

Individual Project Final Report



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Programme: MEng Product Design Engineering

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Project Title: **Creation of an easily moveable guinea pig cage**

Abstract:

The purpose of this project is to create a guinea pig hutch that is designed to be moveable as its main aim. Most hutches on the market have been designed with movability as a secondary thought thus resulting in hutches that are difficult or awkward to move.

This report details the entire design process of creating the Movement First (MF) Hutch. It starts with initial research into existing products, RSPCA requirements and primary research. These are then used in the concept creation. A questionnaire was used to help identify other problems faced by current owners.

One idea was selected from thirteen using a Pugh Matrix to ensure its compatibility with the customer's needs.

Development of the hutch using several different methods such as ergonomic analysis, balance calculations, scale drawings and CAD modelling were used.

A scale model was 3D printed and a full-scale model fabricated. The models were then tested using different methods and the design was evaluated using the PDS and test market.

Manufacturing, cost and commercial considerations were researched to establish how the hutch could be manufactured and to check it could be produced at an acceptable price.

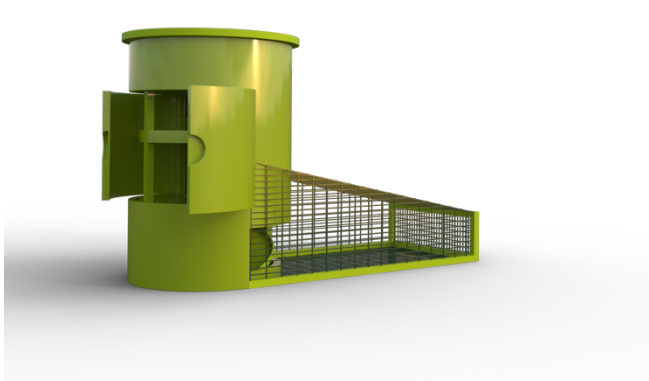


Figure 1 - Image of CAD Render (left) and full-scale model (Right)

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2 Introduction

2.1 Background and Context

Guinea pigs are commonly kept outside in hutches. The guinea pigs often have a play area on grass, which tend to be large and difficult to move. These hutches often need to be moved to both provide new grass for the guinea pigs to eat but also to keep their home clean. This has resulted in hutches needing to be moved regularly and most current hutches on the market are heavy, not ergonomic and difficult to move. Some users may struggle to lift the hutch due to its weight. This leaves the hutch stationary for long periods which can damage the grass, leave guinea pigs with limited food and nutritional sources and can develop infections.

A mobile hutch can help this problem, by allowing the hutch to be relocated with the addition of wheels and/or handles. However, most hutches on the market today are designed with mobility as an afterthought. They are often designed, and then in a bid to make them easier to move wheels are added later to them. They also can have other shortcomings that will be addressed in this report. This report will lead the reader through the research, design, development, prototype, testing, manufacturing considerations and evaluation required to make a guinea pig hutch that is created to make the movement of it as easy as possible by designing it with movement as a fundamental objective.

This project takes a different direction from the work done by Rebecca Carter and Joyston Wadnill Moreira, whom both worked on creating a mobile hutch.

2.2 Aim, Objectives and Deliverables

This project aims to apply and showcase Product Design Engineering (PDE) skills through the design of an ergonomic and attractive guinea pig hutch created by making its movability as easy as possible and making it specific to the project sponsor (Omlet Ltd).

The objectives of the project are as follows [1]:

1. Research the market until a target user has been identified through primary and secondary research.
2. Complete initial technical and market research until enough knowledge is gathered to stimulate potential initial ideas.
3. Understand the target user's needs until enough information is obtained to draft a PDS.
4. Develop initial concept ideas that fit the current specification until a potential solution is reached and all potential routes have been explored.
5. Understand the manufacturing options and the benefits for each component of the product.
6. Develop the ideas until it is feasible to manufacture and meets the customer's needs.
7. Undertake prototype creation and testing to develop the design until the design has been validated.
8. Evaluate the final product and provide recommendations for future enhancements.

2.3 Project Flow

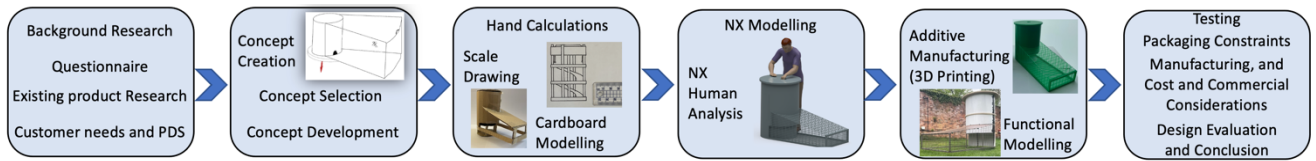


Figure 2 - Flow diagram Showing Order of Key Steps Taken.

3 Initial Research

3.1 Literature Review & Secondary Research

The literature review aims to research the requirements of the Movement First (MF) Hutch as well as look into competitive hutches to ensure its success if placed on the market.

3.1.1 Previous Student Projects

This project takes a different direction from two previous projects, one of which was also sponsored by Omlet. Both these projects have been analysed and the following is what was obtained and used:

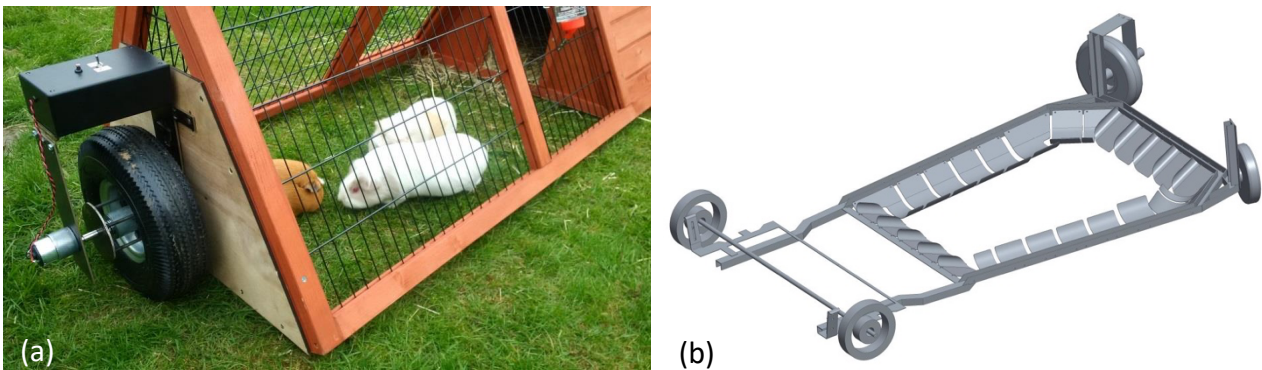


Figure 3 - Final prototype of Robotic Guinea Pig Hutch (a), Final CAD render for Autonomous Guinea Pig Hutch (b)

Living Lawn Care Companion (Robotic Guinea Pig Hutch) (2016) by Rebecca Carter (Figure 3a) aimed to design a mobile hutch system that enabled a guinea pig to have access to fresh grass throughout the day [2]. This project proceeded to research and an electronic guinea pig hutch was developed that would rotate through 360° Degrees. One problem was the operating height, to prevent the guinea pig from escaping, the hutch had a low ride height. The hutch subsequently caught the ground and caused the gearbox to fail.

Autonomous Guinea Pig Hutch (2018) by Joyston Wadnill Moreira was sponsored by Omlet Ltd (Figure 3b). It built on the previous design but increased the ride height and added panels that bridged the gap between the hutch and the ground preventing the escape of the guinea pig. However, this fix made the hutch impractical to use as the design vastly reduced the run area and didn't remove the potential for the hutch to get stuck on larger obstacles. This report also conducted research into the height of bumps in a garden and produced a maximum bump size of 48mm which will be used in testing the final design later in this report.

Another problem that both designs had was the lack of safety features. In both previous designs the mobile hutch could move without a human present which posed a danger to the guinea pig.

3.2 Primary Research

3.2.1 Questionnaire

Ethics Permission for the questionnaire was obtained from the LEON (Loughborough University Ethics Online) and can be seen in [appendix 17.1]. The previous studies both failed to gather public opinion. Therefore, a questionnaire was distributed to 27 people [Appendix 17.2]. This number of participants is not enough to allow the results gathered to be significant, but it can still give an insight into what will be required by the hutch.

Take Away: The hutch will be located on grass for at least an hour each day and needs to consist of a hutch with a cage. The hutch must be able to be moved by a single adult to be competitive with the current products on the market. The hutch will be moved weekly, this is also backed up by the data collected from Rebecca Carter's report where she measures the frequency required to move the cage for the grass to maintain itself. The final question asked the user what they found most difficult about their current hutch. From this, further research was done into the height and shape, to make it easier to move as well as how to make it easy to move when the guinea pig is inside.

3.2.2 Existing products

To make my product competitive against the other products on the market, a small batch of 15 products were compared in three categories to find the advantages and disadvantages of each (including the Omlet's Eglu Go). Only hutches with a unique feature were chosen. The categories were "movability", "types of hutches", and "types of runs", and were chosen to allow for the identification of what was good about each part of a mobile guinea pig hutch. The full analysis can be seen in [appendix 17.3].

Take away: The addition of wheels added mobility but either smaller wheels are added to keep the ride height low, but they may get caught on bumps; or large wheels to allow travel over rough ground but keeping the animals in while moving is problematic. Omlet's Eglu Go has retractable wheels which partly solves both problems, but this required the user to complete multiple steps before they could move the hutch, increasing the time and difficulty it takes to move.

3.3 Research Reflection

Both **Qualitative** and **Quantitative** methods were used in the research stage. For example, interviews with guinea pig owners were used to highlight the key problems faced by owners in an attempt to solve them. Or the Questionnaire was used to gather a large set of data to identify patterns in how owners currently move their hutches and movement frequency.

Videos of the existing products allowed for role-play research in observing how the products were used to allow for better identification of potential improvements. For example, some hutches require the user to bend down and pick it up, however, people of different heights would have to bend down further, and for some children it would be impossible for them to pick it up due to the position of lifting.

Critical analysis of standards was done to identify the minimum requirements the project has to meet but also to determine if it was ethically correct.

4 Problem Definitions

4.1 User Persona

A user persona is a person created to symbolise the ideal target market [appendix 17.4]. The aim was to:

- Identify the major user group.
- Identify the main needs and expectations of this group.
- To provide a clear context as to how and when the user will interact with the hutch.
- Identify key features or aesthetics that are required by the user persona.

Take away: The ultimate user is going to be parents as they will both buy and clean the hutch. They will also be recommending it to other parents. Therefore, using this process to identify some key features like how easy it is to clean would be very important in the design of the hutch to ensure the product is competitive.

4.2 Mission Statement

Product:	A hutch designed to protect the grass and provide a clean living area by moving a guinea pig hutch to a different area of grass.
Primary Market:	New owners of a guinea pig run.
Secondary Market:	1. Prospective guinea pig owners. 2. Owners and prospective owners of other caged animals. 3. Other keepers of guinea pigs e.g. animal petting farms
Project Goals:	1. To design, develop, prototype and analyse a product that meets the project brief. 2. To design the product so that it meets as many of the customers' needs as possible. 3. To produce a full-sized operational prototype, that meets the PDS and is validated with tests.
Assumptions:	1. User has the ability to move a guinea pig cage to a new area of grass. 2. To be able to move with no assistance from others.
Stakeholders:	User; Retailer; Service centre; Production; legal.

4.3 Customer Needs

The customer needs (Table 1) were created from market research, interviews and questionnaires. This led to Movement First (MF) hutch, aiming to satisfy the below customer needs, with a scale of weighted importance (5 = Very important, 1 = Not important).

NUMBER	CUSTOMER NEEDS	WEIGHT
	The MF is designed for the guinea pig	
1.1	The MF can periodically provide the guinea pig with fresh grass	5
1.2	The MF can protect the guinea pig from its predators	4
1.3	The MF can support the guinea pig	3
1.4	The MF can be used without distressing the guinea pig	3
1.5	The MF can provide the guinea pig with all its needs such as water	2
	The MF can be used by all	
2.1	The MF can be used by people of all ages and genders	5
2.2	The MF is not awkward to hold	4
2.3	The MF can meet the ergonomic needs of the user	4
2.4	The MF can be competitively priced to other hutches	2
2.5	The MF can still allow easy access to the guinea pig	2
2.6	The MF can be relatively sustainable	1
	The MF is easy to use	
3.1	The MF can move across a garden easily	5
3.2	The MF is easy to move in any weather	3
3.3	The MF is easy to move when containing guinea pigs	3
	The MF can be used in any setting	?
4.1	The MF can be used outside for long periods	4
4.2	The MF can be used in any garden	3
4.3	The MF can be used on ground with slight undulations	3
4.4	The MF is easy to understand how to use	1
	The MF is safe to use	
5.1	The MF can be moved slower than the speed of a guinea pig	3
5.2	The MF is safe to use for the guinea pig	3
5.3	The MF is safe to use for the user	3
5.4	The MF is signed on how to use it safely	2
5.5	The MF is made of safe, non-toxic materials	1
	The MF can be repaired	
6.1	The MF is easy to clean	3
6.2	The MF is easy to maintain	3
6.3	The MF can last the lifetime of a guinea pig	2
6.4	The MF can be repaired by the user if required	2

Table 1 - Customer Needs

4.4 Product Design Specification (PDS) Summary

The PDS was created to both provide a guide over the course of the project, to determine if it was heading in the right direction, and also to be used during the testing phase to determine how well the product would meet the needs of the customer, as found through all the research.

Each point is ranked regarding its importance; ‘primary’ being very important, ‘secondary’ being slightly less important and ‘tertiary’ being desirable but not essential. Throughout the specification ‘must’ has been used when expressing obligation or an unavoidable requirement, and ‘should’ refers to the point as being a recommendation or simply a desirable goal. MF is an abbreviation of ‘Movement First’ which is the name of the hutch. Table 2 is an example of some of the most important specifications, the full PDS can be seen in [appendix 17.5].

PDS	CN	SPECIFICATION	RANKING
		Aesthetics & Environment	
1.2		The MF should match Omlet’s branding/colour scheme/ shape	Tertiary
1.3	4.1	The MF should work within the 95 th percentile England temperatures range (35°C to -10°C)	Secondary
		Customer & Ergonomics	
3.4	2.1	The MF must be able to be used by all ages (8+ years old)	Primary
		Disposal & Materials	
4.2		The user must be able to recycle all recyclable materials	Secondary
4.3	5.5	The MF must be made using non-toxic, non-flammable and non-harmful materials	Secondary
		Documentation & legal	
5.2	5.2	The MF must comply with RSPCA standards.	Primary
		Performance & Function	
7.1	4.3	The MF should move over grass that contains bumps less than 48mm easily	Primary
7.5		The MF should require minimal effort (>91N 5 th percentile 8-year-old female) over the entire movement of the hutch.	Primary
		Testing	
11.1		The MF should be prototyped and tested	Secondary

Table 2 - Key Product Design Specifications

Take Away: The PDS proved challenging to put together as all of the created points came from a variety of different sources. It covers a range of topics with both descriptive and numerical specifications. This would prove useful later when reflecting upon the success of the final product/prototype by determining how well it meets the PDS through analysis and testing.

5 Concept Selection

The project brief was changed from designing a hutch using electronics to move it, to one without electronics on 20th December 2021, in a meeting with Simon Nicholls (Omlet Ltd), Ian Graham (Loughborough University) and Archie Buxton (Loughborough University). This decision was made because it was felt the product would have been too much of a hazard to the guinea pigs and would need human supervision to ensure the safety of them.

5.1 Initial ideas

Lots of sketching and re-sketching was done resulting in 13 initial ideas [appendix 17.6], each with its unique feature. Each idea was expanded to ensure that it had been fully developed. They were then analysed to identify their key advantages and disadvantages.

Figure 4 is the 11th idea and was inspired by the stacking of two cups. The guinea pigs would live in the bottom cup and the top cup can rotate about it. The top cup will be connected to the cage, as you pick up the handle at the opposite end of the cage (Figure 4b) to rotate, you are just rotating the top cup and don't have to lift the weight of the hutch. Figure 4d shows the addition of some doors so as you rotate the cage, a door is rotated in front of the opening preventing the guinea pig from running out. The advantages and disadvantages can be seen in Table 3.

