Designing a Predator Proof Chicken Enclosure

A Turn Back Time Inc. Project
Paxton, Massachusetts
Designing a Predator Proof Chicken Enclosure

An Interactive Qualifying Project
Submitted to the faculty of
WORCESTER POLYTECHNIC INSTITUTE
In partial fulfillment of the requirements for the degree of Bachelor of Science

Marisol Sanchez
Cray Johnson
Vivek Wong
Nathan Fankhanel

May 13, 2020

Project Advised By:
Elisabeth Stoddard
Derren Rosbach

Project Sponsored By:
Turn Back Time Inc.

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OUR JOURNEY BEGINS
Abstract

Research shows that exposure to nature is critical for child development. Turn Back Time Inc. (TBT) provides farm and nature-based programs for children to learn and develop through play in nature. TBT relies heavily on chickens to aid in educating and entertaining children and also as a revenue generating resource. Unfortunately, TBT was having trouble keeping their chickens safe from local predators. The purpose of our project was to design a chicken enclosure that protects the chickens from predation.
Executive Summary

WHAT'S THE PROBLEM?

Turn Back Time's chickens were being eaten by various predators at a rapid pace. This was unfortunate because TBT spent a lot of time and resources on raising the chickens, and losing them to predators was devastating. To put this issue into context: at the start of our project (March 2020) TBT had roughly 40 chickens. As of late April 2020, only four chickens remained at the farm. The main predators were foxes and weasels according to farm staff. The chickens are important to TBT because they provide revenue and various educational benefits.

OUR GOAL AND OBJECTIVES

The goal of our project was to design a structure that would protect egg-laying hens at Turn Back Time from predators, while providing accessibility and educational benefits for children and staff at the farm. To accomplish this goal, our objectives were as follows:

- Research the durability, safety, strength, predator resistance, and cost of common chicken coop and run materials.
- Develop criteria for analyzing the pros and cons of potential chicken coop and run designs for the farm.
- Create blueprints and a building instruction guide for the most efficient chicken structure for the farm.
- Develop a meaningful and relevant educational module for the children at Turn Back Time.
METHODS

RECOMMENDED SOLUTIONS

Our team designed and proposed a chicken structure that protects the chickens against predators. We designed a new chicken run that was attached to an existing shed at Turn Back Time. The shed serves as the chicken coop while our run provides protection for the chickens when they exit the coop. We used predator proofing techniques, such as skirting the perimeter of the structure with hardware cloth, to ensure that the chickens were fully protected.
COVID-19 Pandemic

In February 2020, the COVID-19 Pandemic rapidly spread across the United States. Due to this pandemic, our courses were moved online and we were unable to finish our project physically at Turn Back Time. We were all heavily affected by this situation. Everyone on our team lives out of state (New York, South Carolina, California and Texas) so we had to rely on virtual meetings where we struggled with time zone differences. Not being able to visit our site made it harder for us to visualize and design our chicken structure because we were not able to survey the site at the farm or interact with staff. This was a major change, both mentally and physically, for all of us. We stayed strong as a team and kept our project as our main focus.
Meet the Team

From left to right

NATE FANKHANEL
Civil Engineering Major. From Clifton Park, New York. Hobbies include being outdoors, fishing, playing golf

MARISOL SANCHEZ
Mechanical Engineering Major. From Fort Worth, Texas. Hobbies include working out, gardening and sketching

VIVEK WONG
Computer Science Major. From Altadena, California. Hobbies include doodling and scuba diving

CRAY JOHNSON
Robotics Engineering Major. From Charleston, South Carolina. Hobbies include Dungeons and Dragons
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INTRODUCTION
Our Sponsor

Lisa Burris and Turn Back Time Farm

Turn Back Time (TBT) is a non-profit, nature-centric school that allows kids of all abilities to be immersed within nature (Turn Back Time Inc., 2020). Located in Paxton, Massachusetts, TBT is a 58 acre farm that was founded in 2011 by Lisa Burris, Executive Director (Turn Back Time Inc. 2020). The farm’s primary mission is to teach about the value of nature in our lives. To accomplish this, Turn Back Time holds sessions for preschool, home-school, and summer camps. The farm has also begun to hold adult wellness programs where adults can go and experience the beauty of nature.

TBT’s goal is to provide opportunities so that everyone can benefit from being in a natural environment as well as interacting with various animals on the farm. Currently, the farm is home to chickens, goats, a pony, a horse, and a donkey named Momo. The benefit of having these animals at TBT is so they can bring smiles and a stress-free environment for students and adults (Kimberley Fowler, 2018). Children can play in the forest but are also free to hang out with the chickens and goats. Interaction with animals helps teach children the importance of compassion for other living things while also allowing children to discover the emotional benefits of pets (Barker & Wolen, 2011). The chickens at the farm are especially beneficial because children enjoy running around to catch and name them. Although they are small compared to the other animals, the chickens make a considerable impact on TBT’s educational programs.
The Need

Turn Back Time faced a significant issue with the predation of chickens. Predators tend to be the most active during the spring, summer, and fall months of the year. During these seasons, the farm had been heavily impacted by the major loss of chickens. At the beginning of our project in March 2020, the farm reported owning about 40 chickens. After about 3 months, only four chickens remained on the farm. The chickens were locked up during the night, in a mobile trailer chicken coop, to prevent predation. However, the trailer coop did not protect chickens during the day when they roamed freely around the farm. Our sponsor wanted to ensure that no more chickens were lost due to predation. Our team decided that we would solve this problem by proposing the most effective predator-proof chicken enclosure.

The predators mainly affecting Turn Back Time were weasels and foxes. These are not the only predators indigenous to New England. Other animals that could attack the chickens included raccoons, rats, and predatory birds (Poindexter, 2016). Some of these predators required extensive measures to protect against, while others only required effective fencing (Poindexter, 2016). According to Executive Director Lisa Burris, predators are likely to either wipe out as many chickens as they can or leave behind remains on the farm property, which can be traumatic for students at the farm. Our project required extensive knowledge of the methods a predator uses to attack chickens.
Our Goal

The goal of our project was to design a structure that would protect egg-laying hens at Turn Back Time from predators, while providing accessibility and educational benefits for children and staff at the farm. To accomplish this goal, our objectives are as follows:

- Research the durability, safety, strength, predator resistance, and cost of common chicken coop and run materials.

