ME 423B - Engineering Design VII

Phase 1 Report

Group: Smart Coop

Due: October 1st, 2019

All digital signatures are in replacement of a physical signature due to electronic submission

I pledge my honor that I have abided by the Stevens Honor System.

Signed:

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Abstract

The aim of this project is to design a chicken coop that will allow for an easier and more efficient way to take care of chickens, thereby, allowing chicken owners to leave their home worry-free. By redesigning and automating components of the chicken coop, chicken owners can go to work, go on vacation, or simply have a helping hand without finding a "chicken-sitter." After analyzing existing coops and interviewing potential customers, the team was able to develop a list of needs that mainly surrounded the safety, design, and performance of the coop. These were turned into specifications, which allowed the needs to be evaluated in a quantifiable way. Three concepts were created with consideration of these needs and specifications. The team used different selection criteria to compare the created concept and found that by taking certain aspects of each concept, the design could be optimized. This combined design included an egg collector, automatic doors, automatic food and water dispenser, a floor cleaner, and coop cameras. In order to ensure the technical feasibility and efficiency of the product, a technical analysis of the chicken coop needs to be performed in the next phase. It was first important to identify the areas of technical analysis which included: the weight of the chickens, the material's properties, the dimensioning of parts, and the electrical components. Through further research, the team found many resources describing how to build a chicken coop or automate certain components. While these resources were likely written for residential chicken owners building one coop, taking this information into consideration is crucial for the success of the team's product. In addition, the team created a project plan and budget to allow for organization and collaboration to be carried out in every phase of the project.

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Project Statement

Motivation

Recently, more and more people have been taking up the hobby of raising chickens in their own backyard. Over the span of 2010 to 2012, the National Animal Health Monitoring System (NAHMS) conducted a study known as Poultry 2010 where they surveyed 10,000 people from four major cities. The cities that they surveyed were New York City, Denver, Miami, and Los Angeles. The results of this study showed that about 100 homes already owned chickens while about 400 homes were planning to own chickens within the next 5 years. This study was conducted almost a decade ago, so the number of chicken owners has surely increased greatly. One of the major reasons why people own chickens in their backyards is the reliable supply of fresh eggs. While there are many benefits to owning chickens there are some downsides as well. Caring for chickens requires constant daily attention of feeding and providing water to the chickens just like with any pet. Also, the coop should be cleaned very often almost daily if possible. The eggs laid by the chickens need to be collected regularly to avoid the chickens from breaking the eggs due to boredom. Furthermore, the chickens need to be let out to roam the yard during the day time and they should be locked in during the night to protect them from predators. There is a lot of care that is required daily when owning chickens that makes going on vacation or leaving the coop for an extended period of time hard to do. Traditionally, backyard chicken coop owners would have to find a “chicken sitter” to tend to the daily needs of the chicken coop but this method is unreliable. The team has decided to develop a design for a chicken coop that would allow the owner to leave the coop unattended without risking the health of the chickens. The group determined that automating key features of the chicken coop would help reduce the required daily interaction necessary from the owner allowing them to go freely and know their chickens are safe.

Goals and Objectives

The team has developed some major goals and objectives for this project. The main objective of the design project is to develop a chicken coop that has automated features that would allow for the owner to leave the coop for an extended period of time without worry. In order to do this the team must develop designs for these automated features including automated food and water dispensers, door, coop cleaner, and egg collector. The group also was thinking about implementing a self sufficient power source so the team would need to conduct research to determine how self sufficient power sources like solar panels can be used and applied to this specific project. The team must conduct extensive research on the care required for chickens and their required living conditions in order to develop a successful product. The team plans to create a prototype that shows a proof of concept before continuing to develop a final product. The use of goals allows the team to get a better understanding of the critical components of the design and what steps need to be taken in order to successfully develop the product described by the group.

Major Issues

Design & Analysis

There are several challenges with the design aspect of this project. One major challenge was whether to make the product an automated chicken coop or make the product a series of universal attachments that can be applied to preexisting coops. The problem with the universal attachment is that many of the coops on the market are very diverse and the coops tend to have very different designs which would make creating a universal attachment challenging. The team decided that developing an automated chicken coop would avoid this problem and make the design easier to produce as well as stand out to potential chicken owners who do not own a coop yet. Another challenge faced by the group is that the coop must have the proper conditions required for housing chickens. The team needs to be sure that the design of the coop will provide enough space in the coop and nesting boxes for the required number of chickens. Also, a major challenge that the team will face is the development of the automated features. The team needs to conduct a thorough technical analysis and use their prior knowledge in order to determine how the different parts of the coop can be automated. Furthermore, since many features of the coop will be automated the team needs to ensure that the product is safe for the chickens and user so there must be sensors or devices that will restrict the automated functions if necessary. For example, if there is a chicken in the doorway, the door should not close on the chicken. Finally, the group was considering making the product self sufficient so the coop will always have a source of power. This is important because the automated features will need power in order to operate so the coop must have a power source that does not need human intervention since that would defeat the purpose of the design. The team needs to conduct research on how different self sufficient power sources could be applied to the design.

Prototyping & Experimentation

In order to effectively evaluate the design developed by the team, the team needs to create a prototype that shows a proof of concept. Several experiments will need to be used for this prototype to allow the team to determine if modifications are necessary to improve the design. There are several challenges that are involved with creating effective experiments that would show the team if the product would be successful. A major challenge faced by the team is that to realistically test the product the team would need to acquire chickens which the team currently does not have easy access to. Simulations and scenarios could be made to try to test the product without the use of actual chickens but the results would be slightly different than results obtained using live chickens. Another challenge is that some characteristics of the product may be hard to test. For example, testing the safety of the design would be difficult. This is especially the case when trying to determine if the design can effectively keep out predators. It would be hard to accurately simulate a predator trying to enter the coop and attacking the chickens. The team must overcome these challenges with prototyping and experimenting to effectively test all aspects of the design.

Literature Review

State of the Art Technology

The team first conducted research on the basic layout of a normal chicken coop on the market. Through this the team would be able to determine the proper dimensions of a coop that is designed to house the required 4 chickens. Also, this would allow the team to learn more about the basic design features of a coop on the market that could be useful to incorporate into their design. The team used Amazon to search for preexisting chicken coops on the market because this website allows the team to research chicken coops with many different designs. The group could clearly see the design aspects and pricing of the chicken coops. Furthermore, the team would be able to clearly see how people thought of the product by looking at the reviews. Some of the researched chicken coops are discussed below:

The Pets Imperial Arlington Chicken Coop is a $280 coop found on Amazon that is designed to house 4 to 6 chickens. The coop is approximately 8 ft^3. Attached to the coop is long run that is about 40 ft^3 which would allow the chickens to have space to safely roam outside without the risk of predators, The coop has a pullout drawer that allows the owner to easily clean the coop with minimal effort. Also, there is a handle attached to the coop which allows the owner to open and close the door connecting the coop to the run without having to go inside the run to close it. There is a nesting box attached to the side of the coop that has a hinged roof that can be opened making gathering the eggs easy. After reading the reviews of the coop, the team was able to see how effective this product design actually was. From the reviews, the group concluded that this coop was actually too small to house 4 to 6 chickens and instead could only house about 2 chickens. This is supported by the research done by the group which stated that for a flock of 4 chickens, a housing area of about 12 ft^2 would allow the chickens to live comfortably.