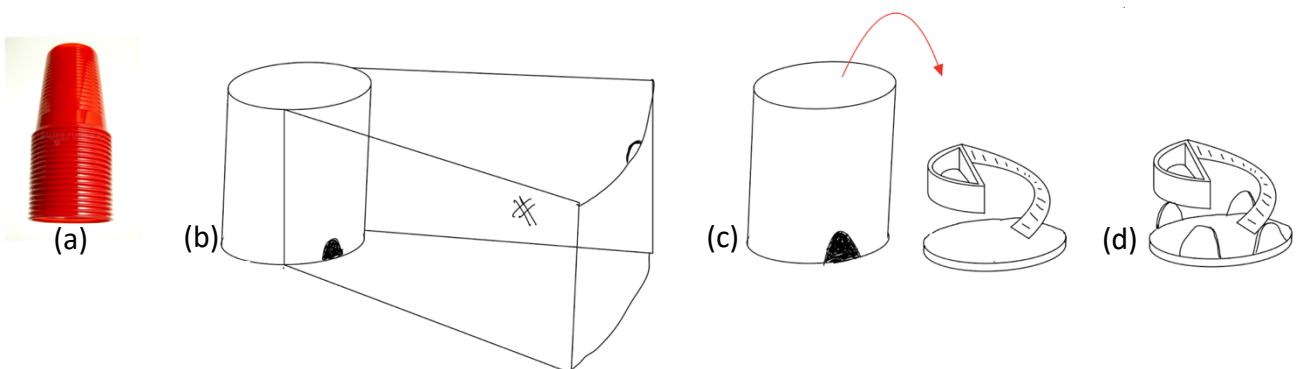


Figure 4 - Initial idea 11

ADVANTAGES	DISADVANTAGES
Easy to move. As the cage only rotates there is no difficulty when moving it over rough ground.	Limited movement. As the cage only rotates, this limits the area of grass the guinea pig can move to.
Easy to clean hutch. As the external body (top cup) can be removed, this can give complete access to the interior for cleaning.	Poor Safety, as the cup goes up and down, so the guinea pig might get caught between these moving parts causing harm to it.
	As the centre doesn't move. The grass will die unless the whole hutch is moved as well as rotated, which is difficult to do unless it's disassembled.

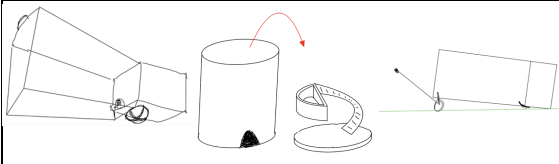
Table 3 - Advantages and Disadvantages of Initial Idea 11

Takeaway: The process of analysing each design allowed a deeper understanding of each one. Analysing the advantages and disadvantages of each design allowed a better comparison to be made between the design and customer needs.

The key negative impact of this process was the time it took to complete and the format, making it more difficult to decipher. However, it was still deemed to be a successful process as advantages from designs not selected would later go on to be developed into the final design.

5.2 First Concept Selection Process

After each of the initial ideas was analysed, they were placed into a Pugh Matrix. A Pugh matrix was chosen as it is a simple tool used to evaluate and compare alternative designs. It can quickly eliminate non-viable solutions and allows for efficient choosing the best from all possible alternatives. Figure 5 shows the top three ideas. To see the full matrix please see [appendix 17.7].



Criteria	Weighting	Idea 8		Idea 11		Idea 9	
		Ranking	Weighted	Ranking	Weighted	Ranking	Weighted
Designed for the Guinea Pig	3	3	9	3	9	4	12
Used by ALL	4	4	16	4	16	3	12
Easy to Use	5	3	15	3	15	3	15
Used anywhere	3	5	15	5	15	5	15
Safe to Use	3	4	12	4	12	4	12
Easy to Repair	1	4	4	3	3	3	3
Total =			71		70		69
Ranking =			1		2		3

Figure 5 - Top 3 Ideas in Pugh Matrix

The criteria were chosen using the customer needs to ensure the idea chosen would be close to what the end customer would want. After an interview with guinea pig owners, weighting was added to each of these criteria. The weighting was between 1-5 with 5 indicating very important and 1 not important. Each product was then ranked with a number from 1-5 with 5 indicating it fits the criteria very well and 1 being it doesn't fit the criteria. When multiplied it produced a total that could be compared against the others.

Take Away: The total scores ranged from 32 up to 71. Three ideas were carried forward to provide Simon Nicholls (Omlet Ltd) with more options. As Omlet is the sponsor of the project, it was felt that his input would have been vital to ensuring the continuing support that would have been necessary later during the prototyping stage.

After a meeting with Simon on the 18th of February 2021, it was decided idea 11 would be developed further. The last possible date for this decision needed to be calculated and placed as a milestone on the Gantt chart. This helped to convey a sense of urgency to the collaborating company and helped to set up timely meetings with defined deadlines and meeting goals.

6 Design Development Summary

6.1 Scale Drawing Creation

Simon Nicholls recommended a great way to determine if a design was possible was to create a scale 2d orthographic projection and isometric drawing. The scale drawings would allow better visualisation of the idea and be vital when creating the computer-aided design (CAD) model using Siemens NX 11.

To create these, research needs to be done into what each of the dimensions should be. This involved ergonomic analysis, and balance calculations to name a few.

6.1.1 Ergonomics analysis

PDS points numbers 3.4, 3.5, and 3.6 [appendix 17.5] specify that the MF must be designed to be used by people whose size ranges between the 5th and 95th percentile male and female and should be designed to be used by people aged 8 years old and above. It was found that the age between 8-11 is when children can handle the responsibility of a small social animal such as a guinea pig [3].

Take away: Values for the maximum height were obtained from the shoulder height of the 5th percentile female 8-year-old as that is the maximum height, they would be able to reach the handle. Other ergonomic values were obtained and utilised [appendix 17.8].

6.1.2 Balance calculations

Equations for calculating the centre of gravity and moments about the pivot were needed to determine the maximum area of the cage and are shown in Equation 1. Major dimensions are shown in Figure 6.

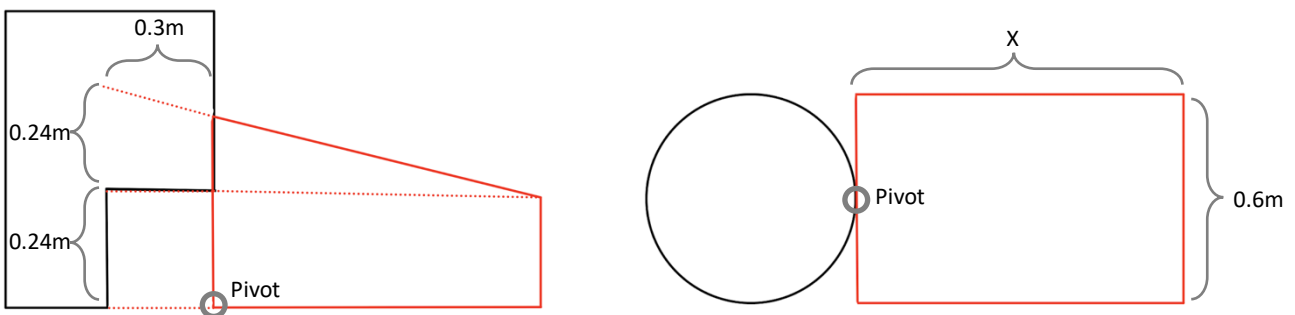


Figure 6 - Simplified Diagram of Hutch with Dimensions (side view on left) (top down view on right)

Assumptions:

1. The acceleration of gravity is approximated to $9.8m/s^2$.
2. Due to the hutch having a similar floor area as the Omlet Eglu Go Hutch it is assumed that the weight will be similar and thus assumed to be 20kg.
3. The material used to make the cage (powder coated mild steel) will be the same as Omlet's Eglu Go cage which has a mass of $1.79kg/m^2$.
4. The pivot will be the bottom edge of the hutch Figure 6.
5. The hutch can be simplified to only have forces acting in one direction and that the part of the cage to the left of the pivot in Figure 6 is included in the hutch's moments. Also, the top of the cage can be assumed to be a rectangle of length Xm and width $0.6m$.
6. Safety Factor of 2 to account for other unforeseen factors.

Calculations:

$$M = F \times d \tag{1}$$

where: M is moments (Nm), F is the force (N) and d is the perpendicular distance from a pivot (m).

$$F = W \times g \tag{2}$$

where: F is the force (N), W is the Weight (kg) and g is the acceleration due to gravity (m/s^2).

$$F = 20 \times 9.8 = 198N$$

$$M = 198 \times 0.3 = 58.8Nm$$

The top and bottom meshes have a combined area of $1.2 \times X m^2$ and therefore have a mass of $2.14 \times X kg$ and a force of $21.04 \times X N$. The centre of gravity is at $0.5 \times X m$, therefore the moments using equation 1 are equal to $10.52 \times X^2 Nm$.

The side meshes combined have moments $\approx 5.31 \times X^2 Nm$, and the end mesh is $= 2.52 \times X Nm$. Total moments on the right side of the pivot in Figure 6 $\approx 15.82 \times X^2 + 2.52 \times X$. This gives our maximum value for $X \approx 1.85m$ and therefore with a safety factor of 2 the value for $X \approx 0.93m$.

The safety factor was included to account for things like wind, uneven ground, and the mass of additional supporting structures. This value also means the area of grass the guinea pig will have access to is $0.88m^2$ which is much bigger than the $0.25m^2$ required by the RSPCA [4].

6.1.3 Scale drawing

Figures 7 a and b shows the scale 2d orthographic projection and isometric drawing of the Movement First Hutch. Figure 7 a is scaled down to a ratio of 1:20, and Figure 7 b is scaled down to a ratio of 1:15. Larger images can be seen in [appendix 17.9].

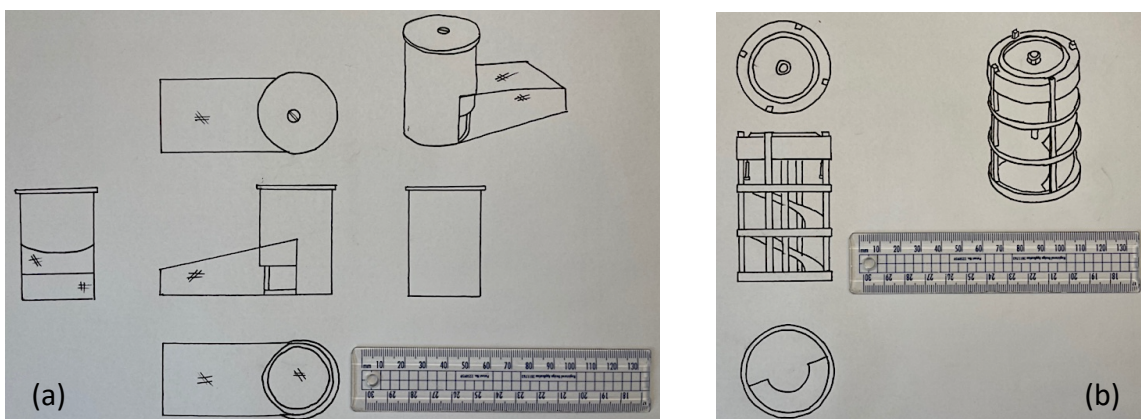


Figure 7 - Scale Drawings of outside structure (a) and inside structure (b)

This process highlighted development in the locking mechanism between the lid and inside which was vital to the degrees of freedom that the hutch can now rotate. This new locking mechanism allows for 360° degree rotation with unlimited angle options. The old mechanism also allowed for 360° degree rotation but could only be locked in increments of about 30°. This was only identified through this process and therefore saved time if it was identified later in the project.

Takeaway: The scale drawing process was vital in determining the dimensions required for the hutch’s lifting mechanism to work. The process also allowed for rapid development in both functionality and attractiveness.

6.2 Cardboard Modelling

A physical cardboard model was created to test some of the ergonomic features of the model and to allow further development through interaction with the model.

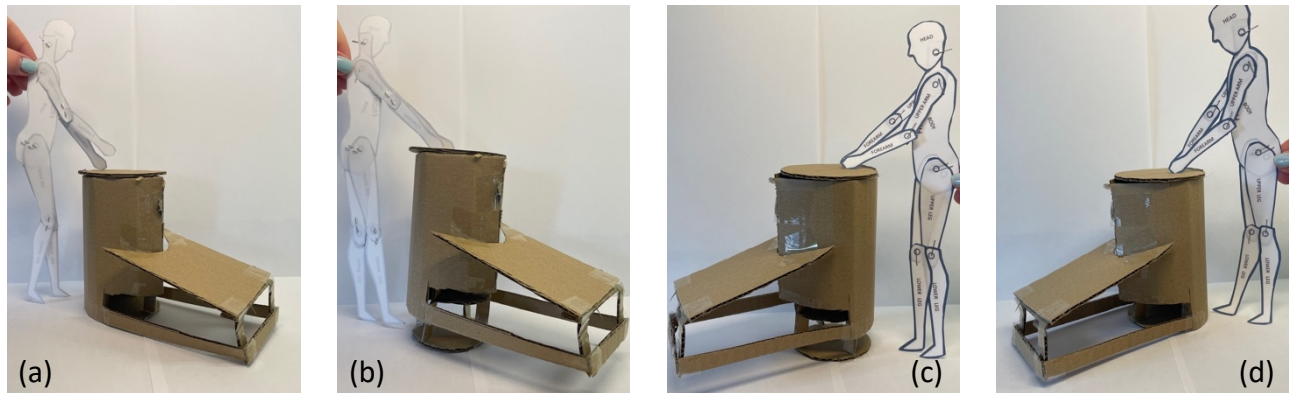


Figure 8 - Cardboard Model with mannequin showing steps of movement

Figure 8 shows the cardboard model that was created on a 1:10 scale. The mannequin in the photo is also scaled 1:10 and is meant to represent the dimensions of a 95th percentile adult male.

Through this process, it was identified that the dimensions would be good for an adult although due to the inaccuracy of this process, further analysis would need to be done to guarantee its ability to be used by the target market.

Take away: The solid base would not provide much sunlight for the grass underneath it. This resulted in the base being redesigned from a solid disk to a ring. This would increase the area of grass that the guinea pigs could graze on and reduce the grass that would die underneath the hutch.

6.3 Computer-Aided Modelling (CAD)

Siemen's NX 11 was used to create the CAD model as it was the software that Archie was most familiar with. CAD modelling is a relatively inexpensive method of modelling as no raw material is needed. It allows for live changes to be made to the model without it being recreated, which saves time. The model can also be used later in the prototyping stage for 3D printing using an STL file.

6.3.1 Siemen's NX Human Analysis

NX Human is a program within NX that can allow analysis between the model and a human. This can be used to identify problems that would have otherwise only been identified once a physical model had been created, which could have been expensive to produce.

To try and analyse the full range of target users. A 5th percentile 8-year-old female using the NHANES database (Figure 9 a&b) and a 95th percentile male adult using the NHANES database (figure 9 c&d) were used. The NHANES was used as it provides a more accurate reading of an average person as the data is collected from a national survey [5].