- Develop criteria for analyzing the pros and cons of potential chicken coop and run designs for the farm.

- Create blueprints and a building instruction guide for the most efficient chicken structure for the farm.

- Develop a meaningful and relevant educational module for the children at Turn Back Time.
Background Knowledge
“Cleaning the coop regularly, make sure chickens go outside, give them high-quality food and lots of vegetable scraps”

-Maureen Austin, Austin Farms
Chickens require a well-balanced diet in order to be healthy. Commercial feed is the most common food for chickens. Chickens naturally eat plants, fruits, vegetables, and insects on top of grains and other feeds (Da, 2020). A supplement that is important for chickens, especially egg-laying hens, is calcium. Calcium allows for healthy bodies and strong eggshells (Da, 2020). Keeping these dietary considerations in mind for chicken feeding will help ensure a healthy flock. Lastly, having clean water is extremely important for raising healthy chickens.

Free-ranging chickens can have both pros and cons for a variety of reasons. Along with saving money on feed, chickens will lay more nutrient-dense eggs that could either be sold or used for personal consumption (Toney, 2018). Lastly, free-ranging chickens requires less maintenance because less waste builds up on a yard or farm due to constant movement and grazing (Da, 2020).

Chickens may be small animals, but they still require a decent amount of space in order to stay healthy. Being cramped and crowded causes stress in chickens and can lead to illness and overall unhappiness in a flock (Claborn Farms, 2016). It is important to remember that space is a critical necessity for the overall health of a chicken.

Some environmental factors affect egg production in hens, such as light. It is common for hens to lay more during the spring and summer because there is more daylight than during fall and winter (Cybele, 2017). Age is also a factor in egg production because older hens tend to lay less (Cybele, 2017). A calcium deficiency may also be the result of less egg-laying because calcium is the primary source chickens require to produce eggs (Cybele, 2017).
Chickens are, unfortunately, preyed on by many predators. Predators range from dogs to minks, foxes, and even hawks (Thesing, 2017). The predators that are known to kill the chickens most are raccoons and dogs since they can be found almost anywhere (Thesing, 2017). Foxes tend to snatch multiple chickens at once and become very active during the spring months. Raccoons will reach through chicken wire and decapitate chickens leaving behind remains (Thesing, 2017).

Effective methods to protect chickens against predation is ensuring there is proper fencing in a chicken run (Thesing, 2017). Proper fencing includes using chicken wire, hardware cloth, or electric netting to keep predators out. Hole size of fencing is also an important factor to consider since some predators, such as weasels, can squeeze through tiny places and cracks (Thesing, 2017). Fencing with holes that are less than an inch wide are recommended to help protect against weasels, raccoons, snakes, and any other predators that can reach into coops or runs.

Along with fencing, skirting around the perimeter of a chicken coop or run can help deter predators from digging (Thesing, 2017). Another popular protection method is having guard animals around the chickens to scare off predators and dissuade them from coming near (Thesing, 2017). While predation is not an easy thing to come to terms with, it is vital to understand how predators attack in order to protect against them adequately.
CASE STUDIES
Designing a Mobile Chicken Coop

In 2015, a WPI Interactive Qualifying Project group took on the task to design a mobile chicken coop. The team decided to design three different ideas for their coop, with each one focusing on a different aspect of the coop that farmers said was a priority. In this project they determined which criteria were most important by interviewing the farmers. One of the designs is a coop with a solid floor to prevent predators from digging under the walls of the coop. Another design to combat digging predators was a fully enclosed coop that was on stilts, raised a foot off the ground (Cole & Zielinski & DeLuca, 2015).

The team was successful in creating designs and constructing them, however, there wasn’t a concrete method for determining how helpful the designs were. In the paper they state how the project was about designing and constructing the coops but does not discuss testing at farms. The design process for this group was based on interviews and theory rather than application and practice. Our team was unable to guarantee the effectiveness of this group’s designs.

However, many of our own interviewees stressed the possibilities and impact a mobile chicken coop can create. Our team’s interviewees expressed how much easier the mobile chicken coops are to upkeep and clean compared to the stationary coops. From the perspective of the farmer, mobile chicken coops are easier because they allow the farmer to move the coop to prevent waste build up and provide fresh pasture for their chickens. For stationary coops, the farmer not only needs to be vigilant in cleaning, but also needs to care for deterioration that can happen over time and from the chickens.
Pros and Cons of Mobile and Stationary Coops

Table 1: Mobile Coops

<table>
<thead>
<tr>
<th>Pros</th>
<th>Cons</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Evenly distributing fertilizer</td>
<td>• Has trouble with scaling (the more chickens it houses the less mobile it gets)</td>
</tr>
<tr>
<td>• They eat many pests and insects</td>
<td>• Has drawbacks when protecting against digging predators</td>
</tr>
<tr>
<td>• Cleaning is a lot less involved</td>
<td>• Level of mobility is heavily dependent on terrain and weather</td>
</tr>
<tr>
<td>• Repairs are more manageable</td>
<td>• Harder to regulate internal temperature (so it is warm in winter)</td>
</tr>
<tr>
<td>• Very good against aerial predators (i.e. hawks)</td>
<td></td>
</tr>
<tr>
<td>• Provides more variety of feed for chickens, leading to a better quality of life</td>
<td></td>
</tr>
</tbody>
</table>

Table 2: Stationary Coops

<table>
<thead>
<tr>
<th>Pros</th>
<th>Cons</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Can always add features on later if needed (rather than having to rebuild the coop)</td>
<td>• Owners must feed the chickens consistently</td>
</tr>
<tr>
<td>• Can house many chickens</td>
<td>• Owners must regularly clean the chicken waste</td>
</tr>
<tr>
<td>• More freedom when designing</td>
<td>• Repairs are needed more often and, in some cases, difficult</td>
</tr>
<tr>
<td>• Most predator proof option</td>
<td></td>
</tr>
</tbody>
</table>
BUILDING CONSIDERATIONS
Chicken coops and runs are often made out of one of the following materials: **pressure treated wood, hardwoods, softwoods, PVC, and pallets.**

Pressure treated wood is a type of wood given a chemical treatment to increase its resistance to the elements. Pressure treated wood can withstand prolonged exposure to moisture, and many builders decide to use pressure-treated wood exclusively for their coop (Brock, Zook & Ludlow, 2018).

