Background

In the United States, 30.6 million people have difficulty with using their legs for movement and 19.9 million have difficulty with lifting and grasping (US Census 2016). Individuals with disabilities have often been segregated in the work place until the passage of the Americans with Disabilities Act (ADA) (SHRM 2011). Our project partner is ChefVet, who is a non-profit organization that reintegrates veterans back into society through culinary services. Their goal is to bring accessibility and accessible tools to the culinary industry in order to create jobs for people with disabilities.

Problem Statement

ChefVet has challenged the team to redesign a commercial baking oven to be more accessible for all individuals including those who are differently-abled. The primary focus of this project will be to redesign of the door mechanism so that the user can open the doors in a minimally labor intensive manner, and also to design a control system to open the oven doors automatically.

The final specifications for the accessible oven were created by collaborating with our project partner and are shown in Figure 1. Later the team also added ADA specifications to ensure the redesign includes accessibility to wheelchair users as well.

Specifications	
Long Lasting Life:	The concept has to be designed to last for the life of the oven 10-12 years
Simple Opening Mechanism:	The user interaction with the door cannot be a complicated action or movement.
Minimize the Door Area:	The area of the doors use in the front of the oven must be less than the original design.
Weight:	The total oven package cannot be so heavy that it is difficult to ship or would significantly increase price of shipping.
Cost:	About a 5% increase to the oven cost or total cost of prototype under $1,500.

Figure (1): ChefVet and senior design team project specifications sheet.

Research Question

Our major questions/concerns throughout this process where:

How to minimize the unusable space caused by opening of the door?
What opening system would be the least labor intensive?
What would be a simple concept that everyone could use?

Methods/Approach/Solutions Considered

Our design processes started by understanding the importance of universal design. The goal was to come to a solution that is accessible but wouldn't marginalize or segregate people from using the product (Burgstahler 2017). The design must provide the user a choice in methods to operate product, and the design should be easy to understand regardless of user's experience (Burgstahler 2017). The team made sure to communicate with people who use these ovens at their workplace every day to understand what difficulties are common with commercial ovens, and how we can design to improve those problems.

We went through a long period of idea conceptualization where all team members would model designs that could meet our specifications and then discussed the pros and cons of each design that resulted in 8 initial concepts. 4 of these moved onto more serious evaluation:

- Sliding and collapsing door (similar to a drive thru window, that seats within the oven door frame when closed) (Figure 2)
- Two door four bar hinges with attached to existing doors (Figure 3)
- Garage style door (where the door would roll into the body of the oven) (Figure 4)
- Single four bar hinge attached to a single door (Figure 5)

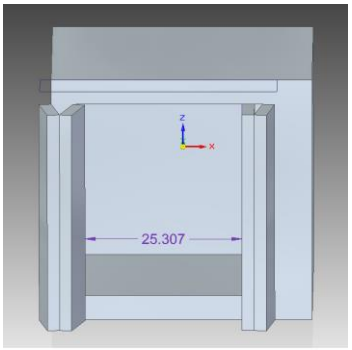

Figure 2: Sliding Door

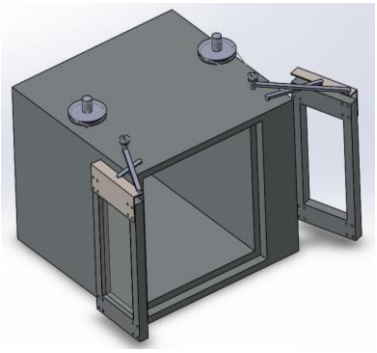

Figure 3: Two door four bar

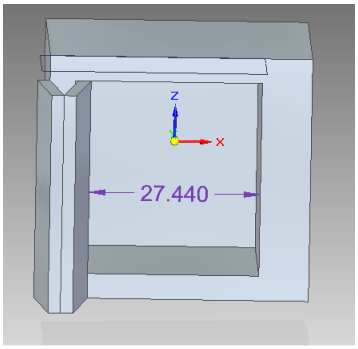

Figure 4: Garage Style Door

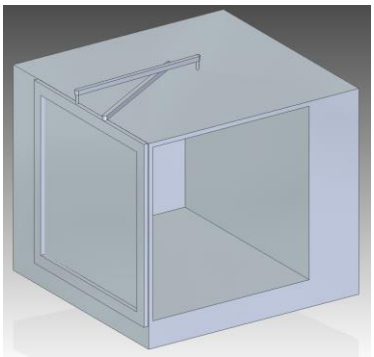

Figure 5: Single for bar

The designs were then compared to each other using a decision matrix with measurable criteria to compare the concepts to each other. The high priority criteria were:

- Amount of working area the doors require to open
- Number of steps to open the door manually
- If the team has to build a door from scratch or use the original doors.
- Cost

Description of Final Approach and Design

The concept we chose was the two door four bar design (Figure 6). Our reasons behind this decision were:

- It did not require the team to create new oven doors that were capable of retaining heat of normal oven use.
- The swinging motion of the door took up minimal space.
- The four bar mechanism can be easily modeled.
- The concept left a significant amount of room in front of the oven for users who may be in wheelchairs.

We also made it a priority for the door to operate using only one motor to simplify the automation of our concept.

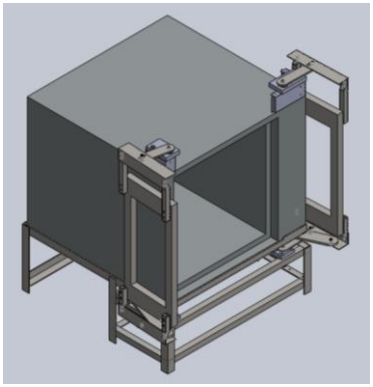

Figure 6: 2 Door 4 Bar Solid Works Model

The team had to create legs for the oven to sit on that had a space where the oven hung over the lower part of the legs (Figure 7). These legs were designed and manufactured to adhere to ADA standards. This space was then utilized to keep the R2 and R4 links of each door, and also the drive system.

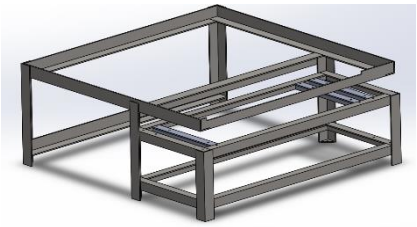

Figure 7: Legs of oven

The six links, R2 (Figure 8) and R4 (Figure 9), were designed as though the individual link was supporting the entire weight of the door. The right side links had to be longer than the left side links, due to a bigger distance of travel that was caused by the oven control panel. On top of the oven, the R2 links were mimicked on the roof rack (Figure 10) in order to give structural and dynamic support to the door. The main factor of designing these links was to minimize deflection.

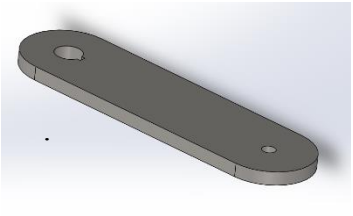

Figure 8: R2 Link

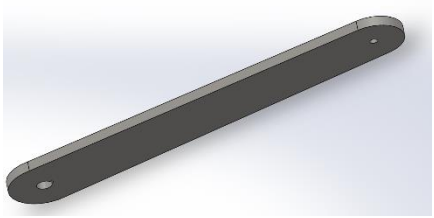

Figure 9: R4 Link

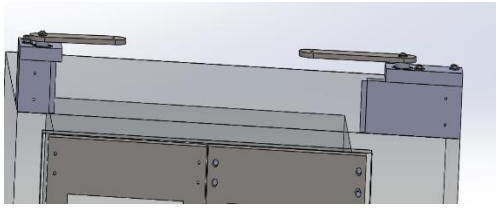

Figure 10: Roof Rack

The R2 (Figure 11) and R4 (Figure 12) links were connected to shafts that sat in mounting plates under the oven. These shafts were designed in order to support the moment of the links and also the torque of the motor. They were then pressed into the mounting plates (Figure 13), which had two ball bearings pressed into it in order to enable motion and support the load. The drive system was then attached to the bottom portion of the shaft.