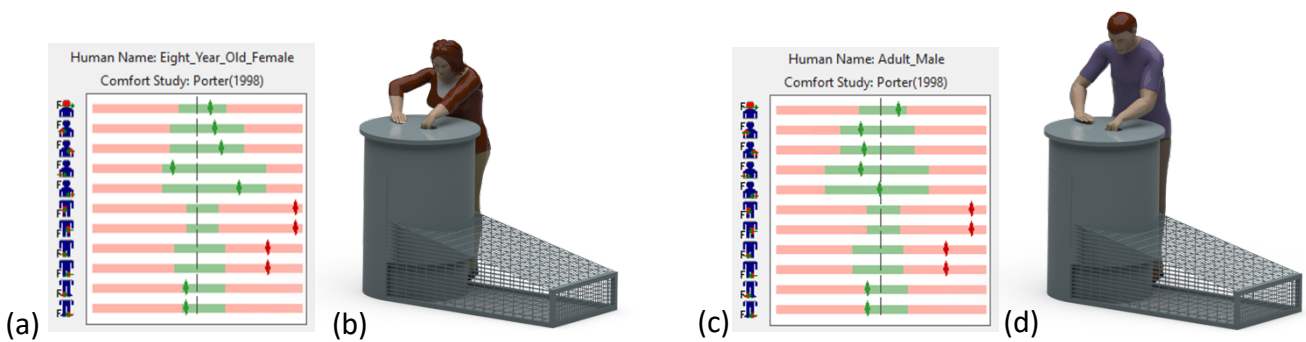


Figure 9 - NX Human comfort analysis of 8-year-old female (a&b) and adult man (c&d)

Figure 9 shows a comfort analysis of the steps of moving the hutch [appendix 17.10]. Figures 9 a and 9 c show each joint. When the point is within the green region it signifies the person could remain in this position for a long time without any pain.

The analysis was successful as the only markers in the red were the joints on the legs which were due to the fact they were standing, otherwise, all other joints were in a comfortable position.

Take away: One problem identified was how the 8-year-old interacted with the handle. They weren't able to move their centre of gravity over the hutch and therefore tended to extend their arms more than the adult. Therefore, the handle was redesigned to be more off centre to shorten the distance they would have to reach.

7 Final Design Concept

The final design concept design was prototyped. Although the design could have been further developed with the addition of new features, it was decided that the purpose of this project was not to produce a fully functional product that was ready for market but rather to prove that the concept could work. The following are a few of the key features of the design. Although other images of the hutch can be seen in [appendix 17.11].

7.1 Lifting System

The hutch's main purpose was to be able to move to new areas of grass without getting caught on bumps in the ground. This design does this by rising off the ground and rotating about its' centre home.

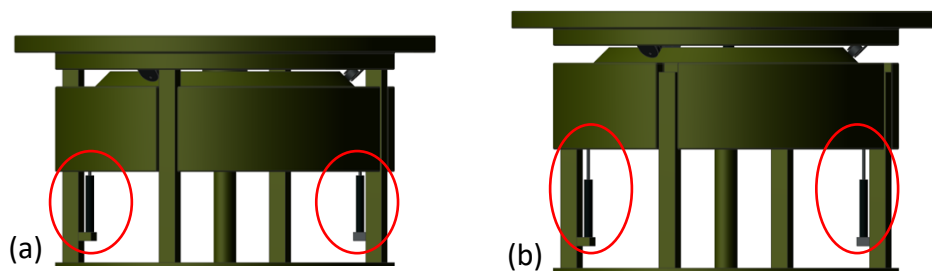


Figure 10 - Diagram of top of Inside Structure with gas struts circled

This is achieved by placing two gas struts with one end fixed to the inside frame, and the other fixed to the rotating disk. Figure 10a shows the hutch in the lower position and Figure 10b shows it in the upper position. The gas struts will be adjustable gas struts that can be finely tuned to the weight of the hutch such that the force required to raise and lower the hutch is minimal.

7.2 Rotational System

Once in the upper position, the hutch is ready to rotate. Three casters attached to the lid are placed at a 45° degree angle and run along a 45° degree slope on the rotational disk as can be seen in Figure 11.

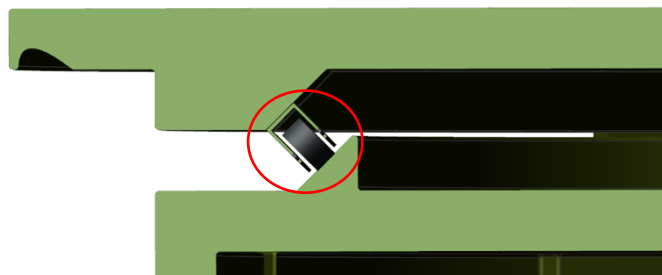


Figure 11 - Cross Section Diagram showing caster (circled) attached to lid and sat on rotational disk

It provides a centralising force ensuring the entire hutch remains centralised to the inside frame by which it rotates about. Everything else (the cage, the outside cover) is all attached to the lid thus when the lid rotates, so the entire exterior of the hutch follows.

7.3 Self-Locking System

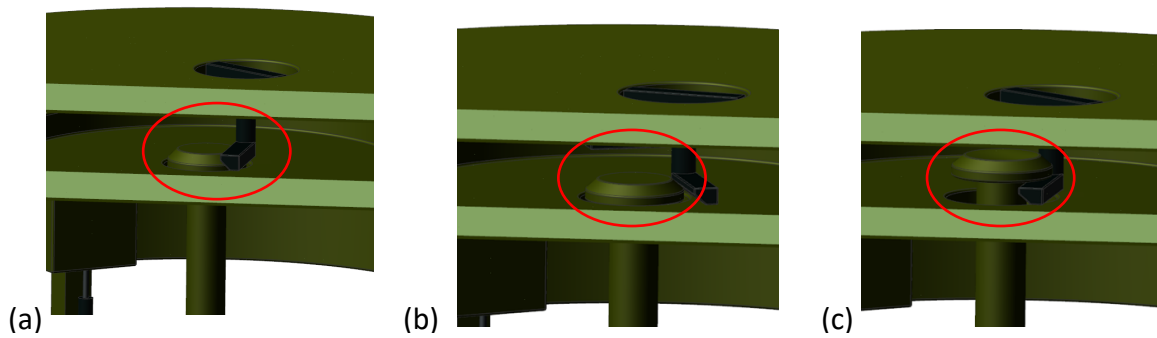


Figure 12 - Cross Section Diagram of Stages of Locking with Handle

To make the process as easy as possible for the user, the hutch will self-lock when it's pushed into the down position. This is due to a spring attached to the handle and a clever design. Figure 12 shows the progression of it being pushed down, the handle moving itself out the way, and then snapping back into place.

7.4 Easy Cleaning System

As identified in the questionnaire in section 3.2.1, users find cleaning the hutches difficult. That is why it was important to design a clever way to allow the users to clean the cage without having to dismantle it.

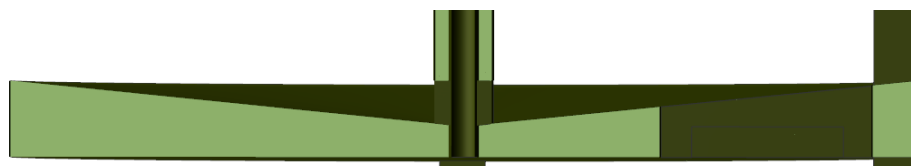


Figure 13 - Cross section of Lower Platform on Inside Structure

Sloping the inside surfaces towards the centre where a hole is (see Figure 13) meaning any water will run through the hutch and out of the bottom onto the ground. Large side doors spanning half the circumference of the outside structure allow easy access when cleaning and accessing the guinea pigs. The centre column is also in tension upwards and therefore, the shape of the surfaces also provides extra structural support.

7.5 Draft free Ventilation System

During hot summers it's important to keep the hutch cool. The clever design of the hutch allows for air to circulate. Figure 14 shows the air flow from the side and down into the hutch. It does this whilst preventing water from entering and keeping the hutch dry.

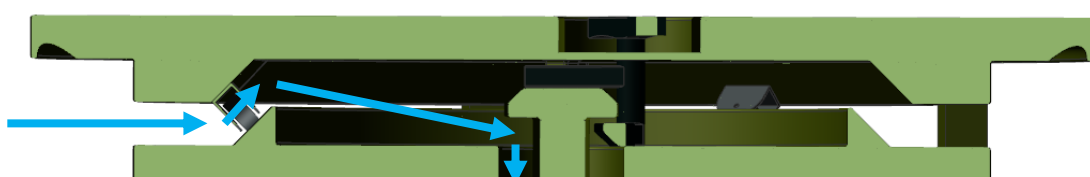


Figure 14 - Cross Section Diagram of Lid and Top of Rotational Disk

8 Prototyping and Testing

Despite all the analysis carried out using the CAD software, a few things still needed testing, such as how the user might interact with the product without instruction. The CAD model was also vastly improved during this process as real-world tests could now be used to see how the product performed. To prototype, engineering drawing were created from the CAD model to be used in the manufacturing stages and can be seen in [appendix 17.12].

Due to the budget being set to only £60, a technical model with functional features, manufacturing process correct, and correct material used was out of the question. As the model was only going to be used to test the human interaction as well as used to analyse its attractiveness. Two models would be created;

1. **A design model.** A scale 3D printed model that would enhance communication. It would allow the entire model to be created, and all features to be seen and explained.
2. **A functional model.** This would allow for some testing of the key features without the expense of using correct materials or including all of the features which might have made it too expensive to prototype.

8.1 Additive Manufacturing (3D Printed) Scale Model

8.1.1 Prototyping

Prototype purpose:

1. Identify any problems at this stage before committing to a full-size functional prototype
2. Demonstration to Omlet to allow for better communication and discussion

Additive manufacturing using 3D printing was chosen due to its rapid prototyping and accuracy as it could be made in a few days with high accuracy. The Raise3D E2, printed with PLA was chosen due to its size allowing a larger model to be printed thus minimising the effect of non-scaled gaps (explained later).

Polylactic acid (PLA) was chosen principally for its ease of use and minimal warping issues due to its low printing temperatures. It comes in a range of colours and is biodegradable [6].

How the prototype differs from the model:

1. The model would need to be scaled by 1:5 to fit within the printing bed of the Raise3D E2. This printer was also chosen for its size allowing for less down-scaling to be done.
2. The gas struts that would be used in MF Hutch would be too big for the scaled model. Springs would have to be used instead as they come in a range of smaller sizes and could be added to the model to make it functional.

To know what springs to use, everything that would be lifted by the spring would be printed first and then weighed.



Figure 15 - Image of the weighing of the Outside Structure to be Lifted by Springs

Figure 15 shows an image of the parts being weighed. The total mass of all the parts was summed to an average of 0.456kg.

Calculations:

$$k = F \div \Delta l \tag{3}$$

where: k is the linear spring constant (N/m), F is the force (N) and d is the change in length of the spring (m).

Due to the scaling down of the prototype, it would only need to lift 10mm off the ground. Using equations 3 and the force equal to the mass of the moving part multiplied by the acceleration due to gravity ($9.81m/s^2$).

$$k = F \div \Delta l = (0.456 \times 9.81) \div (0.01) = 447N/m$$

This is assuming that friction is negligible, therefore the spring would need a spring constant of at least 447N/m. There would be two springs in the prototype so each would only need a constant of half that (223.5N/m). To find this spring a few were taken to the Instron 5944 micro tensile tester.

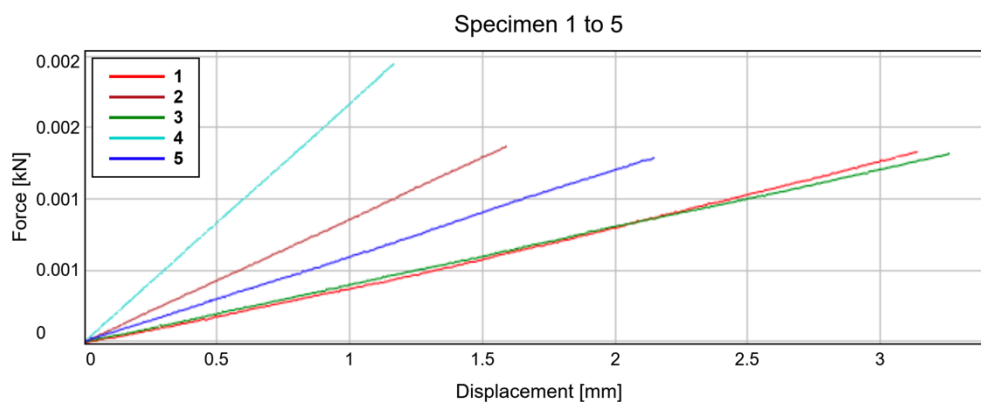


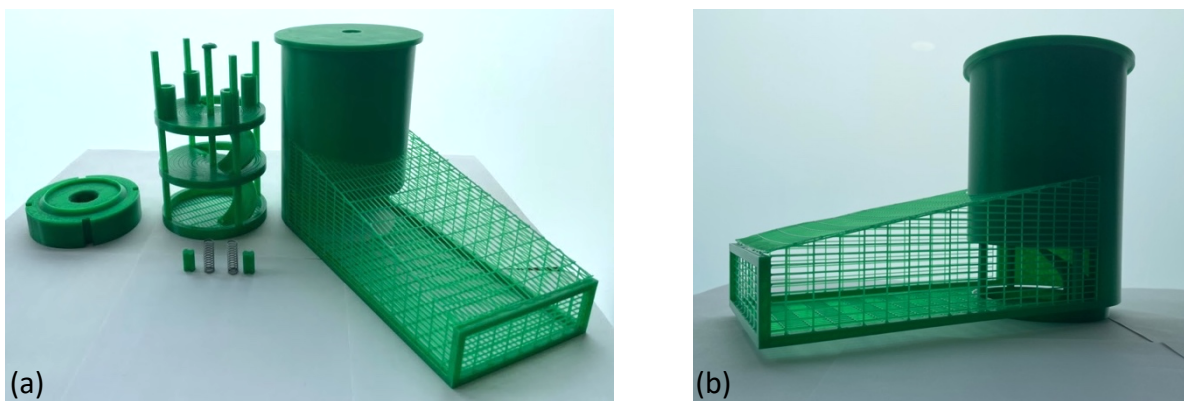
Figure 16 - Graph of Force against Displacement of Different Springs

Figure 16 shows a graph of force against displacement for 5 different springs. From the raw data and using equations 3 we get this data:

SPECIMEN	1	2	3	4	5
SPRING CONSTANT (N/M)	415	880	399	1630	607

Table 4 - Spring Constants for Each Specimen Spring

From Table 4 we can see the best option would be to use specimen 3 as it has the lowest spring constant that is still greater than 223.5N/m. The reason that more springs weren't chosen for measurement was that it was felt that friction would provide a much greater force than just the weight of the object.



This prototype turned out to be very effective in the communication of the aesthetics as it provided a scale accurate model and was therefore deemed a success. The lifting mechanism was also a success, the prototype lifts the entire hutch to the correct height allowing it to be analysed in the testing section (section 8.1.2).

The problems identified when using this prototyping method:

- Non-scaled Gaps. As the parts are required to move, any gap between components needed to be fixed no by less than 1mm. This made the gaps in the prototype not proportional to the model.
- Testing to find the force required to lift the cage is irrelevant due to the change in material and friction.
- Scaling and using springs that are not the size of the gas struts provide an unrealistic image of the hutch.
- Due to the scale and accuracy of the machine, some details and functions were removed. Such as not using wheels or spring on the handles as they would be too small to print.

8.1.2 Testing

The prototype allows analysis of the looks of the model and how attractive it is. As the prototype was fitted with springs it is also a semi-functioning prototype. Despite using springs instead of the gas struts, improvements were still identified. The main one is the design of the handle. It was noticed that when the prototype was pressed into the down position, forces would be applied to the handle that would cause it to tilt off-axis (Figure 17a). This would lead to the prototype being unable to be locked in the down position.

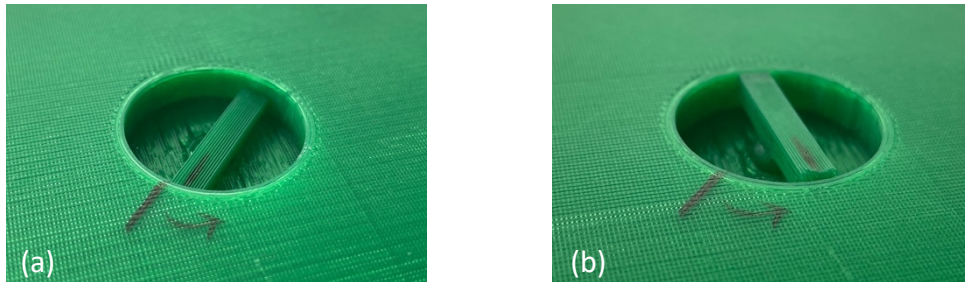


Figure 17 - Images of Handle on 3d Printed Model (a) shows handle down and off axis, (b) shows correction

This would have also caused problems for the user as the handle would have been difficult to turn in this position and could cause a safety problem if the user had their fingers trapped between the handle and the top.