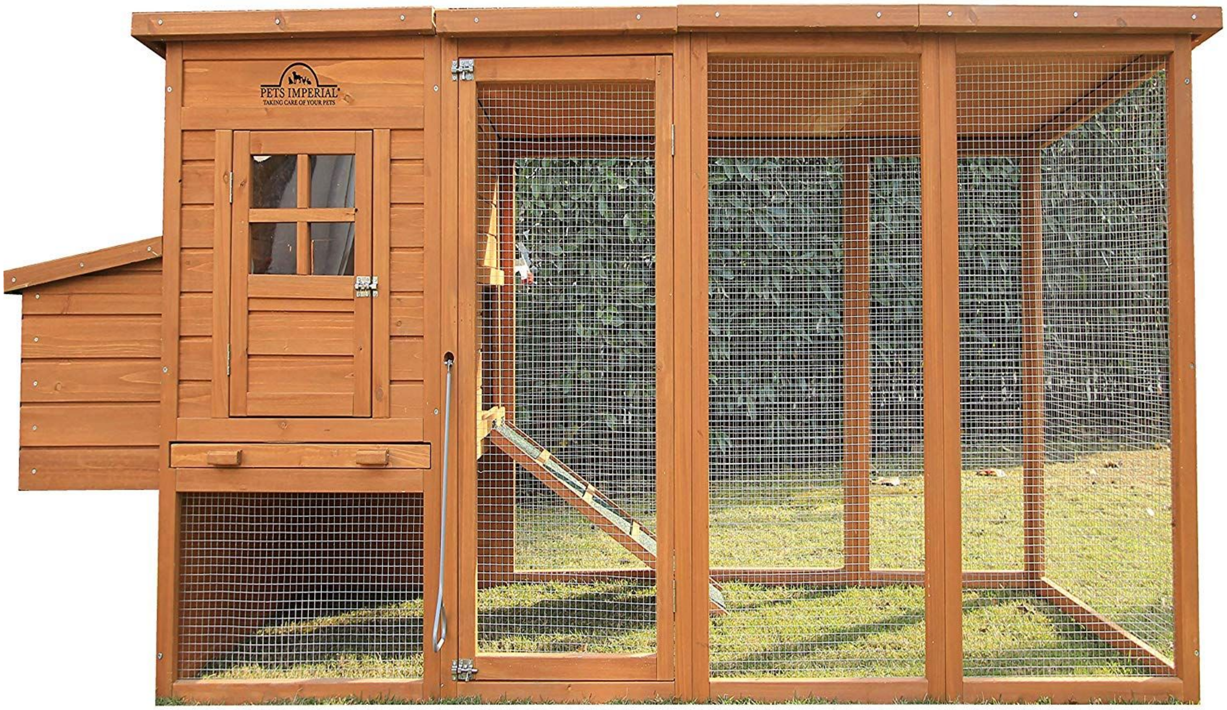


Figure 1: Pets Imperial Arlington Chicken Coop

Another product that the team researched was the Pets Imperial Double Savoy Large Chicken Coop. On Amazon this product costs about $250 to purchase. Unlike the previous product, this chicken coop does not have a run attached. The chicken coop is about 27 ft^3 not including the two nesting boxes on each side. This coop has a pullout drawer which is a very efficient tool for cleaning the coop. Also, the two nesting boxes have hinged roofs allowing the user to easily collect the eggs laid by the chickens. This coop has a sliding window to allow ventilation into the coop without risk of escape. The reviews of the product show that the coop is not very durable and there have been times where the floor of the coop collapsed. The group determined that this product has some good features, but there are also some aspects that could be improved on.

Figure 2: Pets Imperial Double Savoy Large Chicken Coop

When it came to the "smart" aspects of the coop, research was conducted to see what products currently exist, how do they operate, and inspire the team to think of ways to improve on them. Some of the products that were found consist of the following:

The first product found was an automatic door operator created by CHICKENGUARD. This design utilizes either a battery operated or wired connection to function. Both models contain a digital timer and a winch to operate the door, but the more expensive model has a special locking mechanism from preventing predators from clawing the door open.

Figure 3: CHICKENGUARD

The second product, ironically, comes from a website called *thesmartchickencoop.com*, where they sell pre-made chicken coops. Upon further inspection, these coops are designed to make access to the coop easy for cleaning, feeding, and egg collecting purposes. However, there isn't any technology that goes into operating the coop or making it more self-sustaining.

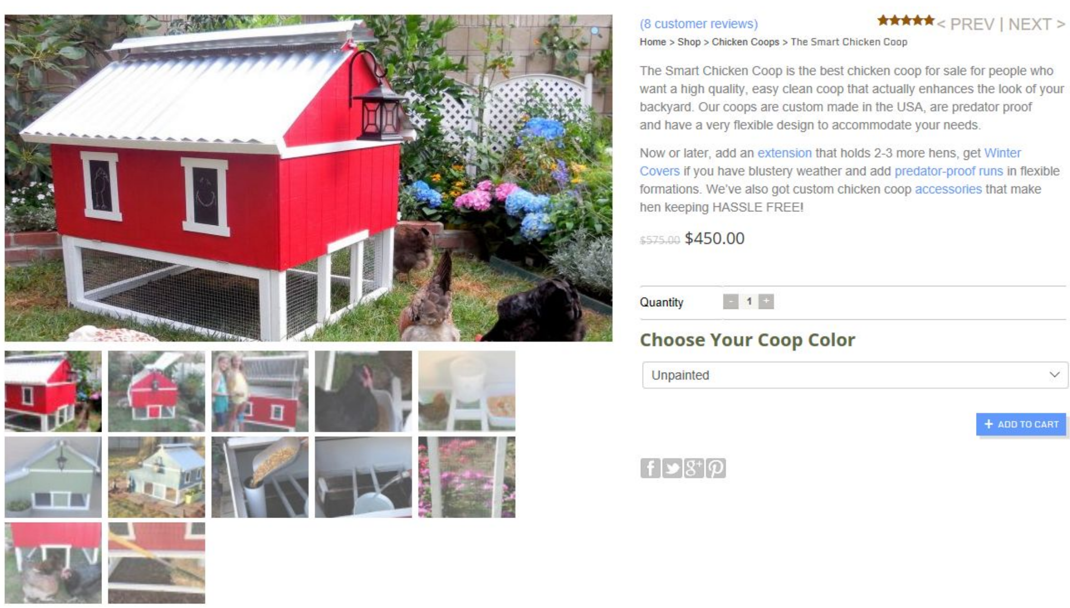


Figure 4: The Smart Coop

The third product is from a start-up company called My Connected Coop. This coop comes premade with many "smart" features to help the owner monitor and maintain the chickens in the coop. Some of the features are a night vision camera inside the coop, their own screw drive door operator, and other sensors to monitor coop conditions. On the other hand, this product still doesn't fully achieve a fully self-sufficient coop design.

Figure 5: My Connected Coop

Based on the research gathered, the team is able to identify which aspects of each product could be worked on and implemented for the group's current design concepts. The group determined that the dimension of the design would have to be larger than the coops researched above in order to comfortably house the required number of chickens.

Commercial Applications

For this product, the commercial applications would relate to current and potential chicken owners. After conducting research, the team realized that there are few current products that attempt to automate some features of the coop; however, most "smart" coops appear to be homemade with no intent on mass production. It is due to the lack of commercial products, that the team believes there is potential for a more effective automated chicken coop. Information which further supports the need for automated "smart" chicken coops can be found in both customer interviews the team conducted and a 2014 article from *Poultry Science*, where surveys were performed and found that "about 13% of respondents… mentioned the lack of reliable "chicken sitters" when going on vacation."

The team's product is currently being designed for a maximum of 4 chickens per coop. However, this number could be increased with further research and development, in order to accommodate larger flocks of chickens. After the team gains a better understanding of the unique parts of the product, it would be a matter of increasing the scale of each component to meet the required needs.

Needs and Specifications

Societal

There are many benefits of owning chickens including receiving fresh eggs, living a more sustainable lifestyle, and enjoying the unique company and personality of each chicken. However, despite being generally easy to care of, chickens still require daily attention. Therefore, one consistent problem that chicken owners run into is that they cannot leave their homes freely without prior planning or a "chicken-sitter". The main aim of this project is to provide residential chicken owners with the opportunity to leave as they please knowing that their chickens are being cared for properly. Whether an owner has to leave for work, vacation, or is looking for daily assistance, the smart chicken coop proposed in this product would alleviate the day-to-day tasks required when taking care of chickens.

Stakeholders

In order to best understand the goals of the design, it is important to define project stakeholders. Primary Stakeholders are those who directly influence the project and have a stake in its success. Secondary Stakeholders have an indirect influence on the project but do not have a stake in the project's success. The following is a list of the main project stakeholders:

- Primary Stakeholders
  - Stevens Institute of Technology
    - Project Team
    - Advisor - Professor Fontaine
    - Senior Design Review Board
    - Mechanical Engineering Department
- Secondary Stakeholders
  - Target Customers

        - Current Chicken Owners
        - Potential Chicken Orders
        - Chickens (indirectly)
    - Potential Third Party Sellers
    - Suppliers of Materials
    - Subcontractors
    - Competitors
    - IoT
        - Phone Companies
        - Security
    - Legal Organizations
        - U.S. Environmental Protection Agency
        - FDA
        - PETA
        - Dept. of Agriculture
        - Liability

Customers

As mentioned above, customers are considered a stakeholder in this product. The potential customers of this chicken coop would be current and potential chicken owners. Our design is aimed to be large enough to fit about four chickens, so current owners with similar size flocks will be the target customer. In addition, people interested in getting a small flock but who are hesitant due to the daily care required would be another main target customer. In order to start to form product needs and specs, the voice of the customer needs to be scrutinized. A table was formed that translated direct quotes from the customer into product needs. This table can be found in the Appendix. Using this needs as well as unspoken but expected needs developed by the team, the final list of product needs were developed. These can be found in Table 1.

