Preliminary Proposal

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2020

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DISCLAIMER

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Contents

1 BACKGROUND

1.1 Introduction

Our project: FMC Enhanced Wheelchair is asked to improve the wheelchair based on our client's requirements and current existing designs.Our project aims to solve three main contemporary problems. First of all,improving brakes and anti-theft devices for wheelchairs.Secondly, it aims to fold the leg support under the wheelchair to save space when no one uses the wheelchair.Thirdly, we try to design a controlled leg support. The leg support can be raised or lowered slowly and steadily, which can prevent patient's legs from being injured again due to the rapid fall of the leg support. The success of this project is crucial

because it can change the status of many wheelchair thefts and reduce hospital losses. Besides, it can improve user experience and increase safety.

1.2 Project Description

Following is the original project description: “ We want to have a FMC Enhanced Wheelchair which has an anti-theft function and provides more safety in the details.”

1.3 Original System

Our original system is a self-propelled manual wheelchair. Therefore,it doesn't have an anti-theft device.Besides, it also doesn’t have a brake system.Also, It doesn’t have a calf support system.The leg supports are fixed to the wheelchair and cannot be folded or rotated.

1.3.1 Original System Structure

The original wheelchair consisted of a frame, seat, two footplates, two leg rests, two armrests and four wheels: there are usually two casters on the front and two large wheels on the back. There is usually also a separate seat cushion with two pushers on the upper and rear of the frame, allowing the second person to push manually. The original wheelchair is made using aluminum.

Figure1.3.1

1.3.2 Original System Operation

Our original system is a purely manual, mechanical movement system. It is operated by pure manual. There are only two main kinds of operation: firstly, someone sitting in it can rotate the large back wheels to move the wheelchair by hand. Secondly, it needs another person to hold the two pushers and push the wheelchair.

1.3.3 Original System Performance

The weight of our original system is 100N. The volume of our original system is 1132*680*980mm^3. The normal speed of our original wheelchair system is 0.45m/s. This data is obtained by the solidworks of our original wheelchair system.

1.3.4 Original System Deficiencies

The original system did not meet the current requirements and engineering requirements because it doesn't have anti-theft design, adjustable calf support, controlled leg supports.From our original system, we can see that the original wheelchair is easily stolen without anti-theft device,so it cannot satisfy the customer needs:anti-theft. Besides, it lacks calf support, so it is not comfortable and unsafe relatively. Last but not least, the leg support is fixed, cannot be lifted or lowered and cannot be put under the wheelchair,which doesn't satisfy our client's needs.

2 REQUIREMENTS

Introduction: Part 2 contains customer requirements and engineering requirements. Based on these two requirements, the team established QFD. At the same time, the team members developed the Black Box and Function model based on the project in charge (FMC wheelchair).

2.1 Customer Requirements (CRs)

Customer Needs	Customer Weights
High safety	5
Comfort	4
Low cost	4.5
Easily cleaned	3.5
Long durablity	4
Good adustability	4.5
Light weight	4
Anti-theft	4.5

Figure 2.1

The customer needs is shown in figure 2.1, because wheelchairs are provided to patients with mobility impairments, their safety occupies the highest weight, and the adjustability of leg support occupies the second highest weight (4.5), because the client's requirement is that the leg pads need to be removable and both horizontal and vertical Can move freely. Of course, price is also a factor that consumers must consider, so price also has the second highest weight

(4.5). Anti-theft equipment for wheelchairs is also one of the factors that customers and sponsors are concerned about. After discussion with the sponsor, the team also set its weight ratio at 4.5

2.2 Engineering Requirements (ERs)

Weight	Selling price	Power of solenoid inside the caster	Friction force when braking	Size(length*width*height)	Maintenance fees	Fault tolerance	
3		3	9	3			
			3			3	
3	9	3	1		9		
				1		9	
			9		9		
						9	
9	3		9		3		
9	3	9					
N	$	W	N	mm^3	$	%	Technical Requirement Units
100	500	20	200	1132*680*980	125	0.02	Technical Requirement Targets
125	66	69	133.5	18.5	88.5	40.5	Absolute Engineering Requirements
3	6	5	1	7	4	2	Relative Engineering Requirements

Figure 2.2

Figure 2.2 shows the engineering needs of the team project, According to the specific requirements of the client and the defined customer requirements, the team defines the following engineering requirements and measurement units. The engineering requirements and

Units of measurement are the following: Weight of wheelchair (N), selling price ($), power of solenoid (W), friction force (N), size (mm^3), maintenance fee ($), fault tolerance (%). the technical requirements values and absolute engineering requirements are shown in this figure, Weight: (125N), selling price ($200), the power of solenoid (20W), the friction force (200N), maintenance fee ($88.5), tolerance for fault (0.02%).