This problem was solved by two changes:

1. Adding two disk shapes above and below the top would restrict the movement of the handle off-axis and would maintain a set distance between the handle and top preventing the user's fingers to be crushed. This would also add to the waterproofness of the hutch and can be seen in Figure 17 b.
2. The hole for the centre column in the rotating disk was enlarged to increase the angle by which the handle can rotate, preventing it from being pushed off-axis.

Both these solutions were added to the model and fixed the problem.

8.2 Functional Full-Scale Modelling

8.2.1 Prototyping

Interaction with a person and the movement of the hutch was tested. Any additional features were not included in the prototype to reduce the cost and time taken to build.



Figure 18 - Images of Full-Scale Prototype, (b) shows hutch in the Upper Position.

Manufacturing was complete at both Loughborough University and Omlet in Banbury. Figure 18 shows the pictures of the final prototype. It took 5 full days to manufacture. Figure 18b shows the hutch in the top position with the cage at a height of 50mm off the ground.

What was tested:

1. **The lifting Mechanism** - The lifting mechanism was the main aspect that was wanted for the testing and so the prototype has deemed a success as it managed to demonstrate that it would work.
2. **The Cage Rigidity** - Due to how it was attached, the solidity of the structure confirmed the design of the cage as a success as the end of the cage didn't dip down under its weight.

Problems identified: There was a large amount of friction created between the inside structure and the outside during its rotation of it. It was felt that this problem wouldn't be transferred to the final design so long as both structures were rigid. This problem was caused by the joining of the outside structure back onto itself as can be seen in Figure 18a by the black masking tape on the right side. This weakness caused the material to form more of a droplet cross-section.

8.2.2 Testing

Functional testing

One of the main PDS points (7.1) is the ability to move across the grass at a height above 48mm. For this test to be successful, the hutch should be able to complete a 360° Degree rotation without any section of the cage dipping below the desired height.



Figure 19 - Images of Full-Scale Prototype in the Upper Position, (c) shows Ruler Measurement of Height at End of Cage

Figure 19a shows the test on a hard and flat surface so that it can be sure the undulations of the grass don't affect the results. A more real-life test was also done on grass (Figure 19b).

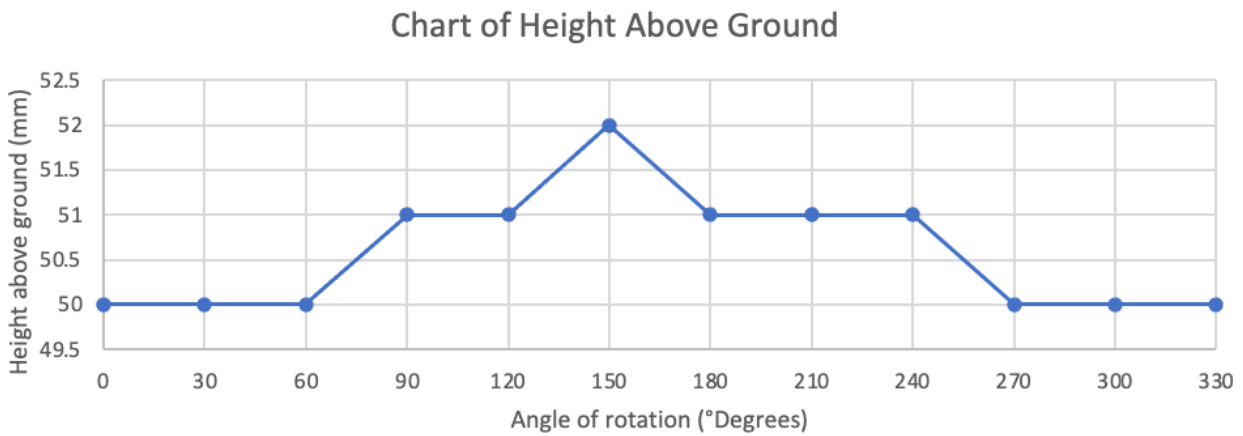


Figure 20 - Graph of Height Above the Ground against the Angle of Rotation

Figure 20 shows a graph of height against angle. Measuring the height of the cage above hard ground from the end of the cage in the centre, would provide an accurate assumption of the lowest point of the cage and ensure no part drooped under its weight. Figure 20 shows the height remains above 50mm though out. The variation in height was created due to the rotation being at a slight angle. The results were deemed successful.

User testing

Ethics Permission for the testing was obtained from the LEON (Loughborough University Ethics Online) and can be seen in [appendix 17.13]. To keep the results obtained unbiased, a friend of Archie's was chosen to conduct the testing, as it was felt that the subjects would give more favourable answers if the questions were asked by Archie. Figure 21 shows an image of the testing.



Figure 21 - Image of User Interacting with Full-Scale Prototype

It was important that the selected people would be a good representation of the global population. Therefore, they were made sure to have heights ranging from the 5th percentile female for ages 8 to the 95th percentile male aged 18 (117cm – 189cm) [7].

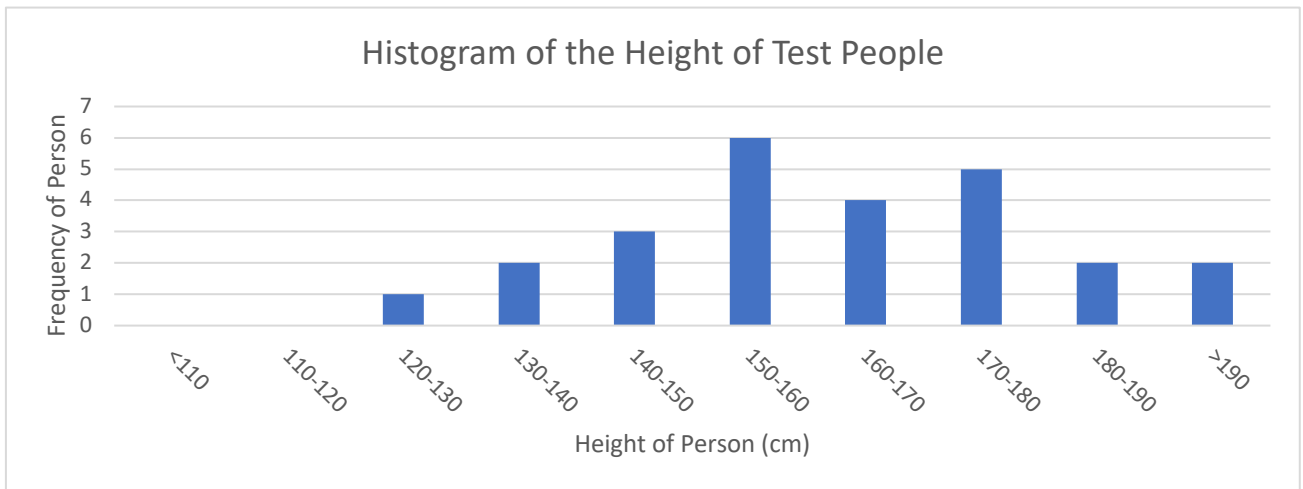


Figure 22 - A histogram of the Height of People selected for Testing

Figure 22 shows a histogram of the height of the people selected. 25 people were selected to be in the testing all had heights ranging from 122cm – 194cm. This range was deemed an acceptable population sample. The questions and graphical representation of numerical answers can be seen in [appendix 17.14].

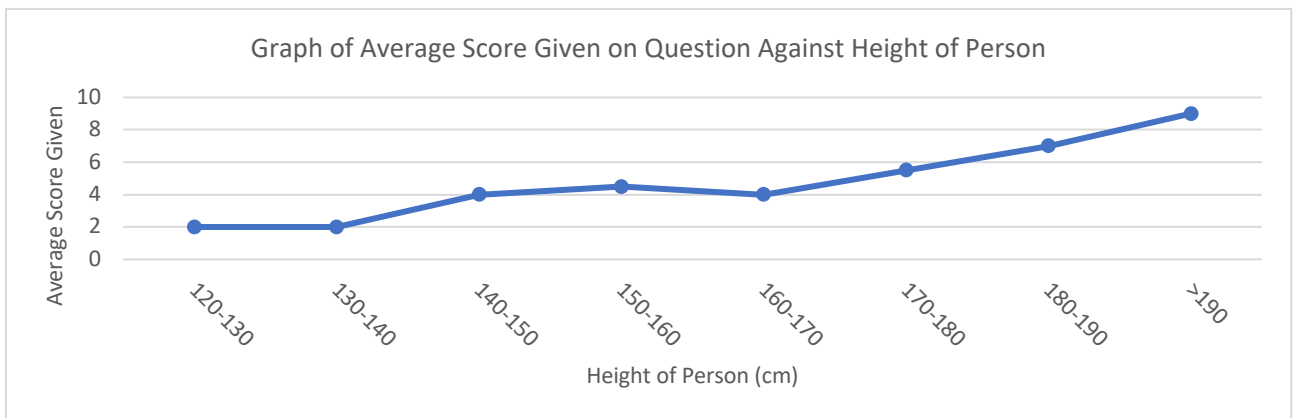


Figure 23 - A Graph of the Average Score given against the Height of the Person

Critical Analysis: There is a positive correlation between height and the average score is given to the question “On a scale of 1-10, how easy did you find it to rotate the guinea pig cage, with 1 being very difficult, 10 being very easy?”. This can be seen in Figure 23. When asked the next question about why they gave that score, one answered “it’s difficult to push down on the lid when I can’t place my whole weight on top” from this and by watching the other people complete the task, it was discovered that on average the people of height below 140cm would only use their arms to push down and people above 140cm could shift their weight over the hutch to aid in pushing it down.

9 Manufacturing Considerations

9.1 Materials

9.1.1 Hutch Material

The Hutch will be made from High-density polyethylene (HDPE) with UV stabilisers due to the unique features that it has. Table 5 shows how each of the advantages of HDPE allows the MF Hutch to meet a specific PDS point.

PDS NUMBER	PROPERTY	REASON FOR CHOICE
6.3	UV stabilised	To be long lasting outside without colour fade or becoming brittle.
6.3	Maintenance-free	HDPE won't rot, warp or crack
6.5	Easy to clean	Easily cleaned with water reduces the time spent cleaning.
1.3	Frostproof	HDPE remains ductile even down to low UK temperatures
4.3/9.2	Non-Toxic	HDPE won't cause harm to either the guinea pig or the user.
1.2	Colourfast	Allows the design to be changed to fit with Omlet Ltd's Branding.
4.2	Recyclable	HDPE can be reused or recycled at the end of its life.

Table 5 - A table of Properties of HDPE that meet PDS points

HDPE is also suitable for the desired manufacturing processes. It is also the same material that Omlet Ltd currently use on their Eglu Go Hutch [8].

9.1.2 Cage Material

The cage would also be made from the same double-layer fully coated mild steel weld mesh that Omlet use for a variety of its products [8]. It would be assembled in the same $75mm \times 25mm$ with $2mm$ wire. As Omlet has determined these dimensions are big enough without letting the guinea pigs out. Table 6 shows how each of the advantages of this material will allow the MF hutch to meet a specific PDS point.

PDS NUMBER	PROPERTY	REASON FOR CHOICE
4.3/9.2	Non-Toxic	HDPE won't cause harm to either the guinea pig or the user.
4.1	Recyclable	Can be reused or recycled at the end of its life
3.7/6.1	Interchangeable	The cage can be replaced using existing Omlet parts.

Table 6 - A table of Properties of Mild Steel Mesh that meet PDS points

The material is also tested strong enough to be self-supporting when under tension due to the lack of drooping under its weight (section 8.2.2).

9.2 Processes

9.2.1 Extrusion

The cage supports [appendix 17.12 Figure 47] would be on a welded box section that is easy to extrude. This process produces an even cross-section at a relatively cheap price which would be essential for compression strength [9]. The uprights of the inside [appendix 17.12 Figure 55] would also be extruded box section.

9.2.2 Cage Stop Welding

The cage [appendix 17.12 Figure 49] would be spot welded and then stamped out into the desired shapes. Spot welding is chosen as it is an incredibly efficient welding technique as no extra material is added, and the process is relatively fast [10].

9.2.3 Powder coating

All of the metallic parts would be powder coated as this provides a great surface finish, available in multiple colours including Omlet’s Green, and also protects any sharp edges left from machining [11].

9.2.4 Rotational moulding

Other components would be rotationally moulded as this would allow for the parts to be hollow, reducing the weight, but also strong and completely sealed [12].

10 Cost and Commercial Considerations

10.1 Cost (BOM) Analysis

Bottom-Up analysis was done to obtain an estimate of the costs of production and the cost which the product should be sold for. The CAD model was used to calculate the exact quantity of material required for each process. The majority of raw data was obtained from Omlet. Table 7 shows the calculations completed.

GBP - USD	1.254015
GBP - EUR	1.187903329
VAT	1.20

Materials Costs per Product

Mild Steel Powder Coated	
Length of 19mmx19mmx1.2mm Box Extrude (m)	4.36
Mass per unit length (kg/m)	0.68
Mass of Box Section	2.97
Metal Fabrication (\$/kg)	\$ 7.00
Total Cost of Box Section (\$)	\$ 20.77
75mmx25mm Mesh (m ²)	1.88
Mass per Square Meter (kg/m ²)	4.77
Mass of Box Section	8.97
Wiremesh (\$/kg)	\$ 3.15
Total Cost of Box Section (\$)	\$ 28.26
HDPE	
Volume of material used (mm ³)	11345136
Mass per mm ³ (kg/mm ³)	9.30E-07
Mass of Used Material (kg)	10.55
Plastic Extrusion HDPE (\$/kg)	\$ 2.00
Total Cost of Box Section (\$)	\$ 21.10
Other Costs	£29.50
Total Material Costs Per Product	\$ 99.63

Design Development Costs:

Design Time (Weeks)	24
Number of Designers	1
Design Overhead £/Week	£1,100.00
Design Costs (Travel, prototyping,	\$1,000.00
Design Costs	\$26,400.00
Tooling Cost	\$100,000.00
Total Development Costs	\$127,400.00

Costings

Estimated Annual Sales	2,000
3 Year Sales	6,000
BOM COST \$	\$99.63
Safety Factor	5%
BOM COST Inc Safety Factor \$	\$104.61
Amortised Development Cost \$	\$21.23
Total Product Cost FOB China \$	\$125.85
Incoming Freight	2.00%
Duty Rate	6.00%
Duty \$	\$6.28
Total Product Cost DDP \$	\$132.14
RRP inc VAT	£319.99
RRP ex VAT \$	\$334.39
Direct Sales	
Gross Profit Direct \$	\$202.25
Gross Profit Direct £	£ 253.63
Gross Margin Direct	60.48%

Table 7 - Table of BOM Analysis

These calculations assume that the break-even point passed after 3 years and that the product should aim to produce a 60% profit margin. Therefore, it was concluded the product would need to be sold at £320 to achieve this.

Take away:

This demonstrates the success of the design as it would be sold for £30 less than the current Omlet guinea pig cage at £350 inc VAT [13]. The design would be competitive in price if added to Omlet’s product range.

10.2 Packaging constraints

Omlet does not sell any of its products in stores, they are only available on its website and sent directly to the customer. Therefore, the products need to be designed to be disassembled into their component parts for packaging. Figure 24 shows the maximum dimensions that can be used by Omlet’s chosen courier. The hutch’s dimensions exceed these numbers. But once split down into the home and cage, they become a more manageable size.

**Very important note.
Critical boxed product dimensions and weight:**

1. Longest dimension (D1) to be ≤ 990mm.
2. Second longest dimension (D2) to be ≤ 590mm.
3. Third dimension (D3) to be ≤ 590mm.
4. $D1 + (2 \times D2) + (2 \times D3) = \leq 3000\text{mm}$.
5. Maximum Weight: 22.67kg

Figure 24 - Packaging Dimension Restrictions of Omlet's Courier

11 Design Evaluation

Upon the completion of the design, prototyping and testing process it is important to see how the product changed since the initial research was done.

