Engineering Strategies & Practice

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APS111
Conceptual Design Specifications (CDS)

Team #	138	Date	December 4, 2023

Project Title	Hart House Theatre Redesign: Addressing Accessibility Needs
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Tutorial Section	120
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Please check off which components you are submitting for your assignment.
_✓_ CDS submitted as a PDF to Quercus with the following components:

- _✓_ Cover Page
- _✓_ Executive Summary
- _✓_ Introduction
- _✓_ Problem Statement
- _✓_ Service Environment
- _✓_ Stakeholders
- _✓_ Detailed Requirements (FOCs)
- _✓_ Generation, Selection and Description of Alternative Designs
- _✓_ Alternative Designs Selection Process
- _✓_ Alternative Design Descriptions
- _✓_ Proposed Conceptual Design Specification
- _✓_ Measures of Success
- _✓_ Conclusion
- _✓_ Reference list
- _✓_ Appendices
- _✓_ Attribution Table

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Executive Summary

The grand warden of Hart House, David Kim has asked teams to create solutions for different parts of Hart House. Our team focuses on the accessibility issues for those with mobility challenges in various parts of the theatre to make the theater experience more inclusive and enjoyable for everyone, before, during and after each performance. The project also prioritizes safety, alignment of style, affordability and efficiency in solutions provided. Our task is to change the steepness in the back aisle, the determined wheelchair seating spaces and the inaccessibility of the stage which were the three issues highlighted by the client. All of Hart House Theatre is in scope, except for the backstage area, control booth, corridors and the ceiling structure.

We took the service environment into account through the evaluation of the physical environment and living things in the area. In analysis of the physical environment, aspects such as the lighting, the floor, the stage, the back aisle and the right-most aisle were considered; whereas, in the analysis of the living things, people with or without disabilities and the service animals were taken into consideration. Like the internal aspects of the project, the external aspects are also of importance in order to meet the client's expectations. The design solutions necessitate interaction with stakeholders on issues such as the historical architectural significance of the building, pricing of the tickets, maintenance of the designs, and meeting the codes and regulations; hence, setting the base for the objectives and constraints of the project, and determining the primary and secondary functions of the designs. These objectives included ideas to increase safety, ergonomics, inclusivity, sustainability and durability while minimizing noise and visual pollution. Moreover, the constraints included the designs being aesthetically aligned with the theater envelope, having in-person solutions to the problems, not making drastic changes in the number of seats by meeting the codes and regulations on occupied theater space, fire and structural protection and the back aisle slope.

In the idea generation process of this project, the "5 why" method was utilized to discuss the fortes and incapabilities of the 50+ design solutions. Multi-voting was used to narrow down the solutions to three possible designs for each section- back aisle, stage access and wheelchair seating. For the back aisle: slope readjustment, handrails and grips and chair attached lift; for the stage access: chair lift, portable stage lift and portable stair wheelchair; for the wheelchair seating: removable seats, swivel seats and foldable seats were selected. The procedure is completed with the use of the Pugh method in order to select the best solution for each section. Upon selection of the solutions, the methods of success were explored and listed in order to reach a set of fully satisfactory solutions for the client prior to the implementation of the designs. These methods would help evaluate the projects from points such as noise, safety, battery life, comfort, transportation time and durability.

In conclusion, the design solutions presented for the issues in Hart House theater ensure client satisfaction through expanding the inclusivity of the theater. Plans for the future include an iterative process for testing the designs in the theatre and see how they do to improve the existing designs until it meets the clients expectations.

1.0 Introduction

David Kim, the warden of Hart House, envisions a theatre experience that prioritizes safety and accessibility, ensuring unobstructed views from all seat positions, a seamless method for stage access, and safe mobility down the aisles for the audience [1]. The assigned task for the team is to devise solutions that enhance accessibility within the constraints of Hart House. This involves a thorough analysis of existing issues in the theatre's layout, considering directives from Mr. Kim, the service environment, and insights gained from stakeholder research.

2.0 Problem Statement

2.1 Context

The Hart House theatre, used for university events, lacks accessibility for individuals with mobility issues, as detailed in the client statement from the Hart House Renewal Document [1]. Steep aisles in the last row create challenges, hindering navigation for those with mobility impairments. Inadequate wheelchair seating and limited stage access limit inclusivity, disregarding community engagement [1].

2.2 Gap

The identified gap pertains to the lack of safe and accessible options for individuals with mobility challenges in the theatre, leading to design problems and hindering full participation [1]. Specifically, individuals with mobility impairments lack secure stage access and face accessibility issues with the backstage restroom. Steep hallways and aisles violate building codes, and poorly located wheelchair seating obstructs views for attendees in those areas [1]. Addressing these issues comprehensively is crucial for ensuring inclusivity.

2.3 Need

The primary need is enhancing theatre accessibility for individuals with mobility challenges. This involves ensuring everyone can comfortably use all amenities while adhering to building codes and regulations. A secure method for stage access, better wheelchair, and seating angles are vital. As per the client's request, establishing an accessible method to access the back aisles and backstage bathroom is suggested.

2.4 Scope

The project's scope addresses specific concerns from the client statement: wheelchair seating, aisle slopes exceeding code, and stage access challenges for those unable to use stairs [1].

Notably, bathroom and hallway accessibility and structural changes are outside the scope [1]. This clear delineation aligns with client requirements, accommodating time constraints and client specifications. The goal is to meet all needs without "altering the theater envelope", as per the client's explicit instructions [1].

3.0 Service Environment

Table 1 provides data on the service environment of the inside of the theater. See Figure 1 below for a view of the Hart House seats. More of the environment can be seen in Appendix B.

Figure 1. A side view of the aisles of the theatre.

Table 1. Service Environment of Theater.

Physical Environment		
Area of Focus	Measured Values	Justification
Lighting	● With dimmed lights we expect	● If an area is too dim it may

	approximately 0-100 lumen/m^2 in the lighted pathways to the seats [2]	limit the mobility of people in the dark. Note that a lumen estimator was used (Appendix B).
Floor/Ramp	• Width of floor walkway is approximately measured 1 m at thinnest point	• Knowing the material and dimensions allow us to know if we can cut, drill, or add certain sized objects
Stage	• Measured approximately 1.2m above first row ground level	
Back Aisle	• Measured approximately 14 degrees off lowest flat portion of theatre • Measured floor distance between rows is approximately 65 cm	
Right-Most Side Aisle	• Measured approximately 4.75m high and 19m in horizontal length	
Living Things		
People Without Disabilities	• Adults and children walk throughout entire theatre, including throughout theater	• Both groups of people will utilize the space during performances
People With Disabilities	• Users of crutches, wheelchairs, canes, and mobile scooters traverse throughout theater	
Non-Human	• Service Animals	• Service animals are permitted by Hart House for people with accessibility issues [3]. We must account for passages and potential hazards service animals may pass through.

4.0 Stakeholders

The key stakeholders of the project and their respective interests are shown in Table 2.

Table 2. Key stakeholders of the project.

Stakeholder	Interest
Historical Preservation Societies or Experts	If Hart House holds historical or architectural significance, historical preservation's input ensures that any design modifications maintain the historical architectural significance of the building.
Outreach & Marketing Inquiries: Lindsey Middleton	The design might influence the pricing of the tickets and how many tickets are available. [4]
Technical Inquiries: Brian Campbell	The design may include mechanical systems such as lifts, which must be maintenanced before usage according to the "O. Reg. 209/0: ELEVATING DEVICES"[5]
Ministry of Municipal Affairs and Housing	The design might involve some building and demolitions, according to the "Building code Act of Ontario"[6], which needs to have mandatory building inspections to make sure that everything meets Building Regulations.

5.0 Detailed Requirements

The scope involves wheelchair seating, the aisle, and stage access, with a focus on enhancing theater accessibility in compliance with regulations and codes. Precise mathematical measurements will be employed without altering the theater envelope to meet these objectives. A comprehensive understanding of the project's functions, detailed objectives, and constraints is crucial.

5.1 Functions

Functions of the design, seen in Table 3, were developed to provide an inclusive and accessible theater space for all participants.

Table 3. Project functions and descriptions.

Function Type	Description
Functional basis	• Present information

Primary function	• Provide accessibility and inclusivity within the theatre space
Secondary functions	• Facilitate ease of movement • Provide equitable seating • Enable universal stage access • Establish barrier-free paths • Support independent navigation • Promote safety and comfort

5.2 Objectives

The Pairwise Comparison method found in Appendix A was used to develop the following objectives listed in Table 4.

Table 4. Project objectives with metrics and justifications.

Objective The design should:	Metric	Justification
1. Be physically safe for its users	The entrance and exit to any transportation device should include at least a 5 ft by 5 ft area for its users [7].	ADA building standards for wheelchair ramps state this metric for ease of use for this with wheelchairs [7]. We can extend this to all users with mobility issues, for any transportation system since wheelchairs users occupy the greatest space.
2. Be quiet	Noise during performances < (30-50) dB	The average room noise is between 30-50 dB [8]. During a theater performance, the noise level should not exceed this level in order to maintain the amount of expected noise distraction.
3. Be ergonomic for its users	CSAT for Ergonomics (customer satisfaction score) > 80	MPM (Mobility Performance Metrics) found that customer transit comfort was determined by the user's perception, notably the amount of service complaints [9]. CSAT scores for travel companies found an average score of 76 in 2023.

		Reaching this minimum would ensure a majority of users are satisfied [10]. See Appendix A for more information on CSAT.
4. Be visually non-distracting	Lights (if any) can be present on the perimeter and boundaries of the theater dimmed to approximately 200 lumens [10].	During performances the theater must be dim in order to focus on what is occurring on stage. Indirect lighting should be low and placed away from center theater areas [10].
5. Create a sense of inclusion for those with mobility challenges	CSAT for Inclusion > 80	Similar to the ergonomic metric, MPM suggests customer satisfaction (in this case inclusion) to be measured using satisfactory scores [9]. A CSAT of 80 would represent a successful customer experience, hence inclusive experience [10]
6. Be sustainable and long-lasting	Breakdowns per year < 2	A preserved elevator has approximately 0.5-2 yearly breakdowns [11]. We can use this as a benchmark for transportation solutions.

5.3 Constraints

Accessibility is the primary focus for the design. Thus, Table 5 shows the constraints that the design must follow to be considered viable.