PVC pipe is a strong building material because it is made out of heavy duty plastic. Since PVC pipe comes in tubes, the material can be reassembled easily using elbows to secure tube ends. A downside to this material is that UV light deteriorates the plastic if directly exposed, however it won't penetrate through thin layers of paint. Schedule 80 PVC pipe is recommended to be used for outdoor construction because it can withstand harmful UV light and extreme heat (The effect of sunlight exposure on PVC pipe, conduit, and fittings.)

Common types of fencing are: chicken wire, electric netting, and hardware cloth. Chicken wire does well to keep the chickens in their runs, however large predators can tear chicken wire down, and some small predators could squeeze through the holes (Johnson & Johnson, 2019). Due to this reason, it is best to use hardware cloth with holes less than an inch wide and reinforce the wire with metal or wood frames.

Common predator proofing techniques includes using wire mesh with less than an inch sized holes, skirting around structures, or utilizing electric netting.
Designing for Weather

Wind:
If the chicken structure is not built properly, wind could knock it down during a storm. A good way to build a sturdy foundation is digging holes to put posts with concrete (Steele, 2019). The Massachusetts State Board of Building Regulations and Standards suggests preparing for up to 126 mph gusts for 3 seconds in Grafton, MA (780 CMR ninth edition, chapter 16: Structural design amendments.2017).

Rain:
Heavy rain can soften up soil and make it very easy for supports in the ground to shift. One example of this in nature is when trees are uprooted during a thunderstorm. To counter this, concrete footings can be placed around vertical support beams and buried four feet below surface. Burying the footings four feet below the surface will also help prevent frost heave on the concrete footings (What is frost heave, 2020).

Snow:
There are a few ways to prevent the building from collapsing: build structure planning for more than expected snow loads, roof pitch of 4/12 or more will allow snow to slide off easier, and removing the snow as soon as possible (Janni, 2016). In Grafton MA the snow loads are 35 pounds per square foot of a flat roof (780 CMR ninth edition, chapter 16: Structural design amendments. 2017). If the preventative measures didn't work, and the building has excessive snow and is too tall to get the snow off with another tool (i.e. rake), then checking for damage would require a person to access the roof of the structure and knock off excess snow (Janni, 2016).
OUR MAIN GOAL

SAVE THE CHICKENS

Here's how we did that
Some quick changes to our initial project understanding...

Due to the 2020 COVID-19 situation, our sponsor lost most of their revenue on the farm. Social distancing caused all educational institutions to move online, so the children were no longer able to attend school at TBT. Since predators wiped out nearly all chickens on the farm, TBT struggled to sell eggs and connect with the community. Our group realized that cost would be a major factor to consider in our project.

We began with the understanding that we would propose three coop and run ideas for the farm: a mobile chicken run, a run that enclosed the current trailer coop, or a completely new coop with a run attached.

After doing some initial research, our team proposed the idea of also using a refurbished shed as a coop along with a run attached. This idea was popular due to its low cost since Turn Back Time luckily already owned a shed on the property. Since this option was very attainable and cost efficient our project changed. Instead of proposing and designing many coops and runs, we decided to focus on a predator proof run design that attached to the shed (shed shown on the bottom right).
What we thought we had to do

Before the pandemic struck

- Decide on a mobile or stationary coop and run.
- Decide if we were going to build a coop and run from scratch or use the current trailer coop located on the farm.
- Build the coop or run design.
WHAT ACTUALLY NEEDED TO BE DONE

Our objectives

 ✓ Research the durability, safety, strength, predator resistance, and cost of common chicken coop and run materials.

 ✓ Create blueprints and a building instruction guide for the most efficient chicken structure for the farm.

 ✓ Develop criteria for analyzing the pros and cons of potential chicken coop and run designs for the farm.

 ✓ Develop a meaningful and relevant educational module for the children at Turn Back Time.
RESEARCHING THE MATERIALS
We began with extensive research on common materials used to build chicken coops and runs. This includes wood, plastic, recycled materials, chicken wire, and others.

Before we began analyzing these materials, we first researched the pros and cons of each one, as seen on the upper left notes and in the next slide. We made sure to understand the durability, safety, strength, and cost of each material.

After this, we decided to make a material criteria chart where we could compare and contrast each material. We created this chart primarily on our notes so we could visually see how they compared to each other and which one would be the most realistic to use. We thought this number system was confusing to be used for materials so we used this criteria chart as a method of comparing the actual designs of the chicken structures instead of just materials.

We then decided to create a table with explanations on why a certain material did not make the initial cut for our final design. This method would be clearer to understand and served as a simple way for us to explain to our sponsor why we made our decisions.
<table>
<thead>
<tr>
<th>Building Material</th>
<th>Pros:</th>
<th>Cons:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pressure Treated Lumber</td>
<td>• Inexpensive</td>
<td>• Older pressure treated lumber samples have harmful chemicals; newer samples are safe</td>
</tr>
<tr>
<td></td>
<td>• Comes in different types of wood</td>
<td>• Expensive fasteners required</td>
</tr>
<tr>
<td></td>
<td>• Insect repellant</td>
<td>• Deteriorates over time</td>
</tr>
<tr>
<td></td>
<td>• Strong and durable</td>
<td></td>
</tr>
<tr>
<td>Softwood: Pine, Spruce, Hemlock</td>
<td>• Moderate overall price</td>
<td>• Lower overall strength</td>
</tr>
<tr>
<td></td>
<td>• Long-lasting</td>
<td>• Takes time to apply treatment to wood</td>
</tr>
<tr>
<td></td>
<td>• Weather-resistant material once sealed/treated</td>
<td>• Does not repel insects (treatment does not either)</td>
</tr>
<tr>
<td></td>
<td>• Standard Fasteners (Cheaper)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Painting is easy</td>
<td></td>
</tr>
<tr>
<td>Plywood</td>
<td>• Cheapest</td>
<td>• Only used for inside chicken coop</td>
</tr>
<tr>
<td></td>
<td>• Used for inside chicken coop</td>
<td>• Not weather resistant (swells and falls apart)</td>
</tr>
<tr>
<td></td>
<td>• Many choices for wood</td>
<td></td>
</tr>
<tr>
<td>PVC Piping</td>
<td>• Flexible (Can be reassembled if necessary)</td>
<td>• Expensive</td>
</tr>
<tr>
<td></td>
<td>• Sustainable (Reused from other projects)</td>
<td>• Recycled PVC may not be readily available</td>
</tr>
</tbody>
</table>

