, recreation, visits, etc.)

A: Work

Q: On a scale of 1 to 10, 10 being the highest, how stressful do you find parking in Los Angeles?

A: 10

Q: What kind of parking do you prefer and why? (Street parking, lot parking, structure parking)

A: Parking lots are expensive, structures are scary, and the streets usually have no parking available, but I would probably prefer the structure because it's safer for my vehicle.

Q: Have you ever found damage to your vehicle after parking in LA? (break-ins, accidents, scratches, etc.)

A: Yes

Q: How was your vehicle damaged?

A: Someone broke into my vehicle and on another occasion, I found a dent in my car.

Q: Where were you parked?

A: on the street

Q: What is the biggest inconvenience to you when looking for parking in Los Angeles?

A: Never available

Q: What do you think is a reasonable price to pay for parking?

A: Reasonable for parking 10 dollars for the day

Q: What is a reasonable price to pay for parking for meters?

A: Well, we pay 25 cents for 3 minutes where I work but I think it would be reasonable would be like $1.00 per hour

Q: Do you worry about your personal or your vehicle's safety parking in Los Angeles?

A: Yes, both I'm always worried because there are a lot of homeless people and addicts nearby and I worry about someone breaking into my car or worse. I think structures are safer because a lot of them have security at the entrances.

Interview #4: Evelyn

Evelyn has lived in Los Angeles for 25 years

Q: What do you typically go to Los Angeles for? (work, school, events, recreation, visits, etc.)

A: Typically for work

Q: On a scale of 1 to 10, 1 being the least and 10 being the most, how stressful do you find parking in Los Angeles?

A: 6

Q: What kind of parking do you prefer and why? (Street parking, lot parking, structure parking)

A: In a structure just because I feel like it's the safest, and I don't want my car to get hit on the street

Q: Have you ever found damage to your vehicle after parking in LA? (break-ins, accidents, scratches, etc.)

A: Yes, someone hit my left side bumper when it was parked.

Q: Where were you parked when it happened?

A: I was at work, and I didn't have access to the parking lot, so I parked on the street that day and when I came out for lunch, I noticed that my car had been hit.

Q: What is the biggest inconvenience to you when looking for parking in Los Angeles?

A: The prices, especially when parking during events, prices increase

Q: What do you think is a reasonable price to pay for parking in a lot or structure?

A: I would say 10 dollars for the whole day, but a lot of structures and lots are charging $25 for the day

Q: What do you think is a reasonable price to pay for meter parking?

A: Well to park for an hour it should be no more than $1.00 per hour

Q: Do you worry about your personal or your vehicle's safety parking in Los Angeles?

A: Yes, absolutely. When I'm parking on the street, I'm worried my car will get hit or broken into. When I'm walking with my daughter, I always try to get to my car quickly because I'm afraid of what some people are capable of.

Interview #5 Victor

Victor has lived in Los Angeles for 30 years

Q: What do you typically go to Los Angeles for? (work, school, events, recreation, visits, etc.)

A: Work

Q: On a scale of 1 to 10, 1 being the least and 10 being the most, how stressful do you find parking in Los Angeles?

A: For me personally a 1

Q: What kind of parking do you prefer and why? (Street parking, lot parking, structure parking)

A: I prefer wherever is available or whatever is closest to the event, typically a parking lot

Q: Have you ever found damage to your vehicle after parking in LA? (break-ins, accidents, scratches, etc.)

A: One time someone broke into my vehicle

Q: Where were you parked?

A: On the street

Q: What is the biggest inconvenience to you when looking for parking in Los Angeles?

A: Parking far away from wherever I'm trying to get to

Q: What do you think is a reasonable price to pay for parking?

A: 5-dollar flat rate

Q: What do you think is a reasonable price to pay for parking meters?

A: $1.00 per hour

Q: Do you worry about your personal or your vehicle's safety parking in Los Angeles?

A: Normally I don't.

Interview #6 Asusana

Asusana was born and raised in Los Angeles and has lived there for 35 years

Q: What do you typically go to Los Angeles for? (work, school, events, recreation, visits, etc.)

A: Work

Q: On a scale of 1 to 10, 1 being the least and 10 being the most, how stressful do you find parking in Los Angeles?

A: 7

Q: What kind of parking do you prefer and why? (Street parking, lot parking, structure parking)

A: I prefer parking in a lot because for some reason, structures give me anxiety

Q: Have you ever found damage to your vehicle after parking in LA? (break-ins, accidents, scratches, etc.)

A: No, thankfully I haven't had anything happen to my car.

Q: What is the biggest inconvenience to you when looking for parking in Los Angeles?