11.1 PDS Evaluation

Table 8 shows if each of the points meets the PDS point. Green means it has, Red means it hasn’t and White is unknown and is therefore discounted from the evaluation.

PDS Number	1.1	1.2	1.3	2.1	2.2	3.1	3.2	3.3	3.4	3.5	3.6	3.7	4.1	4.2	4.3	5.1	5.2	5.3	5.4	6.1	6.2	6.3	
Pass?		Green	Green	Green	Green	Green	Green	White	Green	Green	Green	Green	Green	Green	Green	White	Green	Green	Green	Green	Green	Green	Green
PDS Number	6.4	6.5	7.1	7.2	7.3	7.4	7.5	7.6	7.7	7.8	7.9	8.1	8.2	9.1	9.2	9.3	9.4	10.1	10.2	11.1	11.2	11.3	
Pass?	Green	Green	Green	Green	Green	Green	Green	Red	Green	Green	Green	Green	White	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green

Table 8 - Table of if PDS points have been met. Green means Yes, Red mean No, White means Unknown

The final design meets almost all of the PDS points and so can be considered a success. It should be noted that it met all of the project’s important specifications listed in section 4.4, being those considered vital to the project. For example, the addition of the ventilation system (section 7.5) meant it could work in high UK temperatures (PDS point 1.3).

PDS point 7.6 specifies that the hutch must be able to be moved while it contains the guinea pig. This is fine if the guinea pig is within the home, but if it's in the cage, then when lifted, it could be possible for the guinea pig to escape and would need further testing to confirm this.

PDS points 1.1, 3.3, 5.1, and 8.2 are currently unknown as there is no way to validate that they have or haven't been met therefore they are not considered. These include PDS points about packaging in which more work would need to be done to evaluate if the hutch could be dismantled and sent.

11.2 Test Market Evaluation on Attractiveness

The same 25 people used in the testing of the full-scale model were also shown the pictures of the final renders [appendix 17.11]. Archie's friend was also used to conduct these interviews to prevent bias. Some key phrases that were said were:

- "Blends in well."
- "I like the sloped angles."
- "The cage looks quite prison like."

When asked the question "Would you buy this guinea pig cage if you had a guinea pig based on looks alone?" 16/25 said yes with another 5/25 saying maybe.

Though the number of people is not significant to represent a population sample, the overall positive feedback demonstrates the style of the hutch is considered attractive by most people. To obtain a better result a key factor might be the improvement of the style of the cage in further work.

11.3 Project Aims, Objectives, Deliverables Evaluation

Aims, objectives, and deliverables describe the project as a whole, therefore after the evaluation, if it is felt that they have been met then it suggests more than just the success of the design but also the project overall.

11.3.1 Aim Evaluation

The aim can be split into 3 categories which can be seen in Table 9. To see if each is met a score out of 5 is given with 5 being met completely, and 1 is not met.

The application and showcase of PDE Skills	Through the project, a range of skills was demonstrated such as concept ideation and selection, proper design development and use of CAD software to name a few. (4/5 more skills could have been shown if there was more time).
The Design of an ergonomic and attractive guineapig hutch	NX Human analysis shows the comfort level being within the levels required for all target markets. Target market evaluation of attractiveness concludes that the design can be considered attractive. (4/5 The hutches design could be built for a wider range of users).
A hutch that is created with making movement of it as easy as possible and specific to the sponsor (Omlet)	The hutch can be moved with fewer steps than Omlet's Eglu Go hutch and required very little force to move. The design, materials and process are all similar to that of Omlet's current range of products. (5/5 of all relevant steps were made to ensure the mechanism of the hutch is easy to move and specific to Omlet).

Table 9 - Table of Aims and Evaluation

11.3.2 Objectives Evaluation

The objectives of the project are as follows [1]. A score out of 5 was given to determine how well each objective was met with 5 being met completely, and 1 is not met:

Research the target market until a target user has been identified through primary and secondary research.	5/5 Steps like the questionnaire went further than previous projects in identifying a target market.
Complete initial technical and market research until enough knowledge is gathered to back up potential initial ideas.	5/5 detailed research into existing products and ergonomics was obtained to validate each initial idea.
Understand the target user's needs until enough information is obtained to draft a PDS.	5/5 A detailed PDS was created covering all major points specific to the project.
Develop initial concept ideas that fit the current specification until a potential solution is reached and all the research has been explored.	5/5 A large variety of different development techniques were utilised to develop initial concept ideas.
Understand the manufacturing options and the benefits of each for every component of the product.	4/5 Understanding of materials, costs and other restraints was obtained. More research into the exact production of each part could be done given more time.
Develop the ideas until it is feasible to manufacture and meets the customer's needs.	4/5 All required PDS points were met but further research into the manufacture of each part is required.
Undertake a prototype creation and testing to develop the design until the design has been validated.	5/5 Two prototypes were made to validate the product, and each was tested extensively.
Evaluate the final product and provide recommendations for future work.	5/5 Extensive evaluation of final product and future work was completed.

Table 10 - Table of Objectives and Evaluations

11.3.3 Deliverables Evaluation

All Deliverables were complete and can therefore be deemed successful.

12 Project Planning Evaluation

Overall, the planning was kept on track by keeping as close to the project Gant chart plan as possible. One thing learned was the importance of setting deadlines for sections that need to be completed on certain dates. For example, when the brief was changed by Omlet just before the Christmas break, if the deadline for the start of prototyping hadn't been made then there might have been time to create only one prototype which wouldn't have allowed for the full range of tests to be completed.

What was also important but was only fully understood later in the project was the need to organise files from the beginning on the OneDrive. Due to the number of CAD files and other photos, having the neat folder organisation system meant no file was ever lost.

13 Future work

13.1 Packaging

Despite creating a clever system to reduce the number of parts required to assemble the project, further work into reducing the size of the packaging could be done to optimise the costs of shipping and delivery. Also, testing could be done on how the new packaging system affects the strength and rigidity of the product.

13.2 Cage Design

As identified in the testing stages the design of the cage creates a sense of prison-like appearance. Further work into redesigning the cage to blend in better with the environment whilst maintaining its protection from predators could be considered.

13.3 Closing the Cage

On cold winter days to limit the number of cold air circulations you might want to be able to shut the cage. This could also help if moving the hutch to another area of grass rather than just rotating it, you could lock the guinea pigs inside while transporting it.

14 Conclusion

The literary review of previous projects and ergonomic data as well as the other sources on guinea pig care provided the foundation that was required for the hutch to be designed. The ergonomic data and research into existing Omlet products were crucial in determining the dimensions required. The additional research was vital in developing an understanding of requirements for both the user and guinea pig and these were used in the hutch's development.

The primary research in the form of a questionnaire and analysis of existing products took the research a level above the previous Loughborough projects and was heavily used in the creation of initial concepts. It was also predominantly used in the identification of customer needs and subsequently used in the evaluation stage to justify the design choices.

The creation of a mission statement, customer needs, and PDS all allowed for an effective understanding of the project requirements and were used towards the end of the design evaluation to determine the success of the project.

Ideation of a wide range of initial ideas and the use of an effective Pugh matrix to select one that best fitted the brief allowed for a good range of design opportunities to be identified. This also gave Omlet a good variety of paths by which they could choose to investigate.

An idea was chosen and developed using a wide range of analytical and out the box techniques to ensure every opportunity was explored and the design would remain on track to pass validation in later design evaluation stages.

Prototyping of two models, one scale and one full size, allowed for further development and testing that could only have been done through this process. Crucial problems were identified in the process and improved upon such as the handle design and outer frame rigidity. They will also be essential for the communication of the project in later stages of the project.

Both manufacturing, costing and commercial considerations were researched and evaluated to ensure the product would be compatible with Omlet's product range. The costings were also used for a justification of the design.

The evaluation of the design was extensive, using a variety of methods to ensure no area of the hutch was not evaluated. The design meets most of the PDS points with the identification of further work.

Key successes of the project:

- Creation of a detailed design that was thoroughly developed and well resolved.
- The fabrication of two complete models that were both used for testing specific objectives.
- A well thought out design evolution that highlights areas for improvement.

The success of the project proves that I am capable of designing and developing a novel and complex product with mechanical, user and aesthetic all considered.

Key learning outcomes:

- Further knowledge and understanding of the PDE skills are required to create and develop an idea ready for market. Such as how to select which concept to develop.
- Practical experience in manufacturing prototypes both in fabrication and additive manufacturing, as well as an understanding of the limitations of each.
- Further understanding of the social and ethical requirements involved in the creation of a product.

Implications to the wider society:

- This project will provide a good start for a product for Omlet Ltd if they decide that they want to continue my development and implement my suggested future work. This could result in a new product to add to their range.

Overall, the project has produced a guinea pig cage that is easy to move and fits well with the existing Omlet product range. Through its clever yet intuitive design, the MF hutch has achieved what the project had aimed to do.

15 Acknowledgements

I would like to thank Dr Ian Graham for his continued support throughout the project. He has gone out of his way to help and guide me in this project, and I've learned a lot from him.

I would also like to thank Mr Simon Nicholls of Omlet Ltd who sponsored this project, for his advice given during its design and for giving me the experience and time in the Omlet workshop. Also thank you to the entire team at Omlet, specifically Charlie Watson for helping me fabricate my prototype.

I would like to thank the Wolfson school staff, manufacturing workshop staff, and all who aided in this project by producing the prototypes.

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17 Appendix

17.1 Questionnaire Ethics Approval

(s) Archie Buxton

Saturday, March 26, 2022 at 16:33:51 Greenwich Mean Time

Subject: LEON Decision: 6329 Moving Guinea Pig Cage Device (Omlet Individual Project) (Initial Research)

Date: Tuesday, 7 December 2021 at 1:07:31 pm Greenwich Mean Time

From: donotreply@infonetica.net <donotreply@infonetica.net>

To: (s) Archie Buxton <A.D.Buxton-19@student.lboro.ac.uk>

CC: Leon <Leon@lboro.ac.uk>, Ian Graham <I.J.Graham@lboro.ac.uk>

Project Title: Moving Guinea Pig Cage Device (Omlet Individual Project) (Initial Research)

Project ID: 6329

Dear Archie,

The proposal above has a favourable ethics decision based on review by School of Mechanical, Electrical and Manufacturing Engineering.

You must ensure that you follow the latest Government guidance on COVID-19. You are not permitted to begin data collection which requires any face-to-face interactions with participants in person without the appropriate risk assessments signed by the School Safety Officer/the Dean. Where possible studies should be conducted online. Please refer to the [COVID-19 FAQs](#) for the latest guidance on conducting studies involving human participants.

Studies can be moved online without requiring an amendment, unless this substantially changes the study in which case an amendment is required.

You are required to report any incidents that have an adverse effect using the Adverse Events Report form in LEON.

This decision applies to activity undertaken from the date of this email until 16/07/2022 (*however, please note that if this date has already passed this decision is invalid - you should contact your School*) If the study continues beyond the stated end date you should submit a request for an extension.

Please contact your School if you have any queries regarding this decision.

Kind regards

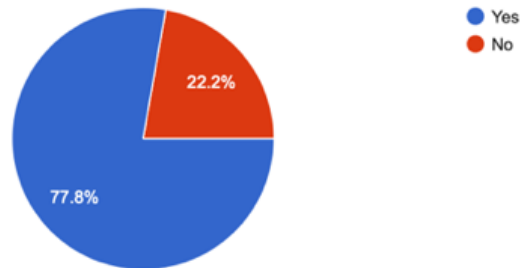
LEON Administration

LEON@lboro.ac.uk

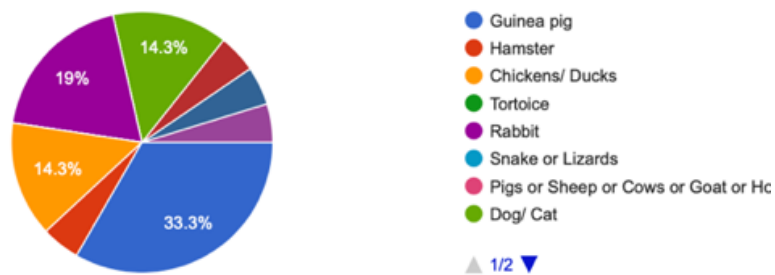
Figure 25 - Email of Ethics conformation for Questionnaire

17.2 Questionnaire

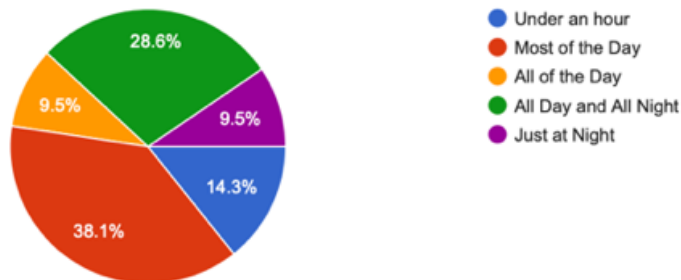
(a) Have you ever taken care of an animal that is required to live in a cage and live outside?
27 responses



(b) Please select what animal you have taken care of that live outside in a cage? (If you have multiple animals, please choose your animal that's closest to the top of the list.)
21 responses



(c) How long would they spend outside on average?
21 responses



(d) Does your animal ever spend time in live grass?
21 responses

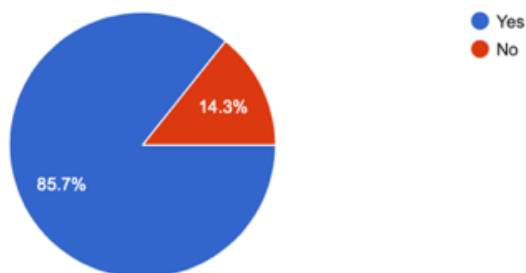
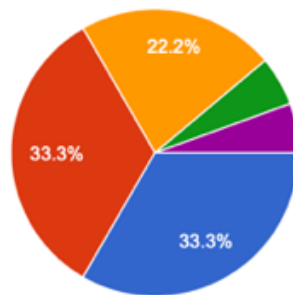


Figure 26 - Questionnaire answers [1]

(e) What does the animal spend most of it's time in?

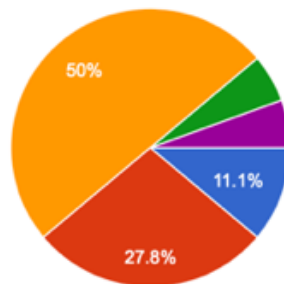
18 responses



- Hutch/ Home/ somewhere they can sleep
- A Hutch with a running area
- A cage just to run around in, it sleeps else where
- Fenced off area
- Our House

(f) Do the animals stay in the hutch/cage while it's being moved?

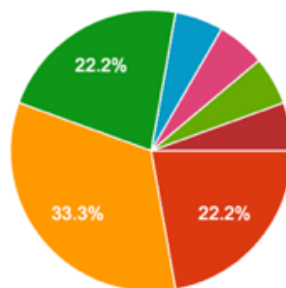
18 responses



- Yes
- Sometimes
- No
- It's not moved
- do not move it

(g) If you move the hutch/cage, how many people does it take?

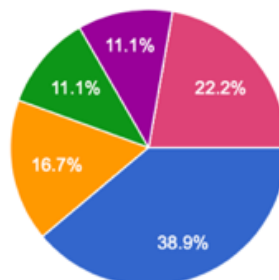
18 responses



- It's electronic / it moves it's self
- The children can do it
- Just one adult
- Two adults
- More than two adults
- It ain't moving
- do not move it
- Cage for dogs outside pen
- It's a fixed kennel

(h) How often do you have to move the hutch/cage/run

18 responses



- It doesn't get moved
- Multiple times a day
- Once a day
- every two days
- every three days
- between four and six days a week
- every week
- less than once a week

Figure 27 - Questionnaire answers [1]

Figure 26a shows that 21 out of 27 people who responded to the survey filled the criteria of having an animal that lives in a hutch outside. The following statistics are from just these 21 people.

Figure 26b shows that most of the animals kept in cages on grass are either Guinea Pigs or Rabbits this is good as it means the majority of the following answers will be tailored towards the target animal.