Table 3: Building Materials Pros and Cons
<table>
<thead>
<tr>
<th>Material</th>
<th>Material Decision Factors</th>
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</table>
| Stone (Out)                    | - Lisa Burris did not want something super permanent such as stone.  
- Stone is also very expensive and would require a lot of extensive labor that we are unable to give at this time |
| Chain Link Fence (Out)         | - The holes of this fence did not fulfill our predator proofing requirements                                                                             |
| Electric Netting (Out)         | - This is not a great option because kids play in and around the coop and it would be unsafe                                                            |
| PVC Pipe -> Schedule 80 PVC Pipe (Out) | - We considered schedule 80 ½ inch piping to ensure it was weather resistant and UV resistant, however, the price for this grade PVC was too high |
| Wooden Pallets (Out)           | - The texture of this material would be hard to work with. Pallets often have splinters on them so sanding would be a large requirement.  
- These pallets would also make it difficult to design a large run |
| Dog Pens (Out)                 | - This would only be realistic for someone with a small flock. This is also not predator proof since chain link fences have large holes that do not keep weasels out |
| Wood-> Pressure Treated Lumber (Yes) | - This wood is cheap and will withstand rotting and the elements. If our sponsor would like to paint it, they can. This wood is also easy to work with and comes in many sizes |
| Chicken Wire-> Hardware Mesh (Yes) | - This material is cheap and comes in a variety of sizes. The holes are small, and the material will resist predators trying to dig their way in. This material is also easy to use and easy to find |

Table 4: Choosing a Material
Initial Material Decision

Although we decided to rule out a couple materials, we knew that this could potentially change throughout our project. For our design process, we decided to consider PVC Pipe, Wooden Pallets, Wood, and a Refurbished Shed. We did not include a refurbished shed in this chart because we were unsure, at the time, about what material the shed would be made out of. We discuss the shed further in our report.

Based on our materials analysis, we decided that the best materials for our design would be pressure treated lumber and hardware cloth with less than 1 in holes.

This was our first material decision before we began the actual design process, so our team was aware that this could possibly change. We also wanted to ensure all options were open, so we designed with other materials as well.
ANALYSIS OF STRUCTURAL DESIGNS
As explained before, we created this chart as a result of the criteria chart we initially made to compare all materials. We decided that chart would be better suited to help compare each structural design since there are categories such as strength and feasibility of building. Each criteria is weighted differently to show importance. For example, safety is a 7 and aesthetics is a 2 because safety is more important to our sponsor than aesthetics. Durability, Strength, and Cost were out of 6 because they were all equally important factors for our designs. Feasibility was out of 4 because we knew that some staff on the farm have extensive knowledge on building and could be a strong asset to the building team.

This Criteria Chart for Designs was made to compare different chicken structures designed using these specific materials. Each member of our team was assigned a specific material to create a design for a chicken structure. At the time of this process, we were still considering building around the current trailer coop, creating a mobile run, or designing a new coop and run.

We had also just begun to present the refurbished shed idea to our sponsor, so we did not know yet that this would be our ultimate path.

### Table 5: Chicken Run Design Matrix

<table>
<thead>
<tr>
<th>Material</th>
<th>Safety(7)</th>
<th>Durability(6)</th>
<th>Cost(6)</th>
<th>Strength(6)</th>
<th>Feasibility(4)</th>
<th>Aesthetics(2)</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pressure Treated Lumber</td>
<td>7</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>4</td>
<td>2</td>
<td>28</td>
</tr>
<tr>
<td>PVC</td>
<td>7</td>
<td>6</td>
<td>3</td>
<td>5</td>
<td>1</td>
<td>1</td>
<td>23</td>
</tr>
<tr>
<td>Pallets</td>
<td>3</td>
<td>3</td>
<td>6</td>
<td>6</td>
<td>4</td>
<td>1</td>
<td>23</td>
</tr>
<tr>
<td>Refurbished Shed</td>
<td>7</td>
<td>5</td>
<td>6</td>
<td>5</td>
<td>4</td>
<td>2</td>
<td>29</td>
</tr>
</tbody>
</table>

CRITERIA CHART FOR DESIGNS
We found that building with pressure treated lumber was extremely feasible and easy to manipulate in many ways. We started off with sketching a common design using a pointed roof and a long run length. We also designed a full coop with a pointed roof and rectangular run attached, as seen in the bottom picture to the left. Our team realized that PTL would be fairly easy to manipulate and could result in an aesthetic and creative overall chicken structure design. After speaking with our sponsor and our advisors, we received feedback and realized that this structure would be the easiest to design and use on the farm.

Pressure treated lumber received a total score of 28. It was assigned 5 out of 6 points for durability because it is a chemically treated wood and can withstand pests and rot. Since it is wood, it will eventually deteriorate so that is why we docked off a point. For safety, this material received a 7 out of 7 mainly because this material poses no harm to children or chickens, unless it is consumed. PTL received a score of 5 out of 6 for both strength and cost. This was because the material is certainly strong and can withstand strong loads but because it is wood, the structural integrity can be lost over time.

As for cost, this material is extremely cheap and comes in a variety of useful sizes. This material design also received a 2 out of 2 for aesthetics because the wood is nice to look at and fits into a farm scenario. For feasibility we gave this design a score of 4 out of 4 because everyone at Turn Back Time is familiar with this material and it is easy to use and build with.
Structures made out of PVC pipe withstand weathering elements such as rain, snow, and heat. However, only schedule 80 PVC pipe can properly withstand UV rays from the sun. When designing, through sketches and Solidworks, a coop and run using this material, we found that making a coop out of PVC pipe was unrealistic because piping is difficult to make solid walls out of. So, using this material would require other materials for the coop. The run would require a PVC pipe outline that is connected by a variety of PVC elbows. This would greatly increase the price of the chicken structure because PVC elbows are expensive.