2.3 House of Quality (HoQ)

Table 2.3

		Engineering Requirements						
Customer Needs	Customer Weights	Weight	Selling price	Power of solenoid inside the caster	Friction force when braking	Size(length*width*height)	Maintenance fees	Fault tolerance
High safety	5	3		3	9	3		
Comfort	4				3			
Low cost	4.5	3	9	3	1		9	
Easily cleaned	3.5					1		
Long durablity	4				9		9	
Good adustability	4.5							9
Light weight	4	9	3		9		3	
Anti-theft	4.5	9	3	9				
Technical Requirement Units		N	$	W	N	mm^3	$	%
Technical Requirement Targets		100	500	20	200	1132*680*980	125	0.02
Absolute Engineering Requirements		125	66	69	133.5	18.5	88.5	40.5
Relative Engineering Requirements		2	5	4	1	7	3	6

Table 2.3 is the QFD designed by the team, which shows the customer needs and engineering needs of the team project, giving the weight ratio of different customer needs and the Technical Requirement Units, Technical Requirement Targets, Absolute Engineering Requirements and Relative Engineering Requirements. Through calculation and analysis, the team came to Three Most Important ERs: 1：Friction force when braking (N), 2:Fault tolerance (%) 3:Weight (N)

2.4 Functional Decomposition

This part contains Black Box and Function model which can help the team understand the specific part of the team's project.

2.4.1 Black Box Model

This part is based on the customer's requirements, adding key components to the existing wheelchair, and analyzing the work output of these components on the entire project (wheelchair). The black box embodies the energy conversion of these components at work. The following is a picture of the black box.

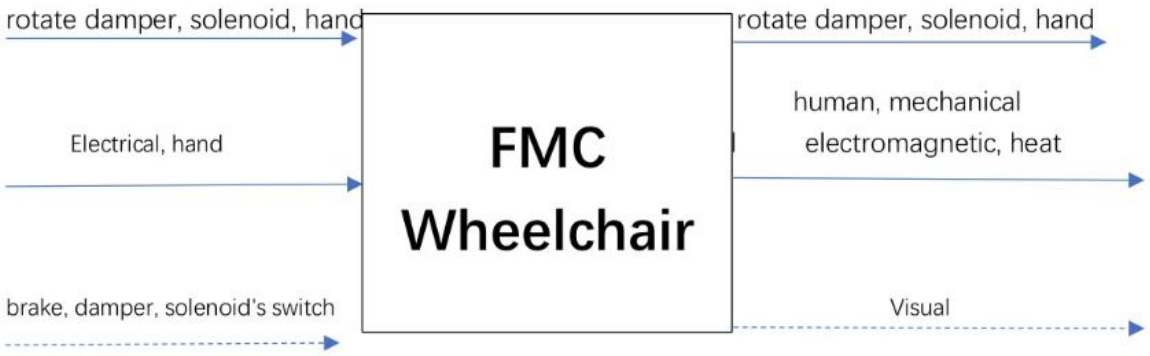

Figure 2.4.1

2.4.2 Functional Model/Work-Process Diagram/Hierarchical Task Analysis

This part is to introduce the analysis of the different functions of the team project (wheelchair). According to the function allocation of funcion model, it can help the team to more specifically clarify the availability of designity.