Table 1: Product Needs

Category	Index	Need	Priority (1-5)
Safety	S2	Coop is predator proof	5
Safety	S4	Coop is ventilated	5
Safety	S1	Coop is elevated	3
Safety	S3	Coop keeps away insects and bugs	1
Safety	S5	Coop and run are enclosed	5
Safety	S6	Coop has a shaded area	2

Performance	P1	Coop has an effective automatic water/food distributor	3
Performance	P2	Coop has an egg collector	3
Performance	P3	Coop has an automated poop cleaner	3
Performance	P4	Coop has an automatic door	4
Performance	P5	Coop has automated skylight opener	2
Design	D1	Coop has a nesting box	5
Design	D2	Coop has a perch	5
Design	D3	Coop has a run	5
Design	D4	Coop is soundproofed	2
Design	D5	Coop is durable enough to withstand daily outdoor weather	5
Design	D6	Coop is easy to assemble	3
Design	D7	Coop is large enough for desired amount of chickens	5
Design	D8	Coop is visually appealing	3
Maintenance	M1	Coop has is easy to clean/easily replaceable bedding	3
Price	Pr1	Coop is priced appropriately	3
Constraints	C1	Coop must fit about 4 chickens	5

From these described needs, a specifications table was then made. This helps to determine how to quantify and achieve the goals of the project. The specifications can be seen here. Each index number from Table 1 corresponds with a Specification listed below in Table 2.

Table 2: Product Specifications

#	Needs	Metric	Priority	Units
1	S1,S3	Grate hole size	5	sq in
2	S1,D5	Load applied before failure	5	N
3	S2,D8	Number of windows	4	#
4	S3,D8	Number of feet off of the ground	3	ft
5	S6	Number of shaded areas	2	#
6	P1-P5	Number of automated parts	4	#
7	D1-D3	Number of required coop components	5	#
8	D4	Amount of sound able to exit the coop	2	dB
9	D6	Number of parts needed for assembly	3	#
10	D6	Time required to assemble coop	3	minutes

11	D7,C1,D8	Area of coop	5	sq ft
12	D7,C1,D8	Area of run	5	sq ft
13	M1	Time required to clean	4	minutes
14	Pr1	Cost	3	$

In order to relate the needs and specifications in a visual way, a Quality Function Deployment was made. This takes the most crucial attributes and qualities of the project and relates them to each other through correlational relationships. The finished QFD can be found in the appendix. From this QFD, the team could make deliberate decisions that will prioritize the important needs and specifications of the project. One main conclusion that can be made from the QFD, is that finding the balance of the complexity of automation with the price of the chicken coop. The team must optimize efficiency while still making the price competitive in the market.

Concept Generation and Selection

Concept Generation

After some research the group developed three unique concepts for the chicken coop. Each coop designed provides variations of solutions to problems the team found. Each concept takes into consideration the needs and specs that were generated by the team. Each concept is discussed in detail below.

Concept 1: Billy's Concept

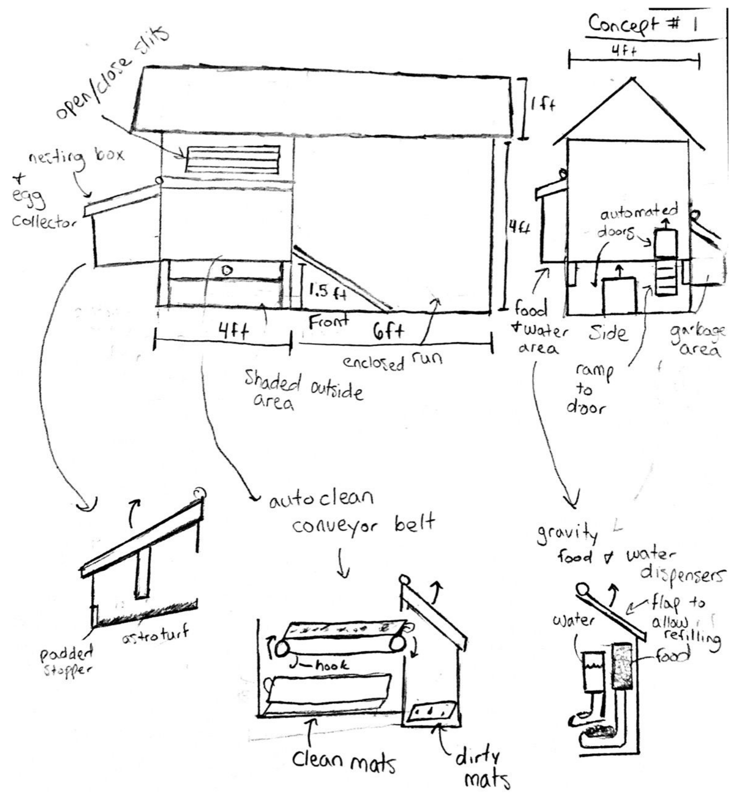


Figure 6: Billy's Coop Design

This concept, seen in *Figure 6,* features a nesting box that is attached to the coop however hangs outside of it. The base of it is slanted for the eggs to be collected in the corner. The box is easily accessible by owner, and eggs are collected by flipping up the top. This coop also contains food and water dispensers that work by gravity. These are also surrounded by a box that is hanging outside of the coop so they are easily accessed to be refilled when needed. In addition, the coop has a conveyor belt under the perch that will automatically clean the matts under the chickens that will collect poop. The dirty mats will be pushed by the belt to a section of the coop that also sticks outside the coop with a flap for it to be accessed and cleaned out. The component that stands out in this coop is the water and food dispensers.

Concept 2: MC's Concept

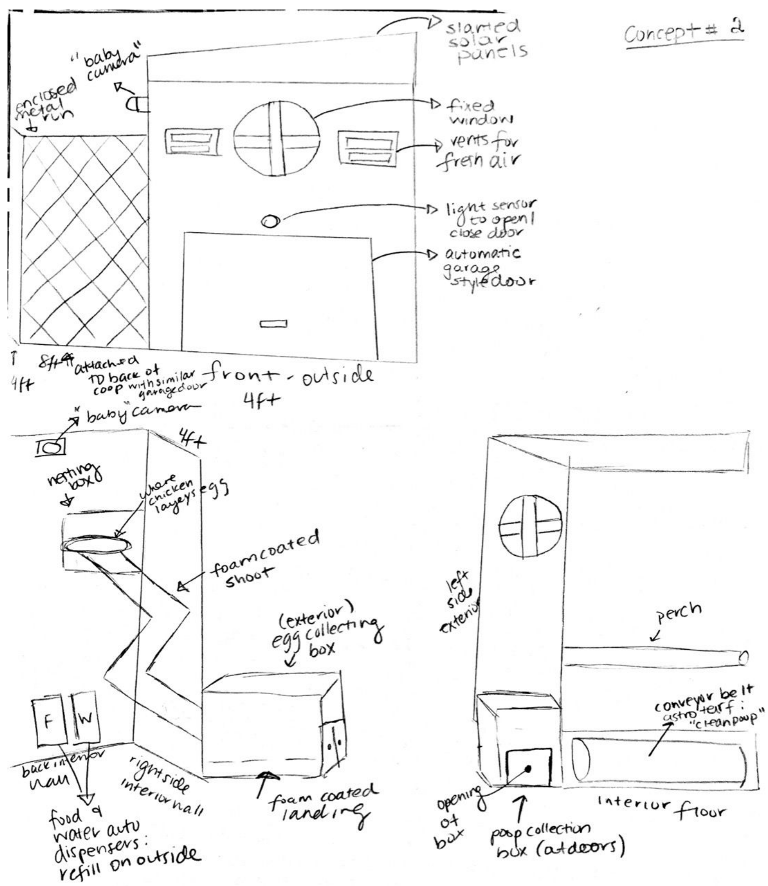


Figure 7: MC's Coop Design

This coop, *in Figure 7,* incorporates a light sensor to automate the opening and closing of the door. It also includes a small camera so owners can check on their chickens from afar. Two ventilation fans are attached to the front of the coop as this was a need the group learned from the survey that was sent out. The nesting box is connected to a foam-coated shoot that would collect the eggs by gravity into a box. Food and water are both in automated dispensers that connect to a door on the outside of the coop for easy refilling. A unique feature about this coop is a slanted solar panel on the top of the coop so the automated parts are all running from the energy harvested by the sun instead of requiring an electrical outlet. The component that stands out in this coop is the ventilation windows and solar panels.

