5th Annual Gateway Arch Engineering Competition

Christian Brothers College High School

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1. Defining the Problem

The Gateway Arch, which stands as tribute to the westward expansion of the United States is a primary attraction for the St. Louis area. Unfortunately, access to the Arch and its grounds from the riverfront attractions and parking areas is difficult for disabled guests because of the long, meandering ramps available for wheelchair users. The CBC student design team proposes the following solution that allows the hindered guest to ascend and descend the ramps with ease, in a safe and modern approach.

1.1 Constraint & Criteria:

1. Shall run without on-site rangers in normal operation
2. Shall be used by a single disabled guest
3. Shall be properly stored
4. Shall be resistant to the elements (weatherproof)
5. Shall be low and cost-efficient maintenance
6. Shall be safe for uninvolved guests
7. Shall be universally translatable on Arch grounds
8. Shall function with existing architecture
9. Shall be stored near ramp
10. Shall be flood proof

2. Idea Generation

The brainstorming process resulted in a plethora of ideas within our group, many of which came from our tour of the ramp on the Arch grounds. We researched all kinds of ideas from walk-behind wheelchair pushers found in hospitals to ideas resembling car wash or Metrolink in ground tracks systems. The process developed several conceptions of plausible solutions, but as more research was gathered and the constraints were studied, we took a step back to reframe the central focus of the problem in question. This reexamination of the problem faced by the park led our group to a new approach, integrating a past design idea with a modern solution. Two years ago, in the 2019 Gateway Arch Engineering Competition we used a stairlift as a part of the solution to the mobility problem at the top of the Arch. Elements were taken from most of the

ideas generated to construct the system. We are proud to propose our 2021 Gateway Arch Engineering Competition solution.

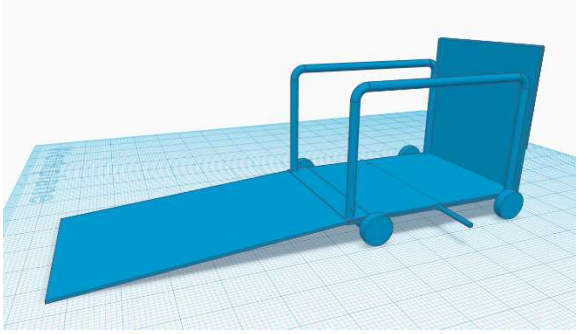
3. Selecting a Design

The selection of an approach from the idea generation phase of the project resulted from an analysis of its ability to fulfill the constraints and requirements given. In section 3, we detail our solution of a powered, autonomous cart, using a rail embedded in the sidewall of the concrete walkway for security. When not in use, the cart is stored, protected from elements, and charged in a custom garage at the bottom of the ramp. Access and monitoring of the system are provided by a custom application accessed from the garage and Arch help desk computer station.

3.1 Cart

Many businesses, event holders, or households rely on a wheelchair stair lift to help move their disabled employees, guests, or family members. Stair lifts are incredibly safe and regulated by the ADA. Our design utilizes a stairlift like design for safety, comfort, and familiarity. Our design is on wheels, powered and controlled autonomously to allow for the ramp to be followed

without interfering with the handrails or walking space. The cart will feature three motors, one for each of the two rear wheels and a third motor in the front of the cart. The two rear wheels will provide the bulk of the drive power. The larger motor toward the front of the cart will provide the autonomous steering. As the cart is powered up and down the ramp, it will be driven by the steering system consisting of ultrasonic sensors on the front and rear of the cart pointing toward the wall. The sensors will monitor the distance of the cart from the wall, both in the front and the rear of the cart. As the cart ascends or descends the ramp, these distances will be compared to a desired value. The steering motor will then correct the cart to maintain appropriate distance in a fully closed system. To allow egress on or off the cart, automatic ramps in the front and rear will be automatically deployed.