The PVC pipe structure would also require exact measurements of piping, otherwise it would need to be cut using heavy duty hardware.

PVC pipe was given a 6 for durability because of its overall strength and weather resistance. Safety score was a 7 because it is safe for children and chicken to be around due to it's lightweight structure. It was given a 5 for strength due to some PVC piping melting in extreme heat. For aesthetics we gave it a 1 since it is not super appealing to the eye and cannot be easily painted. Cost was a 3 and feasibility was a 1. PVC pipe can be expensive due to the many elbows that need to be acquired as well. This also, in turn, makes this hard to build because there are many parts.
Pallets

When sketching a chicken structure using pallets, we found it difficult to be creative in the design. As you can see on the right, the design was merely a box because of the square shape pallets come in. The material would not allow for an open look and feel to a chicken run, so we focused on designing a chicken coop. In order to design a run, the pallets would need to be taken apart. This would make building a run with pallets extremely hard and also dangerous because the wood would lose its material integrity after being pulled apart and nailed together again.

Pallets are made to hold heavy loads over long distances so they are well built and will be durable, if treated right. They are also practically free. A major drawback to using pallets is that they come in a very rough and splintery texture. Since pallets are not normally meant to be touched or worked with, they are not sanded down. Pallets are also pressure treated wood, some are even made of softwood. However, the lack of flexibility with how we can use the pallets is discouraging and limits a creative design for a chicken coop or run.

For pallets, the total score on the design criteria chart was a 23. For durability, this design material received a 3 out of 6 because the wood that makes up the pallets is often not chemically treated (softwood). Pallets also received a 3 for safety because as stated above, they come in a very splintery texture and are not safe for kids to be around.
Refurbished Shed

Using a refurbished shed is one of the more simple ideas and designs. At the time of our analysis, we did not know yet that Turn Back Time already had a shed we could use, as shown in the picture to the right.

Creating a design for a refurbished shed meant that we would be mainly focusing on the run that attaches to the shed. This run would need to be completely predator proofed along with the shed. Since building off the shed would require other materials, we decided to use pressure treated lumber for the run. As a team, we rationalized this would be the best material to use since it was rated highly in our initial material analysis.

As seen in the sketch, there are many ways to make a run by building off of a shed. We started off with a simple rectangular design that comes off the side of the shed and is narrow and long. As a group, we realized that there were many dimensions we could use, so we decided to wait until we received more information from our sponsor.
"Chickens NEED space, LOTS of SPACE."
-Connor Stedman, Agricultural Consultant

“Make sure you consider the physical capabilities of whoever will be maintaining the coop when you design” - Julie Rawson, NOFA Mass
DESIGNING PHASE
The above pictures were inspiration for our run. The picture to the left demonstrates a geodesic chicken run that we saw as both aesthetically pleasing and as cost efficient. The geodesic chicken run is made out of PVC pipe and can be assembled easily if bought from an online source (geodesicchickencoop.com). The con of having a mobile run is that there was not a clear way to protect against predators since digging was inevitable. The picture to the right is a chicken run that could easily fit over the trailer chicken coop currently on the farm. This run design would allow the chickens on the farm to be safe while outside the trailer coop.

Since our project changed, we no longer used the above designs for our Solidworks iterations, however we were inspired by their simplicity and effectiveness. We aspired to design a run that would be equally simple and predator proof.
We heavily relied on the above designs for inspiration in our own chicken run design. The upper left design gave us our inspiration for the support beams and the overall wooden design. The upper right photo gave us inspiration for the dimensions and how we could have attached the run to the shed. Both pictures helped us visualize the many components that our run would require such as proper wood lengths and attachments, wood orientations, support beams, and potential door locations.

Since we focused on mainly a run, these two pictures were the most useful to aid in our designing.
These design ideas were sketched for a PVC pipe run design. At this stage in our project, we were more aware of the fact that we would be designing a run for the shed at the farm. After meetings with our sponsor and advisors, we decided to design two runs out of PVC pipe and pressure treated lumber. These two materials were the most realistic based on our criteria chart and research.

We ultimately realized that the design aspect would be relatively similar for both. The biggest differences between wood and PVC pipe, would be the elbows required to connect the PVC pipe, as well as cost.

After sketching the PVC pipe run, as seen to the right, we discovered that using PVC pipe would be overly expensive due to the many elbows required to build a structurally sound run. Due to this, we eliminated the option of a PVC pipe and continued with using pressure treated lumber for the run.
For our overall run design, we knew that we wanted a rectangular run with support beams at every corner to help with structural strength. The support beam would not only function for strength and durability, but would also aid in the aesthetics of the run. The biggest challenge we needed to still overcome was the overall dimensions and size of the run. From our interviews with various farmers in Massachusetts, we came to learn that using 2x4in and 4x4in wooden beams were the best for building chicken runs. Our team decided we would use 4x4 beams as the structural supports that require digging into the ground and securing with concrete. We would use the 2x4 beams as the outline of the run.
Our preliminary design in solidworks was a simple chicken run with the door and opening for the shed directly parallel to each other. We combined our sketches by utilizing key components from each one. We took inspiration from each teammate’s sketches: Cray’s large open layout design (as seen above), Marisol’s support beam idea (as seen circled above), Nate’s predator proofing techniques (seen and described in the next page) and Vivek’s box layout for the dimensions (as seen above to the right). This design was made before we had our meeting with the director of TBT.
Nate’s predator proofing techniques can be seen to the left. Our team decided we would be either skirting along the perimeter of the run or digging underneath the ground and placing hardware cloth to prevent digging.

As shown to the left, we measured out that two feet of the hardware cloth would go underground or skirt the perimeter while one foot will overlap the base of the chicken run.
These notes demonstrate our progress with dimensions of our run. We finalized that we would be using 2x4in x 6ft beams and 4x4in x 8ft beams. Our run would be approximately 6.3 feet tall to allow the average person to walk into it.

At this stage of our design phase, we were still unclear about the final dimensions of our run design and the overall structure. Our team kept an open mind and knew that our design would change in various ways as we received more feedback and information on our run.