Table 5. Constraints in the Theatre.

Client		
Constraint	Limit	Metrics
1. Shall not alter the theatre envelope	The design shall be aesthetically aligned with the theatre without making changes to the theatre envelope because of the heritage of the corridors and ceiling structure [12]. Walls of the theatre must not be	A scoring system that evaluates how well the design preserves the heritage elements of the theatre.

	renovated due to a case of rust stated by the client.	
2. Designs that not only require online streaming	Designs shall not only include those that require online streamings of performances and activities that happen in the theatre [1].	The stream will buffer slowly when WiFi bandwidth approaches its maximum. An internet speed of at least 25 Mbps to 100 Mbps will make sure the stream will buffer faster [13].
3. Shall not lose any seats in the process	Doug Floyd the manager mentioned how the theatre should not lose any seats and the client mentioned how only a row of seats can be lost [12].	Seats can only lose one row of seats from the current 428 seats [14].
Regulations and Codes		
4. Occupy minimal theater space	ADA building standards for wheelchair ramps state this metric for safety of those using wheelchairs on inclined surfaces [7]. Usually, the standard theatre rise height is approximately 1 ft [15]. Exceeding this amount would result in view obstructions for those sitting behind.	Pre-existing aisles and exits should not narrow aisles to less than 3 ft [7]. Solutions on incline should not exceed 1 ft [15].
5. Must abide Fire and structural protection	Must abide by OS1 Fire and OS2 Structural Protection of Buildings (Appendix E) [16].	The design should take in consideration the code caused by OS1.1 to OS2.6 [16].
6. Slope of the aisle at the back of the theatre must meet code	Slope of the aisle at the back of the theatre must meet the National Building Code 3.3.2.5 Aisles [17]. The aisle must abide by Canadian Safety standards 5.5.6 Edge protection (Appendix E) [18].	Slope of the aisle should be less than 1:8 slope [17].

6.0 Generation, Selection and Description of Alternative Designs

The following section details the methods of idea generation and selection of designs.

6.1 Idea Generation Process

During idea generation, team members contributed ideas on a shared Google document. To enhance creativity, magic solutions were explored, turning unrealistic ideas into feasible ones. Existing solutions were modified for new design alternatives. Collaboration was emphasized, using the "5 whys" method to analyze over 50 design solutions and facilitate discussions [19]. An online whiteboard clarified complex design solutions visually.

6.2 Alternative Design Selection Process

The alternative design process refines the idea list into three designs through consolidation, feasibility, and multivoting. Consolidation involves individual idea generation, yielding over 57 diverse options (Appendix H). Feasibility checks assess designs against standards in a tutorial session, modifying or excluding out-of-scope concepts. If the list falls below 50 ideas, the team returns to consolidation. Multi-voting follows, with the first iteration resulting in the top 7-8 solutions. The second iteration, with two votes per section, identifies the top three solutions. Objective evaluation guides final design selection, revealing common themes like elevating wheelchair seating and proposing innovative solutions for back aisle and stage access, ensuring alignment with success objectives.

6.3 Alternative Design Descriptions

6.3.1 Wheelchair Seating

The following subsection focuses on the design descriptions exclusively for the inadequate wheelchair seating.

Design 1 - Removable Seats

Multiple sets of 2 x 1 seats can easily detach from a push lock in the floor, seen in Figure 2. Seats would be then placed in theater storage, occupying no additional space during a performance. Wheelchair users would then be able to park in the open seating area while being given a complete view of the stage.

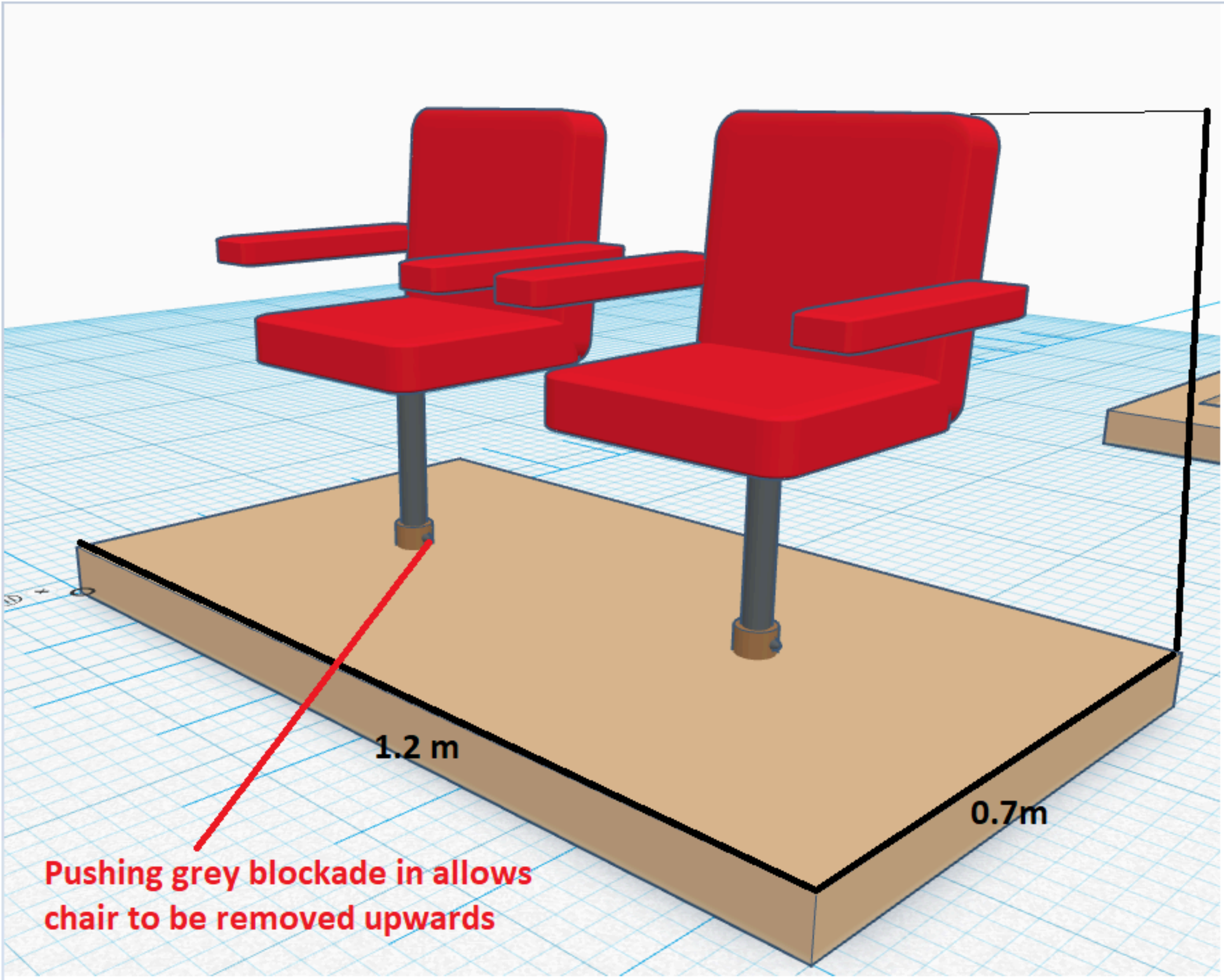

Figure 2. A TinkerCAD model of the Removable Seats design.

Design 2 - Swivel Seats

Seats located at the perimeter of every aisle will be able to pivot 360 degrees for users to enter without the need of going through aisles, seen in Figure 3. Each seat has a locking function in order to stabilize the seat upon entry, exit, and during performances. Users will be able to occupy seats at any edge of an aisle, allowing for seating beside other attendees, in addition to a clearer view of the stage.

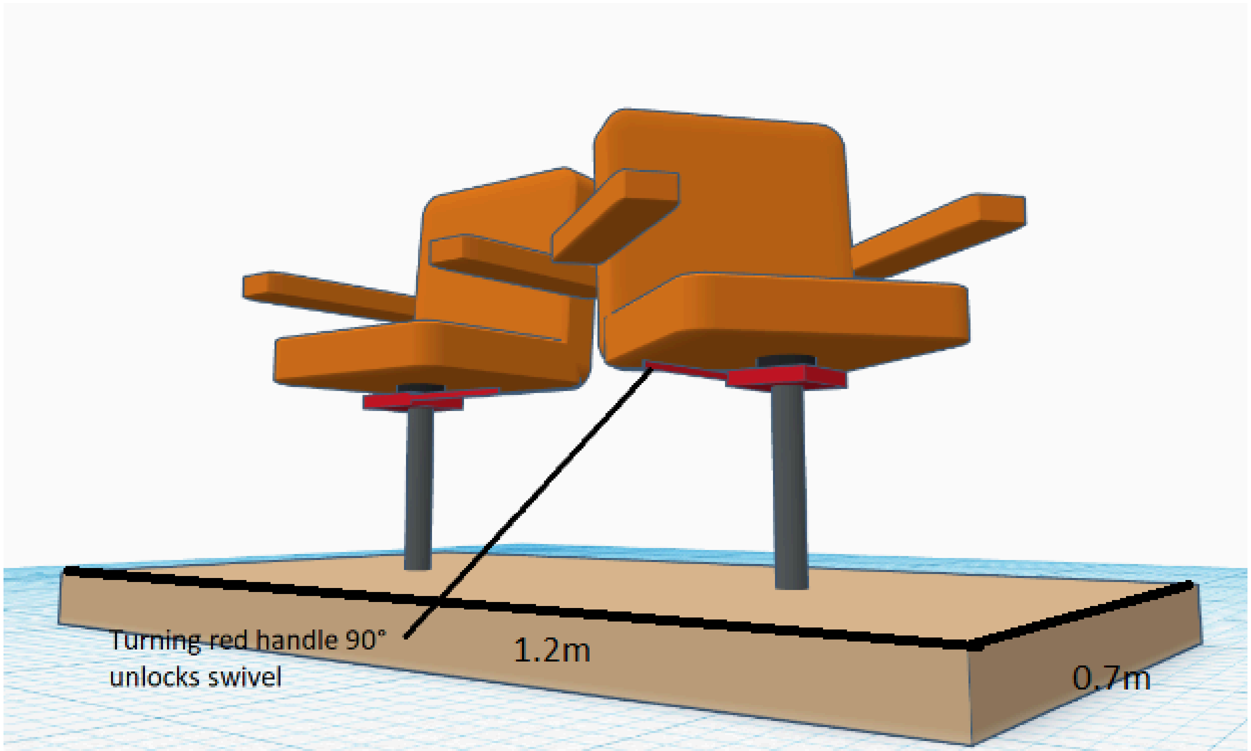

Figure 3. A TinkerCAD model of the Swivel Seats design.

