Team 46's Final Design Proposal Report
Course Section Number: GENG 1201 – Section 51
Team Number: 46
Team Name: Team 46

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Submitted by:
Natalia Pacheco - [redacted]
Luke Laforest - [redacted]
Naimah Ishaque - [redacted]
Nicholas Schembri - [redacted]

Executive Summary

Our objective was to develop a humane and efficient animal transportation method by rail. The team was tasked with developing a railcar that could hold 4 large animals with the option of holding more.

The railcar that Team 46 created has automatic coupling, pivoting wheels that allow for great maneuverability, windows and food trays to ensure animal comfort, and a hinged loading ramp for safety. The goal of the team was to create a safe and comfortable environment for the animals while enabling autonomous navigation by integrating the railcar with an Arduino robot that Team 46 coded.

Estimated production cost: $162.12. This accounted for 3D printing supplies, bearings, servo motor, and wheels.

The final prototype that was made performed very well. The automatic coupling system worked correctly. Any issues experienced during the early development stages were fixed, such as modifying the obstacle avoidance to recognize walls more quickly. During the final performance test, the code for the robot worked well. It avoided walls, line tracked properly, and was able to communicate the with "Stop Light" checkpoint. The railcar followed the robot car accurately, making 90-degree turns or slight turns very easily.

Overall, Team 46 was able to achieve its goal by building a human and efficient railcar that moved properly and was able to hold more than the required amount of animals.

Table of Contents

List of Tables & Figures

List of Figures

Introduction

Our team's name is Team 46. We are dedicated to addressing the need for a humane and efficient method of transporting animals. The design problem was the development of a railcar capable of securely transporting animals while integrating with an Arduino robot vehicle for self-navigating capabilities. The objective was to minimize physical intervention with the robot and railcar while providing a dependable and effective means of transportation that prioritized the safety and comfort of the animals.

Two functions that were focused on were the couple system and the turns that the robot made. A stake and pin system were utilized to create an automatic coupling system. The Robot Sensor Detection that uses vision was used for efficient coupling. When designing the train to turn, a pivot system was implemented. This strengthened the train's maneuverability and allowed it to make turns in either direction.

The train's objective is to transport large animals in a safe and humane rail car and to navigate a preset course without using a remote. The constraints of the project included the number of animals and modifications to the smart car. Four animals were required to be in the railcar. Also, there could not be any permanent modifications to the robot kit, therefore our team made sure that there were not any permanent modifications.

There has been previous research conducted on railcars and the safety of transporting animals. Railcars such as the auto rack, gondola, and tank car (Union Pacific, 2022) would not be good options for our design. These models do not provide the necessary space to move large animals, or they are not enclosed (Union Pacific, 2022). Two models that can be modified for the task are boxcars and hoppers. Boxcars are fully enclosed, look like a box, and can have doors on either side of the car (Union Pacific, 2022). They are normally enclosed to protect the cargo from the weather (Union Pacific, 2022); however, we could modify them to not be fully enclosed if the animals need more fresh air. Hoppers are another possible design, but they pose many challenges to modify. They are designed to move heavy objects, but they are airtight and can only be loaded from the top of the railcar (Union Pacific, 2022). This makes it difficult to load the animals into the car and the animals would not survive due to the lack of oxygen. Therefore, the boxcar is the best existing option to modify.

There has also been research conducted on how to safely transport animals. There is a risk assessment that can be performed that includes hazard identification and characterization, exposure assessment, and risk characterization (Marahrens et al., 2011). This assessment is responsible for defining what design features may put the animal at risk, what are the consequences of that risk, and, determining the probability and severity of the risk (Marahrens et al., 2011). The railcars should have enough room for the animals to perform normal movements and resting positions (Ribó et al., 2008). The animals should be loaded into the railcar carefully, with a ramp not steeper than 20° (Ribó et al., 2008). Additionally, for journeys surpassing 8 to 12 hours depending on the animals, there should be access to food and water (Ribó et al., 2008).

The final relevant research is on safety if a crash were to occur. Passenger-carrying railcars need 4 feet at each side of the car to prevent passenger harm if a crash occurs (Priante et al., 2005). The space could also be used for animal railcars. Furthermore, longer trains have more weight than shorter trains (Priante et al., 2005). More weight increases the kinetic energy of the train, making it harder to stop and causing more serious crashes (Priante et al., 2005). There should not be too many railcars because shorter trains are safer (Priante et al., 2005). Therefore, reducing the number of railcars and animals transported after the quota is met will increase the safety of the train.

Proposed Design

Team 46 has developed a railcar that is safe for animals to travel in while also being very humane. Many features have been included in the railcar.

Each pair of wheels is connected to an axle that is located at the bottom of the railcar. This allows each axle to rotate 360 degrees. This design allows the train to maneuver around objects and change direction if needed (Figure 1).

The next design feature is the sliding door and hidden ramp. The animals are loaded into the railcar on the side of the car. A sliding door can be opened, and a sturdy ramp can be extended for the animals. This ramp has a low grade that the animals can walk on while putting minimal stress on their joints (Ribó et al., 2008). This loading area is beneficial if more than one railcar needs to be towed. If the loading ramp was in the back of the railcar, every railcar would need to decouple from each other to allow animals to move in/out of the car. The ramp is also beneficial because it prevents injury to the animals (Figure 1).