The notes to the right demonstrate some calculations about the amount of hardware cloth needed to fully cover our run design.
After feedback from the director of TBT on how the run would be attached to the shed. The "shed" is actually two small sheds put together, however there is only access to one of them, as shown above. These sheds were previously used for the goats and they are about 18 feet wide from side to side. So, we had to switch our width and length dimensions and also move the door to the side of the run instead of being parallel to the shed door. Above is some work from a weekly progress presentation where we use arrows to clearly show what we are pointing to. We found it extremely difficult to share our designs over a Zoom meeting call because of the inability to physically point at our design.
Hardware cloth will be attached on the outside of the run since there will be little to no gaps for predators to slide through.

Brackets will be used to attach wood, where necessary.
After our weekly progress presentation where we showed Iteration 1, we received feedback on orientation of beams, cutting back on wood, and layout of overall design. We decided to apply these changes for our upcoming meeting with Lisa Burris. As you can see in the above arrows, we added two doors instead of one so that the farm could have easy access to the run. We also utilized the 4x4 beams as support instead of also attaching 2x4s.
After showing Iteration 2 to Lisa Burris and our advisors, we received feedback on our door frames. Our design was not accounting for door opening clearance between the beams. Our door frame, in the preliminary design, was directly on the beams, so we decided to attach the door on the outside of the beam frames, as shown above. This would allow the doors to swing outward. We also researched preferred door openings for chicken runs and realized this was an extremely controversial topic for farmers, so we decided to leave this decision up to our sponsor. Our design allows for the door to either be attached outwards (as already shown above) or inwards so the door can swing open inside the run. Instructions on either attachment are included in our blueprints. We also added a beam to close the gap on the top of the door frame. This would ensure that the doorway has a nice tight fit to prevent any predators from climbing their way in or squeezing through gaps. The overall run design did not change.
CREATING BLUEPRINTS
After initial research, we determined that the first step to a good instruction manual is to list out the materials required along with quantities for each one.

Our team utilized IKEA instructions for inspiration. We found that the IKEA instructions were clear, easy to follow, and served as a great example for our run design.

We decided to also use the exploded view on solidworks to clearly show how to assemble our run.
Side Panels

1. Put Two 2x4s Together

2. Put bracket in corner and screw in each hole

3. Put another 2x4 on the right side

4. Repeat step 2
The Run

1. Screw panel into post along wall of shed

2. Put another post into the ground and screw to other side of panel

3. Screw one 2x4x3 piece of wood to align with top of panel and posts, and one to align with the ground

4. Put another post into the ground and screw 2x4s into it
Step One: Digging the holes

- Using the diagram in the next page, dig holes for the 8 ft 4x4 in beams in the appropriate spots. These holes should be 2 feet deep.
- Once the holes are all dug, first start by placing (one by one) the three 4x4 beams that are next to the shed (Numbered 1, 2, 3). Ensure that they are connected to the shed and there are no gaps between the beam and shed side.
- When putting a beam in the hole, level the beam first and then pour cement into the hole to secure the beam to the ground.
- Pat down the dirt around the holes and beams and ensure that the ground around the beams is level and smooth.
- *** For Beam A and B, ensure they are placed on the outskirts of the run, they will NOT be parallel to the other beams. See diagram on the next page.

Step Two: Attaching the side walls

- Now that the 4x4 in beams are in the ground and the ground around them is level, it is time to make the panels.
- Using the blueprints for the panels, start with Side A, and build the panel.
- Next, build the panel on Side B and work your way to C and then D.
- Ensure that all the parts are secured using brackets and screws.

Full blueprints in separate document
Washer-Screw Method

- Place a washer over the hardware cloth hole (as shown in the picture)
- Place a screw in the washer and screw into the wood
- Place washers about 6-8 inches apart as needed
- Ensure that the washers are placed towards the edge of the wire

**WARNING:** Hardware cloth can be extremely sharp, especially when cut. DO NOT do this without gloves on. After cutting the cloth, ensure to bend the edges of the wire so they do not poke out and hurt someone. Do this after every cut. OR Ensure that cuts are made so that wire does not stick out.

Step Two: Skirting

- Skirting will be used to prevent predators from digging
- Begin at point A. Lay down the 3 foot wide hardware cloth and roll out until Point B. Ensure you have 2 feet of the cloth on the ground, with the remaining one foot coming up from the ground to rest against the run itself (See next page for a picture). Cut out the hardware cloth for the door entrance so the 1 foot coming up from the ground does not interfere.
- Roll out the cloth about 1 foot from the end of the run as seen by Point B. Cut the hardware cloth. Secure to the ground using picks
- Roll out hardware cloth from Point C to Point D using the same procedure as mentioned.
- Roll out hardware cloth from Point E to Point F using the same procedure. Ensure to cut out the cloth for the door entrance.
- Secure cloth to the ground using gardening picks and cover slightly with dirt to hide

Step Five: Ensuring all parts are secured

- Once all the hardware cloth has been added to the run, take a quick check around the run to ensure that wire is not sticking out and harmful for others.
- Clip off any wire pieces that may be poking out.
- Ensure that there are no holes throughout the run and the cloth is secured and taunt.

A picture of the raised one foot of wire being secured to wood
CREATING OUR EDUCATIONAL COMPONENT
What kind of program?

We had many options. These were our initial ideas for educational pieces we could create for the children at the farm. We wanted our program to center around chickens.

The building and design process program would include things such as: how to properly build structures so they don’t fall down, differences in materials and their strengths, or the importance of properly measuring dimensions and materials for a secure structure. This program would allow students to understand the importance of a secure building and how hard the volunteers at the farm and our team worked to design and build the chicken run on the farm.

The predator prey relationship program would include teaching students about: the animal food chain and why all animals must eat or environmental factors that affect predators and prey. This program would allow students to understand why the chickens at the farm were constantly being attacked by predators and why the farm desperately needed a new chicken structure.