Design 3 - Foldable Seats

Seats located near the front and back of seating sections can be folded then pushed into a hollowed out section of the floor seen in Figure 4. The top of the seat and armrest will be folded into the base, then pressed down into the floor allowing for no additional space occupied. Users will be able to stay in their wheelchair throughout the performance directly between attendees, while being given a clear and close view of the stage.

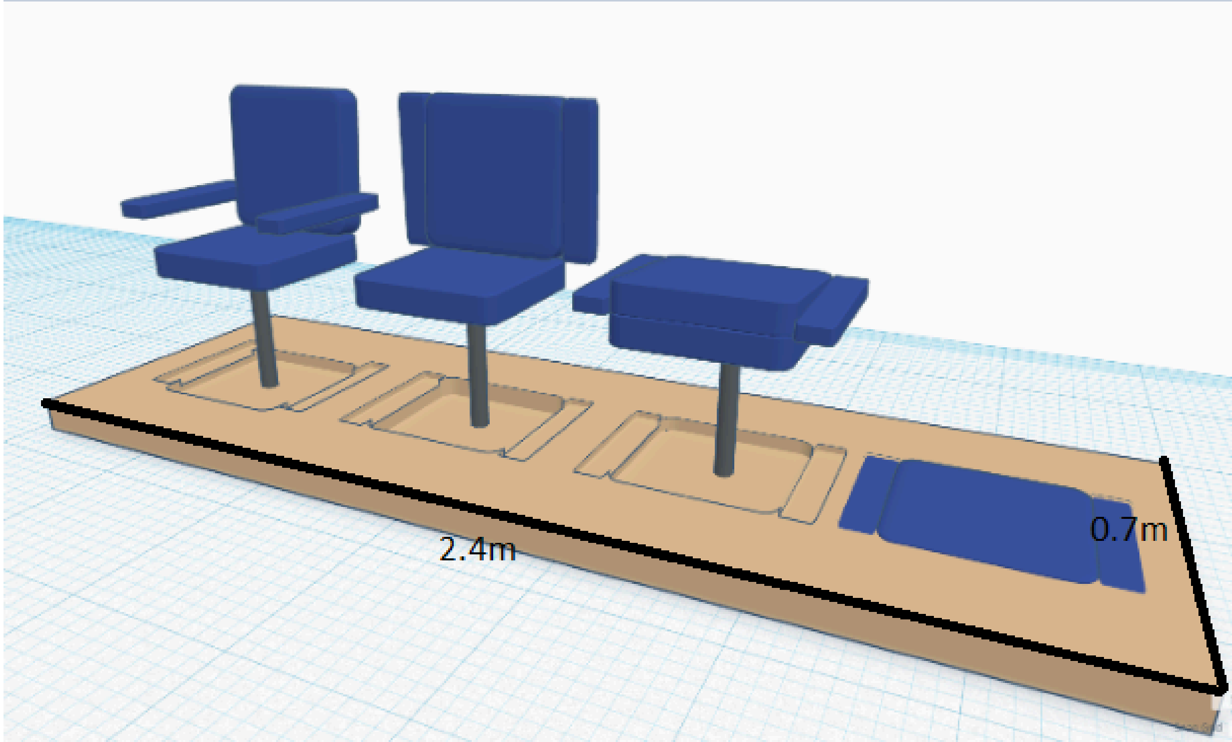

Figure 4. A TinkerCAD model of the Foldable Seats design, displaying each step in the folding process.

The comparison and location of each wheelchair seating design can be found in Appendix C.

6.3.2 Back aisles

The following subsection focuses on the design descriptions exclusively for the steep back aisles. Note the location of all solutions are located in the right-most aisle of the theater, as seen in Figure 6.

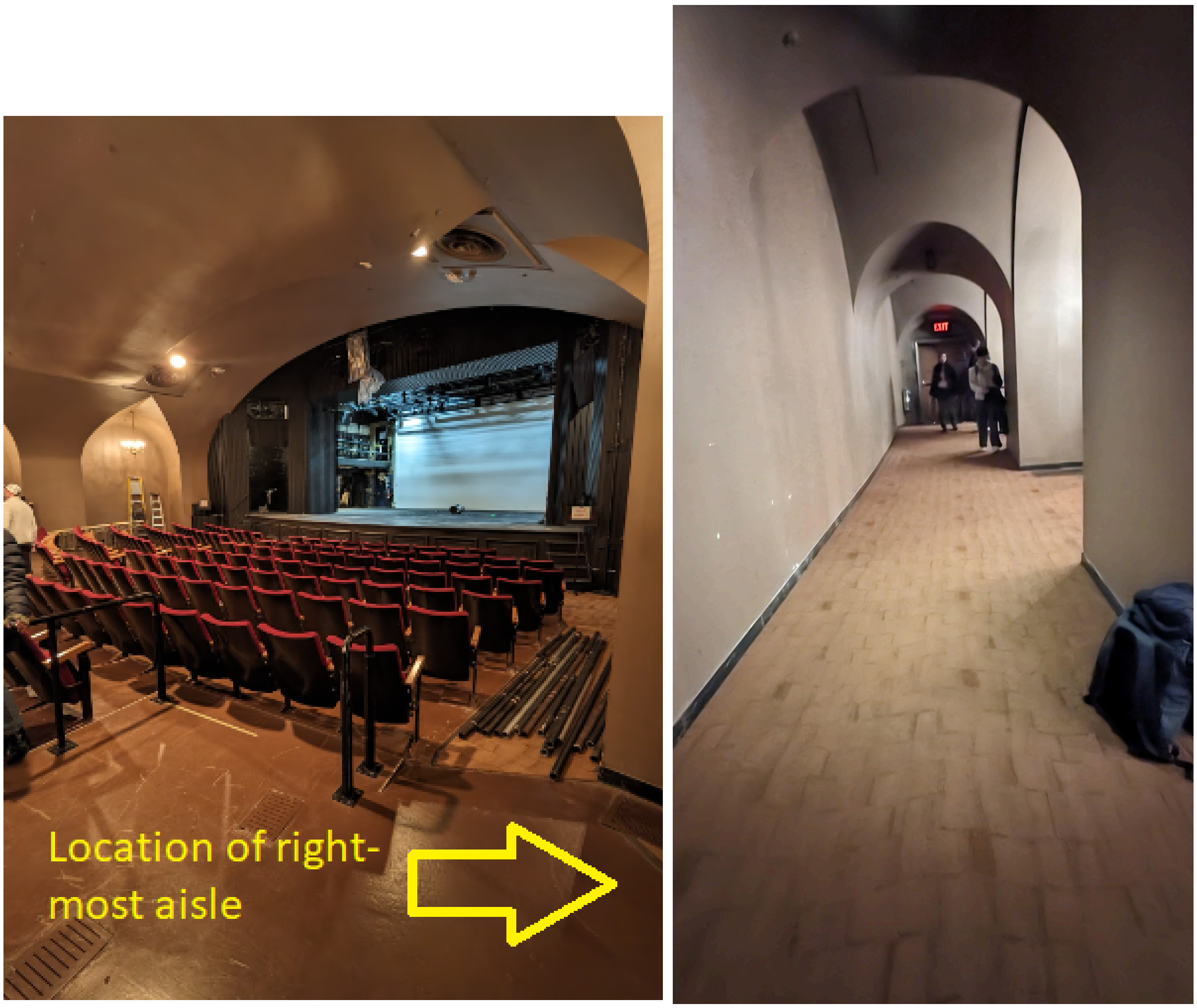

Figure 6. Location of back aisle slopes.

Design 1– Slope Readjustment

Flattening/smoothing the aisle slope directly enhances accessibility for individuals with disabilities, facilitating easier movement in the back aisles without altering the theater's core structure. As depicted in Figure 7, this solution entails a physical adjustment within the current space.

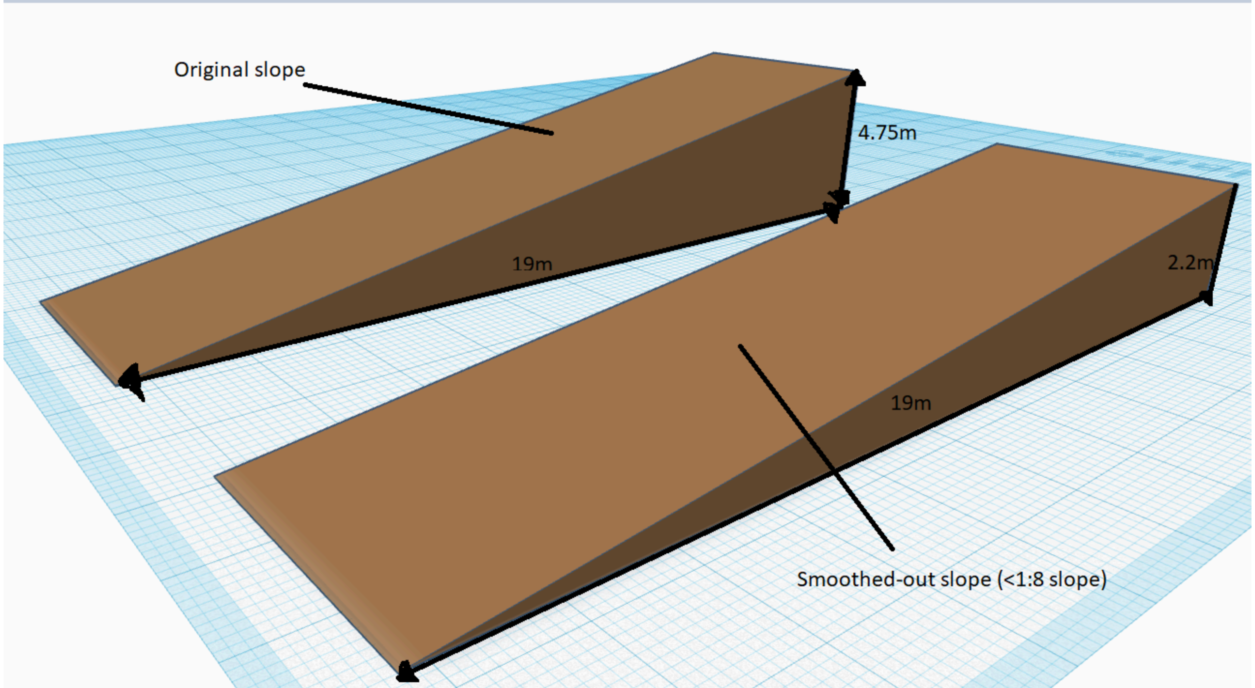

Figure 7. A TinkerCAD model of the Slope Readjustment.