A: Parking too far from my destination

Q: What do you think is a reasonable price to pay for parking?

A: I would think that 2 dollars per hour is a good rate to pay.

Q: What do you think is a reasonable price to pay for parking meters?

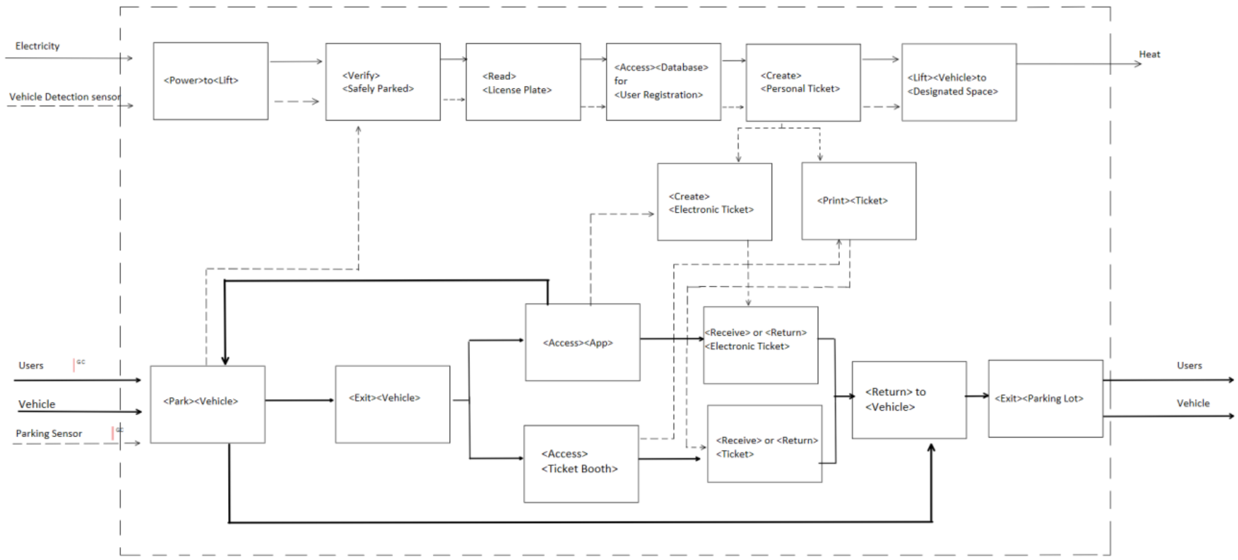
A: 50 cents per hour

Q: Do you worry about your personal or your vehicle's safety parking in Los Angeles?

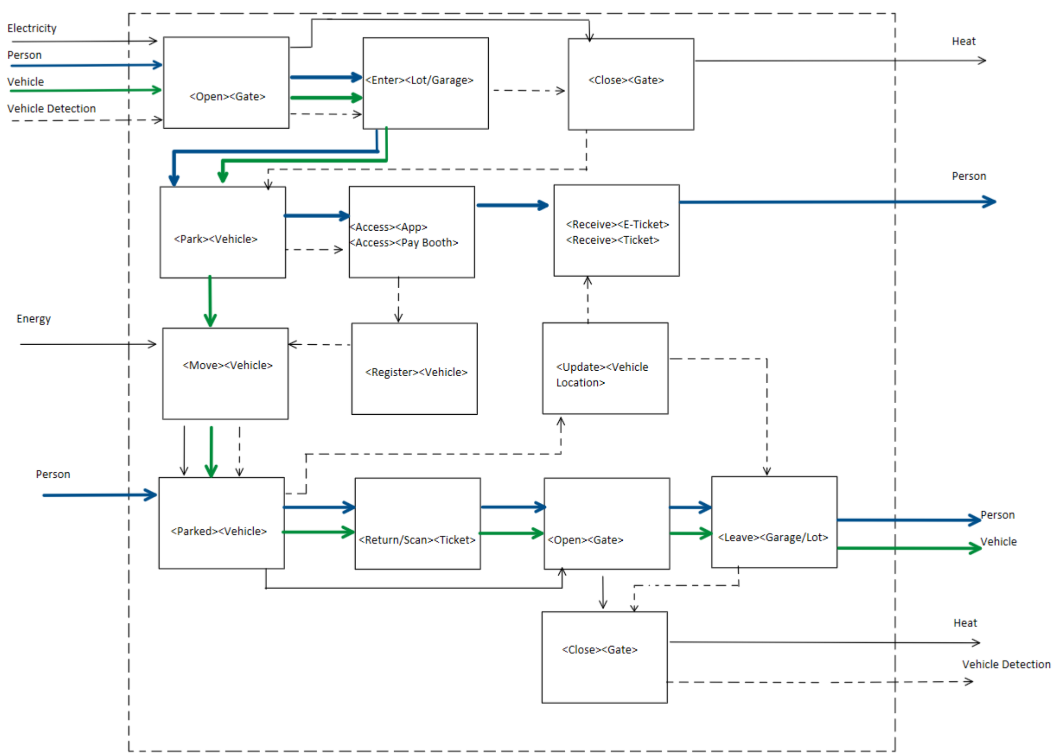
A: Depending on the area we're in, I do get worried that someone may break into my car. There have been a lot of break ins happening lately.