Concept 3: Emily's Concept

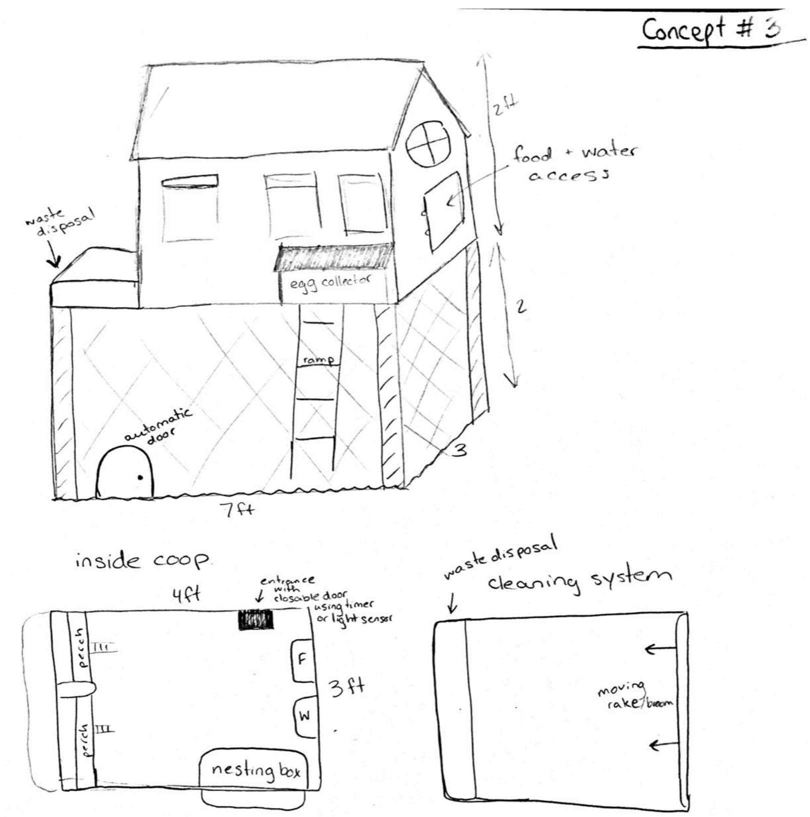


Figure 8: Emily's Coop Design

For the last concept, in *Figure 8,* the coop is perched up above the ground by 2 feet and underneath it is the run. This was a request by various owners we surveyed to prevent predators from coming inside the coop. It also gives the chickens shaded region outside. The entrance to this run is automated and there is a rake at one end of the coop that is automated to sweep and clean the floor of the coop. The rake leads the waste to a waste disposal bin at the end of the coop. The cleaning system in this concept stands out because it is efficient but feasible.

Concept Comparison

In order to quantifiably compare the concepts described above, a concept comparison table was created. (It is important to note that the reference coop in this table is the Pets Imperial Arlington Chicken Coop seen in *Figure 1.*) This table rates each concept in eight selection criteria. Each of these criteria are given a weight, in order to prioritize the most important criteria. Once the total score is calculated, the concepts are ranked from highest score to lowest score. From *Table 3,* it can be seen that Emily's Coop Design had the highest score. However, the deviation between the first, second, and third ranking was relatively small. The team concluded that this was due to each concept having a certain feature that made it superior. In Billy's concept, the food/water, egg apparatus, and window vents were satisfactory features. In MC's concept, the presence of a large window, camera, and solar panels set it apart from the other two. Emily's elevated chicken coop and general layout seemed most effective in accomplishing safety. For this reason, rather than selecting Emily's Chicken Coop Design, the team decided to combine Billy's, MC's, and Emily's Chicken Coop Design into one design.

Table 3: Concept Comparison Against Existing Coop

		Concept Evaluation							
		A		B		C		D	
		Your Average Coop		Billy's		MC's		Emily's	
		Reference		Concept 1		Concept 2		Concept 3	
Selection Criteria	Weight	Rating	Weighted Score	Rating	Weighted Score	Rating	Weighted Score	Rating	Weighted Score
Easy to Clean	15%	4	0.6	4	0.6	4	0.6	5	0.75
Uniqueness/ Aesthetic	5%	4	0.2	4	0.2	3	0.15	4	0.2
Cost	5%	2	0.1	2	0.1	3	0.15	3	0.15
Safety	20%	3	0.6	3	0.6	1	0.2	4	0.8
Ease of Assembly	5%	2	0.1	2	0.1	5	0.25	2	0.1
Automation of Parts	30%	1	0.3	4	1.2	5	1.5	4	1.2
Size	5%	1	0.05	4	0.2	4	0.2	3	0.15
Durability	15%	3	0.45	3	0.45	4	0.6	3	0.45
Total Score		2.4		3.45		3.65		3.8	
Rank		4		3		2		1	
Continue		No		Yes		Yes		Yes	

Concept Combination

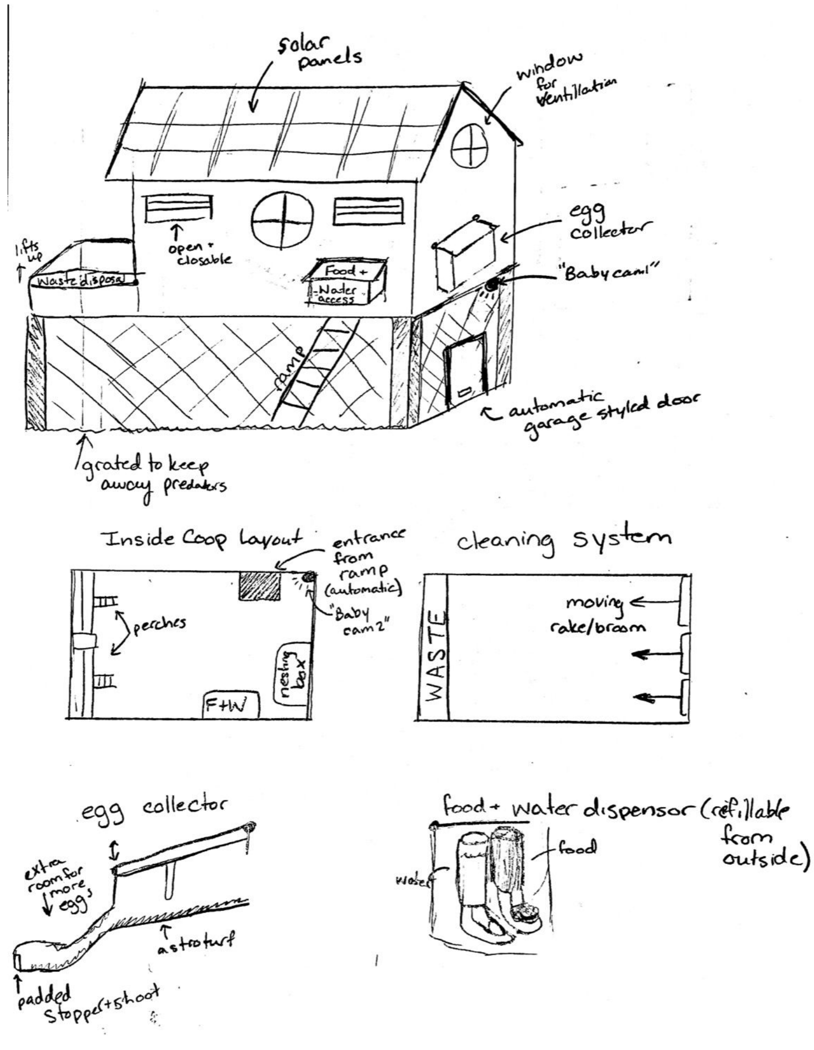


Figure 9: Final Concept

Rather than choosing one of the concepts from above the group decided on taking aspects from each concept to create a new concept. This coop incorporates the shaded run underneath the coop as well as a slanted nesting box to collect eggs which will then fall down a foam-coated shoot with a door at the end for owner to retrieve eggs. The cleaning system for the coop incorporates the rake on the floor to sweep up the waste into a waste box. The food and water would be dispensers that are accessible from outside the coop for the owner to refill. Two ventilation windows are on one wall of the coop that are able to be closed or open. This coop will also run on the energy collected from solar panels on the roof. Lastly, the coop has small camera for the owners to check on their chickens from afar.