There are windows on the sides of the railcar that allow for proper ventilation for the animals (Figure 1). The limitation of this is extreme weather events. If there is extreme weather, there is a possibility of the animals being exposed to harsh conditions; however, most of the time that the railcar is traveling, the windows would not pose a problem to the animals.

Food and water containers have been provided in the railcar. These allow the animals to have the proper nourishment during their time in the railcar.

The final design feature of the railcar is the crumple zone. The sides of the railcar were made extra thick. In the event of a crash, the side walls should absorb most of the force and prevent the animals on the inside from becoming injured (Priante et al., 2005). The only limitation to this feature is the cost. By making the walls thicker, it could make the increase cost of the railcar. This is a reasonable limitation because the goal of the railcar is to get the animals to the destination safely.

Figure 1
Railcar Design

Note. 3D model of Team 46's railcar design.

A coupler has been designed to connect the railcar safely to the train (Figure 2). The base on the coupler sits on top of the robot battery. This is a safety feature because it protects the power source from anything else that can damage the battery. A servo motor is inserted in the base of the coupler. A 3D-printed oval is attached to the servo motor. Finally, a stake with pin holes is placed on one side of the oval and a pin is placed on the other side. The pin is inserted into the proper pinhole of the stake. The oval will slide on the servo while moving the pin and stake up and down. At the bottom of the stake, there is a chamfer with a radius of 10 mm. This is so that the stake can accurately guide itself to the railcar opening. There are two reasons why this is a good coupler design. The simple design allows the coupler to move effectively through the connection location on the railcar. This couple creates a strong connection that can withstand acceleration, turning, and breaking forces. The second benefit is multiple pinholes. Using different pinholes allows for the stake to move different lengths and accommodate any railcar height.

Figure 2

Railcar Coupler Design

Note. Team 46's assembled railcar coupler.

The materials that were selected for the railcar were 3D printing filament and glue. These materials were selected because they are cheap and easy to use. The group designed the railcar with the Fusion software. This made it easy to print the file on a 3D printer. Additionally, 3D filament was used because it was easy to reprint any sections of the railcar if modifications were needed. One of the group member's 3D printers was used to print the railcar parts. The railcar was too big to print whole, so multiple pieces were printed. After the printing was finished, the parts were assembled using glue. This was the best method to connect everything because the glue dried quickly.

The railcar performed very well during the test day. All the requirements assigned by the evaluators were accomplished. The railcar was able to automatically couple to the robot. It was able to hold the four required animals along with an additional four. When the robot was navigating the preset course, the railcar accurately followed while being capable of maneuvering around turns. The only limitation of the railcar was the obstacle avoidance code. Over the two trails, there was one time when the robot did not turn and ran into a wall. Besides this incident, obstacle avoidance worked well. The overall performance of the railcar was excellent.

Seventh Generation Principle - Design Considerations

Before 1977 there were few regulations for animals that were transported. Then rules were changed in 1977 regarding how much food, water, and rest (FWR) the animals must receive on their journeys. Calves could have a maximum of 18 hours without FWR. Injured or old animals did not have any specific rules. Cows and sheep could be transported for 48 hours without FWR. Chickens did not have any specific guidelines. Finally, after the maximum allotted transport time was reached, the animals were only given five hours of rest time outside of their transport container (Government of Canada, 2019).

In 2019, new regulations were made to treat the animals more humanely. Now, calves can only go 12 hours, injured or old animals can only go 12 hours, cows and sheep can only go 36 hours, and chickens can only go 28 hours without FWR (Government of Canada, 2019). Additionally, after the maximum traveling time has been reached, the animals must receive eight hours of rest outside the container. The railcars should have enough room for the animals to perform normal movements and resting positions (Ribó et al., 2008). The transported animals should be loaded carefully, on a ramp that has a grade of less than 20° (Ribó et al., 2008). The animals should be protected from the weather in the railcar (Beef Cattle Research Council, 2023). Finally, there should be proper ventilation for when the container is not moving, especially during warm weather (Beef Cattle Research Council, 2023)

This history has influenced Team 46's railcar to make the most humane railcar possible. There are food and water trays provided inside the railcar. This allows the animals to have enough feed and water for their journey. The railcar has enough room for the animals to move and rest in their normal positions. A low-grade ramp was made so animals can move in and out of the railcar putting minimal stress on their joints. A solid roof was made to protect the animals from weather events such as rain and snow. Finally, many windows were provided, and these allow for proper ventilation during warm temperatures.

Team 46's solution will influence the next seven generations because this railcar can be used as a baseline design in the future. The features of this railcar are very humane and allow for additional ideas to be implemented into it. One change that can be made is the addition of window covers. During warm weather the windows are beneficial in providing ventilation; however, during cold and windy weather, the windows do not protect the animals. If window covers are provided, air filtration technology can be implemented in the railcar so proper ventilation is achieved. Air filtration technology would allow for continuous monitoring and regulation of both air quality and temperature (Banks, 2022). Another future design change is modifying how animals are loaded into the railcar. A low-grade ramp system reduces the stress put on the animal's joints, but it does not eliminate the stress. This makes it possible for animals to get injured moving on the ramp. Hydraulic lifts can be implemented in the railcar and would move the animals in and out of the railcar with no stress put on their joints (Banks, 2022).

