CHAPTER 18
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INTRODUCTION
The objective of this project was to design and construct a manual-racing wheelchair for a young woman, diagnosed with spina bifida, who is a member of a racing wheelchair team. The client underwent surgery two years prior and had since grown out of her old racing wheelchair. However, she has the desire to return to racing and to compete, and therefore, is in need of a larger wheelchair. Traditionally, racers use a V-Cage ride in the kneeling position. Although the client cannot kneel, she prefers this style of cage. Having little flexibility in her legs, she needed a safe, ergonomically custom tailored chair built with a low center of gravity, three-point ground contact and V-Cage style frame. Figure 18.1 shows the aluminum frame that was built along with the side safe guards. The client’s legs rest against the frame, and her feet are strapped to a footplate under the frame; this footrest provides additional comfort. Figure 18.2 shows the prototype Figure 18.3 shows the young female athlete using it, while surrounded by the team of students who built it.

SUMMARY OF IMPACT
Competing in athletic events is an important factor in the lives of many individuals. However, this is more difficult for individuals with disabilities. This client is a 17-year-old with paraplegia who is a former member of a racing wheelchair team and would like to begin racing again. She has outgrown her previous racing wheelchair. This new racing wheelchair will allow her to compete successfully in racing. It is ergonomically custom tailored to fit her needs. It meets the basic guidelines of three-point ground contact, low center of gravity and ease of accessibility.

TECHNICAL DESCRIPTION
Design considerations included constructing a unit that is lightweight, aerodynamic, stable, durable, comfortable, and ergonomically designed. It will enable easy transfers. Several factors influenced the selection of the various components of the wheelchair including the client’s comfort, preference, safety, lack of racing experience, and cost. An I-Cage frame, shown in Figure 18.4a, is
better suited for a person with the client’s limitations. However, she is comfortable with the design of her previous racing wheelchair as she is accustomed to resting her knees on its V-Cage frame, and would like to continue to race in this position. Yet, a standard V-Cage frame as the one shown in Figure 18.4.b, does not support her legs because the front of the cage extends too far outward. A custom made V-Cage frame was thus designed to accommodate the client’s preferences where a footrest was added to it to support her feet. The frame was made of one-inch 6061 T-6 aluminum tubing, and is smaller in the front to allow the client’s legs to rest comfortably on the frame.

All racing wheelchairs are equipped with a steering compensator system. It consists of two sets of handlebars with the compensator serving as the connecting link. The closer set of handlebars, when tapped, turn and lock the wheel at a preset angle. This allows the racer to take the turns around the track and to continue pushing, instead of steering. Once the racer is on a straightaway, she simply hits that set of handlebars the other way and the wheel straightens out. The further set of handlebars is used for steering when needed.

Two different rear wheel sizes were considered for the chair, 26 inches and 700C (27.56 inches). A 28 spoke 26 inch wheel was chosen because it is inexpensive and easily replaceable. Hand rims are attached to the rear wheels and are used to propel the wheelchair along the track. Fourteen-inch tire coated hand rims were selected, which is the standard size for women. The rear wheels on a racing wheelchair are generally cambered at an angle ranging from zero degrees to 20 degrees with a minimum of 12 degrees recommended. The client chose 12 degrees based on her previous racing experience. An 18 inch spoke front wheel was chosen based on racing wheelchair standards. An aluminum front fork was used because of its lightweight, durability, accessibility and low cost.

The frame is equipped with a footrest due to the client’s physical limitations and it provides comfort as well. The seating is made of nylon since it is strong and will not irritate the client’s legs. The standard overall length of a woman’s racing wheelchair ranges from 56 inches to 64 inches, but it is not limited to these lengths. The size of the cage was determined by having it custom fit to the client.

\[
X_{cg} = 1.1965 \cos(\theta_A) + 7.7095 \cos(\theta_T) + 3.3634 \tag{1}
\]

When in the racing position, the angle of the client’s torso varies by about 10 degrees. The torso starts out at 25 degrees and goes up to 35 degrees by the end of her stroke. It was found, using equation one, that the change in torso angle causes a slight change.
in the horizontal location of the center of gravity with respect to the hip.

When designing a wheelchair one must take into consideration the maximum speed the wheelchair and racer can withstand before overturning, this is known as the roll stability critical velocity. Dynamic roll stability analysis is the standard procedure performed to produce that speed. The roll stability critical velocity can be defined as the velocity at the instant when the torque rotating the racing wheelchair and rider is equal to those forces holding it down. It was determined by equating the torques acting upon the center of gravity about a line connecting the outermost rear and front wheels of the racing wheelchair. The purpose of this analysis was to determine whether the new wheelchair design could withstand speeds up to 20 mph during track racing without flipping over. This speed is a maximum for world-class athletes and is well above the average speeds of a beginner racer. The roll stability critical velocity was calculated to be approximately 22 mph using the location of the body’s c.g. at mid-stroke.

Structural analysis was conducted using the I-DEAS Master Series™ Software (Integrated Design Engineering Analysis Software). Two loading conditions were simulated to represent a load of 120 pounds (weight of the person) applied on the fender, and on the front of the left side seat bar. The first loading condition simulated a situation where the rider is going in or coming out of the racing wheelchair. The second loading condition simulated the rider, centered on the very front of the seat, during a turn.

Table 1: Client’s Anthropometric Data.

<table>
<thead>
<tr>
<th>Body Segment</th>
<th>Length (in)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Torso Width</td>
<td>14.00</td>
</tr>
<tr>
<td>Hip to Top of Head</td>
<td>26.50</td>
</tr>
<tr>
<td>Hip to Hip</td>
<td>15.50</td>
</tr>
<tr>
<td>Armpit to Armpit</td>
<td>16.00</td>
</tr>
<tr>
<td>Armpit to Thumb</td>
<td>23.00</td>
</tr>
<tr>
<td>Upper Arm</td>
<td>13.00</td>
</tr>
<tr>
<td>Forearm</td>
<td>10.50</td>
</tr>
<tr>
<td>Wrist to tip of Middle Finger</td>
<td>7.25</td>
</tr>
<tr>
<td>Seat to Armpit</td>
<td>15.50</td>
</tr>
<tr>
<td>Back to Mid-knee</td>
<td>18.50</td>
</tr>
<tr>
<td>Mid-knee to Foot</td>
<td>16.00</td>
</tr>
<tr>
<td>Foot</td>
<td>8.50</td>
</tr>
<tr>
<td>Total Body Weight</td>
<td>115 lbs</td>
</tr>
</tbody>
</table>

Figure 18.4a. I-Cage: For Individuals with Limited Flexibility in Lower Extremities, Usually Needing a Footrest.

Figure 18.4b. V-Cage: For Individuals with a Large Range of Motion, Usually Racing in the Kneeling Position.
Invacare Corporation and Invacare Top End donated several of the components encompassing the chair. Also, Sportaid provided a 20% discount on the two rear wheels. The total cost of all parts and material was $2,800.

Figure 18.5. Client Seated in a Wooden Model.

Figure 18.6. Stick Figure Diagram of the Racer Seated in the Racing Wheelchair with the Arms in the Extended Position.
MODIFICATION OF A MANUAL RACING WHEELCHAIR

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INTRODUCTION

A young male who has been diagnosed with spina bifida has limited range of motion and reduced lower body control. A racing wheelchair was custom-made for him by a previous group of engineering students during a previous semester to provide him with the ability to power and steer it effectively, as well as to make it comfortable. Because of problems with steering and seating, the boy could not use the racing wheelchair. The purpose of this project is to modify the existing racing wheelchair so that the client can use it. As shown in Figure 18.7, the existing chair’s steering system was set at an angle close to horizontal, which made the wheelchair unstable and difficult to steer. The compensator that was used was attached to the fork in a manner that produced little or no resistance to rotation. Due to this ineffective steering mechanism it was impossible for him to propel the wheelchair, since one hand was required to steady the front wheel. The steering mechanism was modified as shown in Figure 18.8 by adding a Y-bar to the front fork, moving the compensator bar below the frame, cutting and re-welding the front of the frame to improve the caster angle, and removing the upper steering wheel. The existing seating used a lap belt for safety and a leg sling for restraining the client’s legs as shown in Figure 18.7. However, these were both uncomfortable for the client and could not hold him in the seat safely. Modifications to the restraint system were conducted by introducing an adjustable set of shoulder straps and a cloth platform on which legs could rest lightly as shown in Figure 18.8.

SUMMARY OF IMPACT

The steering mechanism was modified to eliminate the tendency to uncontrollably roll out of alignment. The seating was modified to allow the client to lean forwards while keeping his legs stable and in a comfortable position. The client was pleased with the modified wheelchair. This design will provide him the ability to participate safely and comfortably in competitive racing.

TECHNICAL DESCRIPTION

A compensator is used for steering and it consists of a bar that is affixed to the main spine of the chair. This bar is then connected to a pair of handles affixed at an angle to the front fork; adjustable stops
on the compensator bar control the limits of motion. The front fork is mounted at an angle, known as the caster angle, which provides stability and helps to keep the wheelchair from straying during a turn. Variations in the caster angle affect the balance between ease of turning and stability. In the original design, the caster angle was such that the rider’s weight produced a large moment about the steering axis, which tended to cause the front wheel to roll out of a straight path and into an extreme turn. In addition, the compensator was mounted from the compensator bar directly to the front fork. This produced no return force out of a turn, and no stability in straight racing, because the compensator was largely pulling along a line parallel to the front fork. During track racing the compensating mechanism’s main function is to provide the racer with an easy way to keep the front wheel of the racing wheelchair at the correct turning angle, so the racer can continue to propel the wheelchair during the turns of the track. When the bar is moved to the “turn” position, the compensator stretches, providing a return force used to align the front wheel when the turn is completed. This return force is more useful during street racing, when the steering is set to the straight-line position and turned against the force of the compensator, causing the front wheel to tend to swing back to the straight-line position.

The steering system was modified by adding a Y-bar to the front fork, replacing the old compensator with a stronger one, moving the compensator bar below the frame, cutting and re-welding the front of the frame to improve the caster angle, and removing the upper steering wheel. The dimensions of the frame were established based on the anthropometric measurements of the client. The new dimensions of the racing wheelchair were checked by calculating the critical roll velocity for a turn radius of 60 feet. This is the maximum speed at which the wheelchair can be safely moved through the turn without tipping on its side. The critical speed was calculated as 21.6 mph, which is much larger than the maximum expected speed of the client of 15 mph.

The seating in many racing wheelchairs places the rider in a tucked position. The legs are generally folded, and the rider sits or leans on them during the race. Some wheelchairs directly restrain the rider’s legs, while others allow the rider’s weight to prevent the legs from moving. Restraints for the upper body are typically used to prevent the rider from leaning too far backwards and tipping the chair. These back restraints also provide a brace, so that the rider’s driving force is not limited by his or her weight. This idea is similar to the lap belts used on weight-room machines so that forces can be exerted downwards greater than the lifter’s weight. The seating system of the original wheelchair, shown in Figure 18.7, featured a simple cloth seat snapped onto the frame, and a cloth strap to support the client’s legs. Unfortunately, the lap belt provided in the existing design was uncomfortable to the client, and the leg strap was ineffective at keeping his legs in a safe and comfortable position. The client had a tendency to slip forwards and out of his seat, which was an obviously dangerous state during a wheelchair race.

To improve the user’s upper-body restraints, adjustable padded shoulder straps were used allowing easier fitting and less restricted movement. To support the client’s legs, a cloth platform was added as a contoured leg platform to hold the user’s knees and feet in a loosely tucked position, while keeping his weight on his seat and shoulder straps as shown in Figure 18.9. This accommodated the user’s preference of not sitting on his legs, and would keep his balance forward and center of gravity low.

Total cost for all parts and material was approximately $260.00. Labor for constructing and painting the modified chair was donated.
INTRODUCTION
The purpose of this project is to adapt a riding lawn mower with a safe and reliable hand operated breaking system to allow an individual with complete paralysis of the lower half of his body to operate it independently. Design requirements include allowing his parents to use the original breaking system as they continue to use the mower. Also no alterations were allowed to be made to the original outside body panels of the lawn mower, which limits any drilling to the frame of the mower. The adaptation includes installing a hand-controlled system that activates the brake. The system consists of a hand lever and a linkage mechanism. The hand lever, shown in Figure 18.10, is pinned to a small shaft that rotates on a bearing that is rigidly mounted on the frame of the mower. The linkage, shown in Figure 18.11, consists of three parts: an upper connecting plate, a connecting rod and a lower connecting plate. The upper connecting plate is welded to the small shaft that the hand lever is pinned to. The lower connecting plate is clamped to the foot pedal of the mower. The connecting rod joins the upper and lower connecting plates. As the rider pushes the hand lever, the small shaft rotates forcing the linkage mechanism to rotate, which in turn pushes the brake pedal down. The system is disengaged as the hand lever is allowed to return to its initial position.

SUMMARY OF IMPACT
A male high school student has L2 paraplegia. This individual has a complete paralysis of the lower half of his body including both legs, but excellent use of his arms and upper body. This person is very active and participates on the high school wrestling team. He has a desire to assist his family in mowing the lawn using their riding lawn mower. This was not possible, as the mower uses a braking system that is activated by a foot brake. Adaptation of the lawn mower with a hand operated braking system allows this individual to operate it independently. This will permit him to enjoy completing family chores, and to possibly earn extra money mowing lawns for neighbors. This custom-made adaptation also allows the use of the original breaking system, which permits the rest of the client’s family to continue using the lawn mower.
TECHNICAL DESCRIPTION

Two approaches were considered for the project: develop an independent braking system, or adapt the original one. An independent system would have to take into account that the brake also acts as a clutch and would require the installation of a new clutch mechanism. This would be complicated and costly. Adaptation of the original braking system requires installing only a simple mechanism to activate it, which was the most simple and cost effective way to accomplish the project objectives. A gear train, a pulley system and a linkage system were considered to activate the braking system. Gears allow a reduction in force, are less complicated and do not require as much space as pulleys. Pulleys allow the reduction in force at the user’s end, but are complicated and require a lot of space. Linkages are the most direct and simple way to transfer force. A hand controlled system that includes a hand lever and a linkage mechanism was thus designed, constructed and installed on the lawn mower to activate the brakes.

The hand lever was pinned to a small shaft that rotates on a bearing that was rigidly mounted on the frame of the mower. The lever was placed on the left side of the tractor, because the brake pedal was already there. In addition, there were already two levers on the right side of the tractor: the speed and deck height adjustments. It would be impossible for the client to brake and change gears on the same side with one hand. The linkage consisted of three parts: an upper connecting plate, a connecting rod and a lower connecting plate. The upper connecting plate was welded to the small shaft that the hand lever is pinned to. The lower connecting plate was clamped to the foot pedal of the mower. The connecting rod joined the upper and lower connecting plates. As the rider pushed the hand lever, the small shaft rotated forcing the linkage mechanism to rotate, which in turn pushed the brake pedal down. The system was disengaged as the hand lever was allowed to return to its initial position. A four-bar linkage analysis was conducted to determine the critical angles and linkage lengths for proper assembly. Using the lengths determined from the analysis, a model was constructed using 10-ply poster board. The model helped to determine the placement of the four-bar linkage to avoid obstructions to its movement.

Figure 18.12 shows a CAD drawing of the final assembly of the linkage mechanism. A spring scale was used to determine the force required to move the brake pedal through its complete range of motion. This force was found to be 50 pounds. Stress analysis was conducted to determine the lowest factor of safety in the different components of the linkage, and was found to be 17. Once the prototype was assembled, it was mounted to the lawn mower. The original design required a shim to be placed under the mounted bearing to account for the brake pedal offset. The brake pedal had a 10-degree offset from the perpendicular of the mower frame causing the lower connecting plate not to be aligned with the upper connecting plate. However, it was decided that bending the connected rod would be more aesthetically pleasing and easier than using a shim. The connecting rod was thus bent into an “s” shape to account for the brake pedal offset. The brake was then tested while riding the mower and functioned properly. The linkage assembly was taken apart and painted with epoxy enamel for a durable finish. A handle grip was also installed at the end of the lever to provide safe gripping.

Concerning safety factors, a seatbelt was going to be installed. However, it negated the mower’s safety shut off mechanism in the seat. The seat, when compressed from the rider’s weight activated the safety switch of the mower allowing the mower to be started. When the rider gets off the seat, it releases the safety switch cutting off the electricity to the engine causing the mower to stop running. The client’s father expressed concern that if the mower overturned, the rider being belted to the seat would prevent the mower from shutting off as intended by the manufacturer. The client also indicated that he had previously used his grandfather’s mower without incident and feels comfortable with the current seat design that does not have a seatbelt.

The total cost of all parts was $180.
MOTORIZED FISHING ROD AND REEL

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INTRODUCTION
The goal of this project was to automate a fishing rod and reel system to allow an individual with CS tetraplegia with limited arm movement and strength to fish for a long time with relative ease and comfort. With a standard fishing rod and reel, one turns a hand crank to retrieve the line. However, the client’s hands get tire quickly from the repetitive rotational motion, and he does not have enough energy to reel the line in. The client desires a fishing rod and reel system that allows him to retrieve the line by just activating a switch that is comfortably mounted to the fishing rod. Adapting a system for casting is not necessary since the client will only be perch fishing off a boat in which the fishing line just needs to be dropped into the water. A DC motor controlled by a switch to bring the line in is used as the retrieval system. The motor is mounted to a steel plate that is mounted on to the reel as shown in Figure 18.13 (A). Two spur gears are used to transfer the required torque and speed to the shaft of the reel as shown in Figures 18.13(A) and 18.13 (B). A gearbox is installed to cover the moving gears to prevent client’s hands or clothes from injury or damage as shown in Figure 18.13 (C). In order to keep the reel stable while the client reels a fish, the unit is mounted to a fixture that is easily attached to the client’s wheelchair armrest as shown in Figures 18.14 (A) and 18.14 (B).

SUMMARY OF IMPACT
A discussion with the client’s physician concluded that he has a form of multiple sclerosis. He has minimal feeling in his legs, and has limited movement with his right arm and hand. He has slightly better strength and movement with his left arm and hand. This individual has been an avid fisherman, yet due to his conditions, he cannot fish for even a short amount of time on his own. The motorized rod and reel system that was developed will allow him to go perch fishing from a boat during the summer. The unit will allow him to...
retrieve the fishing line with the reel without difficulties. Yet, he can still set the drag, play the fish, and experience the feel of the fight.

**TECHNICAL DESCRIPTION**

In order to motorize the fishing rod and reel unit used by the client, the following issues were considered: casting, reeling and mounting of the rod. No modifications to the rod and reel for casting purposes were required since the client wishes to fish from the edge of a boat by dropping the line directly into the water without having to cast. In order to retrieve the line, a motor was used. The adaptation involved using an aluminum plate to allow mounting of the fishing reel. An electric motor and a gear train used to power the reel were also mounted to the plate as shown in Figure 18.13.

Based on normal Lake Erie perch fishing conditions, an eight-pound test line was used on the fishing reel. A tension force higher than eight pounds would cause the fishing line to break. Analysis was thus performed to determine the required torque at the reel handle, “Thandle” in Figure 18.13, to overcome an eight-pound tension in the fishing line. This was calculated by multiplying the torque generated at the spool, “Tspool” in Figure 18.13, by the internal gearing ratio of the reel. Tspool was calculated by multiplying the tension force (8 pounds) by the distance from the center of the reel spool to the spool arm. The required motor torque was calculated as 201.52 pounds per inch by multiplying the reel handle torque by the gear train value where the gears mounted on the motor shaft and to the reel handle have 256 teeth and 85 teeth, respectively. Also, the motor speed should allow a handle reel speed of 60-90 rpm. Using the gear train value, the required motor speed was calculated as 20 to 30 rpm. A 12V DC Motor, model number PM8014-PS2190, was obtained from Electrical Systems Company, Inc. The motor produces 205.5 pounds per inch of torque, runs at 26 rpm, and weighs 10 pounds. A rocker switch purchased from Newark was sufficient to the client’s needs. The operating force of the switch was investigated to ensure that the client could use the device.

Concern of the client’s strength limitations required ensuring rod and reel stability while reeling in a fish. A strap across the client’s chest that would attach to the end of the fishing rod would keep the rod and reel setup from being pulled into the water upon catching a fish. However, this would limit the mobility and compromise the comfort of the client. Instead, a cantilever beam that could feasibly attach to the armrest of the client’s wheelchair and offer a sturdy mounting for the handle of the rod was used as shown in Figure 18.14 (A) to provide stability for the adapted rod and reel unit. An aluminum-mounting block that attached easily to the cantilever beam extending from the client’s wheelchair armrest was used to hold the electric motor as shown in Figure 18.14.

The entire rod and reel assembly was attached to the aluminum block, and was cantilevered in such a way so the rod and reel would hang in front of the client while he sits in his wheelchair. The length of the client’s arm was the deciding factor on where the unit was mounted on the wheelchair. The reel had to be close enough to the client, so he could reach and release the line when casting. Structural analysis has shown that the design was safe.

The total cost of all parts was $300.

Figure 18.14. Adapted Rod and Reel System as Secured to Wheelchair. (A) shows the cantilever beam that offers a study mounting to the adapted unit. (B) shows the motor bolted to the aluminum-mounting block attached to the cantilever beam extending from the wheelchair’s armrest.
INTRODUCTION
An individual with Multiple Sclerosis (MS) cannot move his body from the neck down. He desires to enjoy the beach with his family while seated inside his wheelchair. Conventional wheelchairs have standard narrow wheels which sink in the sand easily. This does not allow him to access the waterfront preventing him from enjoying the beach. The purpose of this project was to design and fabricate a wheelchair that allows him to access the waterfront. The frame of the constructed unit is made out of furniture grade Polyvinyl Chloride (PVC) to resist corrosion. Wide wires are used to prevent sinking in the sand. The design differs from that of conventional chairs in that large wheels are in the front, which makes pushing the wheelchair in the sand easier. Large diameter set balloon tires are used in the front and smaller caster style swivel balloon tires are used in the rear. The structure of the chair includes three parts: a seating frame, a seating sub-frame and a back frame. A footrest, a pushing handle, two armrests and a reclining back seat are incorporated in the unit as shown in Fig. 18.15. Seat and chest restraints are also incorporated to ensure safety.

SUMMARY OF IMPACT
The client the wheelchair easy to use, and started using it on the beach, as depicted in Figure 18.16. This beach wheelchair will allow the client to spend time with his family enjoying the beach.

TECHNICAL DESCRIPTION
The design requirements included developing a beach wheelchair that does not have the limitations of conventional wheelchairs of digging into the sand. It was to resist heat and corrosion, be easily assembled and disassembled, be lightweight and durable, and be ergonomically designed for ease of operation. The frame of the wheelchair was made of furniture grade PVC pipe (two-inch diameter and quarter-inch thick) to prevent corrosion, and be lightweight and durable. Inflatable balloon tires were used because they are easy to move over sand. Large 12 inch diameter Roleez balloon tires were used in the front and seven-inch caster style swivel Roleez balloon tires were used in the rear to prevent the chair from digging into the sand. Despite the
floatability of the oversized tires, the wheelchair is not intended for use in the water. This is stated on a placard attached to the reverse side of the seat. Having the larger wheels in the front make it easier for a person to push the client over the sand. The caster wheels in the back allow easier maneuverability.

The structure of the chair includes three parts: a seating frame, a seating sub-frame and a back frame. The seating frame supports the load of the chair and the person. The seating sub frame transmits these loads to the front and axles. A 1.058 inch hollow shaft, 1/8 inch thick, made of galvanized steel is used for the front axle. The rear caster assembly is comprised of PVC. An aluminum hinging system is used to connect the seating frame and back frame allowing the back of the seat to recline from vertical to horizontal. The seating frame is cushioned on both the seat and back, and incorporated a headrest providing additional comfort. Seat and chest restraints are also incorporated to ensure safety. Footrest and armrests are also incorporated to the seating sub frame to provide extra comfort. The rear axle of the wheelchair is supported by two PVC pipes that are connected to the back frame, as shown in Figure 18.17, and acting as a bracing to keep the rear wheels at the proper elevation as the chair moves over uneven terrain. A rear axle connecting bar made of PVC piping is used to support the rear axle by connecting it to the seating sub frame as shown in Figure 18.17, which provides greater stability to the rear wheels. A pushing handle is attached to the back of the seat to allow the client to be pushed over the sand.

Structural analysis was conducted on the different components of the wheelchair using Mechanical Desktop, an AutoCAD design package. All parts were found to be safe with a minimum factor of safety of three for a total load of 300 pounds.

Total cost for all parts and material was approximately $415.00.
HOT AND COLD WATER DISPENSER

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INTRODUCTION
The purpose of this project is to enable an individual with C-5 tetraplegia to fill his cup with cold or hot water without the assistance of others. A hot/cold water dispenser is adapted electronically, using a programmable logic controller (PLC) that is controlled by a joystick. The PLC controls two stainless steel three-way solenoid valves that were used to replace the existing water taps. The joystick has four possible positions: hot eight ounces, hot four ounces, cold eight ounces, and cold four ounces. The PLC and its power supply are mounted on the side of the water dispenser unit as shown in Figure 18.18. The joystick is mounted on the frame of the water dispenser as shown in Figures 18.18 (A) and 18.18 (B). The tubes coming out of the three-way valves are combined using a Y-connector and end in a final 0.25 inch diameter PVC tube as shown in Figure 18.18 (A). The control valves and part of the tubes are covered with a stainless steel safe guard as shown in Figure 18.18 (B). In order to use the unit, the client drives up so that the left side of his wheelchair is adjacent to the front of the water dispenser. This allows him to reach the joystick. Before operating the joystick, he must insert the PVC tube coming out of the unit into his cup, which is placed in the cup holder of his wheelchair. He then uses the pressure from his palm to push or pull the joystick in one of the four possible positions to fill his cup.

SUMMARY OF IMPACT
The client is a 44-year-old male with no use of his legs and trunk. To ensure that the client consumes the proper amount of fluid each day (8 to 10, 16 oz. glasses), his wife or colleagues will fill a glass with

Figure 18.18. Adapted Hot and Cold Water Dispenser and Components. (A) shows the tubes coming out of the three-way valves and how they were combined using a Y-connector to end in a final 0.25” diameter PVC tube. (B) shows the unit with the stainless steel safe guard. (C) shows the PLC module and its power supply in their enclosure.
cold water or hot tea throughout the day. Using this cold and hot water dispenser, he is able to perform this task independently. The design allows him to pull his wheelchair up next to the dispenser and fill his own cup, needing only to guide a tube into it and select the type and amount of water he would like using the joystick.

TECHNICAL DESCRIPTION
A standard hot/cold office water cooler was adapted with a programmable logic controller (PLC). A joystick that was used to operate the water dispenser controlled the PLC. Two stainless steel three-way solenoid valves, with a maximum pressure rating of 25 psi, were used to replace the existing water taps. Timers that are internal to the PLC, which receives a command signal from a joystick, controlled these valves. The joystick had four possible positions: hot eight ounces, hot four ounces, cold eight ounces, and cold four ounces. The force required to operate the joystick was measured as approximately two pounds, which was within the client’s capabilities. A power supply was used to convert the standard 120 volts AC wall socket into 24 volts DC required to operate the PLC. An enclosure (8”x10”x16”) was used to mount the PLC and its power supply on the side of the water dispenser unit. The PLC is a 170 ADM 370 10 TSX Momentum Controller that controls up to 16 inputs, eight outputs and is rated at one Amp. at 24 VDC.

The joystick was mounted on the frame of the water dispenser at the same level of the joystick of the client’s power wheelchair. To allow this, the unit was placed on a wooden stand to raise the dispenser up eight inches. The tubes coming out of the three-way valves were combined using a Y-connector and ended in a final 0.25 inch PVC tube. A shroud was used to cover the valves and wiring, offering protection from accidental tampering. All of the electrical components were housed in enclosures that had a National Electrical Manufacturing Association (NEMA) rating of four, which means that they could be directly sprayed with water but not fully submersed.

To operate the dispenser the user moved the joystick in one of the four possible directions to select the amount and temperature of the water he desires. A signal was sent from the joystick to the PLC, which told one of the valves (either hot or cold) how long it should remain open. To determine the relationship between time and volume dispensed, the system was tested. It was found that 28.4 seconds and 13.9 seconds were required to dispense eight ounces and four ounces, respectively. After the requested amount of water has been dispensed, the PLC signals the valve to shut completing the task. If the user were to select the wrong option with the joystick he would be able to correct this by using a stop button that is included in the joystick enclosure. The stop button overrides every command sent to the PLC via the joystick. This feature was added to increase the safety of the design. Also since the client will not actually have to hold the tubing while his cup is filling, there is no danger of a finger burn as hot water passes through the tube.

The program that controls the fluid dispenser was created using Proworx NXT software. The system is initially turned on by the energizing of the normally open joystick, but is then kept on by an internal coil that is energized by a timer. This allows the client to let go of the joystick after he has initially activated it. The program consisted of six networks that controlled various commands by the client: networks one and two control the pouring of eight ounces of cold water and hot water, respectively; networks three and four control pouring four ounces of cold water and hot water, respectively; networks five and six control the cold water valve and the hot water valve, respectively.

Since the client likes to drink hot tea in the wintertime, it is recommended that the jug be partly filled with water and multiple tea bags added and mixed. This will alleviate the need of the client to unscrew the cap of the cup to put a tea bag in it. Using tea mixes or other mixes that contain sugars or other substances that could build up in the system over time is not recommended. Maintenance on the water dispenser is low. The tubing may need to be replaced once every few years and the control valves should be periodically flushed out.

The total cost of all parts was $1400.
INTRODUCTION
A 16-year-old male with T3 paraplegia is an active wrestler in his high school and desires to play on a local sledge hockey team. The purpose of this project is to design and construct a sledge hockey sled to allow this individual to play sledge hockey. The sled was designed to satisfy all International Paralympics Committee sport rules which are the same as those of ice hockey except that players use a sled with two skate blades underneath the seat and one runner under the front. The players use two hockey sticks that are shortened and have picks on their butt ends. These picks allow players to propel themselves on ice which is done by digging the picks into the ice and pulling themselves forward. The other end of the stick is used to move the hockey puck. The sled was designed to be safe, lightweight, durable and maneuverable. This was accomplished by making a frame, with a shape of a U, out of powder coated steel tubing and the tuuks and frame mounts out of aluminum. The seat was custom made to fit the body of the client. Figure 18.19 shows the different components of the sled, and Figure 18.20 shows a picture of the final prototype.

SUMMARY OF IMPACT
The client has been contacted to play on a sled hockey team because his strong upper body will allow him to excel in the sport. However, this individual did not participate because he could not afford purchasing a sled. In addition, all available sleds are not ergonomically designed to accommodate his body. The sled that is designed and constructed will allow him to play on the team and enjoy a new sport. In addition, this individual will have an opportunity to stay in top physical condition.

Figure 18.19. Components of the Sled.
Figure 18.20. Final Prototype.
Figure 18.21. Tuuk from a Conventional Hockey Skate.
TECHNICAL DESCRIPTION

Many components of the sled were based on sleds already in use today since sled designs do not vary much, due to the rules set by the International Paralympics Committee’s (IPC). The focus was to improve the design for weight savings, construction, and adjustability. The total weight of the sled was a major concern. The sled had to be strong yet lightweight so that the player could glide easily across the ice. Three materials were considered for the sled’s frame: steel, titanium, and aluminum. Titanium was both strong and lightweight, but problems arose with welding and material cost was comparatively extremely high. Aluminum offered strength and weight reduction, but using it would require special equipment for welding. Hence, 16-gage lightweight steel tubing was used for the frame of the sled. The U-shaped frame has also been powder coated to protect from corrosion.