Table 4: Concept Comparison Against Corrected Design

		Concept Evaluation									
		A		B		C		D		E	
		Your Average Coop		Billy's		MC's		Emily's		Combined	
		Reference		Concept 1		Concept 2		Concept 3		Concpet 4	
Selection Criteria	Weight	Rating	Weighted Score	Rating	Weighted Score	Rating	Weighted Score	Rating	Weighted Score	Rating	Weighted Score
Easy to Clean	15%	4	0.6	4	0.6	4	0.6	5	0.75	5	0.75
Uniqueness/ Aesthetic	5%	4	0.2	4	0.2	3	0.15	4	0.2	5	0.25
Cost	5%	2	0.1	2	0.1	3	0.15	3	0.15	3	0.15
Safety	20%	3	0.6	3	0.6	1	0.2	4	0.8	4	0.8
Ease of Assembly	5%	2	0.1	2	0.1	5	0.25	2	0.1	3	0.15
Automation of Parts	30%	1	0.3	4	1.2	5	1.5	4	1.2	5	1.5
Size	5%	1	0.05	4	0.2	4	0.2	3	0.15	5	0.25
Durability	15%	3	0.45	3	0.45	4	0.6	3	0.45	4	0.6
Total Score		2.4		3.45		3.65		3.8		4.45	
Rank		5		4		3		2		1	
Continue		No		No		No		No		Yes	

Technical Analysis

Areas for Phase 2

Once all the needs and target specifications are established, it is important to come up with an efficient strategy to reach these specifications. This can be done by means of a technical analysis which identifies any relevant equations, concepts, or technical principles that will aid in the product design. Within the scope of this project, there are many areas in which technical analysis must be performed such as size, safety, and efficiency.

Determining the optimal size of the various components involved in the coop is a preliminary technical requirement. For the general dimensions of the coop and run, it is important to consider how much room each chicken requires, while also not making the coop unrealistically large for only four chickens. The size of the perches and nesting box are also crucial factors that play a role in the chickens' lifestyle. Other dimensions to consider include: the doors, the windows, the size of the egg collector, and the size of the food and water dispensers. With many of these factors, the team will have to consider previously known values such as average chicken weight, average chicken size, average strength of a chicken's peck, etc.

In terms of safety, the material used must be strong enough to support the flock and durable enough to withstand various weather conditions. Various materials should be tested to see which material is most applicable to a chicken coop. By looking into the different properties and testing how they handle certain amounts of stress, strain, and force, the most durable and safest material can be chosen. In addition to the material chosen, the amount of ventilation contributes greatly to the safety and wellbeing of the chickens. The team must find a quantifiable way to test this factor such as performing temperature and wind flow analysis.

Since many components of the coop will be automated, there is an electrical component that is part of this as well. A proper electrical setup must be determined to ensure safe voltages and currents and prevent any complications if there were to be an electrical failure. It is also important to ensure that these components are properly contained as to not be compromised by weather and to not provide a risk to the chickens.

The following table, Table 3, provides equations that may be applied during this technical analysis and an example of an area project that they would apply to.

Table 5: Technical Analysis Equations

Equation	**Example Area of Application**
$L*W=A$	Size of coop
$F=ma$	Size of perches, Material chosen
$\boldsymbol{\sigma} = F/A$	Material chosen
$E=\boldsymbol{\sigma}/\varepsilon$	Material chosen
$\text{Strain}=\Delta L/L$	Material chosen
$V=IR$ and $P=IV$	Electrical Component
$A=\Delta v/\Delta t$ and $\Delta x=vt+(\frac{1}{2})at^2$	Egg collector apparatus
$f=\mu N$	Egg chute apparatus
$W=Fd$	Cleaning apparatus

Previous Modeling

While the team was interviewing customers, it was found that many current chicken owners have opted to build their own coops. In addition, to building a basic coop, some chicken owners have even implemented their own automatic doors. This gives way to the idea that there may not be a chicken coop on the market that technically satisfies all of the needs of the customer. In addition, it means that there is a significant amount of information on how people can build their own coop, and their own automatic doors. Therefore, recurring suggestions, problems, layouts, and designs can give supplemental information that will allow for the success of the team's project at hand.

Project Plan

Deliverables

In business, deliverables are constantly used to move projects along to get to the final result. A deliverable can be defined as any unique product, result, or capability to perform a service that must be produced to complete a process, phase, or project. Deliverables are determined based on the goals set at the beginning of a project and act as a set of milestones that need to be achieved to reach the goals at the end of the project.

Phase one presented a basic list of deliverables with the report guidelines. The team used this as a baseline to make deliverables specific to the chicken coop. One effective way the team checked if they were meeting all requirements on time was by utilizing the Gantt Chart. By clearly laying out the tasks that needed to be completed and setting what deliverables should be completed first, using predecessors, the team was able to organize what needed to be prioritized to get deliverables done efficiently. Specific deliverables include defining the motivation, goals, and major issues associated with developing a smart chicken cop, state of the art technology review, researching commercial applications , defining the needs and specifications of all stakeholders involved, concept generation, concept refinement, and selecting a final concept, beginning technical analysis for phase two, consolidating a project plan, and establishing a budget. By breaking down these initial categories into more specific deliverables for the smart coop, the team created a systematic approach to phase one. Overall, phase one can be defined as the proposal and concept generation phase.

Deliverables for the rest of the phases of this year long process will be defined in a similar manner as it was effective for phase one. MS Project is a great tool for organizing and delegating tasks and proved to be helpful for this project. Next steps include phase two and phase three which will be pre- prototype phases. It will be important to develop details in these phases as they will define the success of the prototype. Bad planning leads to bad products, therefore it is critical to thoroughly develop the technical analysis and engineering design of the smart coop. The following phases will be prototype phases that will have deliverables designed to reach the completion of the prototype.

Gantt Chart

The Phase One Gantt Chart was developed in order to organize each deliverable, break it down into manageable components, and add the time constraint of deadlines to configure the best possible schedule for the completion of this phase. This was done by starting with the high level deliverables given by the phase one report guidelines. Once those were input in MS Project, the team began to break them down into specific deliverables relevant to our project and this created smaller, more manageable tasks. As this list was set, the team then prioritized what deliverables needed to be done before others to make sure there was enough information gathered for the next deliverable and to leave enough time to get each task completed. MS Project then generated dates of when different tasks should be completed. The Gantt Chart allowed the team to make sure that dates were met to complete different tasks and to know what to work on next. The Gantt Chart also contains all milestones which are dates that tasks need to be submitted including submitting a draft of the phase one report to the advisor for review, the due date of the phase one report and the phase one presentation date. Lastly, the Gantt Chart contains all team and advisor meeting dates. This allowed the team to keep track of how many meetings took place and if one needed to check meeting minutes, they could refer to the Gantt Chart to see when meetings occurred. Figure 10 outlines the Gantt Chart updated to date.

Task Mode	Task Name	Duration	Start	Finish	Predecessors
	Phase 1	**19 days**	**Mon 9/2/19**	**Thu 9/26/19**	
	Project Statement	**5 days**	**Thu 9/19/19**	**Wed 9/25/19**	
	Motivation	2 days	Thu 9/19/19	Fri 9/20/19	20SS
	Goals/Objectives	2 days	Thu 9/19/19	Fri 9/20/19	3SS
	Major Issues	1 day	Mon 9/23/19	Mon 9/23/19	4
	Create Mission Statement	2 days	Tue 9/24/19	Wed 9/25/19	5
	Literature Review	**5 days**	**Mon 9/2/19**	**Fri 9/6/19**	
	State of the Art Technology	5 days	Mon 9/2/19	Fri 9/6/19	
	Commercial applications	5 days	Mon 9/2/19	Fri 9/6/19	8SS
	Needs & Specifications	**3 days**	**Mon 9/9/19**	**Wed 9/11/19**	
	Societal	1 day	Mon 9/9/19	Mon 9/9/19	9
	Customers	1 day	Mon 9/9/19	Mon 9/9/19	11SS
	Review of Stakeholders	2 days	Mon 9/9/19	Tue 9/10/19	11SS
	Review of Needs	2 days	Mon 9/9/19	Tue 9/10/19	11SS
	Customer Voice Table	1 day	Wed 9/11/19	Wed 9/11/19	14
	Concept Generation / Selection	**6 days**	**Thu 9/12/19**	**Thu 9/19/19**	
	Generated / Drawn	3 days	Thu 9/12/19	Mon 9/16/19	15
	Compared Using Metrics	1 day	Tue 9/17/19	Tue 9/17/19	17
	Concept Refinement	1 day	Wed 9/18/19	Wed 9/18/19	18
	Combined / Selected	1 day	Thu 9/19/19	Thu 9/19/19	19
	Technical Analysis	**1 day**	**Fri 9/20/19**	**Fri 9/20/19**	
	Discuss areas for phase 2	1 day	Fri 9/20/19	Fri 9/20/19	20