Figure 26c shows that 76.2% spend over an hour over the course of the day outside. This is important as it means the hutch will need to move over the course of the day due to the requirements for new food and clean living for the guinea pigs.

Figure 26d shows most of the animals kept in cages are also kept on grass.

Figure 26e shows most of the animals spend most of their time in a hutch with sleeping facilities

Figure 26f shows most animals are removed while the hutch is being moved

Figure 26g shows most hutches can be moved with a single adult.

Figure 26h shows 61.1% of people have hutches that they move. The most common frequency of moving is every week.

The final question was “Is there anything you find hard when it comes to moving the hutch/cage/run?”

1. No, I am very strong
2. Nope, because it doesn't get moved
3. no just lift it and shift it slightly to the side where it did not move it
4. Moving all of the decorations and toys etc. can be time-consuming
5. Weight and serval modular parts
6. Don't move chicken run
7. Hedgehogs are spiky and also, they do not like being moved into a separate box
8. An easier way to clean the cage/crate without moving it outside
9. Moving the cage by myself with the rabbit in it
10. Keeping the animal securely in it
11. The bulkiness and how the fabric of the run tears easily with their sharp claws
12. The weight of it
13. Moving all the food mess
14. so low down
15. A bit heavy
16. The hutch not being able to slide or just pulled along the ground easily.

Some things to point out are the moving of other items in the cage, the height or shape of the cage making it difficult to move and the difficulties of removing the animal before moving it.






17.3 Initial Research: Existing Products

Movability

These images show some products that are currently on the market and that have been useful in the development process.

	<p>Link:https://www.amazon.co.uk/dp/B07V56SYXP?psc=1&th=1&linkCode=g_s2&tag=vortexsky-21</p> <p>Price: £261</p> <p>Advantages: Open roof allows access to the guinea pigs at any time.</p> <p>Disadvantages: The price is relatively high when compared to the others. Difficult to move due to its weight and having no wheels.</p>
	<p>Link: OkieCritters.com</p> <p>Price: Homemade</p> <p>Advantage: Good use of vertical space and on wheels so easy to push.</p> <p>Disadvantage: Not good at turning. Not easy to access the guinea pigs when at the bottom due to the size of that door.</p>
	<p>Link:https://www.thehenhousecollection.com/blog/what-is-a-chicken-tractor/</p> <p>Price:£250-£450</p> <p>Advantage: Easy to move and well balanced due to the position of the wheels.</p> <p>Disadvantage: Relatively expensive.</p>
	<p>Price: £50-£100</p> <p>Advantage: Four wheels make it easy to move.</p> <p>Disadvantage: No access to grass.</p>
	<p>Link:https://www.omlet.co.uk/shop/guinea_pig_products/eglu_go_guinea_pig_hutch/</p> <p>Price: £299</p> <p>Advantage: Well designed.</p> <p>Disadvantage: No wheels to move it and if you add the wheels, it is still quit heavy to move.</p>
	<p>Advantage: Three wheels with one that can rotate allows for easy movement.</p> <p>Disadvantage: Requires a flat surface on which to move.</p>

Types of hutches

	<p>Link:https://www.aosom.co.uk/item/pawhut-rabbit-hutch-off-ground-small-animal-guinea-pig-house-125-5-x-100-x-49cm-3~D51-181-1.html</p> <p>Price: £96</p> <p>Advantage: Simple layout with a small area to sleep and a large area to feed. Relatively inexpensive.</p> <p>Disadvantage: Difficult to move and difficult to access guinea pigs due to size of door.</p>
	<p>Link:https://www.omlet.co.uk/shop/guinea_pig_products/eglu_go_guinea_pig_hutch/</p> <p>Price: £299</p> <p>Advantage: Easier access to the guinea pigs and a well-made product.</p> <p>Disadvantage: Difficult to move as there are no handles</p>
	<p>Link:https://www.amazon.co.uk/dp/B07V56SYXP?psc=1&th=1&linkCode=gs2&tag=vortexsky-21</p> <p>Price: £261</p> <p>Advantage: Easy access to guinea pigs.</p> <p>Disadvantage: Difficult to move and have to bend down to access the guinea pigs</p>
	<p>Link:https://www.amazon.com/Ferplast-CAGE-CAVIE-80GREY/dp/B0133LNCJS</p> <p>Price: £159</p> <p>Advantage: Can be placed on top of a surface to be closer to the guinea pig, light so not hard to move.</p> <p>Disadvantage: No real grass and can't move easily, no handles.</p>
	<p>Link:https://homeandroost.co.uk/product/6ft-kendal-guinea-pig-hutch-and-run/</p> <p>Price: £210</p> <p>Advantage: Well made and has access to live grass, but also easy to access the guinea pig when in the upper section.</p> <p>Disadvantage: Difficult to move and with the ladder underneath, the hutch can only be dragged in one direction.</p>

Types of runs

	<p>Link: https://www.omlet.co.uk/shop/guinea_pig_products/zippi_guinea_pig_tunnel_system_and_burrow_pipe/</p> <p>Price: £234</p> <p>Advantage: Easy to move the run as it's attached with a tube.</p> <p>Disadvantage: Can't move further away from the hutch and can't access the guinea pig when in the tunnel</p>
	<p>Link: -</p> <p>Price: -</p> <p>Advantage: Can be any size area. Easy access to guinea pigs.</p> <p>Disadvantage: Doesn't fully protect against predators as there is no roof on the cage when the animal is outside.</p>
	<p>Link: https://www.omlet.co.uk/shop/guinea_pig_products/outdoor_guinea_pig_run/</p> <p>Price: £679</p> <p>Advantage: Very easy to access guinea pigs when outside.</p> <p>Disadvantage: Very expensive due to its size and very difficult to move.</p>
	<p>Link: https://www.guineapigcagesstore.com/candc-cage-large</p> <p>Price: \$83</p> <p>Advantage: very easy to move, can be any shape</p> <p>Disadvantage: can't move with guinea pigs inside. Doesn't protect against predators.</p>
	<p>Link: -</p> <p>Price: -</p> <p>Advantage: Cheap to make and protects them from predators.</p> <p>Disadvantage: Not that easy to access guinea pigs and can't move without letting the guinea pig out.</p>

17.4 User Persona

Ava Andrews

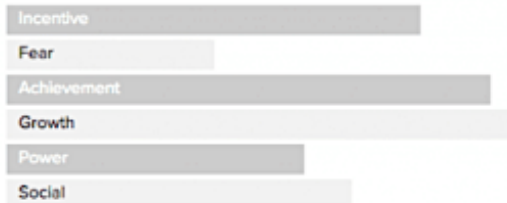
Age: 45
Education: BSc Geography University of Plymouth.
Job: Stay at home mother.
Children? 3
Relationship? Married 15 years.

Friendly	Clever	Go-getter
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"I feel like there's an easier way for me to get into a healthier lifestyle"

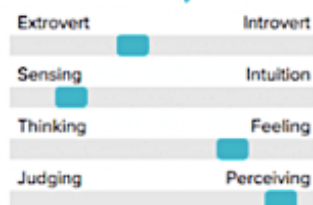
Motivations



About Me:

Hi, I'm Ava, I'm a mother of 3 and love every minute of it. Well not every minute. But I do find it satisfying and heart-warming watching my beautiful children grow older ever day. Alex our youngest daughter is getting a bit lowly now her two older brothers are off boarding at school all term time. Therefore, we decided to get her a little guinea pig called Bubbles. He's a little golden one. Alex chose the name. Although it gets hard having to now care for both Alex and Bubbles.

Personality



Challenges & Pain Points:

- Care for both Bubbles as well as the rest of the family
- Bubbles' cage is heavy to lift, therefore the cage only gets moved when the husband is home.
- Getting older and starting to get back problems.
- Grass keeps dyeing under the cage as it doesn't get moved often enough.

17.5 Full Product Design Specification (PDS)

PDS	CN	SPECIFICATION	RANKING
		Aesthetics & Environment	
1.1	5.4	The MF should have instructions clearly labelled	Secondary
1.2		<u>The MF should match Omlet’s branding/colour scheme/ shape</u>	Tertiary
1.3	4.1	<u>The MF should work within the 95th percentile England temperatures range (35°C to -10°C)</u>	Secondary
		Costs (including VAT)	
2.1	2.4	The MF must not cost more than double the price of the Omlet of Zippi Guinea Pig Tunnel System (£119.92= double cost taken 18 th November 2021)	Secondary
2.2	2.4	The MF must not increase the cost of postage of Omlet of Zippi Guinea Pig Tunnel System (£5.99 taken 18 th November 2021)	Secondary
		Customer & Ergonomics	
3.1	2.1	The MF should be designed for current/ future guinea pig owners	Primary
3.2		The MF should also be designed for Omlet Ltd	Secondary
3.3	6.3	The MF must function during the life of the Guinea pig (5.5 years)	Secondary
3.4	2.1	<u>The MF must be able to be used by all ages (8+ years old)</u>	Primary
3.5	2.3	The MF must be designed to be used by people whose size ranges between the 5 th and 95 th percentile and whose strength is above the 5 th percentile.	Primary
3.6		The MF must be able to be set up and used by the target market	Primary
3.7		The MF should be designed to be sold with existing Omlet Ltd products	Secondary
		Disposal & Materials	
4.1		The MF must be able to separate recyclable and non-recyclable materials	Secondary
4.2		<u>The user must be able to recycle all recyclable materials</u>	Secondary
4.3	5.5	<u>The MF must be made using non-toxic, non-flammable and non-harmful materials</u>	Secondary
		Documentation & legal	
5.1	5.4	The MF should provide documentation on how to use it.	Tertiary
5.2	5.2	<u>The MF must comply with RSPCA standards.</u>	Primary
5.3		The design and Development of MF must comply with ISO 9001:2015	Primary
5.4	5.3	The MF must follow the General Product Safety Regulations 2005 (GPSR)	Primary
		Life in service & Maintenance	
6.1	6.4	Any parts should be easily replicable if damaged.	Secondary
6.2	5.4	Any assembly required by the user should be easy to understand and achieve.	Secondary

6.3	6.2	The MF shouldn't be designed to need maintenance over its life	Secondary
6.4	6.4	If maintenance is required, it should be able to be carried out by the user	Secondary
6.5	6.1	The MF should be easy to clean	Secondary
		Performance & Function	
7.1	4.3	<u>The MF should move over grass that contains bumps less than 48mm easily</u>	Primary
7.2	3.1	The MF should allow the user to move it to a new area of grass.	Primary
7.3	1.2	The MF must protect the guinea pigs from predators.	Primary
7.4		The MF shouldn't require the user to bend over more than 60° to prevent back problems.	Secondary
7.5		<u>The MF should require minimal effort (>91N 5th Percentile female 8 year old) over the entire movement of the hutch.</u>	Primary
7.6	3.3	The MF should be able to move when containing guinea pigs	Secondary
7.7	2.5	The MF should allow access to the guinea pigs at all times.	Secondary
7.8	1.5	The MF should provide all the functionality of a regular hutch (food, water, bed...)	Tertiary
7.9	2.2	The MF should be able to be moved with the user's hand only	Tertiary
		Quantities	
8.1		The MF will be designed for mass manufacture	Secondary
8.2		The MF will have 100 units manufactured and sold in the first year.	Secondary
		Safety & Standards	
9.1	5.3	The MF must not put the user at risk	Primary
9.2	5.2	The MF must not put the guinea pig at risk	Primary
9.3	5.4	The MF must have any hazards identified	Secondary
9.4		The MF must comply with ISO 10377:2013	Secondary
		Size & Storage	
10.1		The MF should be as small as possible while fulfilling all functions	Secondary
10.2		The MF should be easy to post (1.5m depth x 3m combined length and width (Royal Mail))	Secondary
		Testing	
11.1		<u>The MF should be prototyped and tested</u>	Secondary
11.2		The MF should pass multiple tests to test the performance of it	Secondary
11.3		Final testing should be approved by the ethics board	Secondary

Table 11 - Full Product Design Specification [1]

17.6 Initial Ideas with analysis

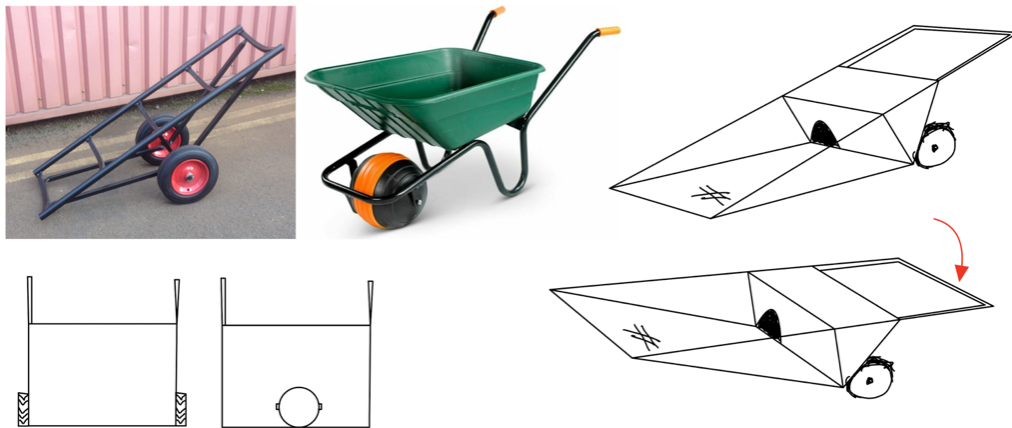


Figure 28 - Initial Idea 1 [1]

Inspired by a one-wheeled wheelbarrow. Idea 1 (Figure 27) can be designed with one wheel or two wheels. The area above the wheels will be a home and the outdoor area will sit on the grass. It has fenced all around to ensure protection from predators.

- ✓ Only requires one step to move it.
- ✓ One wheel allows for more agile moving.
- ✗ Requires a constant down pressure when moving, so not very ergonomic.

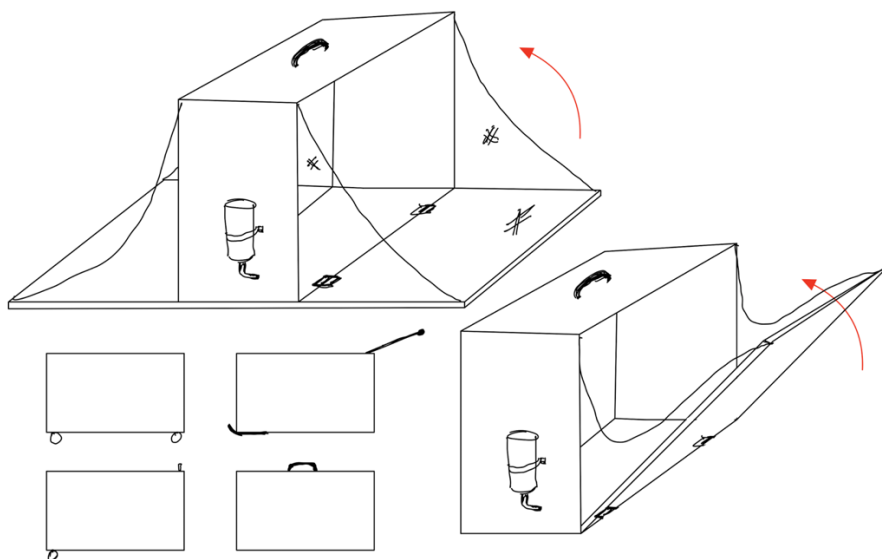


Figure 29 - Initial Idea 2 [1]

Inspired by suitcases. Idea 2 (Figure 28) has two fold down sides to expanding the area in which the guinea pigs can move about. The suitcase could be fitted with two wheels, one wheel or even sledges. The size of the suitcase would be big enough that even when closed the guinea pigs aren't claustrophobic.

- ✓ Folds up into a small footprint when you need to transport the guinea pig
- ✓ Not heavy due to the minimal materials used.
- ✗ If required to be lifted, the handle position results in a poor ergonomically position.
- ✗ When moving requires multiple steps to set up.

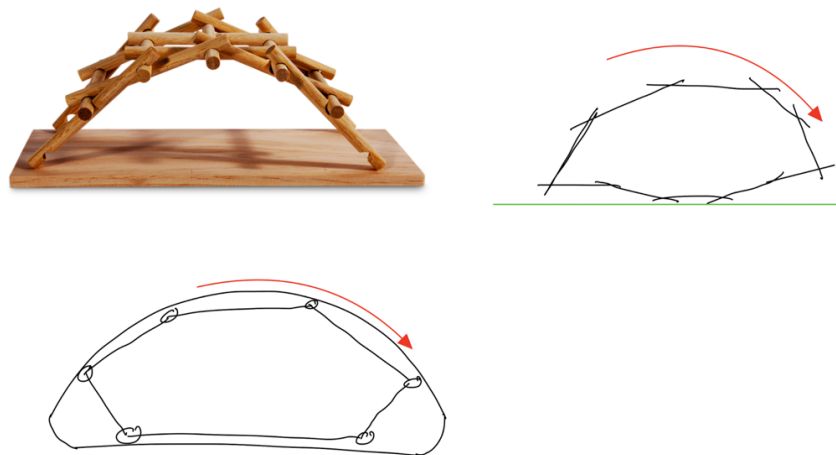


Figure 30 - Initial Idea 3 [1]

Inspired by Leonardo da Vinci's bridge idea 3 (Figure 29) might be a big set of tracks that can be pushed along, they collapse when they are rolled under or might just be a development on the 'tank' with a big track that goes around a set of smaller wheels.

- ✓ Minimal material, and therefore easy to repair and maintain.
- ✗ Difficult to push forward, might have to bend down.
- ✗ Would require lots of development and testing to ensure that the design works.

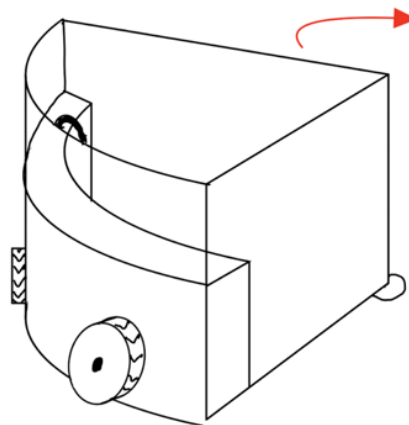


Figure 31 - Initial Idea 4 [1]

Idea 4 (Figure 30) has the handle on the outside as well as wheels. The handle on top is to be pushed round in a circle.

- ✓ Wheels make it smooth to move.
- ✗ Difficult if it encounters a bump, as low ride height.
- ✗ Only goes in circles. This may result crop circles in grass.

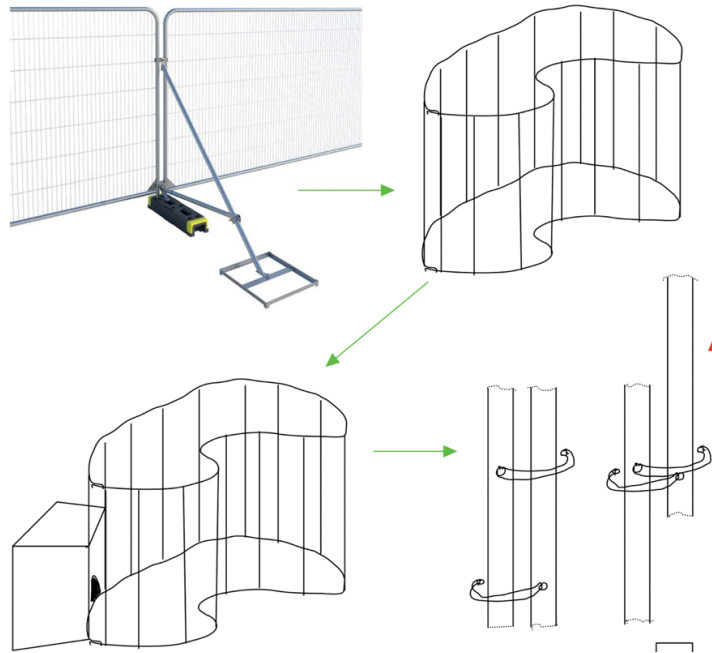


Figure 32 - Initial Idea 5 [1]

Inspired by builders fencing, idea 5 (Figure 31) is a circle of small fence posts that can be lifted individually. This means that the fence can be moulded into any shape or size.

- ✓ No weird grass marks as the fence can be put in unlimited different positions.
- ✓ Easy to access guinea pigs as no roof and cage can be lifted over the guinea pigs.
- ✗ No protection from predators from above, due to the lack of roof
- ✗ Only goes in circles. This may result in weird patterns on the grass.

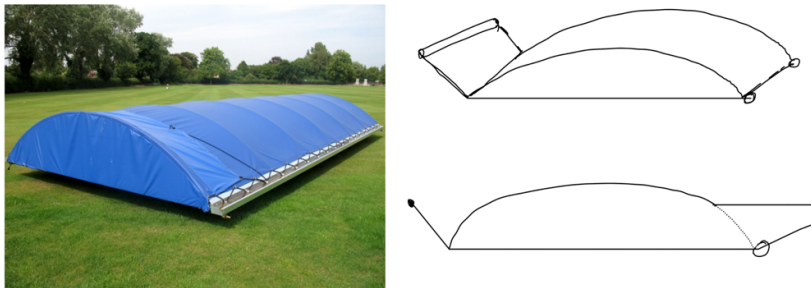


Figure 33 - Initial Idea 6 [1]

Inspired by some cricket covers, idea 6 (Figure 32) is a very light structure that can be lifted at the opposite end of the wheels. The bottom image shows a home placed on the other side of the wheels; this would act as a counterbalance making hutch feel even lighter.

- ✓ The home area at the back makes it very feel light to lift.
- ✗ The handle is not attractive.
- ✗ The force required to lift the hutch will vary depending on the position of the guinea pig and what is in the home.

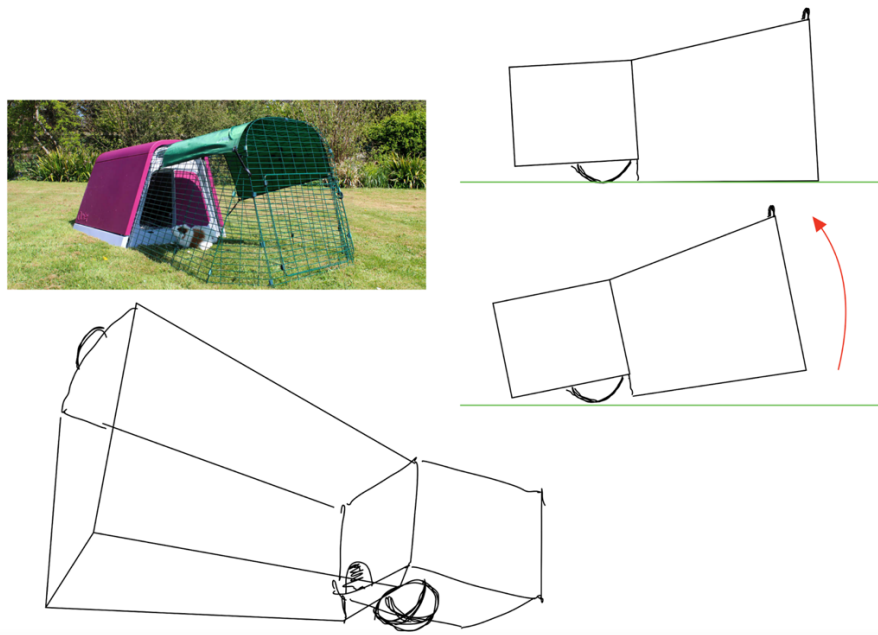


Figure 34 - Initial Idea 7 [1]

Inspired by the Omlet hutch, idea 7 (Figure 33) consists of a round bowl underneath the home of the hutch. The bowl is also positioned over the centre of mass thus making it feel lighter.

- ✓ The bowl makes it very easy for lifting and rotating of the hutch.
- ✓ Can be moved with one hand.
- ✗ The hutch might tip to one side once lifted making it to be difficult to rotate.

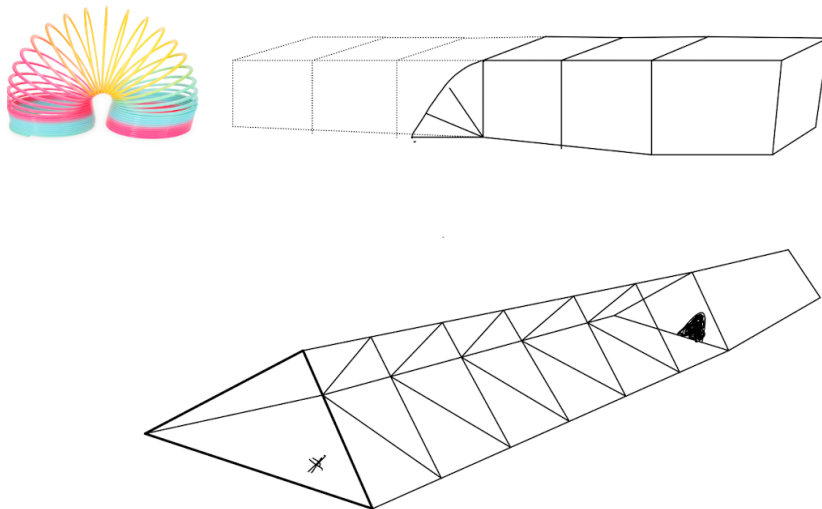


Figure 35 - Initial Idea 8 [1]

Inspired by a slinky. Idea 8 (Figure 34) consists of a series of sections connected by a flexible wire mesh. This allows the product to stretched out or collapsed into whatever length the user wants. This could come in many different cross sections. From the triangle, square, and half-circle.

- ✓ Easy to extend the grass area
- ✓ Easy to access the guinea pig by lifting the grass area.
- ✗ The grass area bit only extends in one direction.
- ✗ Persistent predators might get under the grass area protection.

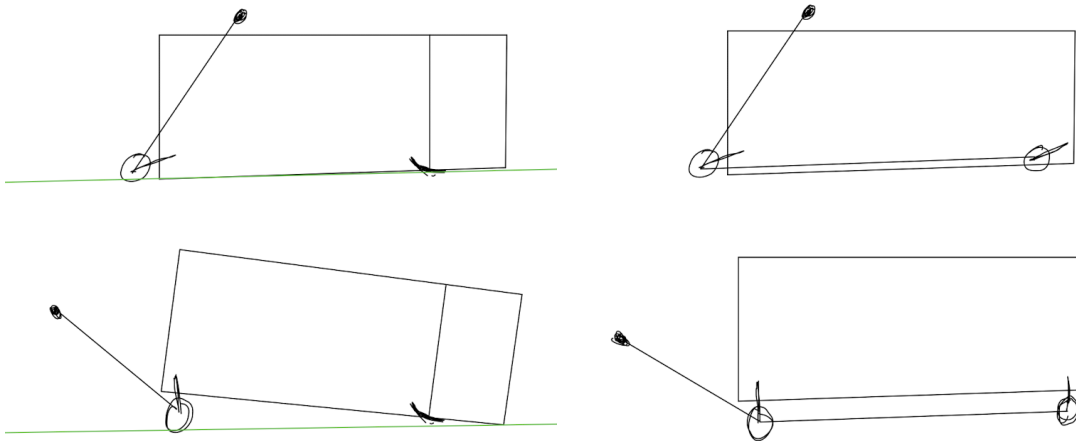


Figure 36 - Initial Idea 9 [1]

Idea 9 (Figure 35) is created to be a one action way of moving a cage. It consists of grabbing the handle and pulling. This will push down the wheels allowing the whole hutch to be dragged. This can either be two wheels or four wheels.

- ✓ Fast and easy move. With only one action.
- ✗ Two wheels mean that it's difficult to pull because you will be dragging it.
- ✗ Four wheels require more force for them to be pulled up onto the wheels.

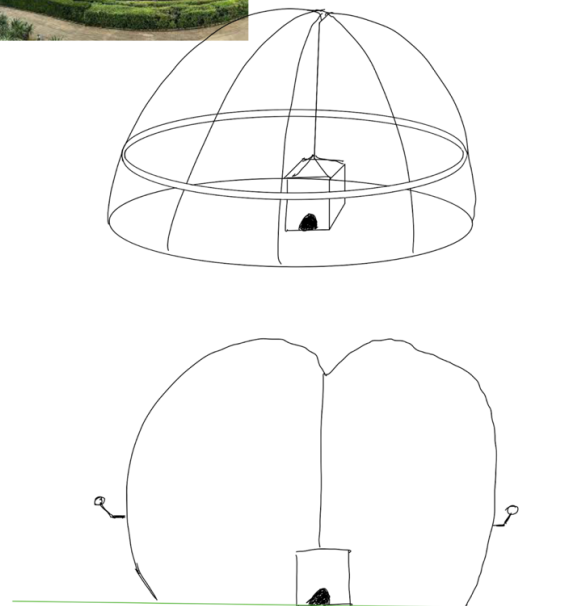


Figure 37 - Initial Idea 10 [1]

Inspired by the Eden Project in Cornwall, Idea 10 (Figure 36) is a bubble that has a handle that goes around the outside. There will be a home in the middle attached to the top. When the side of the bubble is lifted up, the home will swing over to the pivot, therefore making the whole thing lighter.

- ✓ Can be lifted in any direction.
- ✗ When lifting, the initial force required will be quite heavy until the home has swung past the pivot.
- ✗ Difficult to move as you either have to drag it or roll it.

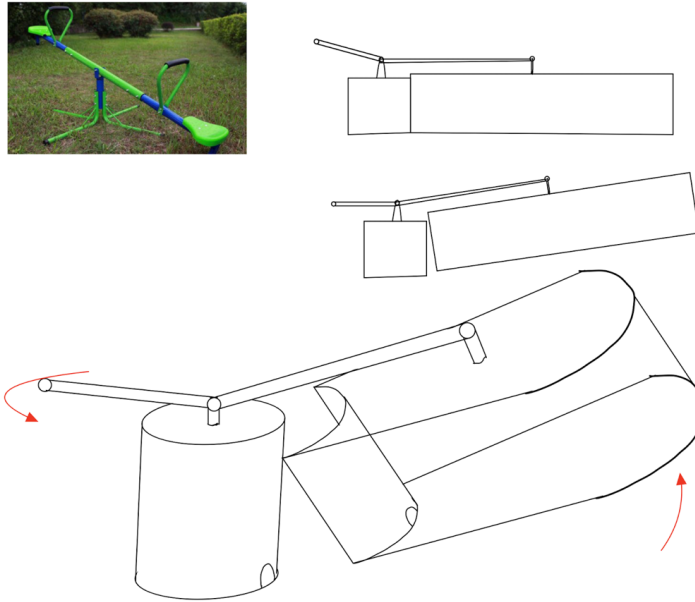


Figure 38 - Initial Idea 12 [1]

Inspired by a seesaw, idea 12 (Figure 37) is the same as idea 11 but instead of a handle at the end of the cage, the cage is attached to a lever. The human end is also weighted to make the cage feel easier to lift and rotate.

- ✓ Quite easy to move.
- ✓ Easy to move over bumps
- ✗ Can only go in a circle
- ✗ Difficult to access the home as you will have to lift the cage off too.

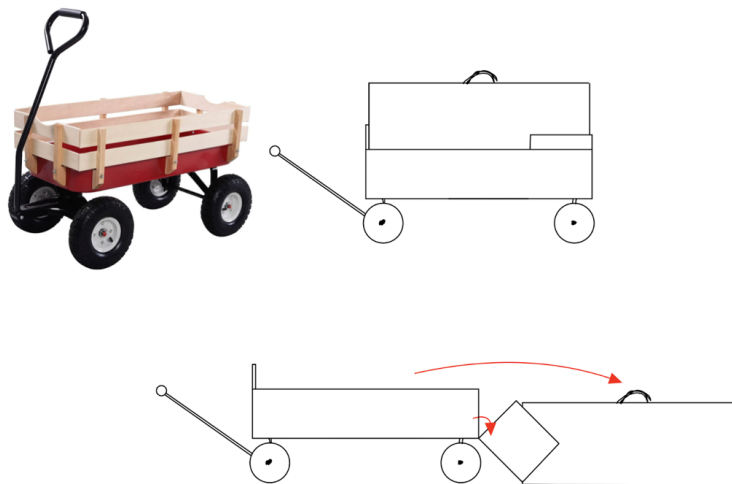


Figure 39 - Initial Idea 13 [1]

Inspired by a pull trolley, idea 13 (Figure 38) is the same as a pull trolley with the home in the front end of it. But the roof can be taken off and placed on the grass with the back end of the pull trolley being used as a ramp.