Design 2–Handrails and grips

Handrails and grips installed in the middle of the aisle facilitate accessible movement for individuals with disabilities, offering physical support without structural modifications to the theater. The design features grip tape on both sides of the central hand railing, as depicted in Figure 8.

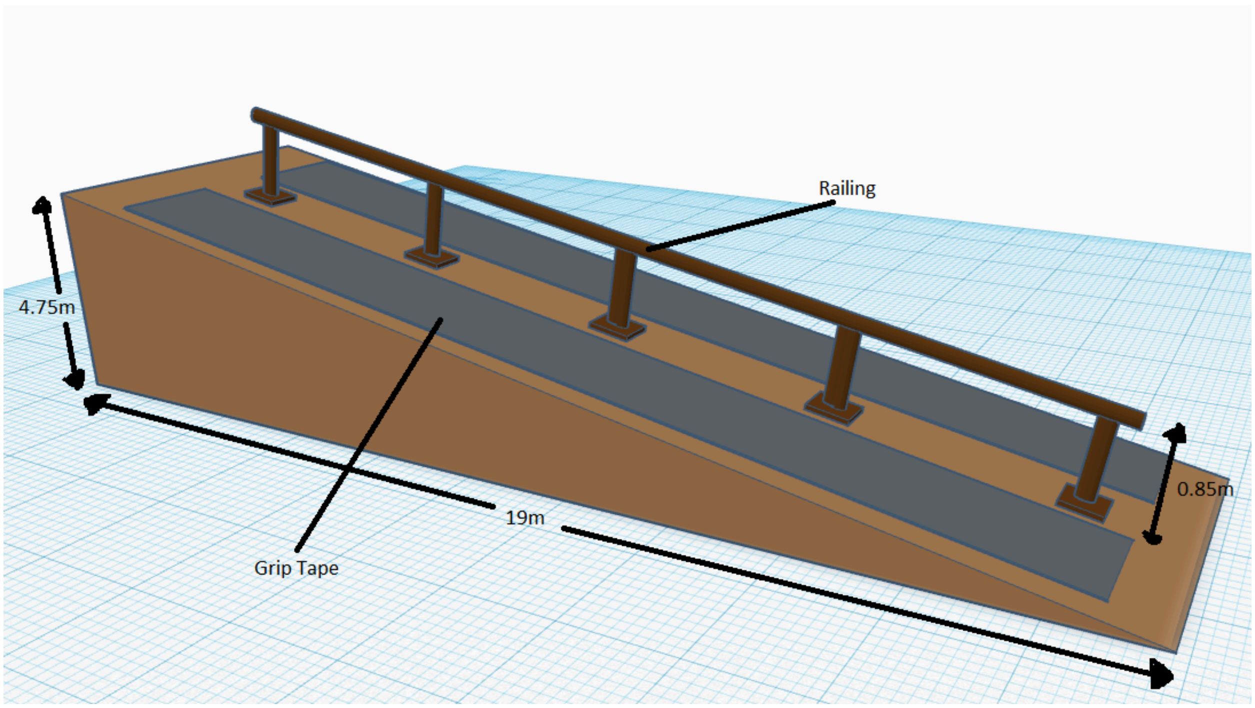

Figure 8. A TinkerCAD model of Handrails and Grips.

Design 3– Chair Attached Lift

Figure 9 illustrates the Chair Attached Lift system, skillfully meeting the need for accessible movement in the back aisles. The design features an electrically motorized chair lift atop the slope, traveling along steel rails to the incline's base. The entrance and exit include an inclined platform for seamless transfer. In Figure 10, the moving chair component incorporates a seatbelt and adjustable armrest for comfortable and secure usage.

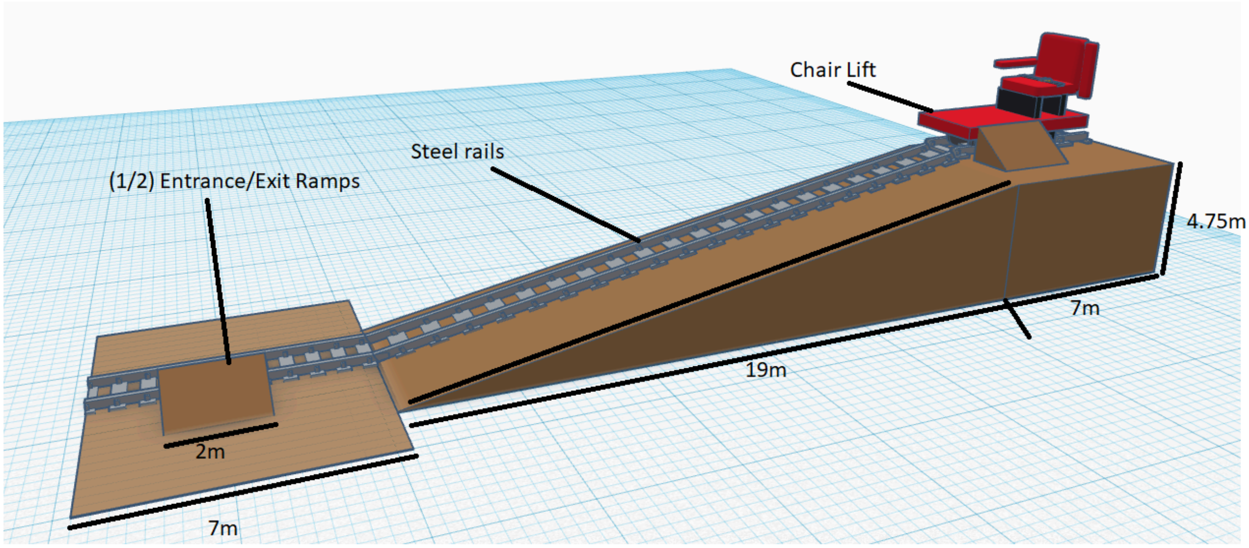

Figure 9. TinkerCAD model of the Chair Attached Lift.

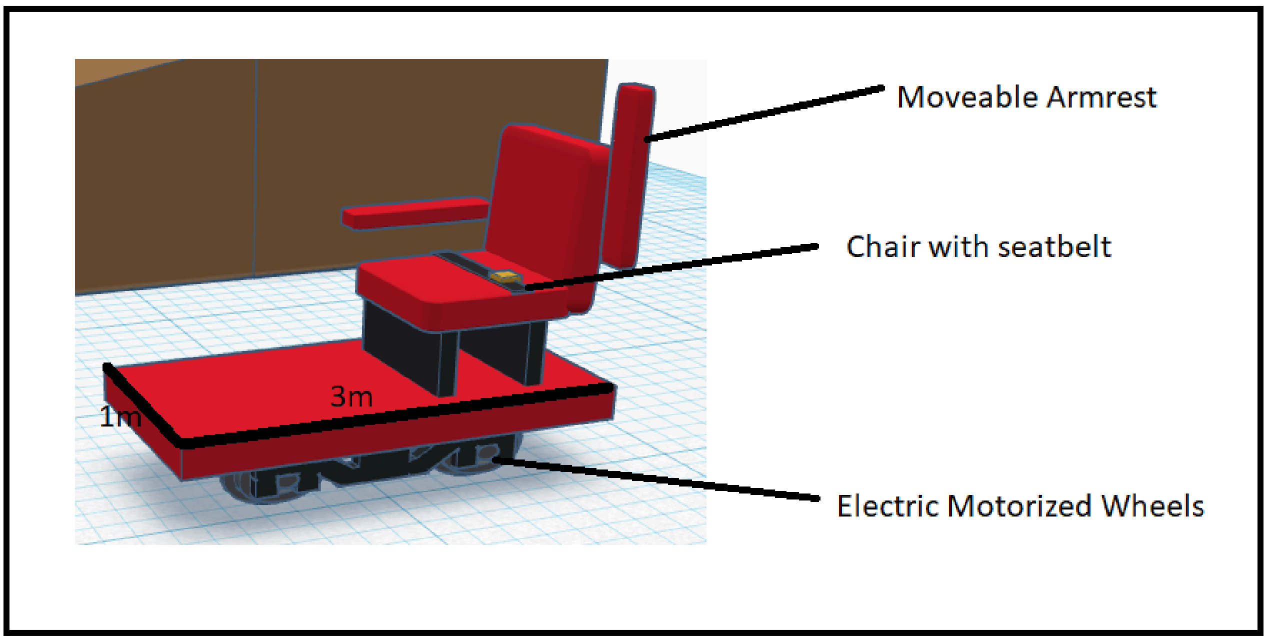

Figure 10. TinkerCAD model of the moving chair of the Chair Attached Lift.

See Appendix D for a comparison of all slope solutions.

6.3.3 Stage Access

The designs in Appendix G prioritize providing accessible stage access for individuals with mobility challenges. Further details are available in the appendix.

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Design 1- Chair Lift

The Acorn Stairlift assists individuals with mobility challenges in navigating stairs. The chair is connected to an aluminum rail system affixed to the theater's side wall, as depicted in Figure (first service environment photo) in Appendix B. Safety features include a safety belt and sensors that halt movement upon detecting an obstruction, visible in Figure 11.