The adaptation and evolution program would include teaching students about how animals can adapt to their environment to avoid predation or starvation. This program would allow students to understand that even though the chickens on the farm have been heavily preyed upon, they can evolve and change to better protect themselves. Students will also be able to understand that predators can evolve as well.
DETERMINING OUR AUDIENCE

We started by researching the appropriate ages for teaching about predator prey relationships. We decided that teaching about these relationships would be critical for young children, especially on a farm. We were also aware to be cautious when mentioning death. Many games that children already play have similar ideas about predator prey relationships, such as the game sharks and minnows. Sharks and minnows is a game where the minnows must get from one end of the play area, or ocean, to the opposite end without getting tagged by the shark. If a minnow does get tagged by the shark, they become the shark. This game is recommended for an age range of pre-k to fifth grade because it is an active game that requires a lot of energy. We decided that a game similar to this one would be perfect for the younger children at Turn Back Time since they have plenty of space to play on the farm.

The second aspect of creating a learning module is understanding what kind of learning works best for our audience. There are three major categories of learning: visual, auditory, and hands on. Research shows that hands on learning is the most effective way for younger age groups because it allows them to understand the concepts in a simple way (Antle, Warren, Cramer, Fan, Matkin, 2016). Based on this research, we decided that a hands on game would be the most effective for the younger children at TBT.
OUR PROGRAM

We developed an outdoor game that illustrates the predator-prey relationships of chickens and their predators. This game is modeled after sharks and minnows.

The game requires the predators to either feed on the chickens so they can reproduce or starve if they fail to catch a chicken. The chickens would strive to create the perfect coop to protect against the predators.

We wanted to teach the students:

The roles that predators and prey play in an environment and why chickens and prey need each other.

The importance of chicken coops and runs and what they need to be predator proof.

Consequences of over predation and a brief intro to carrying capacity.

After each game we encourage teachers, or staff, to change variables so the players can see how the manipulation of variables impact the game. Some examples of the variables are: the ratio between predator and prey, amount of predator proof techniques on a coop, or adaption methods of both prey and predators such as talons for chickens or jumping abilities for predators.

Lastly, the game concludes with a discussion on the situations that occurred throughout the game. This allowed students to analyze why certain things happened and how this was replicated in the real world and even on the farm.
### Development and Content Chart:

<table>
<thead>
<tr>
<th>Age</th>
<th>Development</th>
<th>Content</th>
</tr>
</thead>
</table>
| 3-4 | • Working in teams and cooperation with each other  
• Developing social skills by playing the game  
• Spatial skills, walking/running and avoiding obstacles  
• Following rules  
• Problem solving | • Chicken Coops necessary for chicken’s survival  
• What coops need to protect against predators  
• Predators of chickens |
| 5-6 | • Working in teams and cooperation with each other  
• Developing social skills by playing the game  
• Problem solving | • Chicken Coops necessary for chicken’s survival  
• What coops need to protect against predators  
• Predators of chickens  
• Predators need chickens to survive |
| 7-8 | • Working in teams and cooperating with each other  
• Critical thinking  
• Problem solving | • Chicken Coops necessary for chicken's survival  
• What coops need to protect against predators  
• Predators of chickens  
• Predators need chickens to survive  
• Over predation  
• Carrying capacity |

Table 6: Educational Program Chart

This chart helps visualize what skills each sub age group would be developing and the lessons that each sub age group should take away from our game.
This is a small sample that helped illustrate the roles and rules of the game.
Presenting to

Putting it all together

Presenting to Turn Back Time
The cost above was mainly for wood materials and the hardware cloth. Our sponsor, Lisa Burris, noted that we did not need to focus on things such as screws, zip ties, washers, cement, or other hardware supplies since there were plenty at the farm or they would be purchased separately by TBT.

<table>
<thead>
<tr>
<th>Material</th>
<th>#Pieces</th>
<th>($)Price/Piece</th>
<th>($)Price</th>
</tr>
</thead>
<tbody>
<tr>
<td>2x4</td>
<td>38</td>
<td>2.98</td>
<td>113.24</td>
</tr>
<tr>
<td>4x4</td>
<td>14</td>
<td>7.98</td>
<td>111.72</td>
</tr>
<tr>
<td>Hardware Cloth</td>
<td>15</td>
<td>30.99</td>
<td>464.85</td>
</tr>
<tr>
<td><strong>Total=</strong></td>
<td><strong>$689.81</strong></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 7: Cost Analysis Spreadsheet
WHAT'S NEXT?
When designing our chicken run, we made sure that the design was as changeable as possible for future considerations.

The chicken run, that we have proposed, will allow for Turn Back Time to expand the run in an easy and effective manner. Our blueprints provide detailed explanations for how to attach 'panels', of 6 feet in length, to the run in order to make it wider or longer. Since currently the run is 18 feet wide and 16 feet long, it holds about 37 chickens, based on the required space needed for each chicken. TBT can easily add on and make the run more than 16 feet long, if they chose to in the future.

The director, Lisa Burris, mentioned she was interested in adding a plastic corrugated roof in the future. Our run design already has roof support beams making this addition very feasible and easy to do.

Turn Back Time has also previously mentioned that they would like to buy turkeys and other meat birds in the future. We recommended that TBT buy a mobile geodesic chicken coop for these birds because the geodesic coop is inexpensive and a great option for temporary poultry housing.
The COVID-19 pandemic of 2020 could not stop our team from designing a predator proof chicken structure for Turn Back Time farm. This structure will not only be aesthetically pleasing, but is effective in predator proofing. The children who visit and play on the farm can finally rest assured that their favorite animal friends will be safe and sound in their new home.

The farm will also benefit from a steady egg supply which they deem a truly important way to connect with the community and families. “We have people come from 30 minutes away just to buy our eggs.” quoted from Lisa Burris, 2020. The chickens on the farm serve as a meaningful bridge for Turn Back Time and the community the farm caters to. This run was primarily meant to save the chickens, but it will also help save Turn Back Time and the many people who benefit from this education.

Due to the importance of this run, Turn Back Time planned on building our design immediately after we were done with our blueprints.
THANK YOU!

We'd like to give a big thank you to everyone who helped us throughout this project. We truly could not have done all of this without you all! Doing this Interactive Qualifying Project during a pandemic was truly difficult and unique in it's own way. Our team appreciates the support and guidance all of these people gave us.