3.1.1 Providing Safety

The cart will feature two handrails and two ramps to enclose the guest. The cart will move at a slow walking speed (approximately 3 mph) to accommodate guests in the user's party. In addition to the recommended practice of locking the wheelchair's wheels while on the cart, it will be constructed with contours to provide additional security. The floor of the cart will be constructed of a steel mesh allowing for water to pass and will add grip for the tires of the wheelchair. For emergencies, the cart has a manual system override that stops the motors, activates a mechanism to deploy blocks under the two drive wheels, and alerts the ranger at the help desk of the situation.

3.1.2 Maintenance

Routine maintenance will be required to verify the system operation and safety. The system will not be used frequently but the tire will occasionally need to be changed. The system timing will need to be analyzed. The motors will need to be checked. The electronics will need to be surveyed. And the fail-safe measures will need to be assessed.

3.1.3 Cost

The cart is a custom piece, and costs would require more in-depth design. One option is utilizing a commercially available lift and modifying it to include the necessary systems discussed above. More likely, ground-up manufacture of the cart with necessary systems would be more cost effective. For comparison, a COTS wheelchair lift, as shown in the left side of the figure, without the additional functionality retails for between $3,000 to $5,000. A motorized wheelchair mover, shown on the right side of the figure, retails for $9,000. Our solution is basically an enhanced combination of the two existing systems. With design, prototyping, testing, and manufacturing, we would expect a custom cart with the necessary systems to be around $20,000 - $25,000.

3.2 Rail

3.2.1 Providing Security

The railing system will provide an antitheft mechanism for the cart. The system is composed of a steel c-channel embedded in the concrete wall of the path, which houses a bearing system that rides in the channel. The bearing system is connected to the cart with a universal joint. It is merely a tether to the wall to prevent unauthorized use. It is not rigid, to avoid binding that might otherwise hinder the autonomous steering of the cart. By tethering the cart, it prevents theft or vandals from moving the cart away from the ramp, ensuring it is always available for desired users.

3.2.2 Maintenance

Clean the inside of the rail, in case of leaves, water, and ice. Holes in the bottom of the rail prevent water from accumulating inside the rail. Routine inspection and maintenance of the bearing system and u-joint would also be required.

3.2.3 Dimensions

The rod that connects the cart to the wall will be 1 foot long, with the ability to move within its housing, with limits, as the cart nears the wall. This would prevent the cart from taking up too much space on the walkway, and it would prevent the cart from scraping against the wall. The rod will be made of a carbon steel 1018 cold finish, to reduce any potential friction or scraping.

This joint on the rod serves to accommodate any minor inconsistencies in the vertical distance between the cart and the rail and allows the steering mechanism to operate without binding.

3.2.4 Cost

We estimated that the amount of space we need to lay rail on roughly 500 feet. The pricing of the rail varies by the dimensions. There were two sizes that we considered for the rail: 3 X 1 X 0.18 and 2 X 3 X 0.12. The 3 X 1 X 0.18 steel rectangle tube rail for 500' would cost around $13,503.84 from metalsdepot.com. The 2 X 3 X 0.12 carbon steel rectangle tube hot rolled rail for 500' would cost around $7,073.75. The price of a 1' by 1" by 1" 1018 cold finish carbon steel rod would be $16.17. The price of a 1' by .75" by .75" cold finish carbon steel rod would be $9.78. The price of a 1' by 0.5" by 0.5" cold finish carbon steel rod would be $4.23.'

3.3 Garage

When not in use, the cart will be housed at the bottom of the ramp in a custom "garage". The rail system will guide the cart from the bottom of the ramp into the custom-built housing area. This garage will be built into the existing flower bed/trash can area. The two sides of the trash receptacle enclosure will be removed to make room for the garage. In addition, the garage extends into the planting area (which is connected to the concrete wall from the ramp).

The dimensions of the garage will be approximately 6 feet deep at the existing height and width of the planting bed/wall. The front of the garage will include a motorized roller door approximately 4 feet wide and 3.5 feet in height, similar to the one shown in the figure.