FSD Iterations:

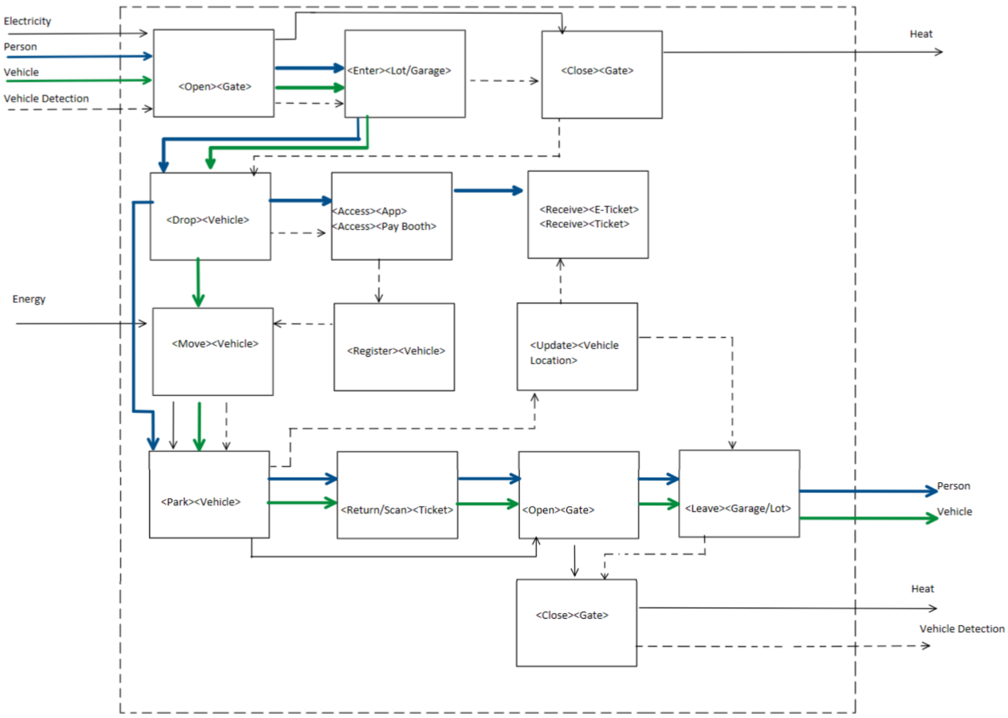
FSD It. 1:



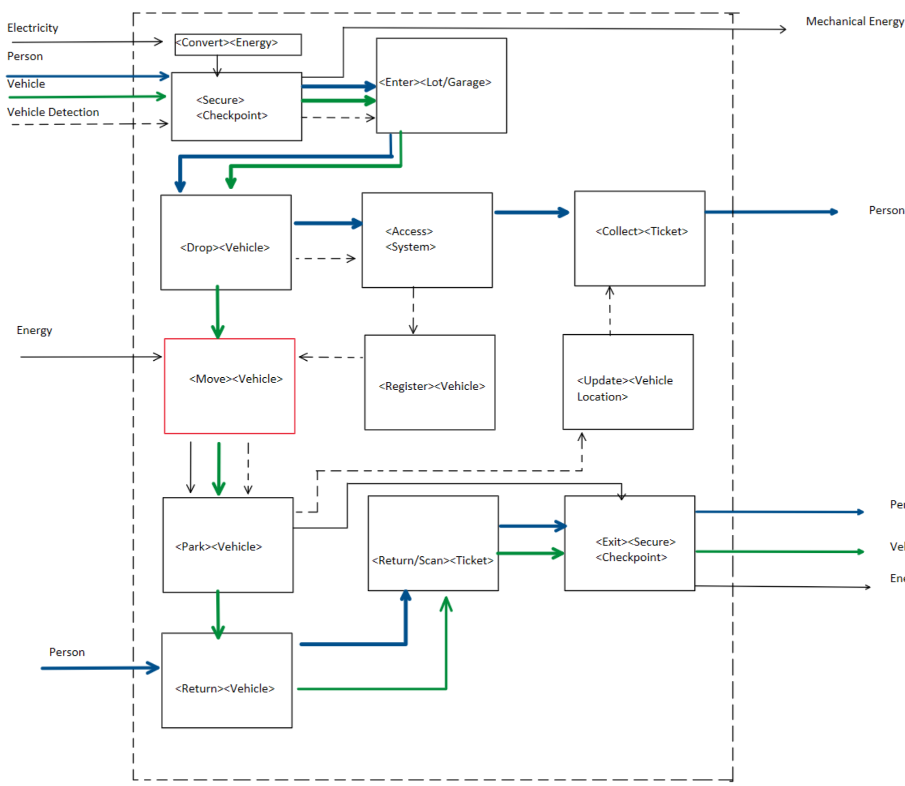
FSD It.2:



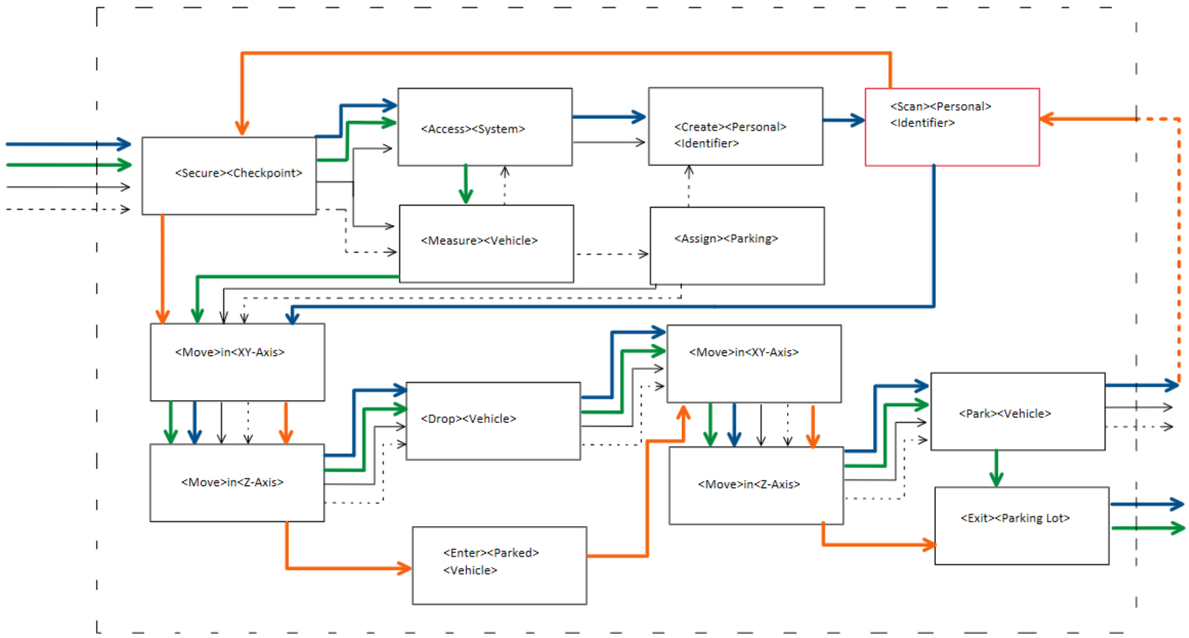
FSD It. 3


Electricity
Person
Vehicle
Vehicle Detection
<Open><Gate>
<Enter><Lot/Garage>
<Close><Gate>
Heat
<Drop><Vehicle>
<Access><App>
<Access><Pay Booth>
<Receive><E-Ticket>
<Receive><Ticket>
Energy
<Move><Vehicle>
<Register><Vehicle>
<Update><Vehicle Location>
<Park><Vehicle>
<Return/Scan><Ticket>
<Open><Gate>
<Leave><Garage/Lot>
Person
Vehicle
<Close><Gate>
Heat
Vehicle Detection

FSD It.4:

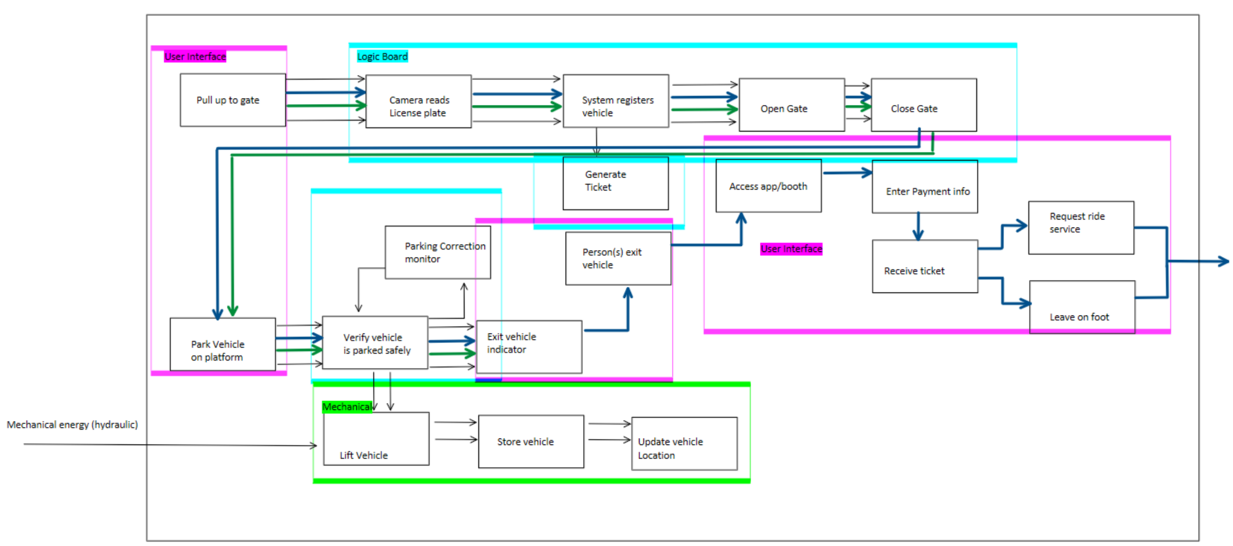

Electricity
Person
Vehicle
Vehicle Detection
<Convert><Energy>
<Secure><Checkpoint>
<Enter><Lot/Garage>
Mechanical Energy
<Drop><Vehicle>
<Access><System>
<Collect><Ticket>
Person
Energy
<Move><Vehicle>
<Register><Vehicle>
<Update><Vehicle Location>
<Park><Vehicle>
<Return/Scan><Ticket>
<Exit><Secure><Checkpoint>
Person
Vehicle
Energy
Person
<Return><Vehicle>

FSI

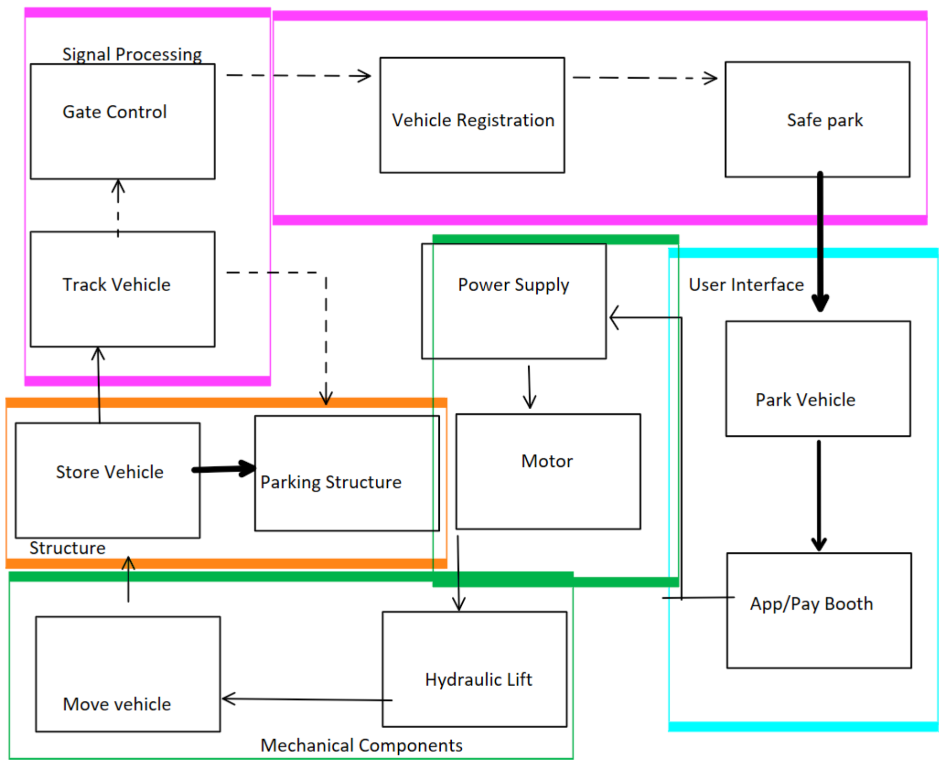


Schematic Iterations:

Schematic It.1:



Schematic It.2:



Schematic It.3: