

Maple Knoll Mobile Medication Cart

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by

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Abstract

This project stems from the collaboration between the University of Cincinnati and Maple Knoll Nursing Home. The project was built upon the last year medication cart project (2016), with modifications made in four areas: an adjustable height, a cooled drawer, an extra working surface and a handle for better control. Through a survey and a meeting with Maple Knoll director of corporate communications and a group of nurses, the design concept of the new cart was developed. The idea behind having an adjustable height is to alleviate and eliminate the muscle strain experienced by the nurses from bending over and pushing heavy carts.

Research and Background

Nurses aim to help patients during their services, however, nurses themselves become the patients after a while. Many nurses have suffered from musculoskeletal pain during their services in hospitals. Common locations of musculoskeletal pain include back, neck and shoulder pain. These injuries come from pushing heavy medication carts every day throughout the hallways and bending over to get some medicines from the lower part of the cart. The nurses' safety should be put first. If hospitals don't provide the appropriate working place for nurses, nurses wouldn't function properly as they should, and they would have more difficulties serving patients. In this project, a medication cart was built to suit different nurses' heights. It gives the nurses the freedom to adjust the cart according the desired height.

The Medication Cart is designed to serve in medical facilities like nursing homes, hospitals, and big clinics if needed. According to a survey that was done in 2016 and completed by 11 nurses in Maple Knoll, the age of the nurses that used the cart were between 23 to 61 years old. The average is 42 years old. The cart will serve both genders. The nurses who are going to use the cart do not have to have a lot of

experience because the cart is easy to use. This cart can be used by nurses who give patients medications periodically. The project is targeting hospitals that are upper middle-class hospitals because the cart would be affordable.

An online research revealed the most common complaints reported by nurses who use medical carts in hospitals. It was found that many nurses suffer neck, back, and wrist pain after a while from working with medication carts in particular. This is attributed to the lack of proper design of the carts and its weight.

Three research methods were used to gather information leading to the right design solution. The methods are an online research, an interview, and a survey. The report of the previous team (2016) was reviewed to have a better understanding of the problem and the possible solutions before visiting Maple Knoll Nursing Home. The interview was done with Megan Gresham-Ulrich, the Director of Corporate Communications of Maple Knoll Nursing Home. During the meeting, Megan talked about what nurses usually complain about and the restrictions they face when dealing with the medication carts. Moreover, nurses took the survey, which was about what features they want to have in the medication cart. From their response, a list of the main problems that nurses face was formed. The survey is detailed in Appendix C.

Customer needs and engineering characteristics

Based on an online research, an interview and a survey, customers' needs and engineering characteristics were summarized below:

- ❖ Customers' needs summary:
 - A cart with an adjustable height.
 - A cooled drawer for some of the medications in the cart.
 - Extra working area.
 - A handle for better control and maneuverability.

- ❖ Engineering characteristics summary:
 - A cart with an adjustable height up to 11 inches.
 - A cooled drawer up to 8 hours.
 - 19.75 x 14.25 inches of an extra working area.
 - 27 inches' long handle.

Cart Design

❖ Previous design

The Previous team in 2016 had built a medication cart for Maple Knoll. The cart's body is similar to the cart in Maple Knoll Nursing Home. They added one feature to the cart, which is the ability to



Figure 1: Design of 2016

change the height of the upper table of the cart only. They accomplished that by using two linear actuators. The bases of the two linear actuators are connected to the body of the cart, and the ends of the linear actuators are connected to the top surface of the cart.

By having an adjustable height of the top surface of the cart, nurses can work at a convenient height for them. Thus, it will reduce wrist injuries due to unsuitable height. Also, it will reduce some of the neck injuries due to the inappropriate height of the laptop screen.

The disadvantage of this design is that nurses still have to bend all the way down if they want to get medicines from that cart and that could cause back injuries.

❖ Alternative Design

During the research about the cart, some alternative designs had been made of some parts of the cart. Here are two of them:

- Rotating drawers

Applying a rotating mechanism to the cart's drawers can solve the problem of back injuries. However, designing a rotating mechanism for the drawers will consume a lot of storage room in the cart. Moreover, by having a rotating mechanism, it will be difficult to keep the drawers at the right orientation while they are moving.

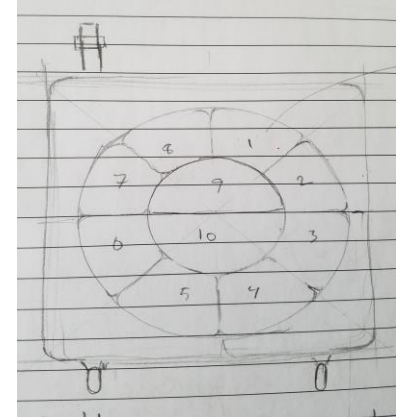


Figure 2: Rotating

- Cooled drawer

One of the customer needs is a cooled drawer. The cooled drawer had just one constraint, which was using a refrigeration system. The refrigeration system consists of a compressor, condenser, expansion valve, and evaporator. If a refrigeration system was used, the cart would have been less convenient in terms of the noise the compressor will make and the weight the refrigeration system can add to the cart, as well as maintenance. So, using the dry ice was an option. The dry ice would be stored in an isolated drawer, so that will keep the medications cold for a longer time.

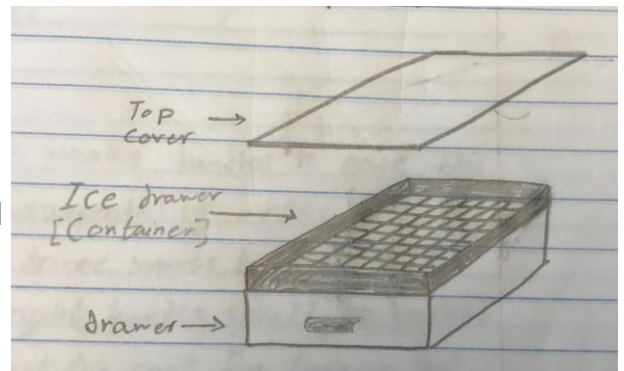


Figure 3: Cooled Drawer Design 1

In the first design, the drawer walls were lined with cool barrier bubble isolation. At the top of the drawer, there would be an aluminum net. On top of the aluminum net, the dry ice would be placed. Then the drawer would be covered by a lid covered by the cool barrier bubble isolation.

This design has one advantage. It can provide a cold drawer for a longer time for medications. But, nurses will have a difficult time reaching to medications because they have to remove the lid, dry ice and the aluminum net before they can take the medications.

❖ Finalized Design

In the finalized design, there are a few modifications and improvements to the previous design. These improvements include an adjustable height, an isolated cooled drawer, an extra working area and a handle.

- An adjustable Height

This is associated with a reduction in the musculoskeletal pain, such as back, neck, and shoulder pain. One more linear actuator and two linear bearings with two linear shaft supports had been added to the new design. As a total of three linear actuators, six linear bearings, and six linear shaft supports for the cart's stability and balance. The three linear actuators are fixed on both cart's base and cart's body. When the actuators are on, they are sitting on the base and pushing against the body frame, so the cart is being elevated upward. The cart is stable when it is all the way up. The whole cart can be raised up to 11 inches.

- Isolated Cooled Drawer

The second improvement is adding an isolated cooled drawer to the cart.

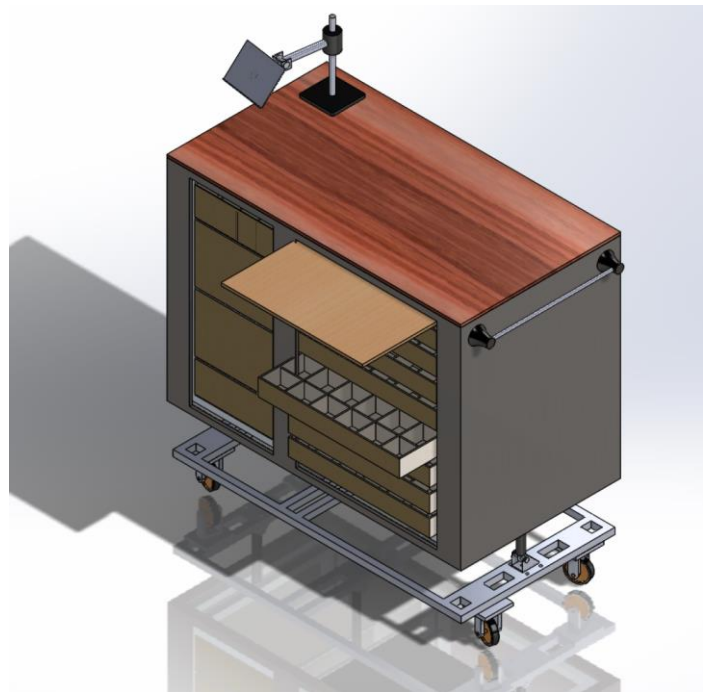


Figure 4: 3D model

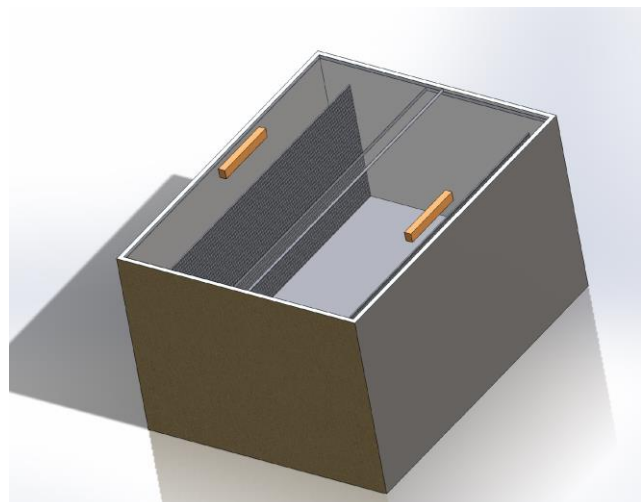


Figure 5: Isolated Cooled Drawer

This feature helps nurses saving some time when serving patients. Some patients need cold medications such as insulin. Instead of the nurse going all the way to the refrigerator and bringing the needed medication, this medication would always be within reach in the cart. The isolated cooled drawer consists of cool barrier bubble isolation; two transparent slide plastic doors, an aluminum net, and Techni Ice. The cool barrier bubble isolation helps to preserve the drawer's temperature. Plus, cool barrier bubble isolation is easy to install inside the drawer. Using rigid foam as an isolation was an option as well, however, it would take more space inside the drawer, so the capacity of the drawer would be decreased. Two Transparent slide plastic doors had been added to the drawer to ease locating the medicine inside the drawer. Using glass instead of plastic was an option as well, however, using glass has more disadvantages. Their advantages are: first, glass is more fragile than plastic, which is going to be a mess if something hit the glass and it broke. Second, plastic is a better isolator than glass; it has a lower thermal conductivity. Third, in terms of weight, plastic is lighter than glass. An aluminum net had been used to separate the Techni Ice from the medications. When the Techni Ice is being separated from the ice, there would be no contact between the medication and the ice. The medications shouldn't be in contact with ice for patients' safety. Lastly, Techni Ice had been used to cool medications in the drawer. Techni Ice stays up to 5 hours at room temperature; however, it stays up to 8 hours inside the isolated drawer.

- Extra Working Area

One of the requests from Maple Knoll Nursing Home is having an extra working space on the cart. Nurses complain about the lack of space on the upper table which is full of cups, gloves and other items. They needed enough space to prepare and mix the



Figure 6: Extra Working Area

medications on the cart before administering them to patients. This cart provides them a space of 19.75 inches' width and 14.25 inches' length slide-out table.

- Handle

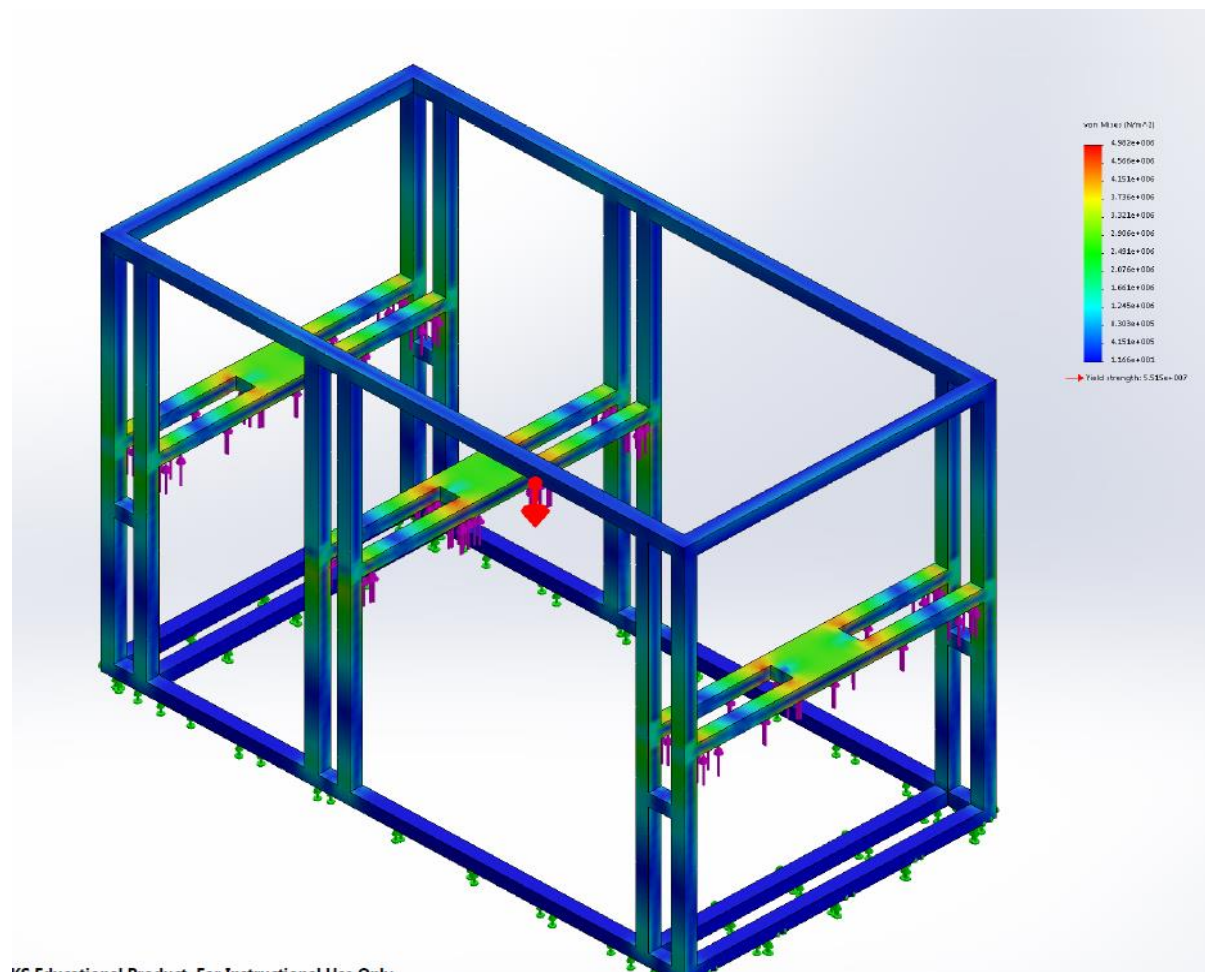
When the cart is full of medications, it is going to be very heavy. Imagine handling the cart without a handle. According to some nurses in Maple Knoll, the cart is hard to handle without a handle, it is harder to maneuver as well through the hallways. In the current design, a handle was added to the cart to ease the maneuverability.



Figure 7: Handle

- ❖ Stress Analysis.

A stress analysis was done on SolidWorks Simulations where stresses on the body were calculated. The stresses on the bars of the cart are shown in the picture in



KS Educational Product. For Instructional Use Only

Figure 8: Yield Strength Test

this section. There was no risk for the beams to be bent or broken. The beams did not exceed the yield strength limit, which means that the beams' size and material are capable of carrying the weight of the cart when it is full without any deflections.

Components and Materials Selection

In this project, different kinds of materials and components have been used. The components of this design have been chosen carefully to minimize the total cost of this cart because it is just a prototype design. Mainly, the current cart was built by aluminum bars, corner brackets, nuts, and hexagon socket head cap screws.

- Aluminum bars

T-Slotted Aluminum bars have been used to minimize the weight of this design. A T-slotted bars gives the flexibility to attach other bars to it by screws and nuts. Mostly, 30mmX30mm aluminum bars have been used in this cart. Aluminum materials were chosen in this cart due to the durability of aluminum against corrosion.



Figure 9: T-Slotted Aluminum Bar 30mmX30mm

- Corner brackets

A 90-degree aluminum corner brackets have been used to connect bars together in this cart. The aluminum material was chosen for its durability against corrosion and lighter weight than steel.

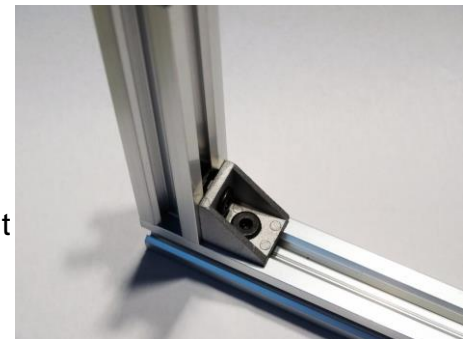


Figure 10: Corner Brackets

- Nuts

Two different types of nuts have been used in this project. The first one is called Self Aligning roll-In T-Nut, and the second one is called

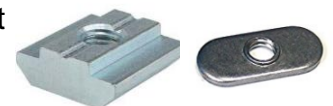


Figure 11: T-Nut & Weld

Weld Nut Center Hole. They are located inside the bars where they can be tightened up by screws from the other side.

- Hexagon socket head cap screws

Aluminum screws have been used in this cart with different sizes. Three sizes have been used, first, ($\frac{1}{4}$ inch- 20-1 inch), second, ($\frac{1}{4}$ inch- 20- $\frac{1}{2}$ inch), third, ($\frac{1}{4}$ inch- 20- $\frac{1}{4}$ inch).



Figure 12: Hexagon socket

- Linear Actuators

Three identical linear actuators have been used in this project. The stroke length of each actuator is 12 inches. Also, the input voltage is 12V DC. Moreover, its maximum load is 225 lb for each one. It is a lubricated metal gears actuator. And its travels speed is 0.39 inch/sec.



Figure 13: Linear Actuators

- Power Supply

It is suitable for 100~120V AC and 200~240V AC input voltage. It can be modified by a switch on the device. It has a 12V DC as an output voltage which is needed to charge the battery. It has a maximum output current of 30 amperages. It has a shortcut Protection, an overload protection, and an overvoltage protection.



Figure 14: Power Supply

- Battery

This cart is provided with a 12V DC rechargeable battery. It is 7.8 x 5.2 x 7.3 inches, which can be stored on a wooden sheet on the base section, so its weight would be on the base, not the body. It is a UTV lead acid battery.



Figure 15: Battery

Assembly

In this project, there are two machines that have been used to cut and drill holes in the parts. The first one is called Metal Cutting Bandsaw where some bars have been cut to certain lengths required for the cart's specifications. This machine was used in a workshop on the main campus under the supervision of Mr. Ronald Hudepohl. The second machine is called Pillar Drill where some holes were made in plates. These plates were used to fix the linear actuators' seats on them. These holes were made at Victory Parkway campus.



Figure 16: Pillar Drill

Testing

The cart has run through different tests. The first test was testing the linear actuators. All three linear actuators were fixed at the same level throughout the cart's base and body. Through this test, all the linear actuators worked at the same time and speed. As result, the cart's body rose up to 11 inches successfully.

The second test was a stability test. Through that test, the cart had just two linear actuators, four linear bearings, and four linear shaft supports. When it was tested, it wasn't stable enough when it was raised. So, a third linear actuator was added with two linear bearings, and two linear shaft supports to the cart. Now the current design is stable throughout all the cart's heights.

The third test was a cooling test, which was done in the isolated cooled drawer. This test conducted by placing a Techni Ice pack inside the drawer and another Techni Ice at room temperature. It was proven that the isolated cooled drawer had kept the



Figure 17: Metal Cutting Bandsaw

drawer colder than the surrounding environment. The drawer had kept the Techni Ice packs frozen by 3 hours longer than the one kept at room temperature.

Schedule

The process in this project was divided into three parts:

Senior Design I (08/22/2016 - 10/09/2016)

Senior Design II (10/10/2016 - 12/03/2016)

Senior Design III (01/09/2017 - 04/21/2017)

During Senior Design I, a report about the problem statement was written. The report talks about the people and the features of people who are targeted by the project.

Senior Design II started by a meeting with Dr. Janet Dong to plan a schedule for the rest of the project. Then, Information about the project was collected through a survey and a meeting with the nurses in Maple Knoll. Also, other aspects of the design were covered such as the body design, the lifting mechanism, materials selection and the budget.

In Senior Design III, the construction of the cart was started as well as the testing of the cart.

ID	Task name	Duration (day)	Start	Finish
1	Medeication Cart	215	8/24/16	###
2	Design I	39	8/24/16	10/16/16
3	start design I	0	8/24/16	8/24/16
4	Design report draft	29	8/24/16	10/02/16
5	Final Design report	15	9/28/16	10/16/16
6	Design I Completed	0	10/16/16	10/16/16
7	Design II			
8	Start design II			
9	Meeting with Prof. J. Dong	45	10/27/16	10/27/16
10	conceptual sketches	45	10/27/16	10/27/16
11	Body design	45	10/27/16	10/27/16
12	Lifting mechanisem	45	10/27/16	10/27/16
13	anwavel mechanisem/ Braking syste	45	10/27/16	10/27/16
14	Storage unit design	45	10/27/16	10/27/16
15	Storage untis moveing mechansim	45	10/27/16	10/27/16
16	Motor selecting	45	10/27/16	10/27/16
17	Material selection	45	10/27/16	10/27/16
18	Preperation for design presentation	14	10/27/16	10/27/16
19	Design presentation	3	10/27/16	10/27/16
20	Design III	74	01/11/17	4/22/17
21	Start design III	0	09/01/17	27/04/17
22	Manufacturing	50	01/11/17	3/18/17
23	test	6	4/1/17	04/06/17
24	Project Presentation	14	04/06/17	4/14/17

Table 1: Tasks' Schedule

Budget

The estimated budget was calculated during Senior Design II. The budget was calculated based on the materials that were needed to be purchased to finish building the medication cart such as the frame's bars, nuts, and screws. Also, the estimated budget included some of the accessories that medication carts usually have, such as the wire basket and the drawer divider.