	Cite research on how others have modelled	1 day	Fri 9/20/19	Fri 9/20/19	22SS
	Project Plan	**2 days**	**Mon 9/23/19**	**Tue 9/24/19**	
	Deliverables	1 day	Mon 9/23/19	Mon 9/23/19	23
	Gantt Chart	2 days	Mon 9/23/19	Tue 9/24/19	25SS
	Budget	1 day	Mon 9/23/19	Mon 9/23/19	25SS
	Team Meetings	**11 days**	**Thu 9/12/19**	**Thu 9/26/19**	
	September 12	1 day	Thu 9/12/19	Thu 9/12/19	
	September 17	1 day	Tue 9/17/19	Tue 9/17/19	
	September 26	1 day	Thu 9/26/19	Thu 9/26/19	
	Advisor Meetings	**11 days**	**Tue 9/3/19**	**Tue 9/17/19**	
	September 3rd	1 day	Tue 9/3/19	Tue 9/3/19	
	Septemer 17th	1 day	Tue 9/17/19	Tue 9/17/19	
	Phase 1 Report Advisor Review	1 day	Thu 9/26/19	Thu 9/26/19	27
	Phase 1 Report Due	1 day	Mon 9/30/19	Mon 9/30/19	35
	Phase 1 Presentation	1 day	Wed 10/2/19	Wed 10/2/19	36

Figure 10: Project Gantt Chart

Budget

In phase one, it is extremely difficult to define a fully developed project budget. However, based on the concept generation and initial research of what is on the market, a preliminary budget can be made to get a picture of what is needed to complete the smart coop. The project budget will be a live document that will be constantly developed and enhanced as the concept design is developed. This will specifically be apparent in phase two and three once technical analysis and engineering drawings are complete. Table 6 outlines the updated budget to date.

Table 6: Project Budget Option 1

Component	Function of Component	Estimated Cost
Wood	Coop Exterior Walls	$100.00
Brush	Poop Cleanup	$20.00
Metal	Run Enclosure	$50.00
Foam	Egg Hatching	$10.00
Light Sensor	For Garage Doors	$20.00
Baby cam	To monitor chickens	$30.00

Glass	Windows	$20.00
Metal	Garage Doors	$30.00
Solar Panel	To provide power for the coop	$180.00
Vents	Fresh air	$30.00
Motors	To Control Auto Door and Rake Mechanism	$75.00
Belts	Cleaning system	$15.00
PVC	Food and Water Mechanisms	$40.00
Gear Rack	Door opener	$4.00
Gears	Cleaning system / door operator	$30.00
Raspberry Pi 4	Control System	$40.00

It is important to note that the budget comes to $694.00, which is close to the $700.00 budget provided by Stevens. However, it is also important to note that the team has around $180.00 allocated for a solar panel to power the smart coop. The solar panel is in the initial plans, however depending on how feasible and how effective the solar panel will be, this may change. The phase two technical analysis will provide more information on the best approach for this item.

Table 7: Project Budget Option 2

Component	Function of Component	Estimated Cost
Wood	Coop Exterior Walls	$100.00
Brush	Poop Cleanup	$20.00
Metal	Run Enclosure	$50.00
Foam	Egg Hatching	$10.00
Light Sensor	For Garage Doors	$20.00
Baby cam	To monitor chickens	$30.00
Glass	Windows	$20.00
Metal	Garage Doors	$30.00
Vents	Fresh air	$30.00
Motors	To Control Auto Door and Rake Mechanism	$75.00
Belts	Cleaning system	$15.00
PVC	Food and Water Mechanisms	$40.00
Gear Rack	Door opener	$4.00

Gears	Cleaning system / door operator	$30.00
Raspberry Pi 4	Control System	$40.00
exterior male plug	Power	$3.00
Plastic outlet cover	Power	$50.00

It is important to note that this version of the budget is $567.00. Instead of using a solar panel, this budget option would utilize an exterior male plug to allow an extension cord to connect the coop to the house for an electricity source. This is a more feasible option, however dependent on how efficient this is and the technical analysis from phase two, the best approach will be decided.

Discussions / Conclusions

After posting our survey on an online chicken owner forum the group received a lot of helpful information and recommendations for our project. We learned there was a general need to make food and water distributed automated, as well as more ventilation in the coop. These were just a few takeaways from the 30 responses we received. Some responses were negative, saying that people should be more hands on and not need an automated coop. The team was surprised by these responses as it appeared initially that more people would want the coop automated, however they realized these responses were from older farmers that were more traditional and less inclined to change their existing routine. A debate the group ran into was determining if they wanted the coop to be universal attachments or a pre-defined coop. The fact that a wide range of types and sizes of chicken coops exist, the team realized this would make it difficult to design products that could be customized to each coop. The team determined that the target audience is potential chicken owners, as opposed to individuals who already own coops because of the new craze of sustainability. The group decided on making their own pre-defined coop including the various automated parts. Three concepts were generated, all aimed at solving the same problems in different ways. After comparing the three coops the group determine that because all the designs scored closely while looking at selection criteria, the final concept should combine features from each of the three. The final coop would incorporate solar panels on the roof that would supply electricity for the coop, dispensers for food and water , automated door, camera, rake cleaning system, egg collector shoot, and the coop elevated above the ground with an outdoor run for the chickens underneath. The group is satisfied with this final concept and agrees it has the most innovative ideas from each concept all incorporated together. For the next steps of the project, the team will perform technical analysis to determine how to properly build the coop and to refine our product to match the specific needs of the customers.

References

https://www.amazon.com/Pets-Imperial-Arlington-Suitable-Depending/dp/B07MHXRRGS/ref=sr_1_5?keywords=chicken+coop+imperial&qid=1569529959&s=gateway&sr=8-5

https://www.amazon.com/Pets-Imperial-Double-Chicken-Suitable/dp/B07N2SG7D4/ref=sr_1_6?keywords=chicken+coop+imperial&qid=1569529959&s=gateway&sr=8-6

https://www.americaninno.com/chicago/my-connected-coop-brings-the-internet-of-things-to-chickens/

https://www.aphis.usda.gov/animal_health/nahms/poultry/downloads/poultry10/Poultry10_dr_Urban_Chicken_Four.pdf

C. Elkhoraibi, R. A. Blatchford, M. E. Pitesky, J. A. Mench, Backyard chickens in the United States: A survey of flock owners, *Poultry Science*, Volume 93, Issue 11, November 2014, Pages 2920–2931, https://doi.org/10.3382/ps.2014-04154

https://www.chickencoopcompany.com/collections/automatic-door-openers

https://www.digitaltrends.com/home/smart-chicken-coop-my-connected-coop/

https://thesmartchickencoop.com/?v=7516fd43adaa

https://explore.easyprojects.net/blog/how-to-define-project-deliverables

Appendix

A1: Voice of the Customer Table

Verbatim (VOC)	Related as a Customer Need	Derived Requirement
If I could have designed the coop myself, I would have built it high enough off the ground that the chickens could go underneath the coop for shade/rain protection, I'd have had more ventilation/bigger windows, and a poop board.	Coop is elevated	Design / Safety
	Coop has a shaded area	
	Coop is ventillated	
	Coop is easy to clean*	Maintenance
I want there to be an easy way to distribute food and water	Coop has an effective method for food/water distribution*	Performance / Safety
I have an auto chicken door already, but auto water would be nice.	Coop has an auto water distributor*	Performance / Safety
If I could choose something to be automated it would be having an automated poop collection/ cleanup, egg collection, automatic door opener and closer	Coop has an automated poop cleaner*	Maintenance
	Coop has an automatic door	Performance
	Coop has an egg collector	
I dont have one but maybe an automated skylight would be enjoyable	Coop has an automated skylight	Design/Performance
I spot clean almost everyday. About once a month I'll rake out the old shavings and put down new ones. Their coop and run sits on sand, so I don't have to clean it that often.	Coop is easy to clean*	Maintenance
	Coop has reusable / easily replaced bedding	
I don't want to lose a chicken to a hawk again	Coop keeps out predators	Safety
My last coop was not big enough once I bought more chickens	Coop is big enough for desired amount of chickens (4)	Size
It was hard finding a sturdy coop within my budget	Coop is sturdy / durable	Design / Safety
	Coop is priced appropriately	Price
One chicken is able to fly and get out of the fenced (no roof) enclosure but after it gets out it does not stray to far	Coop / run needs to be enclosed	Design / Safety
I bought my coop at a store and built it at home	Coop is easy to assemble	Design / Maintenance
I have some roosters which are very loud. It would be nice if the coop was soundproof.	Coop needs to be soundproofed / resistant to sound	Design