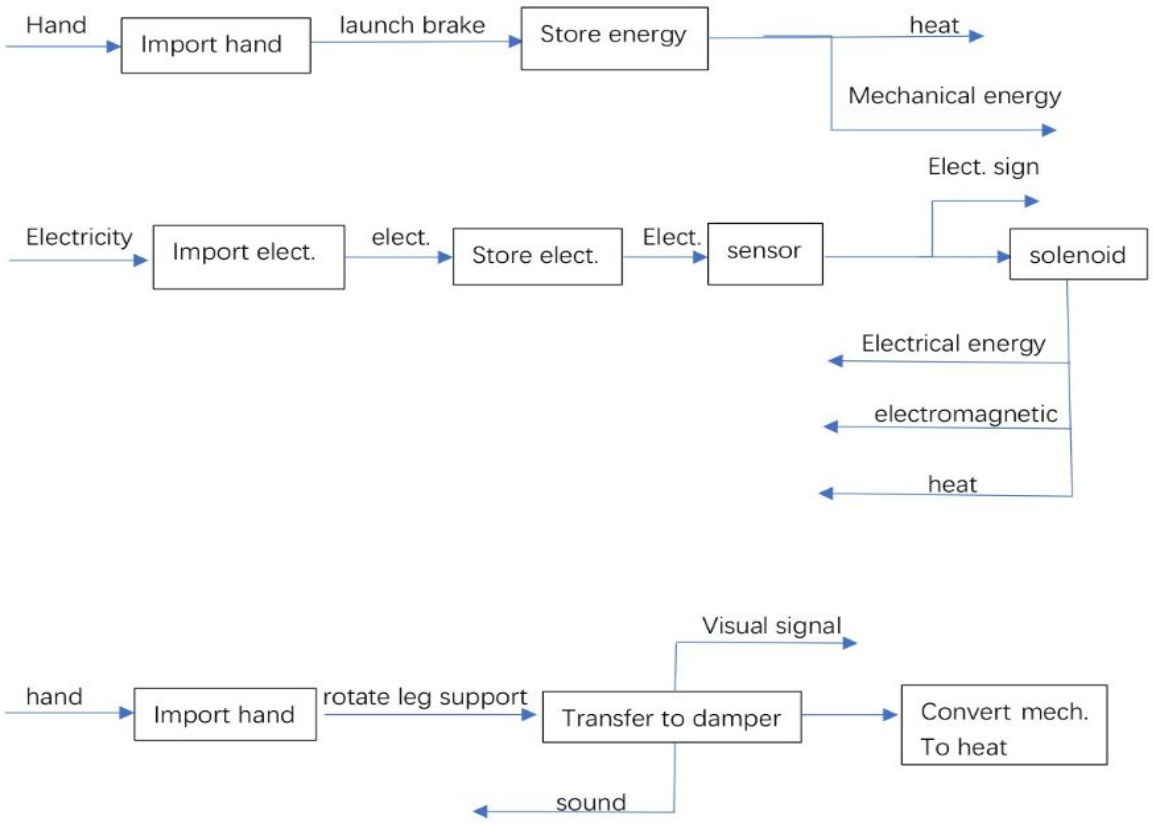

Figure 2.4.2

3 DESIGN SPACE RESEARCH

Pre Research is an important part before prototyping. Literature review is a good approach to help organize different sources and reading materials. Team members conduct literature review in regard to their research field. Each of them is responsible for an important subsystem. Some could find exactly the existing design applied for the project. For example, Jilan studied calf support, comparing different kinds of models and picked the best one. However, there are some customer requirements that no existing models can be found. Team could only get inspired from other designs. For example, apply anti-theft theory from shopping carts to wheelchair anti-theft. Benchmarking is another approach that can be used to compare the strength and weakness of a selected system or subsystem. Team could have a more profound understanding of what system or subsystem to pick.

3.1 Literature Review

3.1.1 Student 1 (Jialan Sun)

The technical aspect of the project I focused on was calf support. The calf supports are angle and height adjustable pads that attach to the leg rests. [1] The position of the calf supports on the leg rests should be adjusted based on users' requirements to meet their different comfort levels. Calf strap is one of the calf supports which is lightweight, but durable. Easy-opening straps for quick adjustments in fit. [2]Calf strap is a thin long leg pad suspended between the leg rests. Calf panel is a solid fixed mounting hardware. [3] Calf panel is a large soft cushion board suspended between the leg supports. The calf panel can cover more surface than calf strap. These lightweight yet durable calf pads provide the best in pressure distribution while supporting the end user's lower legs. [4] Calf pads are two individual air cushions suspended between the leg rests. We finally choose calf pads because calf pads can be more adjustable based on different people's requirements. For example, the left side of the individual calf pads can be higher or lower than the right side of the calf pads to accommodate the user. [5]

3.1.2 Student 2 (Simeng Cai)

The technical aspect that Simeng is concerned with is the design of an anti-theft device placed on a wheelchair caster by using a powered solenoid. After consulting the information, he found a caster self-locking device like a shopping cart. Self-locking system activates the motor through the sensor to drive the transmission gear when the cart moves into a special area, so that the crank connected to the inner wheel and the transmission gear is tightly secured [6]. The term solenoid brake refers to a group of braking mechanisms which rely on an electric solenoid for their actuation. [7]A solenoid brake is an electrically controlled brake. The brake is turned on and off by an electrical solenoid. Typically, a spring engages the brake when unpowered, and the solenoid releases it when powered. [8] So, Simeng designed a new type of solenoid brake to achieve the purpose of anti-theft. A long straight coil of wire can be used to generate a nearly uniform magnetic field similar to that of a bar magnet. [9] When two magnets or magnetic objects are close to each other, there is a force that attracts the poles together [10]. This can achieve the purpose of slowing down.

3.1.3 Student 3 (Zhenkai Xia)

The technical aspect of the project I focused on was soft motion of wheelchair leg support. A shock absorber or damper is a mechanical or hydraulic device designed to absorb and damp

shock impulses. It does this by converting the kinetic energy of the shock into another form of energy (typically heat) which is then dissipated. [11] I analysed different types of dampers. Hysteresis of structural material, for example the compression of rubber disks, stretching of rubber bands and cords, bending of steel springs, or twisting of torsion bars. Hysteresis is the tendency for otherwise elastic materials to rebound with less force than was required to deform them. Simple vehicles with no separate shock absorbers are damped, to some extent, by the hysteresis of their springs and frames. [12] . In 2013, the Chevrolet redesigned seventh-generation sports car is the first vehicle to use a General Motors'-developed lightweight shape memory alloy wire in place of a heavier motorized actuator to open and close the hatch vent that releases air from the trunk. This allows the trunk lid to close more easily. [13] As they said, such alloys are better actuators. To conclude, hysteresis of structural material may behave well in seismic use, but in regard to applying this kind of dampers in client's leg support, it may not work well in preventing free fall as a natural damper. However, team may still take shape memory alloys into consideration when designing a digital damper. The Chevrolet's motorized actuator was a guide.

Rotary dampers absorb and slow down rotary motion for the amendment of vibration, noise, and machine component wear. [14] They are characterized by their ability to demonstrate high torque, despite being so compact. These are mechanism components that can meet demands such as ensuring safety, buffering and impact, and adding a high-end, luxurious feel to your product. In a word, rotary dampers are perfect in soft close.