Figure 11: R2 Shaft

Figure 12: R4 Shaft

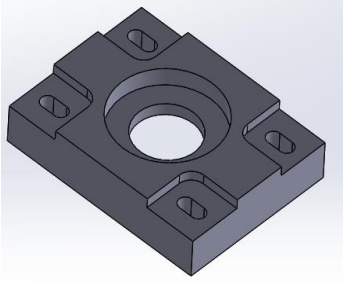

Figure 13: Mounting Plate

The drive system (Figure 14) consisted of a stepper motor and a chain system that connected the shafts of the R2 links in a figure eight fashion, which enabled the doors to be able to swing open in opposite directions. The motor was pressed into the bottom of the shaft in order to transfer the torque which was controlled by an Arduino. Both R2 shaft had sprockets that were attached to the chain which enabled the motion of the doors.

Angle iron was then used to attach the oven door to the four bar links, using shoulder bolts to allow rotation of the links. The angle iron was then bolted to steel rectangular tubing attached to the oven. The tubing utilized spacers to attach to the oven in order to ensure there were no fitting issues (Figure 15).

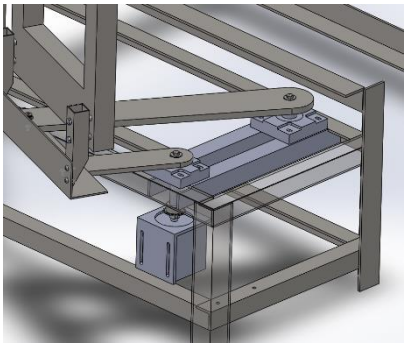

Figure 14: Drive System

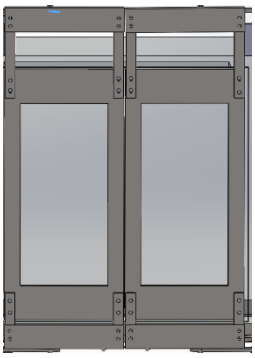

Figure 15: Door Assembly

4) Outcome (Results of any outcomes testing and/or user feedback)

Our prototype (Figures 16 and 17) was demonstrated at Ohio University's Mechanical Engineering Demo Day. The oven doors successfully and repeatedly opened and closed as desired with a push of a button which made the system simple, and less labor intensive. The motion of the doors also minimized unusable space surrounding the oven. . Our oven will be moved into a research kitchen and utilized by professors teaching students both with and without disabilities. Moving forward, we will be making minor improvements to our oven in order to create a better fit for the doors and a smoother motion.

Figure 16: Oven prototype in open position

Figure 17: Oven prototype in closed position

Cost (Cost to produce and expected pricing)

The cost estimation of the prototype built is provided in Table 1 and the total cost at the bottom includes the shipping cost as well.

Sub Assembly	**Description**	**Total**
Legs	Materials to make legs of oven	$ 87.25
Links/Door Materials	Materials to make links of four bar hinge	$ 147.04
Mounting Plates	Material for mounting hinge mechanism to oven	$ 110.82
Electronics	Stepper Motor, motor driver, controller, power source	$ 136.80
Machine Elements /Misc	Bearings, Chains, Paint, Misc	$ 420.10
Total Materials/Shipping Cost:		$ 956.48

6) Significance

Aspects of our design, such as the stepper motor driven system, could be applicable to many other appliances in commercial and residential kitchens. 96% of occupational therapists believe that adaptations in housing for the elderly and disabled will cut the need for social care (Marcubie 2017). Since the oven is the most widely used piece of equipment, it was the logical start of redesigning kitchen equipment to be more accessible for people with disabilities.

In the future, the team and project partners have goals to mass produce this oven and create a higher standard for commercial kitchens. This accessible oven will not only help disabled people and provide more diversity in the workplace, but it will also benefit everyone who works in a commercial kitchen and help people perform daily activities.

7) Acknowledgements

We would like to thank Thom Stevenson for giving us this amazing opportunity to design something so meaningful.

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