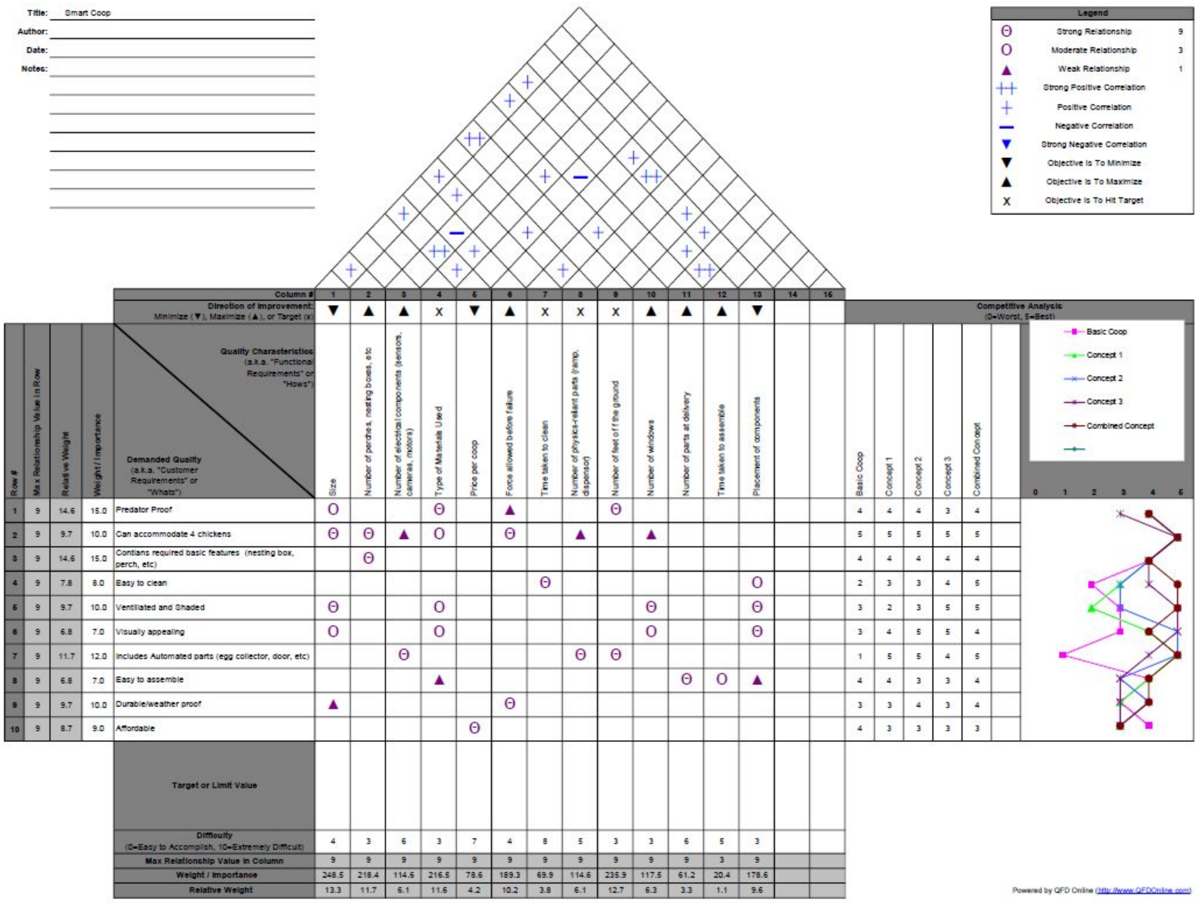
A2: Concept Comparison Against Existing Coop

		Concept Evaluation							
		A		B		C		D	
		Your Average Coop		Billy's		MC's		Emily's	
		Reference		Concept 1		Concept 2		Concept 3	
Selection Criteria	Weight	Rating	Weighted Score	Rating	Weighted Score	Rating	Weighted Score	Rating	Weighted Score
Easy to Clean	15%	4	0.6	4	0.6	4	0.6	5	0.75
Uniqueness/ Aesthetic	5%	4	0.2	4	0.2	3	0.15	4	0.2
Cost	5%	2	0.1	2	0.1	3	0.15	3	0.15
Safety	20%	3	0.6	3	0.6	1	0.2	4	0.8
Ease of Assembly	5%	2	0.1	2	0.1	5	0.25	2	0.1
Automation of Parts	30%	1	0.3	4	1.2	5	1.5	4	1.2
Size	5%	1	0.05	4	0.2	4	0.2	3	0.15
Durability	15%	3	0.45	3	0.45	4	0.6	3	0.45
Total Score		2.4		3.45		3.65		3.8	
Rank		4		3		2		1	
Continue		No		Yes		Yes		Yes	

A3:Concept Comparison Against Correcting Design

		Concept Evaluation									
		A		B		C		D		E	
		Your Average Coop		Billy's		MC's		Emily's		Combined	
		Reference		Concept 1		Concept 2		Concept 3		Concpet 4	
Selection Criteria	Weight	Rating	Weighted Score	Rating	Weighted Score	Rating	Weighted Score	Rating	Weighted Score	Rating	Weighted Score
Easy to Clean	15%	4	0.6	4	0.6	4	0.6	5	0.75	5	0.75
Uniqueness/ Aesthetic	5%	4	0.2	4	0.2	3	0.15	4	0.2	5	0.25
Cost	5%	2	0.1	2	0.1	3	0.15	3	0.15	3	0.15
Safety	20%	3	0.6	3	0.6	1	0.2	4	0.8	4	0.8
Ease of Assembly	5%	2	0.1	2	0.1	5	0.25	2	0.1	3	0.15
Automation of Parts	30%	1	0.3	4	1.2	5	1.5	4	1.2	5	1.5
Size	5%	1	0.05	4	0.2	4	0.2	3	0.15	5	0.25
Durability	15%	3	0.45	3	0.45	4	0.6	3	0.45	4	0.6
Total Score		2.4		3.45		3.65		3.8		4.45	
Rank		5		4		3		2		1	
Continue		No		No		No		No		Yes	