Linear dampers provide a smooth linear motion. They are available with dampening in one direction while allowing free run in the other and dampening in both directions. The dampers are used for common automotive applications especially glove-boxes while also extending to the furniture industry. [15]

3.1.4 Student 4 (Haoran Yin)

Wheelchairs with reclining leg supports are often used for individuals with leg and trunk disorders, including those with post-stroke hemiplegia and spinal cord injuries. Individuals who have difficulty sitting in the hospital can sometimes be more easily transported sometime in wheelchairs with reclining back support. In a previous study of reclining wheelchairs, individuals with flaccid hemiplegia were often found to often slide forward when returning to a seated position from a reclined position[16]. It was presumed that the size and shape of the pelvis would affect the results of this study. The participants were 17 healthy adult men without leg or trunk disease: mean age, 22.6 ± 6.6 years; mean height, 170.1 ± 4.4 cm; mean body weight, 62.4 ± 8.9 kg. [17]Exclusion criteria were: the participants that had back pain, a history of surgery, rheumatism, or neurologic disorders.Measurements were obtained which each participant sat comfortably with bilateral symmetry and rested on the back support and force plate located on the chair seat.[18]To fulfill customer needs, what we need to do is to learn wonderful design from other design,we decide to try the telescoping structure which can be flexible by requirement.The utility model is a retractable hollow cylinder rod made of metal strip or plastic sheet.[19]It is characterized in that the metal strip or plastic sheet is pre shaped into

an elastic crimp layer with memory function smaller than the outer diameter of the rod body, thus having the self tightening function and making the crimp layer always have the elastic potential energy to exert pressure on the stretching and shrinking rod. Although the existing wheelchair on the market has solved the travel problem, its functionality still needs to be improved. Now, there is no specific patient in the traditional wheelchair, such as the patient with leg injury and fracture and the wheelchair without a leg bracket. The patient's leg is easy to be affected by the placement posture or external effect, resulting in inconvenience.[20]

3.2 State of the Art - Benchmarking

[Use this section to describe the benchmarking process. Benchmarking involves on-site visits to organizations, observation, and interviews with employees to see how others have approached this type of design problem. Benchmarking can also be done online through extensive research. Based on your completed Original System analysis and the Project Description, identify relevant problems / issues / opportunities that would benefit from the Benchmarking Study. More than one area of the project should be identified for benchmarking. Include the findings of the Benchmarking Study in the remaining sections of this chapter.]

3.2.1 System Level State of the Art - Benchmarking

System level benchmarking is essentially important as it provided the basic concept for the project. The hospital-use wheelchair project could improve with the existing design. Team found a basic prototype of a wheelchair and used benchmarking resources to improve the performance of the wheelchair. Following are several existing designs.

3.2.1.1 Existing Design #1: Portable Folding Mobility Old Elderly Disabled Electric Wheelchair

Figure 3.2.1.1 Portable Folding Mobility Old Elderly Disabled Electric Wheelchair
This design can have the power of 250W and provide the maximum speed of 8 km/h. It meets the requirements that the wheelchair could be foldable. More importantly, it has Electromagnetic Brake, which increases the fault tolerance on a big scale. However, the team needs to investigate a lot of technical issues.

3.2.1.2 Existing Design #2: Folding Transport Chair

FIgure 3.2.1.2 Folding Transport Chair
This design is the preliminary model of the wheelchair, it could be used as the basic model to compare with. The properties are: a weight capacity of 300 lbs, Folding transport wheelchair is

portable. It can meet the basic requirements of customers, however, the leg support could be easily stolen as the way it is assembled.

3.2.1.3 Existing Design #3: A wheelchair with lever propulsion control for climbing up and down stairs

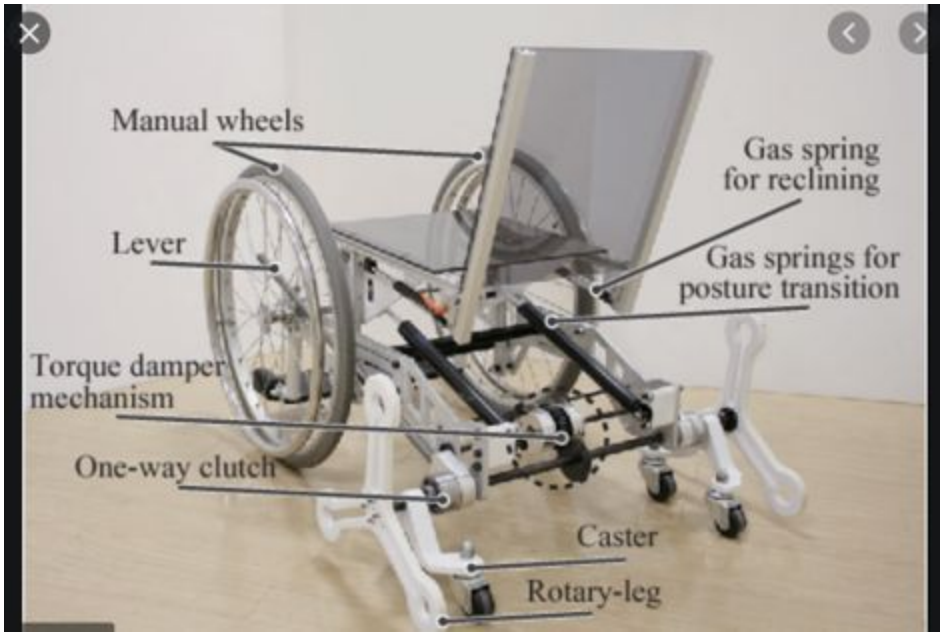

Figure 3.2.1.3 A wheelchair with lever propulsion control for climbing up and down stairs
This model provides the full description of the mechanism of the wheelchair. It could inspire the team to explore more prototypes of the subsystem of wheelchairs.