Pro/ENGINEER computer aided design software was used to produce the detailed drawings of the different components of the sled. The seat, made of sturdy foam, was custom fit to the client’s body and included safety straps to meet the IPC’s regulations. Blades from CCM® hockey skates were used as they provide durability and the ability to be sharpened. They were made of stainless steel to prevent oxidation. Tuuks and adjustment rails were made of aluminum. The ability to adjust skate stance and length of sled has also been incorporated into the design, which allowed the sled to fit the client better and improved the dynamics and maneuverability of the sled. The blades at the bottom of the sled can be adjusted outward while the client is learning the sport for increased stability. As he becomes more advanced in the sport, he can move the blades in to increase the maneuverability.

Tuuks were used to attach the skate blade to the base of the sled. One idea was to use the tuuks that are normally used on a pair of conventional hockey skates that are shown in Figure 18.21. This type of tuuk was light and strong but it was molded to fit the bottom of a foot. However this skate tuuk had some height concerns. In order to comply with IPC rules the bottom of the base of the sled had to be between 8.5 and 9.5 centimeters from the ice. Using this tuuk would require that another piece to be attached to it to achieve this height, which could affect safety. A tuuk made out of a block of aluminum with holes machined into it to reduce the weight was thus chosen as shown in Figure 18.22.

This design was strong and compact and fit well under the sled. Also this style of tuuk would easily accommodate all IPC rules and give the sled a very professional look.

Three runners for the front of the sled were considered. The first was another blade that would just slide on the ice as seen in Figure 18.23 (A). It was found that it is illegal to have a blade in the front due to safety reasons, as it would make the sled hard to turn. The second was a hard nylon ball that would be held in place with three pins screwed into it and anchored to the sled, as shown in Figure 18.23 (B). This would make the sled glide easily over the ice; also this type of runner could be replaced quickly and easily with simple hand tools if it were to become damaged. However machining of this runner was involved, as it required setting the ball directly in the center of the sled and attaching it to the sled. The third was the method of choice and consisted of a U-shaped bent pipe welded to the frame. This runner was strong and lightweight and glided over the ice very well. This design was also easy to manufacture and is durable.

Structural analysis has shown that the design was safe. The total cost of all parts was $1000.
ADAPTATION OF A POWER WHEELCHAIR FOR CARDIOVASCULAR ENHANCEMENT

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INTRODUCTION
An active professional with C5 quadriplegia desires to adapt his old style power wheelchair to exercise his arms actively and his legs passively. The purpose of this project is to adapt his wheelchair with a cardiovascular enhancement system that will allow him to exercise his arms actively as the chair is moving. The wheelchair propels forward as the client pushes a joystick. In order to allow the client to propel the wheelchair as he exercises his arms actively, an integrated mechanical and electrical cardiovascular enhancement system is designed and constructed. This system is mounted onto the power wheelchair to generate the same propelling command signal, but by not using the joystick. This integrated system includes two hand cranks, two pulley systems and two motors. In order to exercise, the user rotates these two hand cranks using his arms causing the chair to move. Each hand crank, along with its pulley system and motor, are attached to one of the wheelchair sides using a removable stainless steel framework as shown in Figure 18.24. Tri-pin handles are attached to the cranks to provide adequate wrist support. A switch is incorporated into the system to allow the client to propel his wheelchair either using the existing joystick, or by exercising his arms and rotating the hand cranks. Figure 18.25 of the next project depicts the wheelchair after it is adapted with the cardiovascular enhancement unit (this project) and the motion generation system that allows passive exercise of the user’s leg (next project).

SUMMARY OF IMPACT
An active professional has limited use of biceps, trapezius and deltoid muscles, but cannot move his lower extremities. He owns an old style power wheelchair that he uses as a backup means for transportation. However, since he has become a wheelchair user, he does not exercise any part of his body. The energy requirements for using his power wheelchair are not adequate to stimulate a cardiovascular response. Over time insufficient exercise will lead to the increased risk of blood clots and decreased blood flow in the lower extremities. In order to reduce these risks, a system was developed and installed on his wheelchair to allow him to exercise his upper body actively and generate a cardiovascular response as he propels his wheelchair forward. Hand crank rotations will provide him a cardiovascular exercise that improves blood flow and increases heart rate.

TECHNICAL DESCRIPTION
The upper body exercising rotation of two tri-pin hand cranks powers the wheelchair causing it to propel forward in the same manner as if the user were maneuvering with the joystick. Two motors,
Each crank shaft, along with its pulley system and motor, are mounted on one of the two sides of the wheelchair using two stainless steel frames as shown in Figure 18.24. Each frame is attached by a pivot to the rear of the chair and held in place in the front by a pin. The rear pivots consists of two overlapping steel tubes, one rotating inside the other. The larger tube is welded directly to the chair while the smaller tube can be easily lifted and removed. Each crank is supported to its mounting frame using four-bolt flanged block bearings. The position of the hand cranks is determined based on the user’s shoulder height in a seated position, his comfortable arm reach, and his upper arms range of motion. To allow a comfortable operation, the radius of rotation of the tri-pin handle around its axis of rotation has been established as three inches such that during one revolution of the hand cranks, the distance from the tri-pins to the floor will rise and fall between a maximum of 34 inches and a minimum of 28 inches (average of 31 inches as shown in Figure 18.24); also, the distance from the handles to the back of the chair will change from a maximum of 17 inches to a minimum of 11 inches (average of 14 inches as shown in Figure 18.24). The wingspan of the wheelchair with the upper body exerciser unit mounted on it is 34 inches as shown in Figure 18.24. The arm frames swing open on the rear pivot providing easier entry and exit from the chair. The critical loading condition is simulated by applying a 100-pound load vertically to the arm frame when the frame is hinged open 90 degrees with respect to the chair as shown in Figure 18.25. Using a factor of safety of two, the size of the rear mounting bolts and the diameter and thickness of the pivot one-inch square tube were determined by assuming that they support this entire 100 pound load applied at 17.3125 inches from the rear pivot as shown in Figure 18.25. SAE grade eight low carbon steel bolts (Sy = 130kpsi) with 0.375 inches in major diameter, and 304 stainless steel tubing material (Sy = 40kpsi) 0.125 inch thick were used.