However, after making the first test of the cart, it was decided that the balance and the lifting force of the cart were not enough. As a result, the actual budget list included extra components such as the linear actuator and the linear bearings to

overcome the problem of insufficient balance and force. Also, the actual budget eliminated some components such as the drawer divider and the wire basket. So, the estimated budget ended up being \$564.5 and the actual budget is \$479.88

Estimated Budget		Actual Budget	
Item	Estimation price (\$)	Item	Actual Price (\$)
Frame	100	Frame	85.94
Nuts and Screws	100	Nuts and Screws	93.9
Wood 20" X 20" X 0.5"	10	Linear Actuator	73.89
Battery	60	2 x Bearings and Shafts	94.99
Wire basket	70	2 x Aluminum Shaft Support	19.9
Drawer divider	24.5	Bumpers	48
Lockable sharp container	107	Power Supply	30
Thermal Insulated Bubble	12	Thermal Insulated Bubble	12
Bumpers	81	Battery	21.26
Total	564.5	Total	479.88

Table 2: Budget

Recommendations

❖ A safety locker for drawers.

The safety locker for drawers was in the original design plan, however, it couldn't be installed in the cart because the body of the cart needed to be covered with a case. The locker will be installed in the body and the case together. Moreover, all drawers should be placed before the safety locker can be installed.

❖ Autonomous cart

An electric motor could be used to drive the wheels instead of pushing the cart. However, this idea means that an extra weight will be added to the cart because the motor needs bigger batteries. Also, having an electric motor in the cart requires that the two wheels in the back of the cart are fixed and the front wheels are used for navigation. However, it will be difficult to have the whole cart slide right or left (i.e. for parallel parking). Instead, the cart has to go forward then slightly right or left while backing up.

❖ Replace the battery

The battery that is used to power the linear actuators is used for outdoor purposes. For indoor applications, there is another kind of battery that is usually used, such as U1-12RT from Valence Advanced Energy Storage Solutions.