3.2.2 Subsystem Level State of the Art Benchmarking

Subsystem level state of art benchmarking is the core content of benchmarking as the subsystem could directly realize different functions as the client required. This level of benchmarking helped the team found the best design suitable for current project goals.

3.2.2.1 Subsystem #1: Rotary dampers

When users try to put down the wheelchair leg support, a free fall of leg support would happen. Thus, some injuries would occur with sudden fall. Rotary dampers absorb and slow down rotary motion for the amendment of vibration, noise, and machine component wear. These are mechanism components that can meet demands such as ensuring safety, buffering and impact,

and adding a high-end, luxurious feel to your product. In a word, rotary dampers are perfect in soft close.

3.2.2.1.1 Existing Design #1: · Hysteresis of structural material damper

Hysteresis is the tendency for otherwise elastic materials to rebound with less force than was required to deform them. Hysteresis of structural material, for example the compression of rubber disks, stretching of rubber bands and cords, bending of steel springs, or twisting of torsion bars, such alloys are better actuators. To conclude, hysteresis of structural material may behave well in seismic use, but in regard to applying this kind of dampers in client's leg support, it may not work well in preventing free fall as a natural damper.

3.2.2.1.2 Existing Design #2: Linear damper

Linear dampers provide a smooth linear motion. They are available with dampening in one direction while allowing free run in the other and dampening in both directions. However, it could only offer free run in linear motion, which indicates its unpractical performance in wheelchair design because leg support needs a range of angle of motion, and this motion could not be linear.

3.2.2.2 Subsystem #2: Magnetic field anti-theft device

For the team's project, we give solenoid a current to create the magnetic field and generate suction with the magnetic material of the wheelchair caster, thereby forcing the deceleration of the caster. This subsystem is proposed by sponsor and clients.

3.2.2.2.1 Existing Design #1: Shopping cart anti-theft device

The anti-theft principle of the shopping cart is the self-locking system inside the casters, which activates the motor through the sensor to drive the transmission gear when cart move into special area, so that the crank connected to the inner wheel and the transmission gear is tightly secured, so as to achieve the purpose of anti-theft.

3.2.2.3 Subsystem #3: Calf pad

Calf pads are two individual air cushions suspended between the leg rests.

3.2.2.3.1 Existing Design #1: Calf panel

Calf panel is a large soft cushion board suspended between the leg supports. The calf panel can cover more surface than calf strap. These lightweight yet durable calf pads provide the best in pressure distribution while supporting the end user's lower legs.

3.2.2.3.2 Existing Design #2: Calf strap

Calf strap is a small long leg pad suspended between the leg rests. Calf panel is a solid fixed mounting hardware.

4 CONCEPT GENERATION

Concept generation is a procedure that begins with a set of customer needs and target specifications and results in an array of product concept design alternatives from which a final design will be selected. This step requires a more abstract style of thinking than perhaps most engineers are used to.

4.1 Full System Concepts

We provide three different models, they are electric wheelchair, manual wheelchair prototype and advanced foldable manual wheelchair. Electric wheelchair stands for modern technology applied in the system. In the electric wheelchair design, the leg support could be controlled with electric control. The manual wheelchair prototype is the basic design for most of the wheelchair, it could be used to study and compare. The advanced foldable manual wheelchair is the one that is analyzed by the team and designed according to research and experiments.

4.1.1 Full System Design #1: Electric wheelchair

Figure 4.1.1 Electric wheelchair

Electric wheelchairs are mainly composed of car body, controller, electric motor, clutch, battery, wheels, brake system, backrest, pedals and other accessories. Compared with ordinary wheelchairs, the biggest difference is the addition of electric power control systems: electric motors, batteries, and controllers. This is the key to an electric wheelchair that can travel freely.

Advantage:Powerful, fast moving

Disadvantage:High price, poor endurance

4.1.2 Full System Design #2: Manual wheelchair prototype

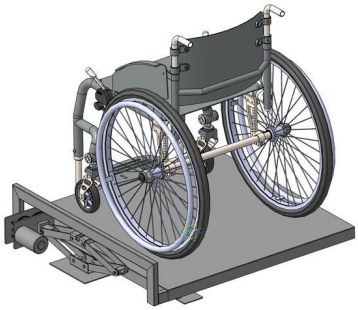

Figure 4.1.2 Manual wheelchair prototype

By adjusting the seat cushion, the comfort of the wheelchair is increased, and the two tires are connected to enhance its stability. But at the same time, the wheelchair cannot be folded, which has a big problem in transportation.

Advantage:Comfortable seat

Disadvantage:No brake system, difficult to carry

4.1.3 Full System Design #3: Advanced foldable manual wheelchair

Figure 4.1.3 Advanced foldable manual wheelchair

In this design, we designed a foldable calf pad to make it more convenient for users. Two brake systems are added at the same time, one for the patient and the other for the person pushing the wheelchair, which enhances its safety. At the same time, adding damping between the leg support and the calf pad can make the calf pad move in a small range to prevent it from falling.