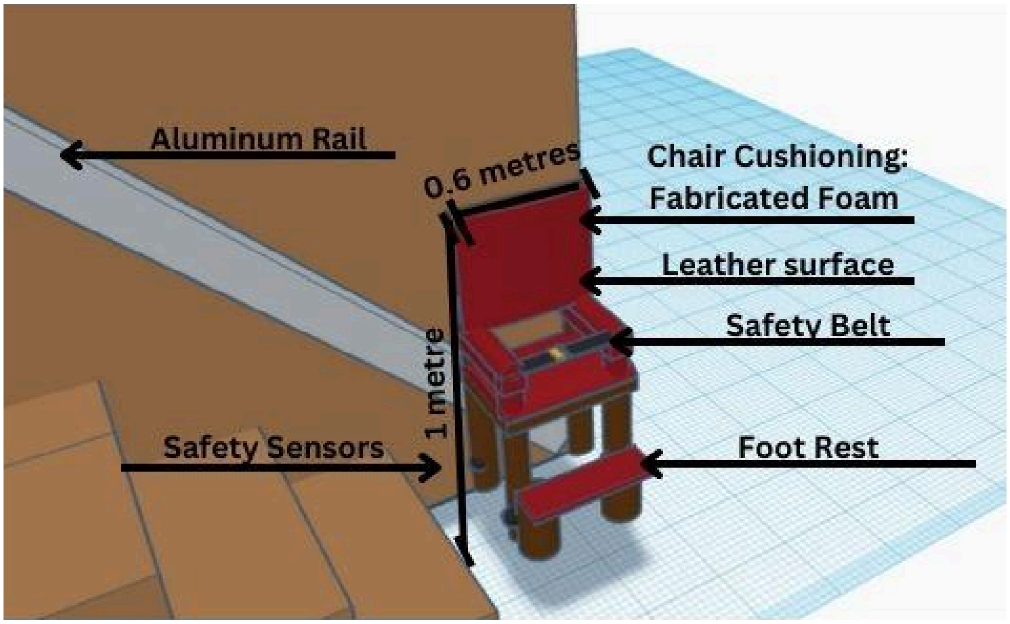

Figure 11. Design of the chair lift made in TinkerCAD

Design 2- Portable Stage Lift

The portable stage lift serves individuals facing challenges with the existing stage stairs. Its steel base ensures stability and can withstand substantial weight. With a 1-meter length and 0.92-meter width, the platform accommodates wheelchair users. Vertical movement, facilitated by a scissor mechanism (Figure 12), allows wheelchair accessibility. Equipped with wheels, the lift is easily transportable and can be conveniently stored at the theater's side.

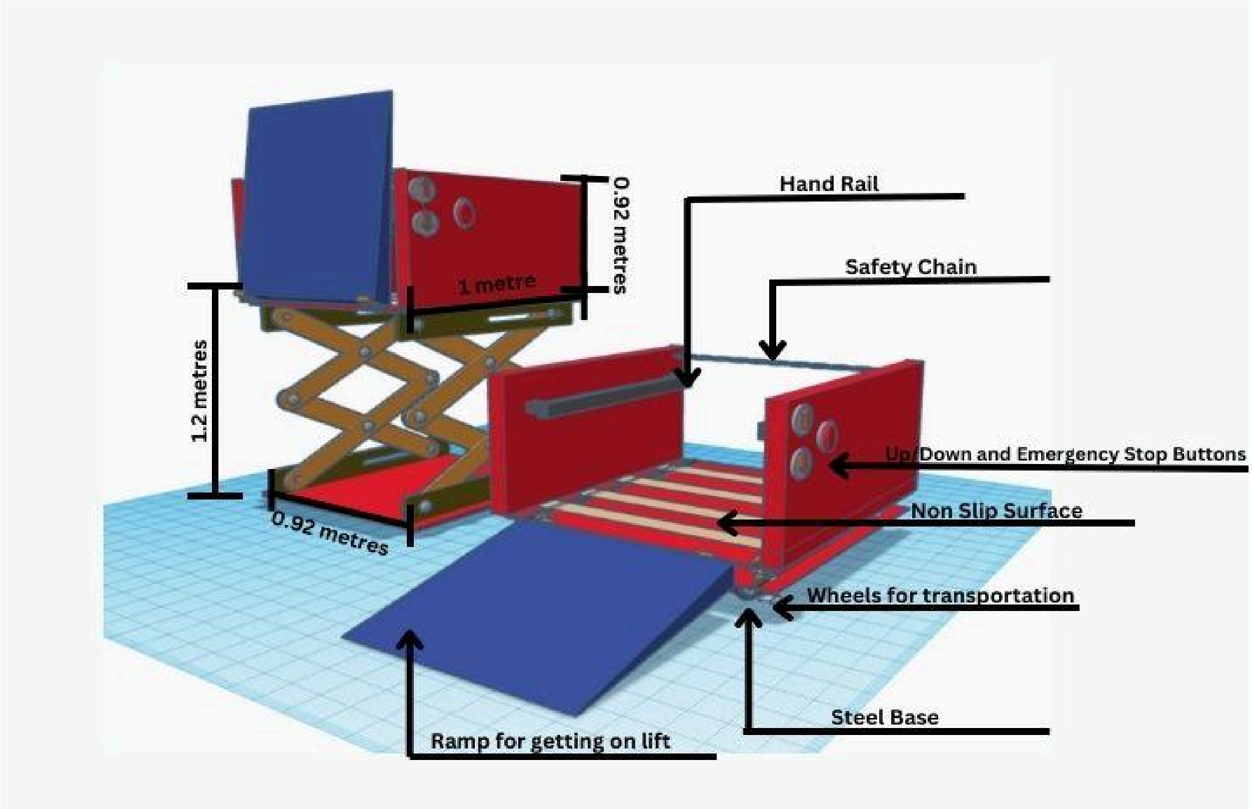

Figure 12. Design of the portable stage lift made in TinkerCAD

Design 3- Portable Stair Wheelchair

The aluminum mobile stairlift, depicted in Figure 13, is tailored for individuals with mobility challenges navigating stairs independently. Its foldable design facilitates convenient storage and transport. The battery-powered lift boasts the capability to transport an individual upstairs and downstairs 120 times on a single charge [20]. However, safety concerns include the risk of scarves, long clothing, or blankets getting entangled in the moving mechanism, potentially leading to damages and injuries.

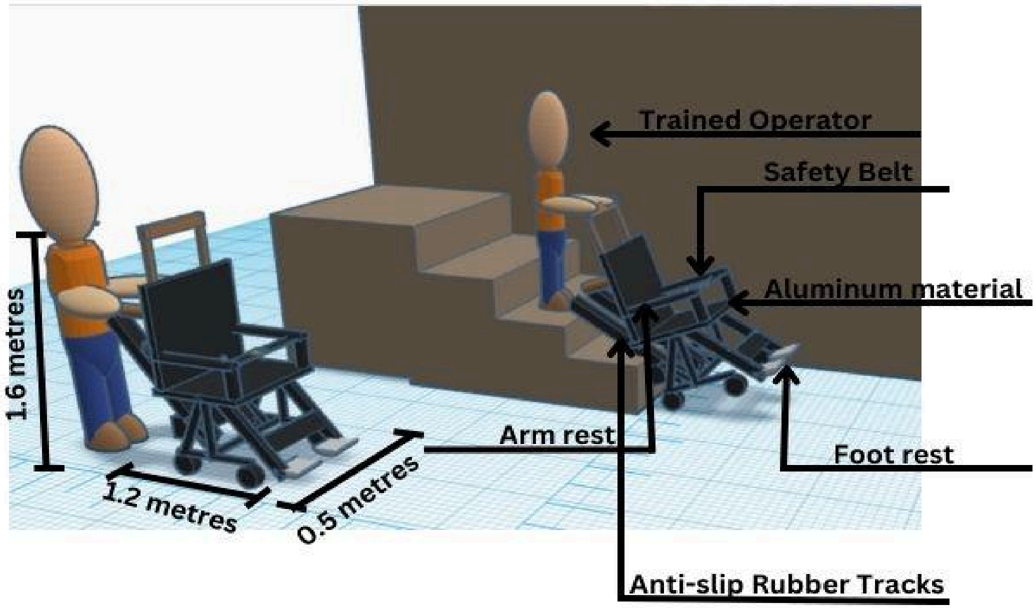

Figure 13. Design of the portable stair wheelchair made in TinkerCAD

7.0 Proposed Conceptual Design Specification

The team employed the Pugh method to select the conceptual design (Appendix H), streamlining the process after narrowing down three solutions for each identified problem [21]. This method's simplicity facilitated the efficient elimination of solutions not meeting functions, objectives, and constraints. To mitigate the equal-weight treatment of objectives, the preceding alternative design process incorporated varied weights through the objective evaluation tool. The Pugh method resulted in the identification of one solution for each section. In the back aisle, a chair-attached lift system excelled in durability and accessibility. For stage access, a portable stage lift system excelled in safety and ergonomics, addressing space constraints. In wheelchair seating, modifying specific seats to fold and be stored under the floor met objectives related to optimal stage view and inclusivity.

8.0 Measures of Success

Prior to implementation, various tests must validate functionality and quality. Success is established when the designs meet client needs and fulfill specified measures of success.

8.1 Noise

To ensure minimal disturbance to the audience and performers during performances, devices' ambient sound should range between 30-50 decibels, akin to average room noise [8]. Measurement of emitted noise in the theatre will employ sound level meters or noise dosimeters, commonly using a condenser microphone for precision and reliability [22]. The noise decibel test plan involves measuring sound levels post-installation on a day with minimal activity, such as when the theatre is closed, using the aforementioned devices.

8.2 Safety

The safety test plan underscores strict adherence to key standards—ISO 45001:2018, ISO 13849-1:2023, and CSA/ASC B651 [23], [24], [25]. Initiating with hazard analysis for the chair attached lift system, portable stage lift, and foldable seats, the systematic approach includes Failure Modes and Effects Analysis (FMEA) and risk assessments to address potential safety risks. Tailored safety simulations for back aisle slope, stage access, and wheelchair seating are integral. Simultaneously, a meticulous evaluation of emergency response mechanisms in each design is conducted. Data compilation includes observational and quantitative data, ensuring alignment with standards for a robust safety evaluation of each proposed solution.

8.3 Battery life

Battery degradation during use is influenced by charging cycles. Frequent charging to 100% or after full depletion accelerates degradation, and fast charging adds to it due to heat generation [26]. Maintaining the battery between 20 - 80% enhances longevity. Testing methods in section 8.2 assess battery life, with no signs of decay indicating success.

8.4 Transportation time

To gauge user transfer efficiency, transportation times for the Portable Stage Lift and Chair Attached Lift are measured. The average time for 20 participants to enter, exit, and have the lift return to its original position is recorded. This sample size aligns with Marmara University's report on sampling in quantitative research [27]. Success criteria for both lifts is achieving a time under 60 seconds, benchmarked against the Mobility CX Lift in Appendix F.