Two groups of students worked on this project during two different semesters; a system was developed by the first group, and then modified by the second group. The total cost of the different components of this cardiovascular enhancement system incurred by the two groups was $1400.
ADAPTATION OF A POWER WHEELCHAIR TO ENABLE LEG EXERCISE

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INTRODUCTION
An active professional with C5 quadriplegia desires to adapt his old style power wheelchair in order to be able to exercise his legs passively and his arms actively (see previous project) as the chair is moving. The purpose of this project is to design and construct a motion generation mechanism and attach it to the wheelchair to rotate this individual’s otherwise motionless legs. This mechanism includes two heel style foot pedals that are mounted to the wheelchair. These pedals rotate causing the rotation of the individual’s legs. The pedals are rigidly attached to a shaft that is driven through a pulley system which, in its turn, is driven by two pulley systems that are driven by the two drive shafts of the two motors powering the wheelchair. This mechanism is supported by an added fifth wheel and the frame of the wheelchair. Boot-type splints and ankle foot orthoses are used to provide ankle support. Figure 18.26 shows a detailed engineering drawing of the different components of this motion generation system that are added to the wheelchair. Figure 18.27 depicts the wheelchair after it was adapted with the motion generation system (this project) and the cardiovascular enhancement unit (previous project).

SUMMARY OF IMPACT
An individual with C5 quadriplegia has limited use of biceps, trapezius and deltoid muscles, but cannot move his lower extremities. He owns an old style power wheelchair that he uses as a backup means for transportation. However, since he has become a wheelchair user, he does not exercise any part of his body. This has a negative effect on the blood flow in his body, in particular within his lower body. The motion generation system that was developed and installed on the wheelchair will allow this individual to exercise his lower body passively by rotating his otherwise motionless legs as the chair is propelled forward. This provides pleasant passive leg motions, making thus exercising more interesting to this individual.

TECHNICAL DESCRIPTION
The exercise mechanism adapted to the power

Figure 18.26. Components of Adapted Wheelchair.
wheelchair provides passive exercise of the user’s lower body by means of two foot pedals to which the user’s feet are strapped. These pedals rotate as the wheelchair is moving forward. As the user’s feet are strapped into the pedals the individual’s feet are also rotated inducing the passive exercise of his legs.

The power wheelchair adapted was an old style chair that uses two pulley systems, one on each side, to drive each of the two rear wheels. The pedals’ motion generation mechanism was developed making use of this feature by employing a system of belts and pulleys that would utilize the power generated by the wheelchair motors. The pedals were thus attached to a shaft that was driven through a pulley system located in the center of the wheelchair. This pulley system, and in its turn, was driven by two other pulley systems that were located on each side of the wheelchair and driven by the two drive shafts of the two motors powering the wheelchair. This system did not affect the stability of the chair. Also, the speed of the leg rotations was controlled by properly sizing the different pulleys.

The drive pulley consists of a 3.55 inch diameter steel pulley that was connected to the drive shaft on one of the wheelchair motors. Square tubing was bolted to the front of the wheelchair in order to provide a mounting surface for two bearing joints and a place to connect the pedal assembly to the wheelchair. A 3.95 inch diameter pulley and a two-inch diameter pulley were attached to one end and onto the center of an 18 inch aluminum shaft with an outside diameter of 0.75 inch, respectively. This shaft was then placed through the bearing joints, and a half-inch V-belt was used to connect the 3.95 inch pulley to the drive pulley. A connecting frame made of tubing was used to attach the pedal assembly to the square tubing bolted to the wheelchair. This frame was mounted on top of a free moving wheel.

The pedal assembly consisted of two pedals, each attached to a crank arm that was attached, and in its turn, to one end of an eight-inch long aluminum shaft. The pedal assembly was driven by a second pulley system which consisted of the two-inch pulley mounted on the 18” inch shaft and a 5.5 inch diameter pulley mounted at the middle of the eight-inch aluminum shaft connecting the two crank arms; a V-belt connected these two pulleys. The pedal assembly was attached to the connecting frame using also square tubing. Based on the anthropometric data of the client, pedal crank arms three inches in length were used in order to prevent his legs to be moved out of his maximum range of motion. The pedals that were used were heel style pedals with Velcro straps. Ankle support was provided by incorporating a boot-type splint; this splint ensures that there is no leg movement to the user’s left and right as his legs are being passively exercised. The splint was secured with Velcro straps to the client’s foot and mid-calf. Ankle foot orthoses were adapted to fit around the outside of the user’s shoes and were mounted to the pedals as shown in Figure 18.27

Two groups of students worked on this project during two different semesters; a unit was developed by the first group, and then modified by the second group. The total cost of the different components of this motion generation system incurred by the two groups was $700.
WHEELCHAIR LIFT FOR MOBILE HOME ACCESS

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INTRODUCTION
An individual using a wheelchair lives in a mobile home with an attached deck, ramp and steps. The steps are in the front of the deck while the ramp is on the side. She has a difficult time getting in and out of her trailer during the winter. When it snows, it is difficult for her to clean the ramp, and she must use the steps, which requires her to get out of her wheelchair and scroll down the steps on her buttocks. The purpose of this project is to design, construct and install a free standing lift that will allow this individual to remain in her wheelchair while transporting herself to and from the deck of her mobile home. The lift is powered by a 12 VDC marine battery allowing it to be used in case of power outage. It includes a platform that is raised and lowered using a linear actuator. The platform consists of a horizontal square frame covered with a quarter-inch thick steel plate as shown in Figure 18.28; the frame is made of three-inch steel square tubing, 3/16 inches thick. Wheels made of round nylon stock are attached to the platform to allow it to travel on two I-beams that are used as guide rails and are rigidly attached to the base of the lift. A storage rack is rigidly installed on the platform, as shown in Figure 18.29, to permit easy loading and unloading, and to allow the user hands to be free as she is using the lift. This provides safety and convenience. Also, a dead man switch is used to operate the lift which provides additional safety. Figure 18.29 shows the lift in an elevated position as it is being tested by its user.

SUMMARY OF IMPACT
Before the ramp was installed, the client had to climb out of her wheelchair, scroll down the steps on her buttocks to the ground, pull the wheelchair down off of the deck, and then climb back into the wheelchair. In order for her to go up to the deck, this procedure was reversed. The ramp provided her easier access to her home, but during the winter months it was increasingly difficult for her to use it due to snow and ice. Both processes were tiring, especially if she had to do it several times to retrieve groceries or anything else from her automobile. Also, when she scrolled up and down the stairs, she had to take an extra set of clothes with her when the weather was bad because she would get wet and dirty lowering herself down the stairs. The lift unit that was constructed and installed in her mobile home will allow her to transport herself from her automobile to her home in a safe and efficient manner. The client appears to be happy with the lift.