Advantage:Foldable, high safety

Disadvantage:Slow moving speed, low power

4.2 Subsystem Concepts

A subsystem is a set of elements, which is a system itself, and a component of a larger system.A subsystem description is a system object that contains information defining the characteristics of an operating environment controlled by the system

4.2.1 Subsystem #1: calf pad

The calf pad is used to increase comfort and provide leg support.

4.2.1.1 Design #1: calf panel

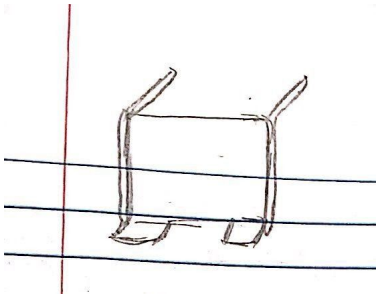

Figure 4.2.1.1 calf panel

A nylon strap is attached to the calf panel, which can be fastened behind the chair for easy installation.

Advantage:Easy to install, detachable, good pressure distribution quality and durability

Disadvantage:Unable to fold adjustment

4.2.1.2 Design #2: Square calf pad

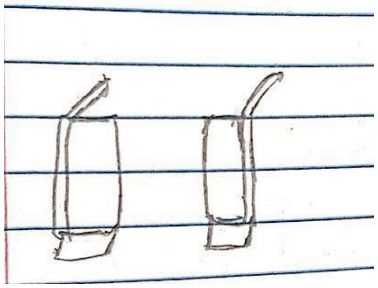

Figure 4.2.1.2 Square calf pad

The function is similar to that of the calf board, but different from the calf board is that it has two identical rectangles.

Advantage:Detachable, foldable, more comfortable

Disadvantage:Unable to adjust

4.2.1.3 Design #3: Semicircular calf pad

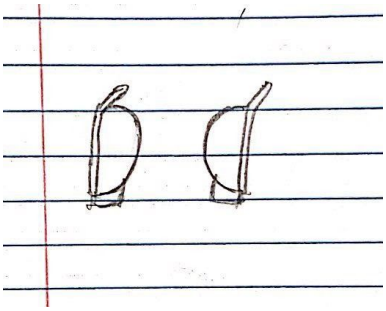

Figure 4.2.1.3 Semicircular calf pad

The function is similar to that of the calf board, which is different from the calf board in that it has two identical oval shapes.

Advantage:Removable, good pressure distribution quality and durability.

Disadvantage:It is fixed, unable to adjust

4.2.2 Subsystem #2: Damping

Damping can effectively prevent leg support from falling freely, which is equivalent to a soft close

4.2.2.1 Design #1: linear damper

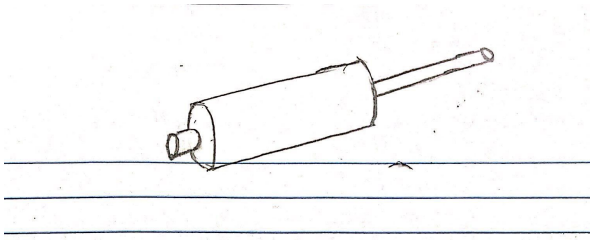

Figure 4.2.2.1 linear damper

Linear dampers provide a smooth linear motion. They are available with dampening in one direction while allowing free run in the other and dampening in both directions.

Advantage:Smooth linear motion

Disadvantage:Can not provide free running, angular movement

4.2.2.2 Design #2: structural material damper

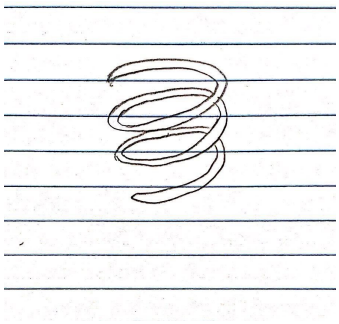

Figure 4.2.2.2 structural material damper

Hysteresis of structural material, for example the compression of rubber disks, stretching of rubber bands and cords, bending of steel springs, or twisting of torsion bars.

Advantage:Has good impact resistance

Disadvantage:May not be effective in preventing free fall

4.2.2.3 Design #3: Rotary dampers

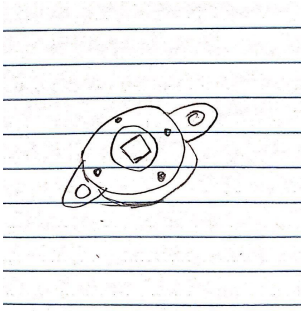

Figure 4.2.2.3 Rotary dampers

Machine elements that operate like mini-gears to slow down or inhibit the motions of moving pieces of machinery. Rotary dampers absorb and slow down rotary motion for the amendment of vibration, noise, and machine component wear. They are characterized by their ability to demonstrate high torque, despite being so compact.

Advantage:High torque, high safety

Disadvantage:The structure is too compact

4.2.3 Subsystem #3: Leg Support

4.2.3.1 Design #1:Horizontal Folding

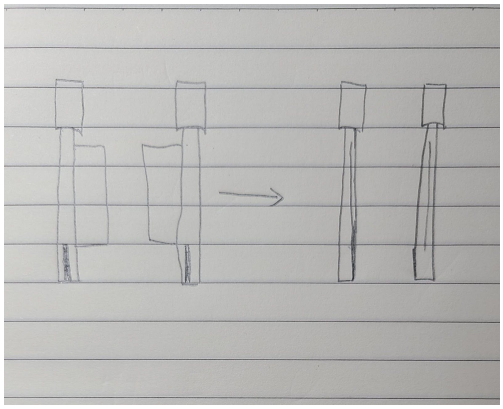

Figure 4.2.3.1 Horizontal Folding

Use the top of the device to rotate the rod inside, which can switch the direction of the calf pad. The folding system can be made be plastic or metal the only thing we need to consider is fix the beginning and ending position of the rod.