Appendix A: 3D models



Figure 18: 3D model

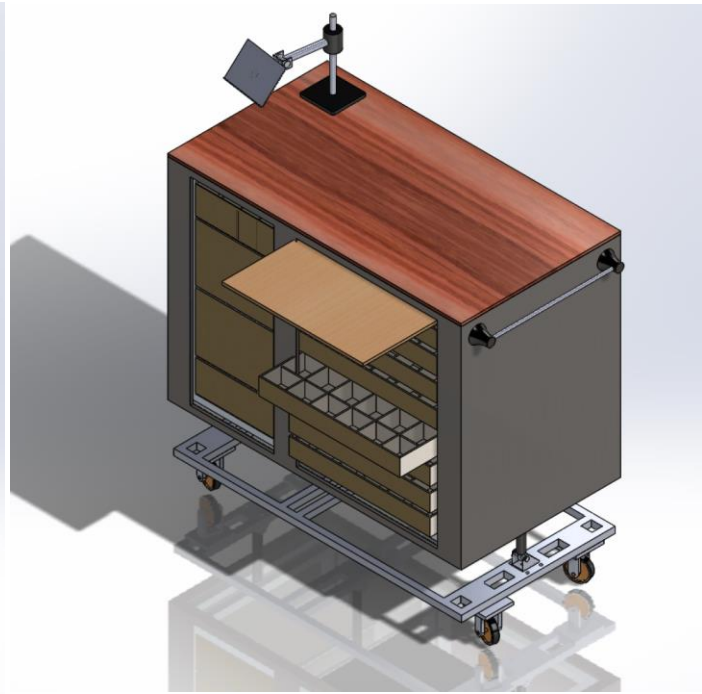


Figure 19: 3D model-2

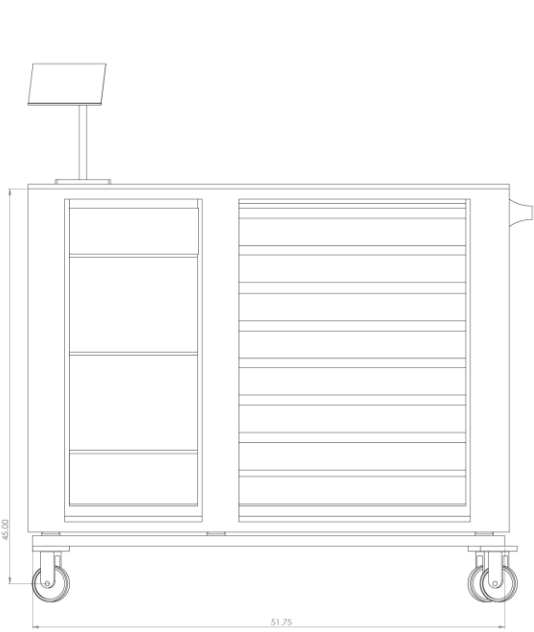
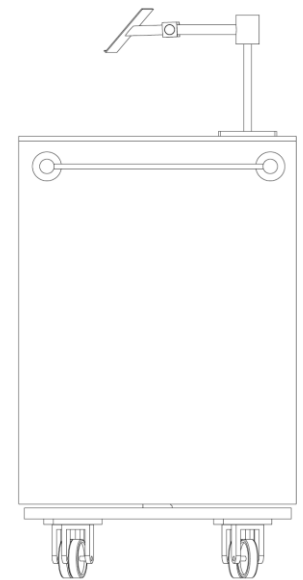


Figure 20: Front view



Figure 21: Top view



17
Figure 22: Side view

Appendix B: Actual prototype



Figure 23: Actual prototype 1



Figure 24: Actual prototype - 2

Appendix C: Survey

Survey questions:

1. How many drawers do you need in the cart?
2. What is the size of each drawer?
3. What are the dimensions for this cart?
4. What do you need in the cart?
5. Do you need a locker for the drawers Yes/No?
6. The doors' dimensions
7. How many patients do you help in daily bases?
8. What is the capacity of the cart?
9. The weight of the cart that they use now?
10. What are the problems with the current cart?
11. How far would you like the table raises up?
12. Any restrictions on the materials of the cart?
13. What are the safety requirements for the cart?
14. How many wheels need a locker?
15. Do you need braking system to stop the cart while moving?
16. Do you need a keyboard?
17. Do you need a place for sterilization tools?
18. What are the wheel's size and type?
19. Do you need to charge the laptop while using the cart?

References

1) Maple Knoll Nursing Home website.

<https://www.mapleknoll.org/index.php>

2) An article was written by *Kathryn Norcutt* talks about top nurses injuries, and it was published on January 25, 2013.

<http://www.nurseuncut.com.au/top-nursing-injuries-and-how-to-avoid-them/>

3) An article was written by Tove Schuster on February 4, 2015. It is talking about how hospitals fail to protect nurses from becoming patients.

<http://www.npr.org/2015/02/04/382639199/hospitals-fail-to-protect-nursing-staff-from-becoming-patients>

4) Rep Rap Champion website used for buying the power supply.

<https://reprapchampion.com/products/12v-dc-30a-360w-power-supply-reprap-3d-printer-led-strip-light-cnc-robotics>

5) Walmart website used for choosing the battery.

<https://www.walmart.com/ip/EverStart-U1R-7-Lawn-Garden-Battery/16795214?wmlspartner=wlp&selectedSellerId=0&wl13=2447&adid=2222222227025374824&wl0=&wl1=s&wl2=c&wl3=80432038249&wl4=pla-177672177889&wl5=9015711&wl6=&wl7=&wl8=&wl9=pla&wl10=8175035&wl11=local&wl12=16795214&wl13=2447&veh=sem#about-item>

6) Medical cart battery recommended for the project.

<https://www.valence.com/resources/case-studies/case-study-medical-cart-battery/>