Product Cost

Table 1

Project Cost Breakdown

Product	**Cost**	**Reference**
Arduino Robot Car	$99	Amazon, 2017
3D Filament for Railcar Chassis and Coupler	$30	Amazon, 2023
3D Printed Wheels	$20	3D Prints Windsor, 2022
Servo Motor	$9	Amazon, 2021
Bearings	$4.14	Amazon, 2022
Total Cost	**$162.14**	

The overall cost for Team 46's design was $162.14. The cost breakdown can be found in Table 1. The most expensive item was the Arduino Robot Car at $99 (Amazon, 2017). The 3d filament cost $30 (Amazon, 2023) and was used to create most of the railcar and coupler components. There was no cost to print any of these components because one of the group members had a 3D printer. The 3D-printed wheels cost $20 (3D Prints Windsor, 2022). They were purchased because the team member's 3D printer could not print rubber objects. The additional servo motor cost $9 (Amazon, 2021). Finally, the bearings used for the wheels and axles cost $4.14 (Amazon, 2022).

Conclusions and Recommendations

The purpose of this project was for Team 46 to develop a humane and efficient railcar to transport large-scale animals.

The team coded a robot to navigate a course on its own. Features including automatic coupling, pivoting axles, windows, food containers, and low-grade ramps allowed the car to provide optimal comfort and safety to the transported animals.

The final testing of the railcar prototype went well. The code for the robot worked, allowing it to move throughout the testing track with minimal difficulties. The line tracking and "Stop Light" code worked perfectly. The obstacle avoidance code worked most of the time, only failing to recognize a wall once. Additionally, the coupler automatically connected the robot and railcar quickly and without issues.

One limitation throughout the design and testing process was the lack of practice opportunities. It was difficult for the team to properly develop the code because there were only a few days to test the final code. Additionally, all the other groups had the same problem. This made practice testing days very busy. The team had to wait over 20 minutes to test changes made to the code. As a result, the code could only be tested two or three times a session.

Another limitation was the ban on modifying the robot car. Anything that was added to the robot car could not be permanent. This restricted how creative the solutions could be for the design of the railcar.

The final limitation was financial resources. All the members of Team 46 were students. This limited the amount of money they could spend on the prototype because no member has a full-time job. If the team was able to allocate more money to the railcar, there could have been more creative design solutions.

The recommendation for change in the railcar design was the code. Even though it worked well, the obstacle avoidance section was not perfect because the robot car hit a wall. The recommendation would be to further develop the code so all sections of it work perfectly together.

The team learned many lessons from the project. Not everyone knew each other so they had to learn to work with new people. This strengthened their communication and teamwork skills. The team learned how to properly plan for deadlines using various methods such as Gantt charts and to-do lists. They also had to learn how to budget resources because they did not have a lot available. Finally, the team learned how to solve a real-world problem using skills that are used in industry like AutoCAD, Fusion, and the C++ coding language. Overall, the team solved a problem while developing many unique skills to make them more qualified for future work.

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Appendix A – Railcar AutoCAD Drawings