Advantage：Easy to bulid and fold, low requirement for material

Disadvantage:Only a little room safe

4.2.3.2 Design #2: Telescoping Structure

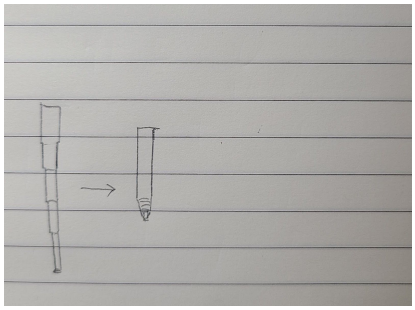

Figure 4.2.3.2 Telescoping Structure

This idea comes from flexible telescopes. It can easily adjust the length of the support and user friendly, what we need is high quality steel.

Advantage:Save a lot of space, user friendly for patients, easy to flex

Disadvantage:Hard to build and maintain, high requirement for material, expensive

4.2.3.3 Design #3: Vertical Folding

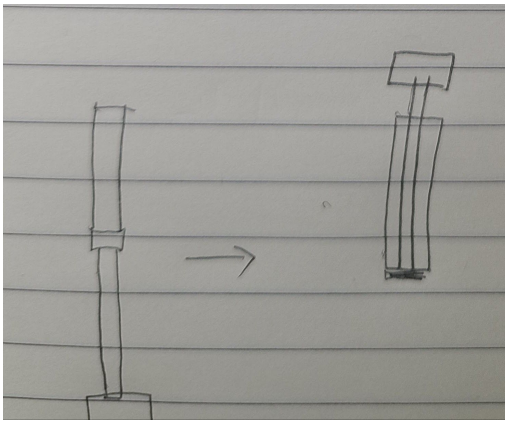

Figure 4.2.3.3 Vertical Folding

This design is easy to fold and save space, there can be a lot of material for us to use. The most important part is the joint.

Advantage:Easiest to build and fold, easy to maintain, low requirement for material, save space

Disadvantage:a little more expensive

5 DESIGNS SELECTED – First Semester

In Chapter 5,we will combine the subsystems we come up with and create the concepts. Then we got our six designs which are shown in Appendix A. Firstly,We will use Pugh Chart to narrow six designs down to three by ranking them based on the chosen design criteria.Then we will use the Decision Matrix to decide our top two designs.

5.1 Technical Selection Criteria

The criteria we use in Pugh Chart are high safety,comfort,low cost,easily cleaned,long durability, good adjustability, light weight and anti-theft.Safety is decided by the design's ability to prevent leg support falling quickly and causing hurt again. Comfort is a criteria users are looking for when selecting a wheelchair.Low cost is an important factor for users to consider because it is based on their financial ability. Easily cleaned is important because users do not want to be infected because of dirty.Long durability ensures that users can use the wheelchair for a relatively long time.Good adjustability guarantee that users can adjust their wheelchair to meet their own requirements.Light weight can ensure they can run or stop the wheelchair easily when they use their wheelchair by themselves.Anti-theft is also an important criterion because it can prevent their wheelchairs being stolen and causing unnecessary loss.

The criteria we use in the Decision Matrix are Weight,selling price,power of solenoid brake,friction force when braking,size, maintenance fee and adjustable leg support.These criteria can be quantitatively analyzed, the units are the following. Weight (N), selling price and maintenance fee ($), power of solenoid (W), friction force (N). Adjustable for leg support and power of solenoid are the two most important criteria, because these two are the client's requirements for the team's project. So, for the two criteria teams gave a weighted weight of 0.25. Price is also the second highest proportion of criteria. Obviously, customers must consider the market price when considering buying products. Weight and maintenance fee are relatively unimportant. So,the team gave them 0.025 and 0.1.

5.2 Rationale for Design Selection

The final design we selected was design4 and design5. For the design4 based on normal design, we level up our leg support and added a hand brake to improve the safety of the design. Our rationale comes from customer needs. What we need to do is to fulfill their requirements as much as possible. We used a rotary damper to decrease the speed of folding which can help our customer feel comfortable. Thanks for our pugh chart and decision matrix to help us solve problems and get the most user friendly design. The hand operating braking system aims to improve the safety. Moreover, we develop an anti-theft system due to some losing wheelchair cases. The anti-theft principle of the shopping cart is the self-locking system inside the casters, which activates the motor through the sensor to drive the transmission gear when cart move into special area, so that the crank connected to the inner wheel and the transmission gear is tightly secured, so as to achieve the purpose of anti-theft. For the team's project, we give solenoid a current to create the magnetic field and generate suction with the magnetic material of the wheelchair caster, thereby forcing the deceleration of the caster.