8.5 Durability

To ensure longevity, design strength is crucial. Testing the key materials—aluminum pole for the Foldable Seat, steel platform for the Chair Attached Lift, and steel for the Portable Stage Lift—under designated loads reveals their durability. Calculating compressive strength involves applying weights across their initial cross-sectional area [28]. For safety validation, if the lift materials withstand 1800 lbs without deformation, meeting Federal Transit Administration standards, they are deemed safe [29]. Similarly, the aluminum pole should support 250 lbs without deformation [30].

9.0 Conclusion

This document emphasizes the goal of ensuring universal access to Hart House events, fostering equality. Addressing back aisle, wheelchair seating, and stage access, our design prioritizes accessibility, safety, and ergonomics, enhancing the theater experience for those with mobility challenges. Noise and suitability considerations align with the theater's ambiance. Following implementation, rigorous testing, detailed in section 8.0, Measures of Success, will be executed. Regular client reviews, every ten days, will guide adjustments to meet expectations, aligning with the one-month completion timeline per the client statement [1].

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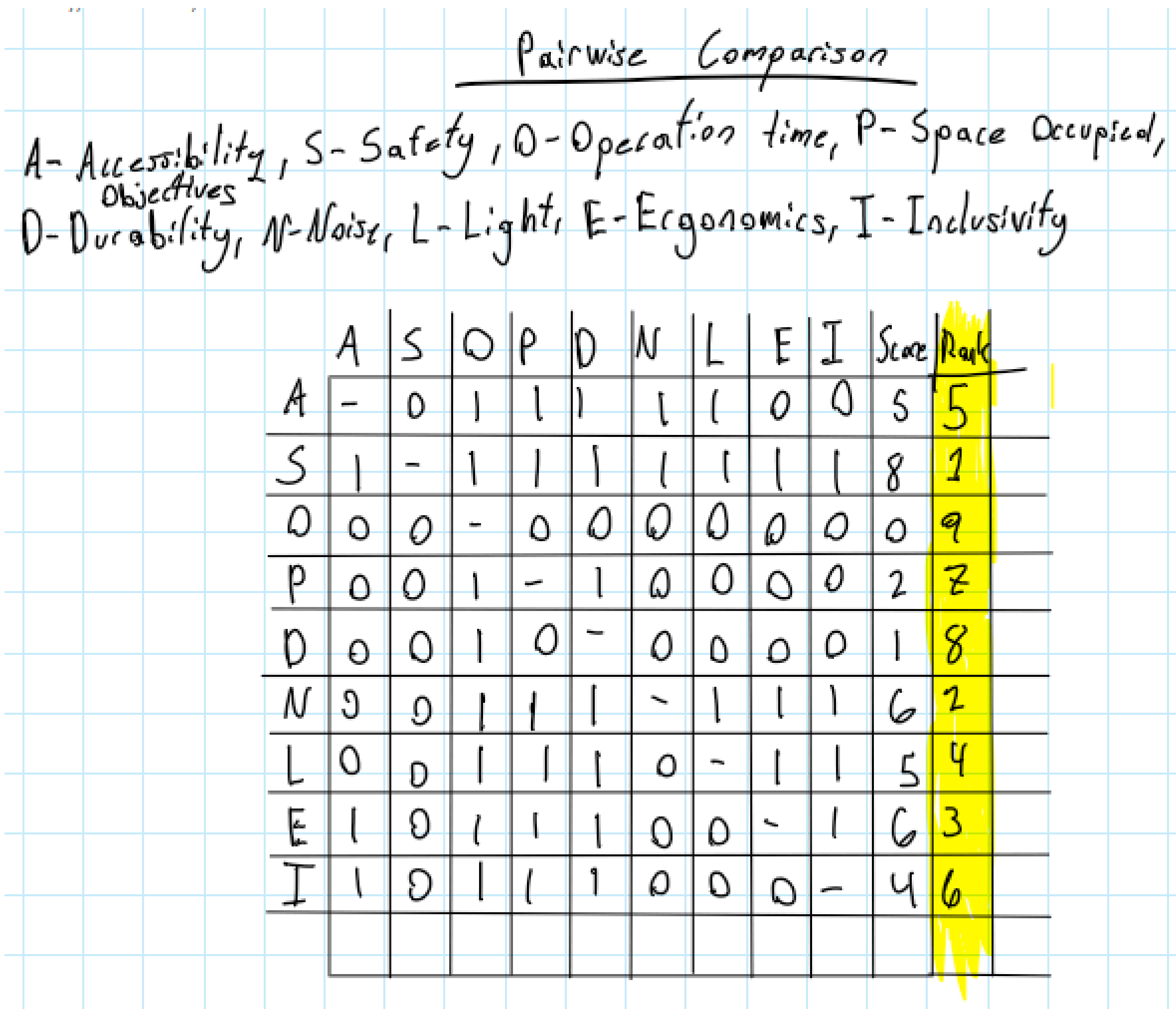
Appendices

Appendix A - Objectives

The following Pairwise Comparison seen in Figure 13 presents the ranking of objectives. Note some objectives were removed due to lack of measurability or conversion to a constraint.



	A	S	O	P	D	N	L	E	I	Score	Rank
A	-	0	1	1	1	1	1	0	0	5	5
S	1	-	1	1	1	1	1	1	1	8	1
O	0	0	-	0	0	0	0	0	0	0	9
P	0	0	1	-	1	0	0	0	0	2	7
D	0	0	1	0	-	0	0	0	0	1	8
N	0	0	1	1	1	-	1	1	1	6	2
L	0	0	1	1	1	0	-	1	1	5	4
E	1	0	1	1	1	0	0	-	1	6	3
I	1	0	1	1	1	0	0	0	-	4	6

Figure 13. Pairwise Comparison of Objectives.

CSAT (Customer Satisfaction Score) measures the contentment of a user quantitatively.

CSAT = (#of positive responses for a product or service / # of responses) * 100

For example, If 140 people out of 200 people stated they had a positive experience with a product/service, the CSAT score would be 70 for that product/service.

Appendix B

Figures 14-17 were taken inside the Hart House Theatre, displaying the service environment.

Figure 14. Central view of stage.

Figure 15. View of left seat section.

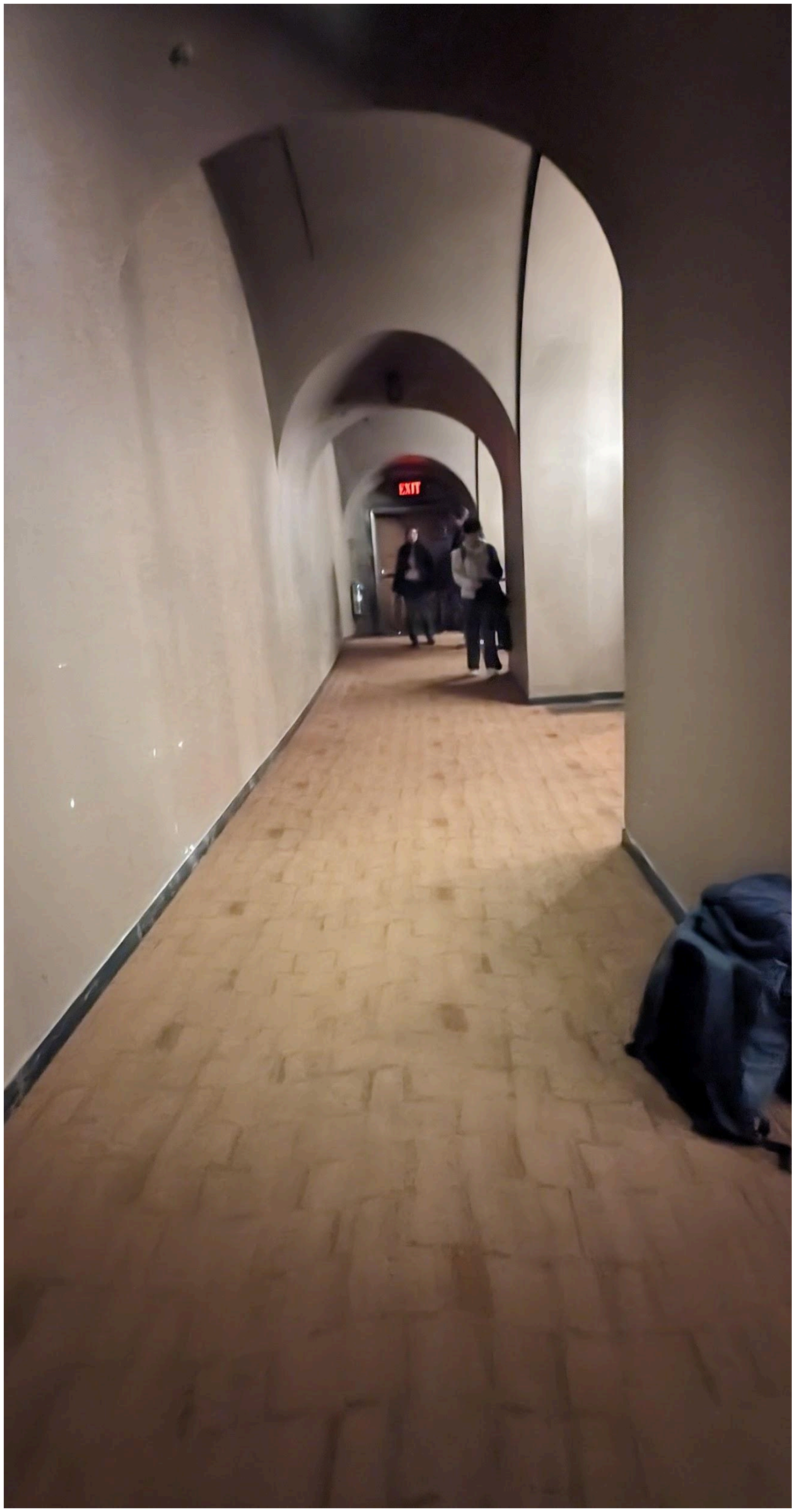


Figure 16. View of the right-most aisle.

Figure 17. View of stage stairs.