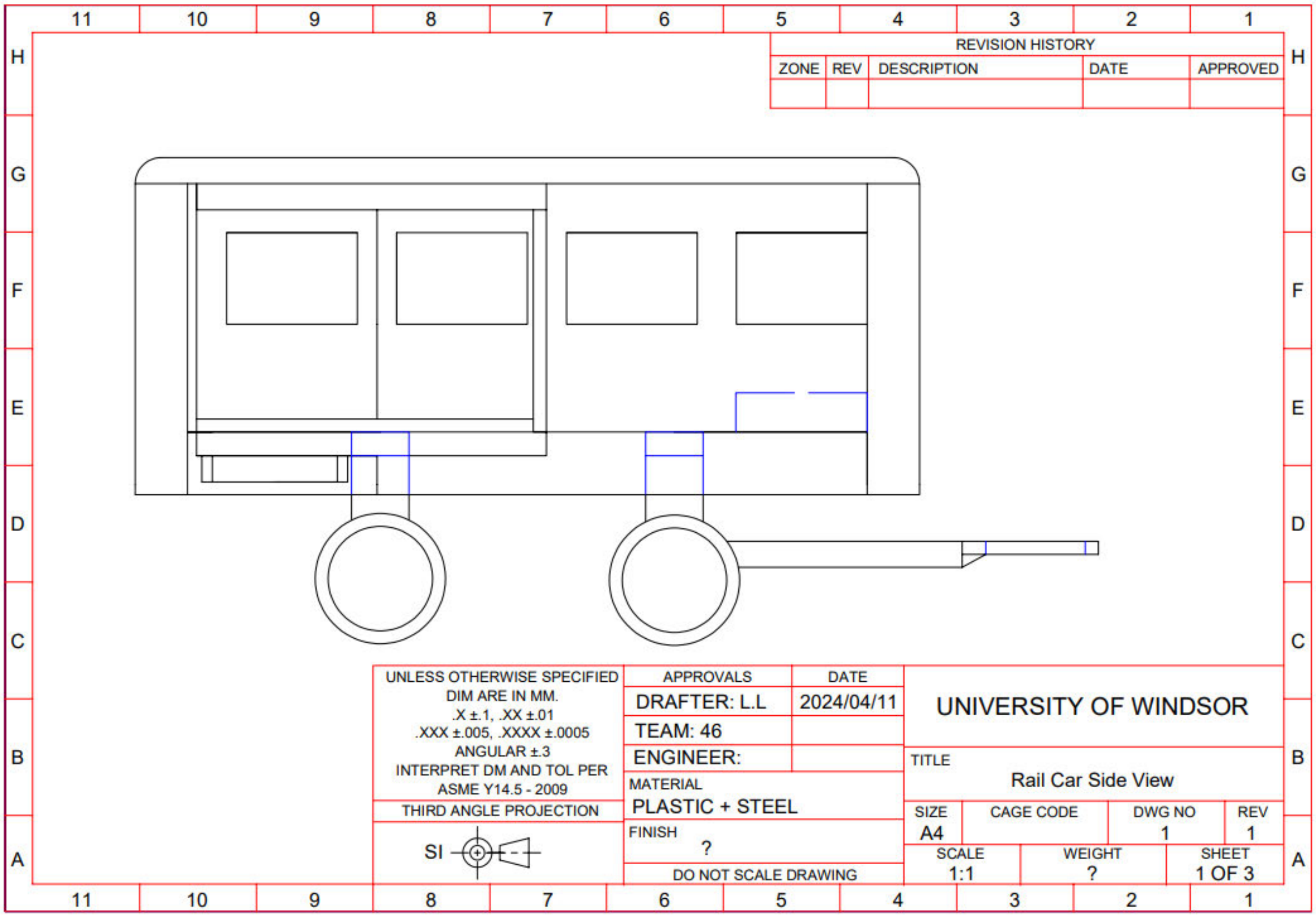

Figure A1. Side view of Team 46's railcar in AutoCAD.

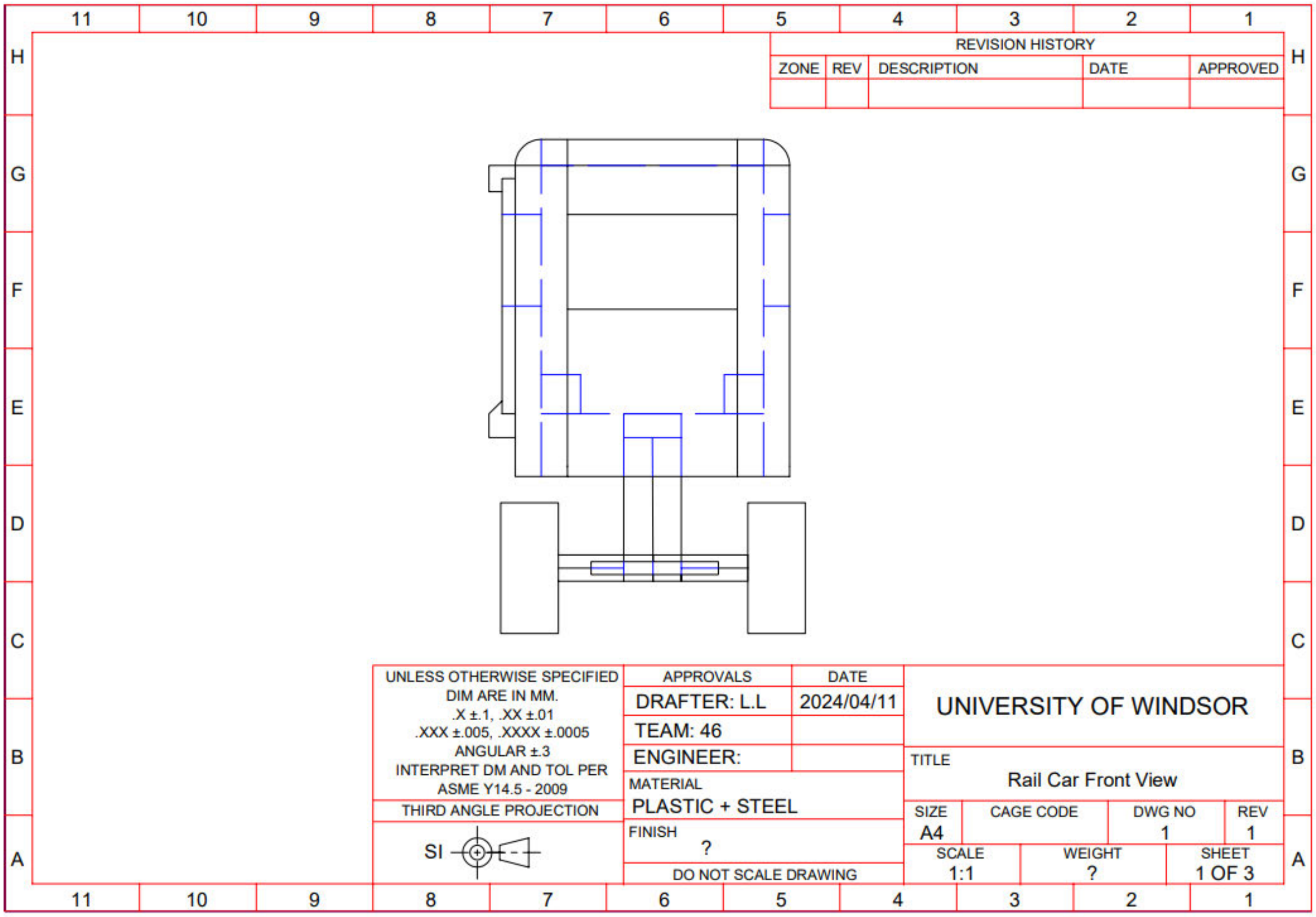

Figure A2. Front view of Team 46's railcar in AutoCAD.