Compared with design4, design 5 changed the calf panel to the calf pad.Another thing we did was the hand brake. We made an electrical control panel to keep the wheelchair at a reasonable speed.

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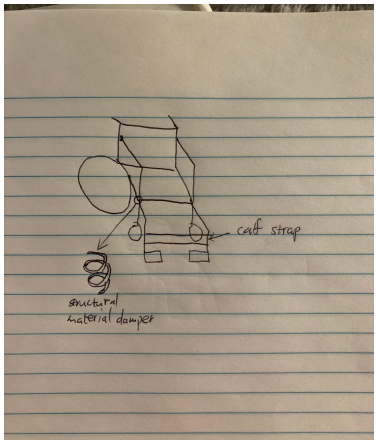
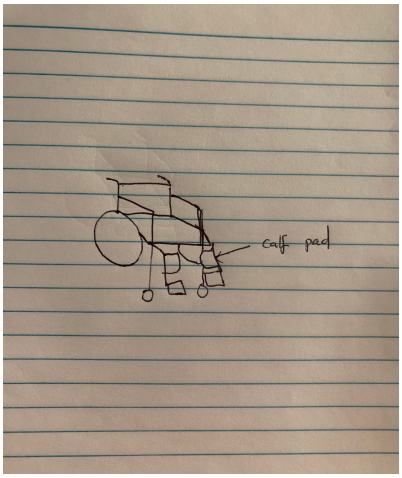
7 APPENDICES

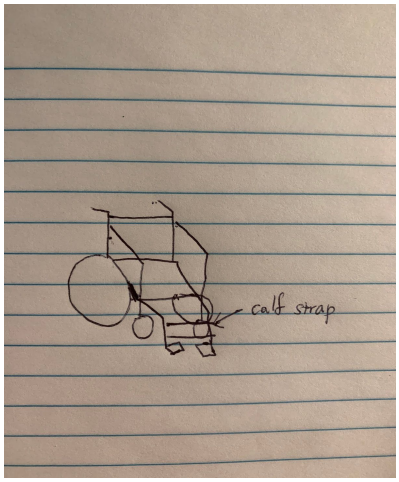
7.1 Appendix A: Designs



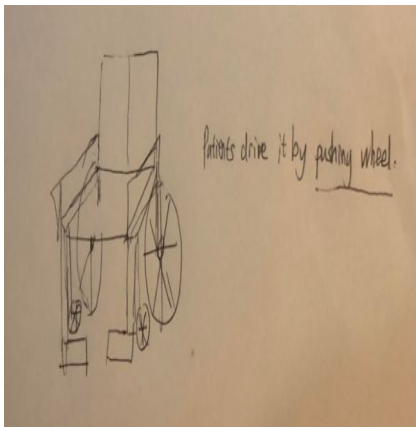
Design0



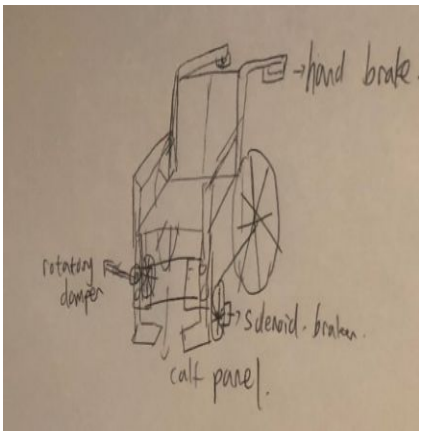
Design1



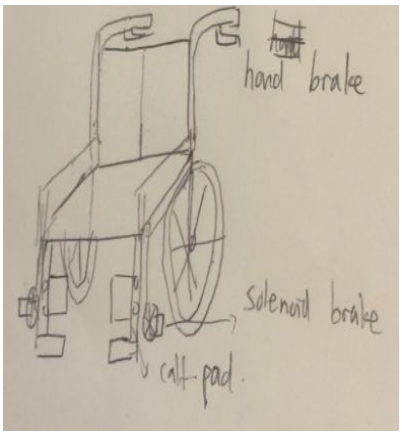
Design2



Design3



Design4



Design5

7.2 Appendix B: Puge Chart & Decision Matrix

Table 5.1

Selection Criteria:	Design0	Design1	Design2	Design3	Design4	Design5
High safety	Datum Point	s	s	-	+	s
Comfort		-	-	-	+	+
Low cost		+	+	+	s	s
Easily cleaned		s	-	s	-	-
Long durablity		s	s	s	-	+
Good adjustablity		+	+	s	+	+
Light weight		s	s	s	+	s
Anti-theft		s	s	-	+	+
	Number of +	2	2	1	5	4
	Number of -	1	2	3	2	1
	total	1	0	-2	3	4

Table 5.2

		Design1		Design4		Design5	
Criterion	weight	unweighted score	weighted score	unweighted score	weight score	unweighted score	weighted score
Weight	0.1	75	7.5	85	8.5	85	8.5
selling price	0.2	70	14	40	8	50	10
Power of solenoid brake	0.25	0	0	50	12.5	50	12.5
friction force when braking	0.15	0	0	40	6	35	5.25
size	0.025	40	1	65	1.625	65	1.625
maintenance fee	0.025	80	2	35	0.875	30	0.75
adjustable leg support	0.25						
Totals:	1		24.5		37.5		38.625
	Ranks:		3		2		1