For the roof of the garage, there will be a 3-degree slope, which is substantially over the international building code standard for water runoff and the lower end will be on the south side, away from the ramp. Drainage will be provided in and around the garage. The garage will also serve as the charging station for the cart. In the garage will be a wireless charging pad (similar to wireless cell phone charging), and when the cart is idle it will charge through the wireless charger. Similar systems are in use to charge some electric city buses. Power is available

at the ramp termination. One design option is a solar system to power the recharging station.

3.3.2 Maintenance

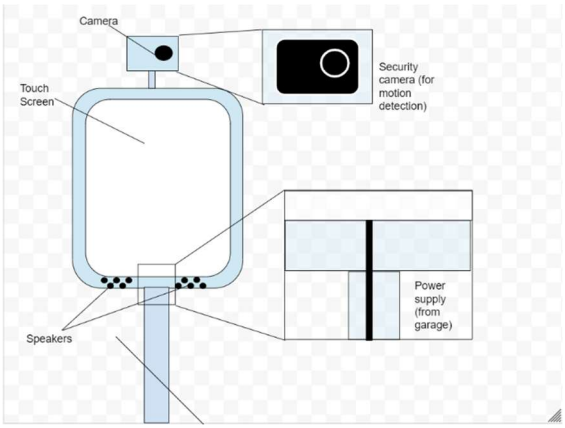
For maintenance inside the shed, the roof will open with hinges to provide access to charging station and other electronics.

3.3.1 Cost

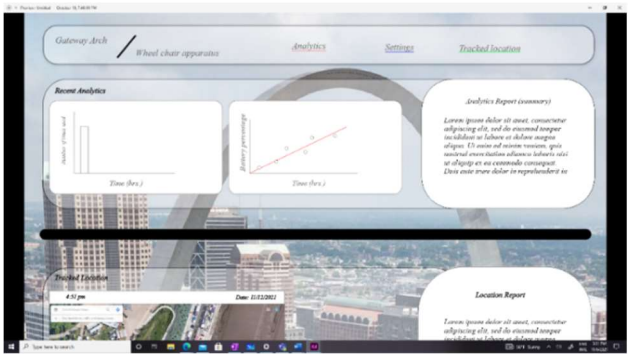
Garage door wall and roof (sheet metal 3 ft by 8ft): $35, motorized garage door quote: $350, (Potential) solar panel: $300, battery (lawn mower battery): $40, charging station (wireless charging pad + receiver) to be developed from existing technology, heavy duty hinges (set of 2): $20, steal pad lock with double hinge safety hasp for the opening roof: $30. Electronic dead bolt door lock for garage door: $100, channel drain and grate: $60

3.4 User Interface

To utilize the system, the guest interacts with a user interface at the garage, which coordinates with the ranger or receptionist interface located at the help desk. The system is only available for use when the Arch Welcome Center is open to guard against theft and vandalism. The guest will request permission to use the system from their interface located at the garage. The ranger will be able to see and speak with the guest via closed circuit system (similar to systems in use at some schools) as shown.



The receptionist will allow access to the system and be able to monitor progress. A sample of the receptionist interface is shown in the figure.



3.4.1 Cost

The data acquired from traffic to the site and the information logged into the websites' system will be covered under the AWS Gateway, which will be free under predicted usage. Applications that monitor, display, and control all aspects of the system operation would need to be developed. The estimated cost of this development depends on more in-depth analysis, but preliminary estimates are around $5000 based on projects we've done in the past.

4. Conclusion

The Gateway Arch was erected as a monument to the role St. Louis played as a launching point to the westward expansion

of the nation. Imagine, in the shadow of an elegant arch sweeping into the sky as a tribute to this movement of mankind, a single man or woman with mobility issues huffing and puffing, pushing themselves up a ramp with no family member or able person to help them. The guided cart system will provide disabled persons a glimpse into the hope of the west without losing hope in the Arch grounds. The autonomous cart system, with the security of the rail system, the protection of the garage, and the interactive interfaces for monitor and control, seamlessly connect the environment of the Arch and its grounds to the St. Louis riverfront. Our autonomous cart system is meant to serve disabled persons with the purposes of theft protection, weather resistance and conveyance so all may enjoy the opportunities provided by the National Park Service at the Gateway Arch National Park.