Professor Stoddard  
Professor Rosbach  
Leslie Dodson  
Professor Davis  
Lisa Burris  
Turn Back Time Inc.  
Maureen Austin  
Connor Stedman  
Julie Rawson  
Eliza Maclain

Sincerely,
Marisol Sanchez, Nate Fankhanel, Vivek Wong, and Cray Johnson
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Appendix A: Interview With Staff at Turn Back Time

1. What is your name and your position at the farm?
2. Do you own chickens? How long/Why not?
3. Have you encountered chicken predators? If so, what are they? If not, what predators do you know of that are in the area?
4. What preventative measures do you have for these predators and why was it effective?
5. What is the biggest obstacle you faced with construction?
6. What do you do to ensure that your buildings survive the weather?
   a. Is there a specific type of material or finish that does particularly well in this weather?
   b. What do you do to prevent roof collapse?
7. (Any follow up questions)
Appendix B

Appendix B: Interview With Outside Farmers

1. What is your name?
2. How/When did you become interested in farm work?
3. What is the most common non-harmful deterrent for predators?
   a. Why is that so effective?
   b. How expensive would that be to implement?
   c. Have predators been known to adapt to these measures?
4. What experience do you have with chicken coops and runs in terms of building or fixing?
   a. What has been the most challenging about upkeeping a chicken coop or run?
   b. What advice can you give us for a chicken coop or run?
5. (Any follow up questions)
Appendix C

Appendix C: Interview Responses from Julie Rawson

Work at NOFA Mass. I have my own farm where we have a mobile chicken coop. The predator problem is challenging. I don’t think it’s really possible to build a vermin-proof coop. I’ve encountered many. Our dogs are our second line of defense against predators. I have an 8 by 12 house tractor for about 25 to 35 birds. I have a 2 by 3 rip of wood on the ground to keep predators from digging in and underneath the coop. My husband built and designed our coop. We found moving the chickens around is great for chickens and well for our pastures. Our first structures were flat roofed and the roof tended to sag. We had a lot of leaks with a flat roof, so we changed it to a 4 inch pitch that worked well for the roof. We never didn’t have a roof because of birds of prey. Predators work at night so a motion sensor camera with light would work best. Don’t worry about making it look pretty. You don’t want it too heavy. Consider the physical capabilities of who will be maintaining the coop when designing
Appendix D

Appendix D: Interview Responses from Connor Stedman

I work in farm planning and agricultural consulting. I’ve been around different chicken coops but not so much a professional. But I have worked with them enough in order to have a conversation about them. So what’s the daily cycle of working with your chickens? Really think about that when designing your coop. Do they have a permanent area? So think about the nighttime, this is when mammal predators come out. How do you prevent them from getting in? Think about weasels. They’re incredibly narrow and can fit into small crevices. The coop itself is where they can get into. Gaps can be your biggest problem. An enclosed box can be elevated and moveable so they can move it around in the future. But if the location is permanent, really think about how beat up it can get and how degraded it can be. You won’t be able to use it much in the future if that’s the case. It’s smart to design a rotation part to the coop and run even if people say they don’t want to move it. Having chickens close to a horse pen is called a lead follow system. But for this you’d need constant moving and a very very large space. You could have them adjacent to each other but you’d have to move the chickens and horses at the exact same time. Also think about the horse pen, will this contain the chickens? Probably not. You’d need electric fencing or something. Chickens NEED land, LOTS of SPACE. You might want to think about how can we make it possible in the future to move the coop to be mobile. I recommend using 4x4 instead of 2x4, and having a metal roof instead of wood, but this might be more expensive. Good luck getting ahold of most farmers right now during this pandemic. A lot of farms are probably hiring though! Good luck, make the coop fast and tight! If weasels can be kept out then you are good to go with all predators.
Appendix E

Appendix E: Interview Responses from Eliza Maclain

I mostly raise pigs, geese, turkey, and other animals. I’ve found the main difference is just food. Some chickens require different nutrients. I have Delaware chickens for large eggs, Buckeyes for eggs and dual purpose. The predators I’ve mainly seen are foxes that like to climb onto the roof or over the fence. There’s also raccoons that tear through wire, so I’ve been using a heavier gauge. I’ve also encountered snakes as well that slither in. I really like using heavy grade hardware cloth. I also love my huge geese that sound as alarms and scare off predators. I have two sets of bird watch dogs I keep cloths. I use ½ in by ½ in wire. I also move the chickens around, which is also good for the ground too. I have 3 egg mobiles I use from hay trailers. Chickens like diagonal things in coops and runs so I have a couple of those in there as well. Chickens also like to lay away from the doors and they don’t like it when people walk through the egg-mobiles.
Appendix F

Appendix F: Interview Responses from Maureen Austin

So my sister in law and I started raising chickens about 5 or 6 years ago. There was a demand for free-range local chickens. I learned more by reading things online and talking to people. I enjoy the chickens immensely. I go up twice a day to pick up eggs and take care of them. We have a lot of customers right now buying eggs. So 3 or 4 years ago we tried to keep about 50 chickens and we'll get new ones when the old ones stop producing eggs. We started seeing feathers laying around and dead chickens that showed us we were missing even more. Foxes were the ones eating our chickens during the day. We have a fenced-in area with electric netting, but sometimes it doesn't work or there can be holes where predators get through. We also had bobcats come in and take some chickens. So our chicken coop has a covered porch area and then an outdoor area fenced in with electric fencing. In the summer, we just let them out to free-range. Occasionally the electric fence doesn't work so we have to keep checking it. So this coop was actually here for years before we arrived. We had to repair it and put the electric fencing up. But even with it up, we still had our chickens get out of the run and coop. It's made out of plywood and was hand-built. It has old windows and a metal roof that had to be replaced. In the winter it does well. Chickens like to go out all winter and they have access to the screened-in porch. I recommend you read things online. To keep them healthy, I clean the coop regularly and make sure they go outside, I give them high-quality food and vegetable scraps. I also put cement in the coop as a floor because waste builds up super fast and the cement makes it easy to clean. I think mobile is great, but I'm not too sure if it will keep the predators away. We've been really successful with our stationary coop. Also, keep in mind that activity helps deter predators. We have large animals here at the farm and because of theirs so much movement throughout the day, we don't have as many predators as we did before.
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**Canva Photos:** pages 7, 16, 18-19, 24-25, 34, 37-40, 56, 72

**Personal Photos:** pages 7, 8, 20, 28, 31, 35, 37-40, 42, 45-55, 58-61, 67-69


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