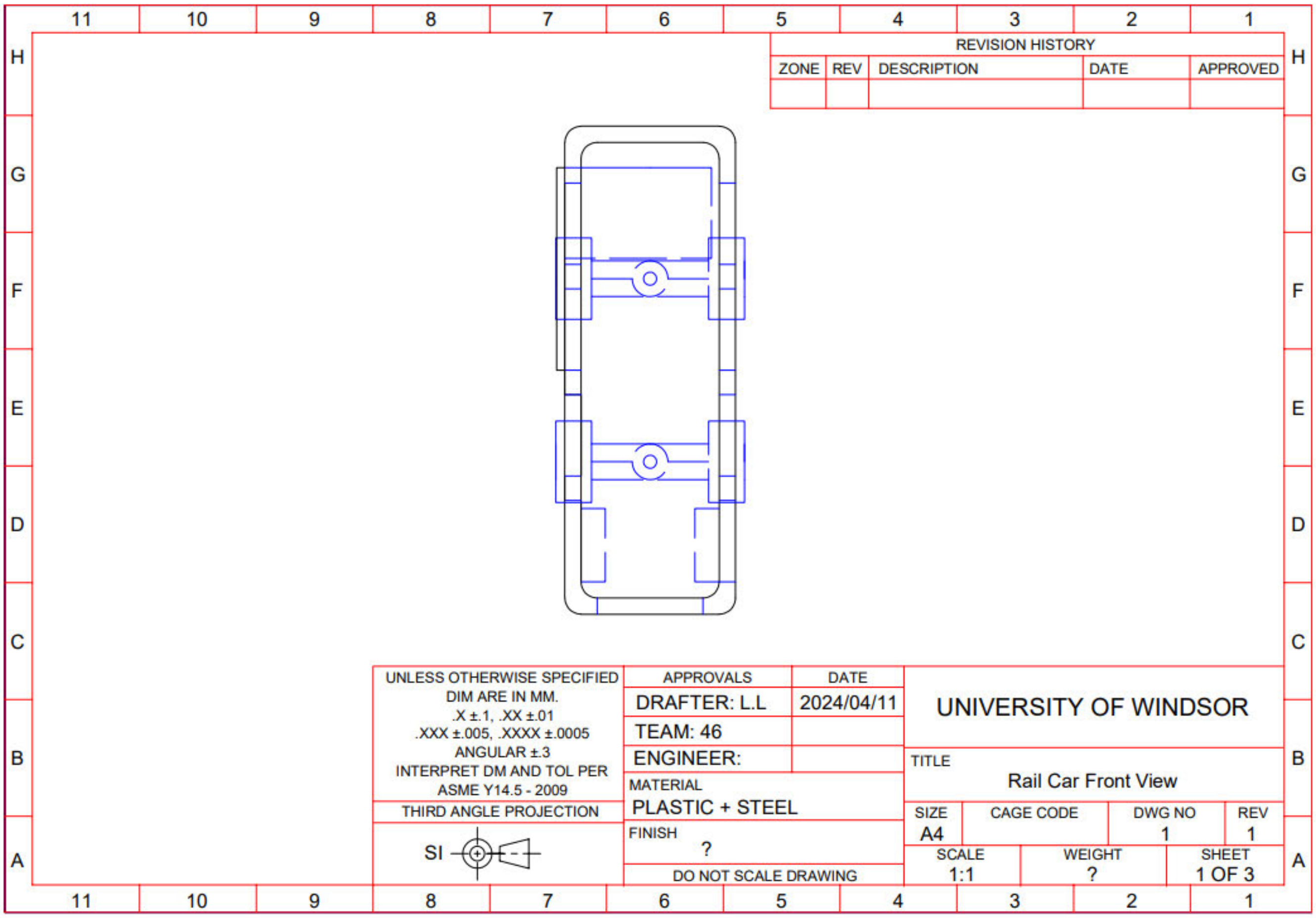

Figure A3. Top view of Team 46's railcar in AutoCAD.