TECHNICAL DESCRIPTION
The purpose of this project was to design, construct and install a wheelchair lift to allow a wheelchair user easier access to the deck of her mobile home. The lift was designed to raise her 34 inches from ground level to the level of the deck that leads to her front door. The fixed base of the lift was free standing and included vertical guide rails to raise and lower a moving platform. The guide rails were two I-beams rigidly attached to the base of the lift. The platform consisted of a horizontal square frame made of three-inch steel square tubing, 3/16 inches thick. The frame was covered with a quarter-inch thick steel plate that was directly attached to the square tubing. Wheels made of round nylon stock were bolted to two U-channels that were welded to the moving frame as shown in Figure 18.28 and Figure 18.30, allowing it to travel on the guide rails. The wheels were made of round nylon stock to prevent a large amount of friction. These wheels, similar to the wheels on a forklift, supported the platform by counteracting the moment produced by the load.

A linear actuator mounted vertically and capable of lifting 1500 pounds was used to produce the motion. It consisted of a mechanical screw drive encased in a cylinder. A motor, mounted on top of the cylinder, drove the screw. The actuator was attached to the moving frame with a pin through its eye hole. It was mounted at the bottom of the fixed base using two cylinders welded together which created a pin around which the actuator could rotate. This design allowed the actuator to rotate if subjected to any torque, preventing thus the bending of the enclosing tube. If this tube were to bend at all, the screw drive inside the actuator would not be able to travel up and down, causing the lift not to function. A 12 Volt DC Marine battery along with an inline trickle charger was used as power supply, which required minimum wiring.

A storage rack was rigidly installed on the platform to permit easy loading and unloading, and to allow the user hands to be free as she is used the lift, which provided safety and convenience. Also, a dead man switch was used to operate the lift to provide additional safety. Structural analysis was conducted using the I-DEAS Master Series™ Software (Integrated Design Engineering Analysis Software). All parts were found to be safe with a minimum factor of safety of three. The unit was tested before installation as shown in Figure 18.29, and was found to be safe.

Figure 18.29. Testing of Lift.

Figure 18.30. Wheels Bolted to the Moving U Channels to Travel Along the Fixed I-beams.

Total cost for all parts and material was approximately $1200.
ADAPTING A VAN DRIVER SEAT FOR AN UNEVEN SEATING CONDITION

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INTRODUCTION
A wheelchair user has a form of infantile arthritis with a limited range of motion and little muscular strength from the middle of her torso down. Also, because of her arthritic condition, motions at her left hip joint are drastically reduced since the joint is fused. This causes her to have uneven seating as she sits on any flat surface, and she cannot safely drive her van. As she drives her van, she uses her purse to elevate her left buttock as shown in Figure 18.31, which helps slightly improve her stability. Due to weak torso muscles, she becomes unstable as she makes turns: she falls left as she makes right turns and falls right as she makes left turns. The purpose of this project is to adapt a seat for her van to allow her to drive safely.

The existing van seat was replaced by another bucket style seat taken from a sports car. A removable Roho High Profile Quadtró® adjustable air filled cushion was used to elevate her left buttock. The cushion, shown in Figure 18.32, has four compartments that can be individually inflated at different specified pressures. To provide side-to-side support, a lateral restraining system was designed, constructed and attached to the frame of the seat. The cushion and the lateral support system are easily removable to allow other people to drive the vehicle.

SUMMARY OF IMPACT
This individual is active and has a demanding schedule that requires her to travel frequently. Because of lack of trunk muscles to provide proper lateral support, she became unstable as she made turns. While driving her vehicle, she would fall out of her seat when she made a sharp turn. She would fall over laterally into a position where she could not get herself upright without taking her hands off the wheel of the vehicle. Obviously this created a dangerous and unsafe situation, putting her and others at a high risk of a serious accident. The successful adaptation of a bucket style sports car seat that was permanently installed into her van allowed her to drive safely and comfortably. The removable air filled cushion elevated her left buttock, allowing her even seating. The removable
lateral restraining system prevented her from falling out or shifting in the seat.

**TECHNICAL DESCRIPTION**

The existing seating arrangement does not adequately ensure a comfortable and a safe ride to the user since constant readjustment to sit upright in the seat is needed. The existing seat was replaced with a bucket style sports car seat with vertically angled foam supports on its sides (both horizontal and vertical sections of the seat) as shown in Figure 18.33. The seat was taken from a Mitsubishi eclipse. It was chosen because it offered a wide seating base, and an adjustable back support positioning. This allowed the driver extra support when turning, to remain seated in an upright position. Using a sports car style seat with a removable cushion was preferred over using a permanent contoured seat since the user indicated that the van was to be driven by other members of her family. The client had acquired a body molded seat cushion that she placed on the seat of her wheelchair, allowing her even seating. While she was pleased with it, making a similar one for her van was not considered because of the high associated costs: the price of one unit is $1750. Instead, a commercially available “air filled” cushion was used, namely the Roho High Profile Quadro adjustable air filled cushion. This cushion had four separate compartments that could be individually inflated at different specified pressures allowing the support of the one side of the user that needed more support (due to the missing hip), while adequately positioning the user to be properly situated for driving. This was an effective solution since the total cost for the cushion, fabric covering, air pumps, and valve was approximately $380.

Lateral supports were needed to prevent this individual from tipping over laterally when making a sharp turn. Based on how the client gets in and out of her van, a fixed side support was developed. To get into the van, the client stands up out of her wheelchair, moves to the side and “falls” back into the driver’s seat which, mounted on a six-way movement mechanism, could move to the back of the mini-van and swivel parallel to the user’s wheelchair. The side support system consisted of two parts: fixed and removable, as shown in Figures 18.34 and 18.35. The fixed part included two one-inch square tubes, 1/8 inch thick that run parallel to each other and were welded directly to the frame of the seat. The removable part included a second set of three-quarter inch square solid tubes that slid into the fixed square tubes. Two square brackets, six inches by four inches, were bolted to the ends of the sliding tubes to provide an extended area of side support. Pins were used to properly position the sliding tubes inside the fixed tubes. All parts of the side support system were made of low carbon, hot rolled steel. Permanent foam padding was attached to the square brackets to properly hold the client in position.

Structural analysis was conducted to verify that the square brackets could sustain safely vertical and horizontal loads of 300 pounds using the I-DEAS Master Series™ Software (Integrated Design Engineering Analysis Software). The three-point harness that existed in the car was preferred over using a five-point harness as a seat belt. Due to her limited movement, the client would not be able to connect all of the straps needed for a five-point harness.

A large portion of the bottom of the adapted seat was cut off, and a flat pan was welded at its bottom which allowed bolting the seat to the mounting plate located in the van. To complete the installation of the adapted sports car style seat into the vehicle, the seat belt lock was attached onto the seat frame and the base of the seat frame was connected to the mechanism that moves the seat inside the van. The total cost of all parts and material was $750.00.