The lumen estimator was used to calculate the expected lumen in the theatre. 150 lumen/m^2 was used as it corresponded to theatre lighting [31].

Appendix C

The comparison of each wheelchair seating design can be found in Table 6. A TinkerCAD link for a full view of designs can be found: https://www.tinkercad.com/things/8VvseYS5KRJ-seats?sharecode=FBLCoRDgGJOTqJs08npZVGIYFxAzQFkWuPU9QQr1bQY

Table 6. A comparison of wheelchair seating designs.

	Removable Seats	Swivel Seats	Foldable Seats
Location See Figure 5 for illustration of design locations.	Front and back rows of two closest seating sections to the stage, and front row of farthest seating sections.	The perimeter chairs of any seating sections.	Front and back rows of two closest seating sections to the stage, and front row of farthest seating sections.
Access	Seats must be manually disattached, then wheelchair users roll and	Seats must be unlocked, then turned to the user. User then must be	Seat must be unlocked then pressed into the floor. Wheelchair users

	park during performance.	helped out of the wheelchair and into the swivel seat.	roll and park during performance.
Space Occupied	Wheelchairs and seats must be stored in the theater.	Wheelchairs must be stored in the theater.	No additional space during performance.
Material: All seats have an aluminum pole, fabric seats and armrest, aluminum chair frame	Iron blockade holder at base of chair connected to floor, push-in aluminum blockade on pole.	Plastic handle and locker underneath seat.	Plastic and metal hinges for folding chairs, aluminum pole tightens underneath the seat to fall into the floor.

Figure 5. An outline of the location of each design. Taken and adapted from [32].

Appendix D

See Table 7 for a comparison of each slope solution. A TinkerCAD link for a full view of designs can be found:

https://www.tinkercad.com/things/itVld0gQVLK-back-aisles?sharecode=NnOuze_7KIUZYiY-JrwpfVlRQnrqJWPojx2dF4N9Hug

Table 7. Steep aisle solution comparison.

	Slope Readjustment	Handrails and grips	Chair attached lift
Access	According to the measurements of the theatre, the slope could be fixed to a minimum elevation of 1:8, which is accessible for the vast majority of those with mobility challenges. [33]	People with mobility challenges can grab these handrails along the aisle, to keep balance.	Automatically carries people up or down the ramp. The entrance to the lift requires users to
Safety	An elevation less than 1:12 is safe for the majority handicaps to use. [33]	These handrails are specifically designed to help people with mobility challenges up or down a ramp, making the process safer [34]	The lift will include safety features like obstruction sensor and seat belt [35]. Also requires maintenance biannually [36].
Material	Concrete and cement to build the floor.	Steel handrails with paint to cope with the environment of the theatre.	Steel rail, fabric chair with aluminium frame, steel platform, electric motor

Appendix E
The following are codes/regulations that have been stated in section 5.3, Constraints.

"5.5.6 Edge protection by CSA states that ramp edge protection is required to prevent wheels or walking aids from moving off the ramp surface." [18]

"An aisle with a 1 in 8 (7.12 degrees) slope shall not be stepped; an aisle that is more than 1 to 8 shall be stepped"[17]. When our team visited Hart House theatre we measured the slope of the aisle at the back of the theatre which resulted in a 1 in 4 slope (14.04 degrees).

The Fire Protection of the Building Code is to limit the possibility of its design or construction, of the building being exposed to damage due to fire. [16]
This includes:
"OP1.1- fire or explosion occurring
OP1.2 - fire or explosion impacting areas beyond its point of origin

OP1.3 - collapse of physical elements due to a fire or explosion
OP1.4 - fire safety systems failing to function as expected" [16]

Appendix F

The Mobility CX Lift takes 20 seconds to reach a height of 5 feet, which is higher than the stage [37]. We expect 20 seconds each for boarding and exiting of the lift, then 20s + 20s + 20s = 60s, the expected time of operation.

Appendix G

Design 1
The sensors are backed up by a battery that can last around 2 to 5 years depending on the usage of the lift.[38] The stairlift can be recharged when sitting at the charging point. If a power outage were to occur the stairlift batteries will continue to work. Fully charged batteries are good for at least 15 to 20 rides up and down the stairs. Refer to this link:
https://www.canva.com/design/DAF1-Su9qms/tEouozx5V7jUE9FeKx-X1A/edit?utm_content=DAF1-Su9qms&utm_campaign=designshare&utm_medium=link2&utm_source=sharebutton

Design 2
Scissor mechanism is a mechanism where there are 2 sets of linked supports shaped like X and they are connected to each other at a point. When the weight is applied on the platform, the supports rotate around that connection point. The rotation of the supports changes the distance between the sets which allows the platform to go up and down. Refer to this link:
https://www.canva.com/design/DAF1zM6aWXI/DddFA7euwrcwgK9aiwyvRg/edit?utm_content=DAF1zM6aWXI&utm_campaign=designshare&utm_medium=link2&utm_source=sharebutton.
A typical wheelchair is around 25 inches wide and 32 inches long therefore the platform gives plenty of space for the wheelchair [39].

Design 3
For better view of the design, go to:
(https://www.canva.com/design/DAF122q_iYA/lIfHgVLotEc_3oip3AHJvQ/edit?utm_content=DAF122q_iYA&utm_campaign=designshare&utm_medium=link2&utm_source=sharebutton).
Table 8 shows a comparison of each stage access solution.

Table 8. Stage Access solutions.

	Chair Lift	Portable Stage Lift	Portable Stair Wheelchair

Safety	Safety belt and sensor that stops the mechanism if any obstructions are detected on the way	Non-slip surface to keep the wheelchair stable while lifting it up and handrails aside the platform to assure the safety of the person	Safety belt and brake sensors that stop the mechanism when an obstruction is sensored. The operator needs to be properly trained in the stairlift's use.
Comfort	Folding footrest,backrest, adjustable armrest The chair cushioning is made out of fabricated foam which is an ergonomic material	Spacious platform Non-slip surface Ramp that makes it easy to get on and off the platform	Lap belt Safety head restraint Footrest and armrest
Material	The seat surface has a leather wipeable and most water resistant material and the rail is made of aluminum which is a light but strong material.	Platform and the scissor mechanism made of steel to make sure it supports heavy weights	High-grade lightweight aluminum alloy used in aerospace
Installation Time	As the stairlift fits directly to the stairs and not the wall, installation takes 1 or 2 hours. If it is a more complex installation it takes 4-5 hours [40].	It takes a full day minimum to install the stage lift [41].	Estimated installation time is around 6 hours for stairlifts [42].

Appendix H

1. Consolidate Team List

The consolidated team list includes any type of solution the team could think of.

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Back aisle:

1. Putting a chair-attached system that would take the person and carry them until the stage.
2. A slide
3. A railway
4. Ramp that does not exceed the code/ permanent ramp
5. A chair-attached system hanging on the ceiling across the back aisle (zipline)
6. Threshold ramp
7. Suitcase ramp
8. Modular ramp
9. Portable/ folding ramps
10. Make back aisles stairs (like in lectures)
11. Aisle redesign
12. Hand rails and grips along the back aisle
13. Switchback ramp
14. Non slip material on the ramp
15. A wheelchair escalator that goes down the side aisle
16. Teleportation device to teleport the person down/up the slope
17. Escalator

Stage access:

1. Ramp beside the stairs (Cannot exceed 1 in 8 slope)
2. Wheelchair lift
3. Catapult
4. Ladder
5. Crane that hooks on to the person and carries them
6. Motorized platform
7. Slingshot
8. Ejector
9. Acorn stairlift idea
10. Elevator
11. Escalator
12. Inclined platform lift
13. Hotwheels track
14. Track that connects to wheelchair, automatically rolls wheels on ramp up
15. See-saw/ tipping scale
16. Elevatable stage
17. Companion to help
18. Rolling chairs that can roll out of the way to make space for wheelchair seating
19. Magic carpet

20. Hoverboard that flies
21. Magnetic hoverboard
22. Throw a magic bead that can teleport you on and off stage
23. Portal
24. Winch system
25. Foldable ramp
26. Scissor lift

Wheelchair seating:

1. Orientate wheelchair seating so they face stage better
2. Move wheelchair seating in the middle of the theater
3. Remove obstructions from the wheelchair seating
4. Removable seats that can be taken out for wheelchair seating
5. Sliding seats where we can slide the seats to the side to make seating for wheelchairs
6. Foldable seats that can be stored under the floor to make room for wheelchair seating
7. Elevated platforms to raise wheelchairs
8. 360 Degree Swivel Wheelchair to Normal Seat
9. Move dedicated wheelchair seating area to front, middle, back based on preference
10. Adding second level to seating (almost like a bunk bed), able people climb to top and wheelchairs roll underneath
11. Remove outer seats on aisles for spread out wheelchair seating
12. Remove seats in middle of theater and add pathway to it
13. Accessible box seats for private viewing experience
14. Hover chairs

2. Feasibility Check:

The Feasibility Check included a new list of feasible solutions.