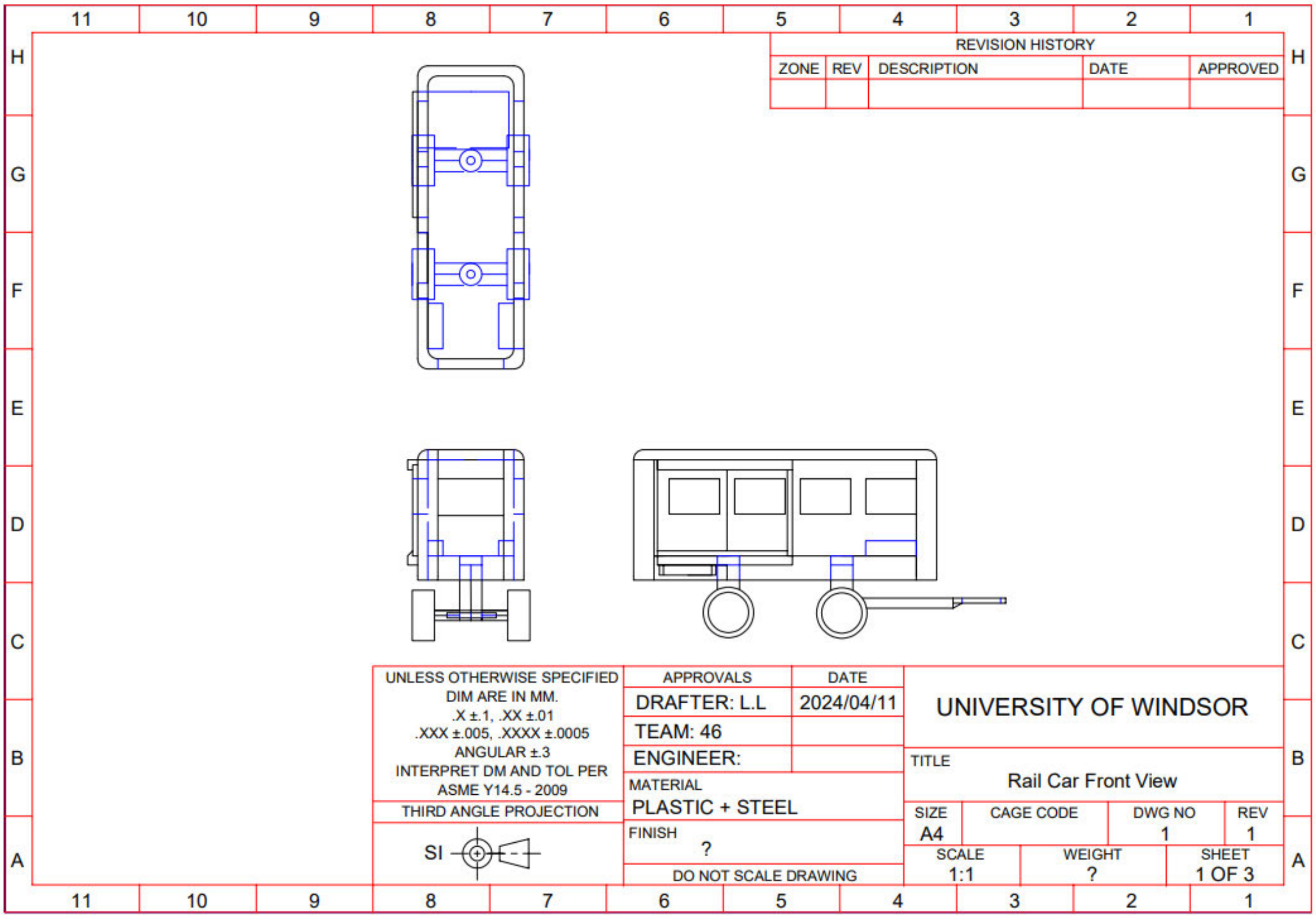

Figure A4. Top, front, and side views of Team 46's railcar in AutoCAD.

Appendix B – Railcar Prototype Fabrication Instructions

Materials Needed: 3D printer, 3D filament, bearings, purchased wheels, strong glue.

1. Create a 3D version of the AutoCAD drawing in Fusion.
2. Split the drawing into parts.

**NOTE: Depending on the printer size, the drawing may need to be split up into multiple sections to print the railcar properly

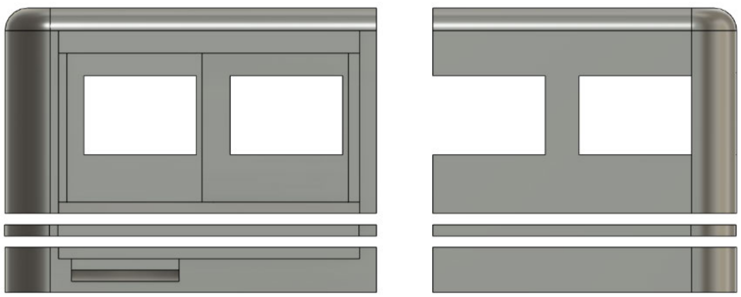

Figure B1. The railcar split into 2 pieces.

3. Convert the Fusion file to a stl file.
4. Send the file to the printer.
5. Print the file.

**WARNING: Do not touch the 3D printer while it is printing. If you touch it, it could mess up the alignment of the extruder and ruin the print.