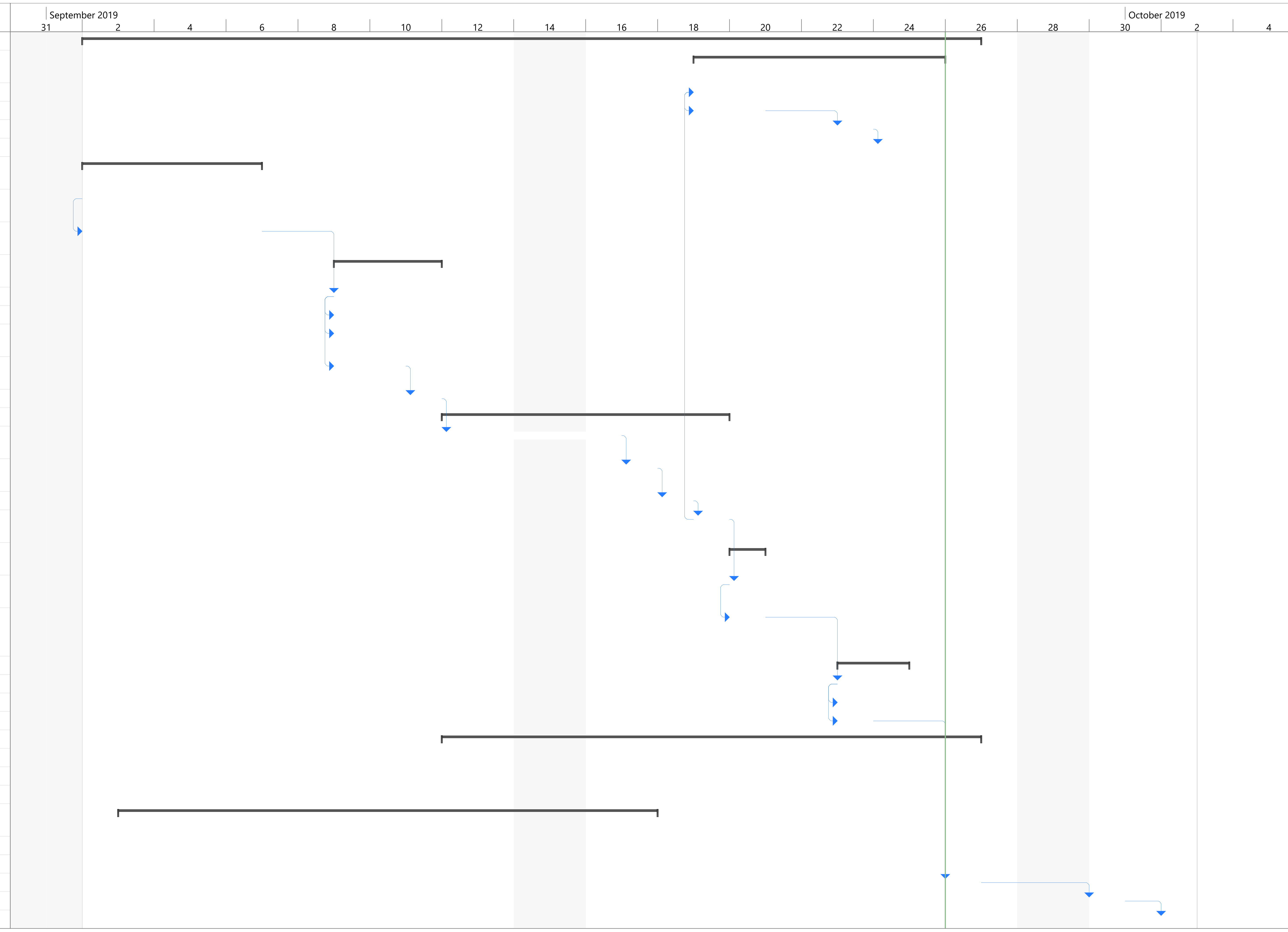
A4:QFD



Row #	Max Relationship Value in Row	Relative Weight	Weight / Importance	Demanded Quality (a.k.a. "Customer Requirements" or "Whats") / Quality Characteristics (a.k.a. "Functional Requirements" or "Hows")	Size	Number of perches, nesting boxes, etc	Number of electrical components (sensors, cameras, motors)	Type of Materials Used	Price per coop	Force allowed before failure	Time taken to clean	Number of physics-reliant parts (ramp, dispensor)	Number of feet off the ground	Number of windows	Number of parts at delivery	Time taken to assemble	Placement of components			Basic Coop	Concept 1	Concept 2	Concept 3	Combined Concept
				Column #	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15					
				Direction of Improvement: Minimize (▼), Maximize (▲), or Target (x)	▼	▲	▲	x	▼	▲	x	x	x	▲	▲	▲	▼							
1	9	14.6	15.0	Predator Proof	O			Θ		▲			Θ							4	4	4	3	4
2	9	9.7	10.0	Can accommodate 4 chickens	Θ	Θ	▲	O		Θ		▲		▲						5	5	5	5	5
3	9	14.6	15.0	Contians required basic features (nesting box, perch, etc)		Θ														4	4	4	4	4
4	9	7.8	8.0	Easy to clean							Θ						O			2	3	3	4	5
5	9	9.7	10.0	Ventilated and Shaded	Θ			O						Θ			Θ			3	2	3	5	5
6	9	6.8	7.0	Visually appealing	O			O						O			Θ			3	4	5	5	4
7	9	11.7	12.0	Includes Automated parts (egg collector, door, etc)			Θ					Θ	Θ							1	5	5	4	5
8	9	6.8	7.0	Easy to assemble				▲							Θ	O	▲			4	4	3	3	4
9	9	9.7	10.0	Durable/weather proof	▲					Θ										3	3	4	3	4
10	9	8.7	9.0	Affordable					Θ											4	3	3	3	3
				Target or Limit Value																				
				Difficulty (0=Easy to Accomplish, 10=Extremely Difficult)	4	3	6	3	7	4	8	5	3	3	6	5	3							
				Max Relationship Value in Column	9	9	9	9	9	9	9	9	9	9	9	3	9							
				Weight / Importance	248.5	218.4	114.6	216.5	78.6	189.3	69.9	114.6	235.9	117.5	61.2	20.4	178.6							
				Relative Weight	13.3	11.7	6.1	11.6	4.2	10.2	3.8	6.1	12.7	6.3	3.3	1.1	9.6							

A5: Gantt Chart

ID		Task Mode	Task Name	Duration	Start	Finish	Predecessors
1			**Phase 1**	**19 days**	**Mon 9/2/19**	**Thu 9/26/19**	
2			**Project Statement**	**5 days**	**Thu 9/19/19**	**Wed 9/25/19**	
3			Motivation	2 days	Thu 9/19/19	Fri 9/20/19	20SS
4			Goals/Objectives	2 days	Thu 9/19/19	Fri 9/20/19	3SS
5			Major Issues	1 day	Mon 9/23/19	Mon 9/23/19	4
6			Create Mission Statement	2 days	Tue 9/24/19	Wed 9/25/19	5
7			**Literature Review**	**5 days**	**Mon 9/2/19**	**Fri 9/6/19**	
8			State of the Art Technology	5 days	Mon 9/2/19	Fri 9/6/19	
9			Commercial applications	5 days	Mon 9/2/19	Fri 9/6/19	8SS
10			**Needs & Specifications**	**3 days**	**Mon 9/9/19**	**Wed 9/11/19**	
11			Societal	1 day	Mon 9/9/19	Mon 9/9/19	9
12			Customers	1 day	Mon 9/9/19	Mon 9/9/19	11SS
13			Review of Stakeholders	2 days	Mon 9/9/19	Tue 9/10/19	11SS
14			Review of Needs	2 days	Mon 9/9/19	Tue 9/10/19	11SS
15			Customer Voice Table	1 day	Wed 9/11/19	Wed 9/11/19	14
16			**Concept Generation / Selection**	**6 days**	**Thu 9/12/19**	**Thu 9/19/19**	
17			Generated / Drawn	3 days	Thu 9/12/19	Mon 9/16/19	15
18			Compared Using Metrics	1 day	Tue 9/17/19	Tue 9/17/19	17
19			Concept Refinement	1 day	Wed 9/18/19	Wed 9/18/19	18
20			Combined / Selected	1 day	Thu 9/19/19	Thu 9/19/19	19
21			**Technical Analysis**	**1 day**	**Fri 9/20/19**	**Fri 9/20/19**	
22			Discuss areas for phase 2	1 day	Fri 9/20/19	Fri 9/20/19	20
23			Cite research on how others have modelled	1 day	Fri 9/20/19	Fri 9/20/19	22SS
24			**Project Plan**	**2 days**	**Mon 9/23/19**	**Tue 9/24/19**	
25			Deliverables	1 day	Mon 9/23/19	Mon 9/23/19	23
26			Gantt Chart	2 days	Mon 9/23/19	Tue 9/24/19	25SS
27			Budget	1 day	Mon 9/23/19	Mon 9/23/19	25SS
28			**Team Meetings**	**11 days**	**Thu 9/12/19**	**Thu 9/26/19**	
29			September 12	1 day	Thu 9/12/19	Thu 9/12/19	
30			September 17	1 day	Tue 9/17/19	Tue 9/17/19	
31			September 26	1 day	Thu 9/26/19	Thu 9/26/19	
32			**Advisor Meetings**	**11 days**	**Tue 9/3/19**	**Tue 9/17/19**	
33			September 3rd	1 day	Tue 9/3/19	Tue 9/3/19	
34			Septemer 17th	1 day	Tue 9/17/19	Tue 9/17/19	
35			Phase 1 Report Advisor Review	1 day	Thu 9/26/19	Thu 9/26/19	27
36			Phase 1 Report Due	1 day	Mon 9/30/19	Mon 9/30/19	35
37			Phase 1 Presentation	1 day	Wed 10/2/19	Wed 10/2/19	36



Project: Smart Coop - Gantt Ch
Date: Thu 9/26/19

Task	Summary	Inactive Milestone	Duration-only	Start-only	External Milestone	Manual Progress
Split	Project Summary	Inactive Summary	Manual Summary Rollup	Finish-only	Deadline	
Milestone	Inactive Task	Manual Task	Manual Summary	External Tasks	Progress	