Back Aisle:

1. Putting a chair-attached system that would take the person and carry them through the aisles
2. A railway with detachable chair used to push a person across aisle
3. Ramp that does not exceed the code/ permanent ramp
4. A harness system hanging on the low ceiling across the back aisle (zipline)
5. Portable/ folding ramps that decrease the existing slope
6. Make back aisles stairs (like in lectures) (between chairs)
7. Hand rails and grips along the back aisles
8. Non slip material on the ramp (such as grip tape)
9. Smoothing out the back aisle to have a smaller slope

10. Back row of seats on tracks to create more space between rows
11. Hydraulically powered railings positioned between rows that can retract
12. A wheelchair carriage attached to the wall
13. Companion to help
14. Hanging railing and straps from ceiling to grab while traversing (similar to TTC rails)

Stage access:

1. Wheelchair lift
2. Small crane that hooks on to the person and carries them
3. Crane that hooks on to the person and carries them
4. Vertical platform lift (porch lift)
5. Acorn stairlift (https://www.stannah.ca/?infinity=ict2~net~gaw~ar~571823030050~kw~acorn%20stairlift~mt~b~cmp~%2ACanada%20-%20Non-Brand~ag~Acorn&cn=ppc&sr=google-sem&kw=acorn%20stairlift&gad_source=1&gclid=CjwKCAiA04arBhAkEiwAuNOsItnYpjHUb8uu_K3u5EkwUy0gmTcE3_-WvkiHRxf8eJbwzqVTu1eSZxoC-eAQAvD_BwE) where the stairs to the stage connect
6. Track that connects to wheelchair, automatically rolls wheels on ramp up
7. Inclined platform lift where the stairs connect to the stage
8. Inclined platform lift where the stairs connect to the backstage area
9. See-saw/ tipping scale
10. Companion to help
11. Winch system where the stairs go up to the stage
12. Foldable ramp where the stairs go up to the stage
13. Foldable ramp where the backstage connects to the stage
14. Scissor lift where the stairs to go up the stage is
15. Flat escalator/ Conveyor where the stairs go up the stage
16. Steeper and narrower ramp with track that connects to wheelchair wheels
17. Cut-out section of stage that lowers/rises like a platform lift
18. Pulley system that works off electricity and brings the person up on stage and off stage.
19. Genesis Mobile Stairlift (https://www.mobilestairlift.com/collections/mobile-stairlifts/products/mobile-stairlift-battery-powered-portable?utm_campaign=Product%20-%20MSL&utm_source=ppc&utm_medium=Search&utm_term=portable%20stair%20climber&utm_campaign=Search+-+CA+-+Products&utm_source=adwords&utm_medium=ppc&hsa_acc=1155207825&hsa_cam=18820626459&hsa_grp=144807444642&hsa_ad=633364204292&hsa_src=g&hsa_tgt=kwd-5074387357&hsa_kw=portable%20stair%20climber&hsa_mt=b&hsa_net=adwords&hsa_ver=3&gad_source=1&gclid

=CjwKCAiA04arBhAkEiwAuNOsIp5XkSm2IzzALenXmL4jOY6nR9pWo_zWN0RFAFFgdkV0Sxy_YV-FPhoCxXgQAvD_BwE)

20. Mobilift CX - Portable Stage Lifts (https://handiramp.com/portablestagelift.htm)
21. Stairmate Major TRE-70 Stair Climber Machine (https://www.indiamart.com/proddetail/stairmate-major-tre-70-stair-climber-machine-2852092653888.html)
22. A ramp that connects to the backstage of the theater for mobility devices and any other mobility difficulties to get to the stage from the back
23. A flat escalator that goes to the backstage area instead of where the stage is
24. Floating platforms that can be filled up with air to lift the wheelchair up
25. Hydraulic lifts that can raise and lower individuals

Wheelchair seating:

1. Orientate wheelchair seating so they face stage better
2. Remove obstructions from the wheelchair seating
3. Removable seats that can be taken out for wheelchair seating
4. Sliding seats where we can slide the seats to the side to make seating for wheelchairs
5. Foldable seats that can be stored under the floor to make room for wheelchair seating
6. Elevated platforms to raise wheelchairs (at the back)
7. Move dedicated wheelchair seating area to front, middle, back and clear chairs based on preference
8. Accessible box seats for private viewing experience
9. Adding second level to seating (almost like a bunk bed), people climb to top and wheelchairs roll underneath (at the back)
10. Seats that can turn 360 degrees in the middle of the theater for people in wheelchairs to switch from their wheelchair to the theater seat.
11. Platform in the corners of theater that elevate wheelchairs above for clear view of stage
12. Have tv viewing on walls, coming down the roof when viewing is obstructed

3. Multi-Voting

After two rounds of multi-voting, solutions were narrowed to the following shown below.

First Round:

<u>Back Aisles:</u>

Engineering Strategies & Practice

1. Putting a chair-attached system that would take the person and carry them through the aisles
2. A railway with detachable chair used to push a person across aisle
3. An added ramp that does not exceed the code/ permanent ramp
4. Make back aisles stairs (like in lectures) (between chairs)
5. Hand rails and grips along the back aisles
6. Smoothing out the back aisle to have a smaller slope
7. Robot to help
8. Hanging railing and straps from ceiling to grab while traversing (similar to TTC rails)

Stage Access:

1. Vertical platform lift (porch lift)
2. Acorn stairlift (https://www.stannah.ca/?infinity=ict2~net~gaw~ar~571823030050~kw~acorn%20stairlift~mt~b~cmp~%2ACanada%20-%20Non-Brand~ag~Acorn&cn=ppc&sr=google-sem&kw=acorn%20stairlift&gad_source=1&gclid=CjwKCAiA04arBhAkEiwAuNOsItnYpjHUb8uu_K3u5EkwUy0gmTcE3_-WvkiHRxf8eJbwzqVTu1eSZxoC-eAQAvD_BwE) where the stairs to the stage connect
3. companion to help
4. Flat escalator/ Conveyor where the stairs to go up the stage
5. Cut-out section of stage that lowers/rises like a platform lift
6. Genesis Mobile Stairlift (https://www.mobilestairlift.com/collections/mobile-stairlifts/products/mobile-stairlift-battery-powered-portable?utm_campaign=Product%20-%20MSL&utm_source=ppc&utm_medium=Search&utm_term=portable%20stair%20climber&utm_campaign=Search+-+CA+-+Products&utm_source=adwords&utm_medium=ppc&hsa_acc=1155207825&hsa_cam=18820626459&hsa_grp=144807444642&hsa_ad=633364204292&hsa_src=g&hsa_tgt=kwd-5074387357&hsa_kw=portable%20stair%20climber&hsa_mt=b&hsa_net=adwords&hsa_ver=3&gad_source=1&gclid=CjwKCAiA04arBhAkEiwAuNOsIp5XkSm2IzzALenXmL4jOY6nR9pWo_zWN0RFAFFgdkV0Sxy_YV-FPhoCxXgQAvD_BwE)
7. Mobilift CX - Portable Stage Lifts (https://handiramp.com/portablestagelift.htm)
8. A ramp that connects to the backstage of the theater for mobility devices and any other mobility difficulties to get to the stage from the back

Wheelchair Seating:

1. Orientate wheelchair seating so they face stage better
2. Removable seats that can be taken out for wheelchair seating
3. Sliding seats where we can slide the seats to the side to make seating for wheelchairs

4. Foldable seats that can be stored under the floor to make room for wheelchair seating
5. Elevated platforms to raise wheelchairs (at the back)
6. Move dedicated wheelchair seating area to front, middle, back and clear chairs based on preference
7. Seats that can turn 360 degrees in the middle of the theater for people in wheelchairs to switch from their wheelchair to the theater seat.
8. Platform in the corners of theater that elevate wheelchairs above for clear view of stage

Second Round:

Back Aisles:
1. Hand rails and grips
2. Smoothed-out slope
3. Chair Attached Lift

Stage Access:
1. Chair lift
2. Portable stage lift
3. Stair wheelchair

Wheelchair Seating:
1. Swivel Seats
2. Foldable Chairs
3. Removable Seats

4. Graphical Design Chart

The pugh method was then used to narrow down solutions. The leftmost solution in each table was used as a benchmark. See Tables 9-11 for each Pugh method.

Table 9. Puth method for Back Aisles.

Objective	Fix the angle of the ramp	Hand rails and grips	Chair attached lift
Accessibility	S	-1	+1
Safety	S	0	+1
Operation Time (1 month)	S	-1	0
Space Occupied	S	-1	0

(standard is within aisle space)			
Durability (Needs to be updated yearly)	S	-1	+1
Noise (40 dbs)	S	-1	0
Suitability (color, style)	S	-1	0
Ergonomics	S	+1	0
SUM	0	-5	3

Table 10. Pugh method for Stage Access.

Objective	Chair lift	Portable Stage Lifts	Stair wheelchair
Accessibility	S	0	0
Safety	S	+1	-1
Operation Time	S	+1	+1
Space Occupied	S	0	+1
Durability	S	+1	-1
Noise	S	0	+1
Suitability (color, style)	S	+1	+1
Ergonomics	S	+1	0
SUM	0	5	2

Table 11. Pugh method for Wheelchair Seating.

Objective	Removable seats	Foldable seats that are stored under the floor	Seats that can turn 360 degrees
Accessibility	S	0	0
Safety	S	0	0

Operation Time (1 month)	S	0	0
Space Occupied	S	0	-1
Durability (Needs to be updated yearly)	S	0	0
Suitability/inclusivity (color, style)	S	+1	+1
Ergonomics	S	0	0
Stage view	S	+1	+1
SUM	0	2	1

Appendix I

AI Usage:
A large language model was employed to reduce the word count in specific sections, namely section 8.0 (measures of success), section 7.0 (proposed conceptual design specification), and section 6.0 (alternative design descriptions). The tool's use aimed solely at succinctly conveying the intended message while minimizing word usage.

Prompt Given:

"Can you edit the paragraph below to deliver the exact same message but with a reduced word count"

Sources:

OpenAI (2023) *ChatGPT* [Large language model], accessed 3 December 2023. https://chat.openai.com/

Engineering Strategies & Practice

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Section	Student Names					
	Zain Glover	Emma Yaromich	Vishwa Sivapalan	Yiyang Liu	Doga Calikiran	Deren Karaaslan
Executive Summary		ET			WD, MR,FP	
Introduction		WD, MR, FP	ET		FP	ET
Problem Statement			WD, MR, ET, FP		ET, FP	
Service Environment	WD, MR, FP		ET		FP	

Stakeholders				WD	FP	
Functions	FP			WD		
Objectives	WD, MR, ET, FP				FP	
Constraints		WD, MR, FP			FP	
Idea Generation Process		WD	ET		FP	WD
Alternative Design Selection Process			WD, MR, ET, FP		FP	
Alternative Design Descriptions (ADD) - Wheelchair Seating	WD, ET, FP		ET			
ADD - Back Aisles	MR			WD	WD, MR,FP	
ADD - Stage Access		WD, ET, FP				WD,ET
Proposed CDS			WD, MR, ET, FP			
Measures of Success	WD, ET	WD	WD, ET, FP	WD	FP	WD,ET
Conclusion			ET		WD, FP	WD,ET
Reference List	ET		ET			WD,ET,FP
Appendices	WD	WD	WD	WD		WD

Fill in abbreviations for roles for each of the required content elements using the abbreviations found on the next page. You do not have to fill in every cell.

Engineering Strategies & Practice

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Student #1 Name Vishwa

Student #2 Name Yiyang

Student #3 Name Zain

Student #4 Name Emma

Student #5 Name Deren

Student #6 Name Doga

Student #7 Name ______________