6. Once the print has finished, lay out all of the pieces to the railcar.

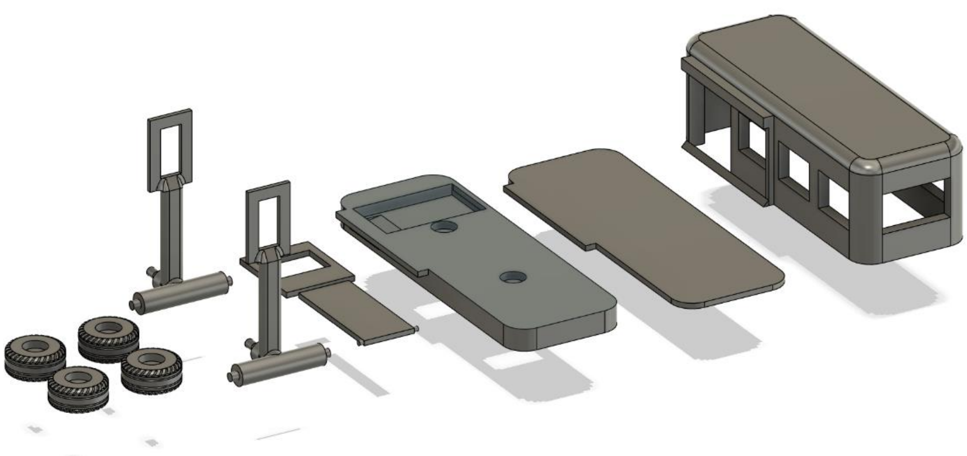

Figure B2. All railcar components laid out.

7. Glue the base of the railcar together.

**NOTE: Make sure the pieces line up exactly when they are glued together. If they are not, adjust the pieces before the glue dries.

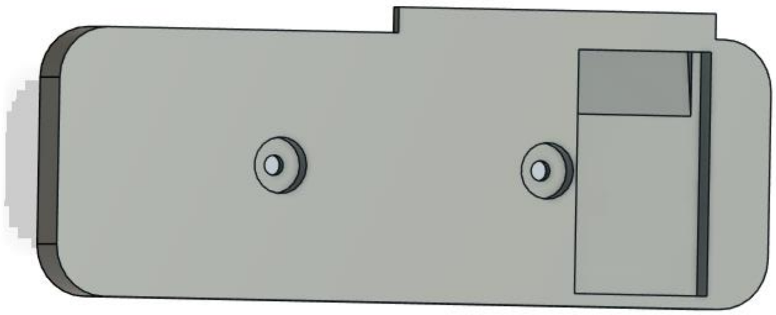

Figure B3. Railcar base glued together.

8. Insert one bearing into each hole in the base after the glue has dried.

Figure B4. Bearings inserted into the railcar base.

9. Insert a bearing on each side of the axle.
10. Insert the two axles into the bears in the base of the railcar.

Figure B5. Railcar axles are inserted into the railcar base.

11. Place the purchased wheels on the four bearings on the axle.

Figure B6. Railcar wheels placed on the axles.

12. Place the sliding ramp in the rectangular hole on one half of the base.

Figure B7. Sliding ramp placed in the rectangular hole.

13. Glue the sides and roof halves on the base and put the sliding door on its rails.

Figure B8. Railcar sides glued onto the base.

14. The construction of the railcar is now complete!

Figure B9. The completed construction of the railcar.

Appendix B – Coupler Prototype Fabrication Instructions

Materials Needed: 3D printer, 3D Filament, Servo motor.

1. Create a 3D version of the AutoCAD drawing in Fusion.

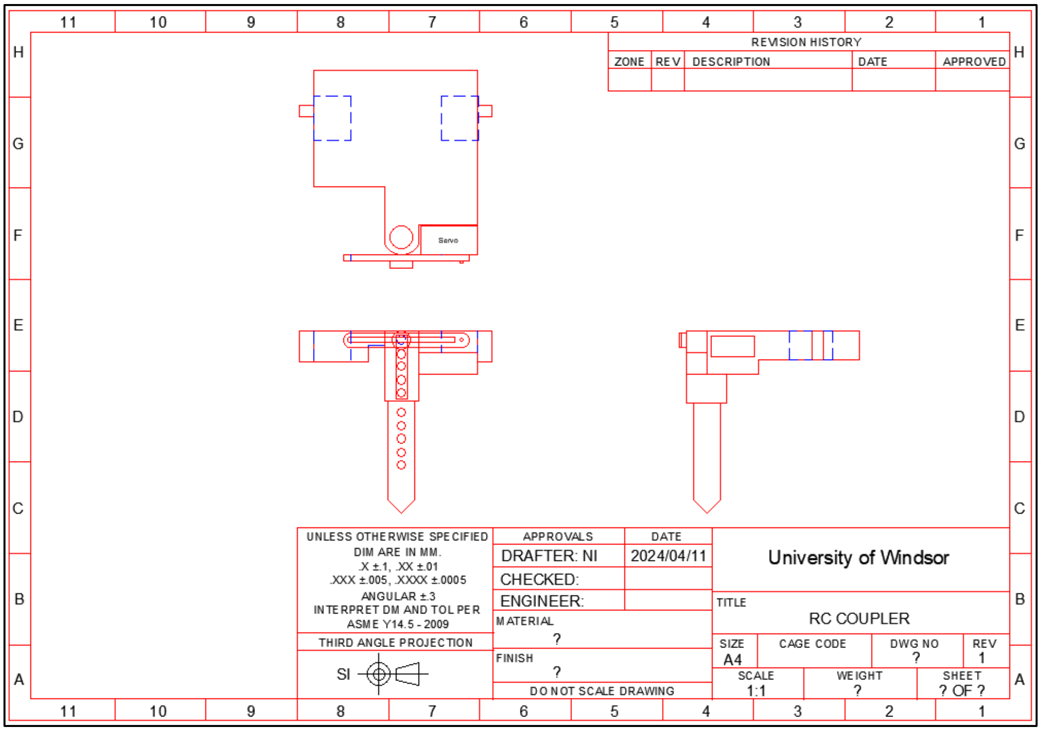

Figure C1. Top, front, and side views of the railcar coupler.

2. Convert the Fusion file to a stl file.
3. Send the file to the printer.
4. Print the file.

**WARNING: Do not touch the 3D printer while it is printing. If you touch it, it could mess up the alignment of the printing spout and ruin the print.

5. Once the print has finished, lay out all of the pieces of the coupler.
6. Insert the Servo motor into the base of the coupler.

7. Attach the oval 3D printed piece onto the Servo motor.

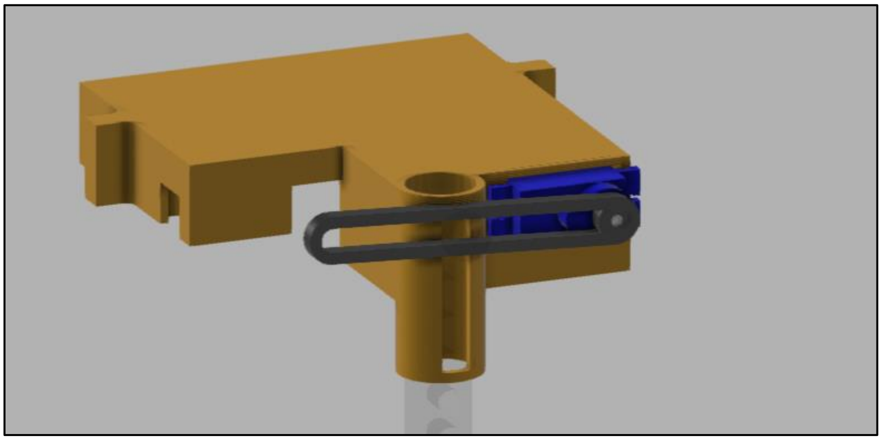

Figure C2. 3D printed oval piece placed on the servo motor.

8. Place the 3D-printed stake and pin between the oval piece.

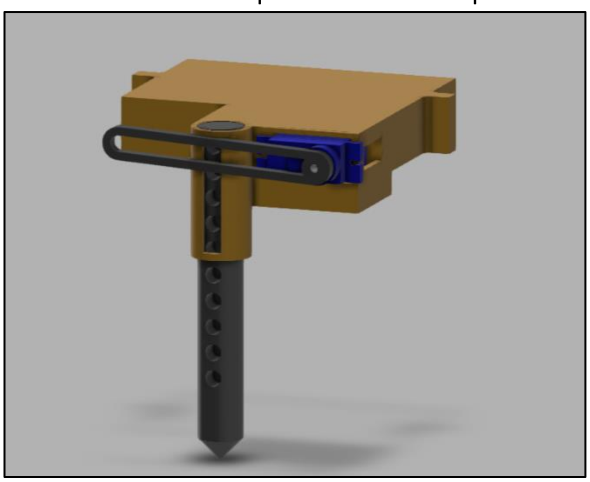

Figure C3. Stake placed behind the oval.

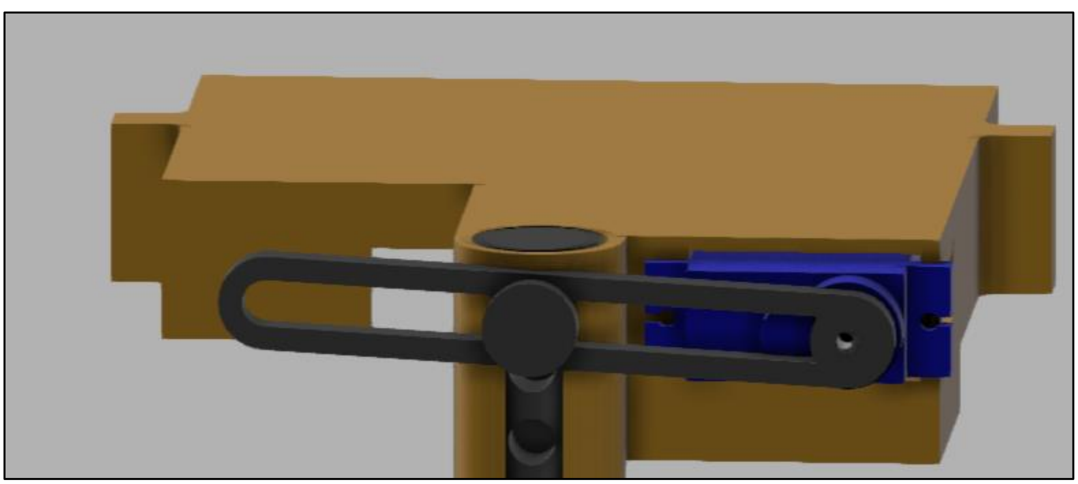

Figure C4. Pin inserted into the stake.

**NOTE: It is recommended to place the stake closer to the base and the pin away from the base. This makes it easier to change the height of the coupler.

9. If needed, change the hole the pin is inserted into to achieve the desired coupler height.
10. The construction of the coupler is now complete!

Figure C5. Completed railcar coupler.