- ✓ Easy to move as the wheels and handle make it easy to pull
- ✓ Entertaining for the children to take guinea pigs on a walk.
- ✗ Requires multiple steps before it can be moved.
- ✗ Doesn't protect from predators when in the open position with the roof on the grass.

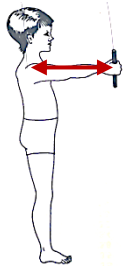
17.7 First Pugh Matrix [1]

Criteria	Idea 1		Idea 2		Idea 3		Idea 4		Idea 5		Idea 6		Idea 7		Idea 8		Idea 9		Idea 10		Idea 11		Idea 12		Idea 13	
	Ranking	Weighted	Ranking	Weighted	Ranking	Weighted	Ranking	Weighted	Ranking	Weighted	Ranking	Weighted	Ranking	Weighted	Ranking	Weighted	Ranking	Weighted	Ranking	Weighted	Ranking	Weighted	Ranking	Weighted	Ranking	Weighted
Designed for the Guinea Pig	3	12	3	9	4	12	3	9	2	6	3	9	2	6	3	9	4	12	4	12	3	9	3	9	4	12
Used by ALL	4	16	2	8	3	12	4	16	4	16	4	16	2	8	4	16	3	12	3	12	4	16	3	12	4	16
Easy to Use	5	20	1	5	4	20	4	20	3	15	2	10	4	20	3	15	3	15	1	5	3	15	2	10	3	15
Used anywhere	3	9	1	3	4	12	4	12	4	12	2	6	4	12	5	15	5	15	3	9	4	12	5	15	4	12
Safe to Use	3	9	1	3	3	9	3	9	3	9	2	6	3	9	4	12	4	12	4	12	4	12	4	12	4	12
Easy to Repair	1	3	4	12	2	6	2	6	3	9	2	6	4	12	4	12	3	9	2	6	3	9	3	9	3	9
Total =		66		32		67		66		61		52		59		71		69		49		70		65		68
Ranking =		6		13		5		6		9		11		10		1		3		12		2		8		4

Table 12 - Pugh Matrix for Initial Idea Selection [1]

17.8 Ergonomics Evaluation

For the purpose of this project, as per the product design specification, the minimum aged target market person is a 5th percentile child aged 8-years-old and the maximum aged target market person should be a 95th percentile adult male aged 18+. Childata the handbook of child measurements and capabilities was used as it can provide this data in a range of different measurements [14]. This data will be used to identify the limits of the user as well as possible problems that could be faced.

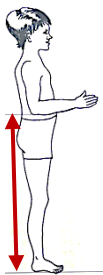


Arm length to grip

425mm for a male 5th %ile

405mm for a female 5th %ile

Therefore, the female 405mm will be used. This can help us establish at what the minimum distance the handle can be away from the user.



Elbow height

705mm for a male 5th %ile

705mm for a female 5th %ile

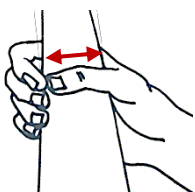
The female value will help us identify the minimum height at which the handle must be in order to ensure that the most ergonomic position when pulling. This identifies a problem as the most ergonomic height of a handle might be too low for an adult whose elbow height is closer to 1175mm (95th %ile male). Therefore, further research into how to solve this problem is needed.



Fist Breadth

760mm for a male/female 95th %ile

This shows us the minimum handle widths. If the user is expected to have two hands on the same handle, then the handle needs to be double the width, as well as adding a bit extra for a gap in-between the hands.



Maximum grip diameter (between thumb and index finger)

88mm for a male/ female 5th %ile

This shows the maximum diameter of a handle if required.

If the product is required to have the user lift or pull the product to when moving it around the garden then, as per the PDS, the target user shall be the 5th percentile 8 year old. As that will mean the product is designed to be used by that target market and above.

Pulling Strength



Bar is horizontal = 156N male 5th %ile, 193N female 5th %ile

Bar is vertical = 141N male 5th %ile, 79N female 5th %ile

This has highlighted that for an 8 year old child, pulling a horizontal bar is far easier than pulling a vertical bar. Therefore, this should be taken into consideration when designing the handle for the product.

Lifting Strength



Bar is horizontal = 176N male 5th %ile, 91N female 5th %ile

Bar is vertical = 52N male 5th %ile, 26N female 5th %ile

Again, this highlights what when lifting it is far easier to lift with a horizontal bar than it is with a vertical bar. This should also be considered when designing the handle if the product is required to be lifted.

Review: This analysis has pointed out the handle design should be horizontal in order to allow the user to move the product with ease. Also, when looking at the position of a handle. The height off the ground should be considered as if the 5th percentile 8 year old should be used, this would not be suitable for a 95th percentile adult and would result in the having to bend over to move the hutch, putting themselves in a potentially harmful ergonomic position.

17.9 Scale Drawings

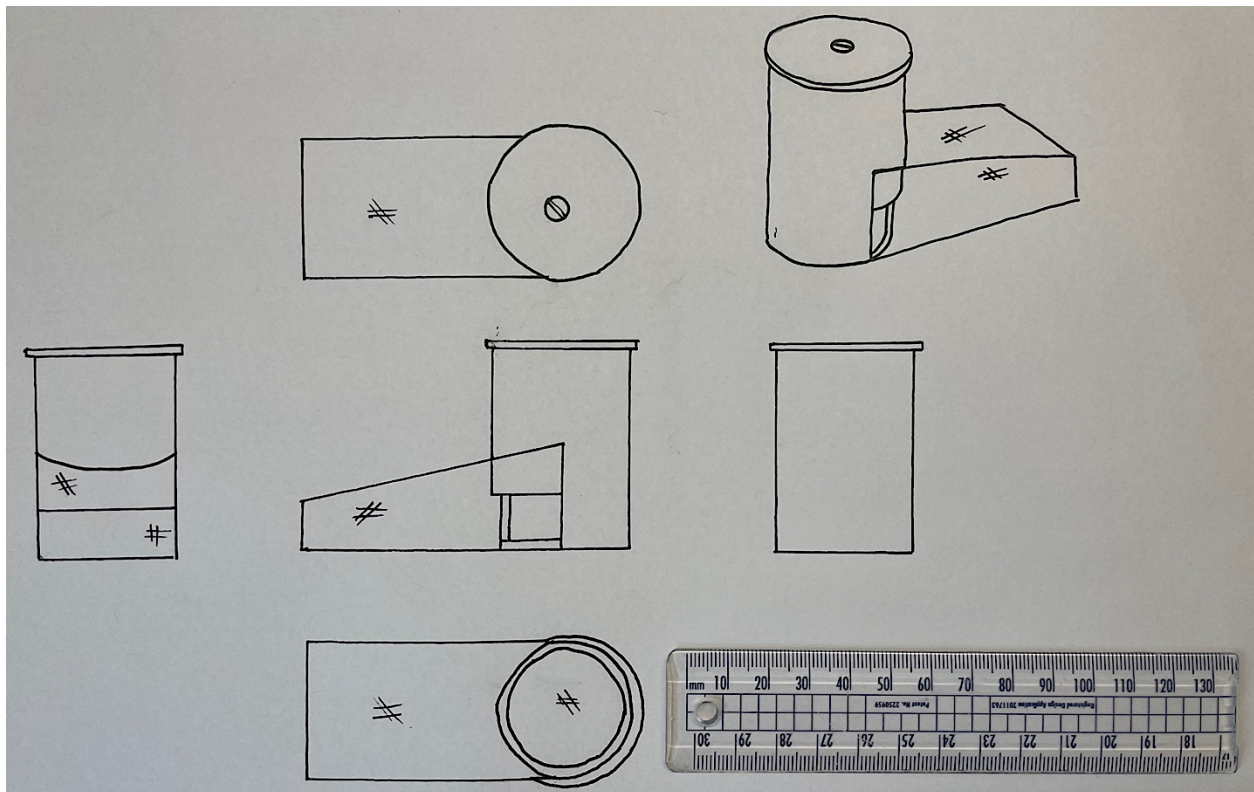


Figure 40 - Scale Drawing Outside Structure

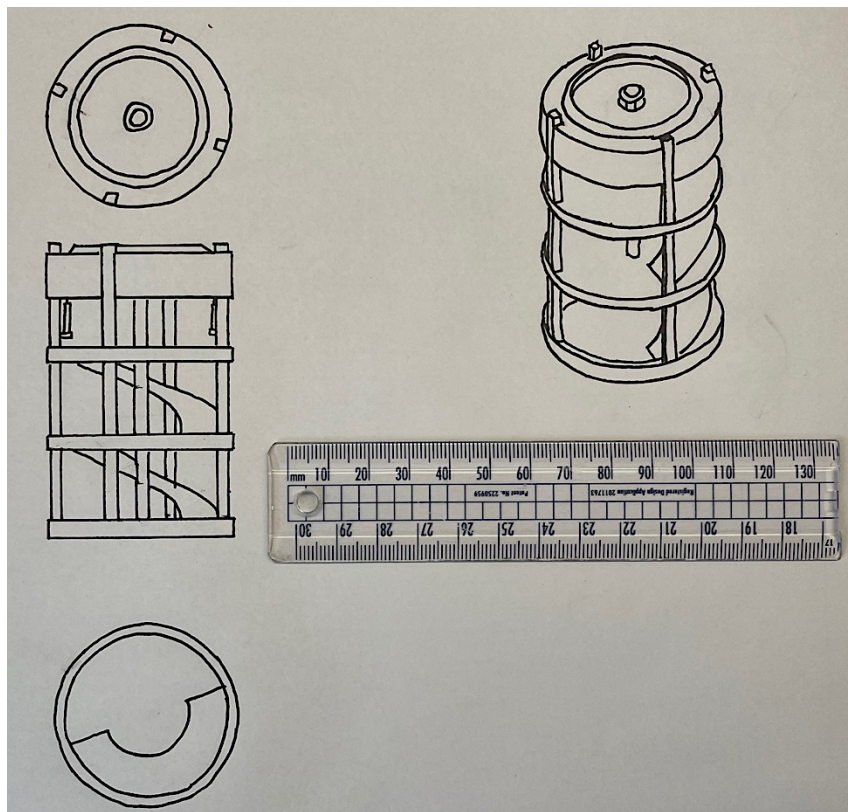


Figure 41 - Scale Drawing Inside Structure

17.10 NX Human Steps Analysed

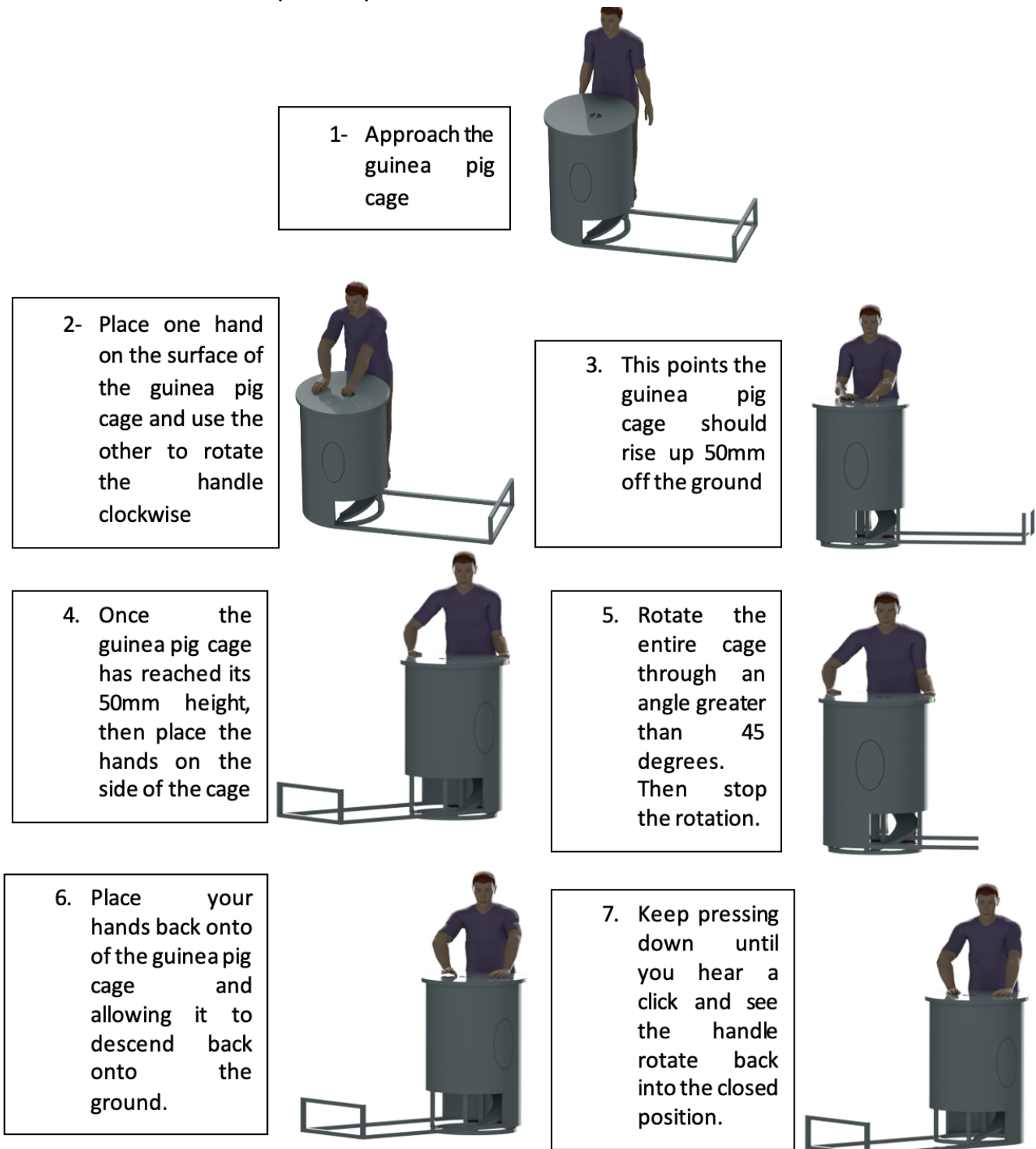


Figure 42 - Steps for which NX Human Analysis was Carried out

17.11 More CAD Images

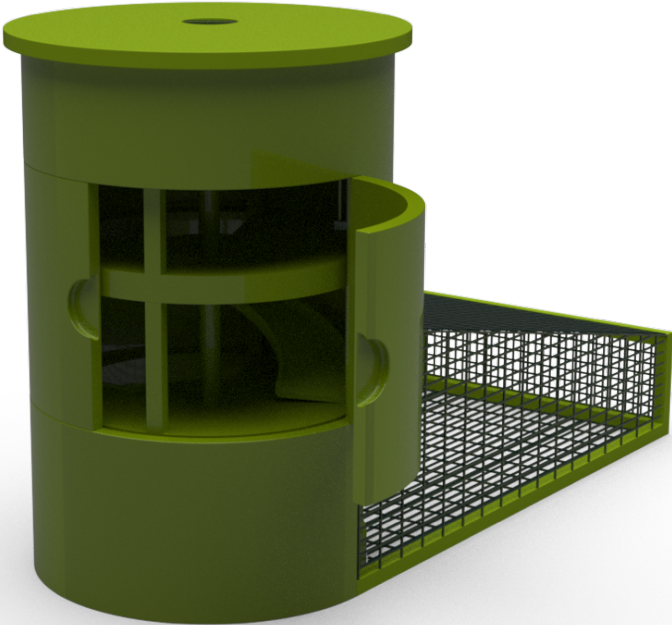


Figure 43 - CAD Render of Hatch

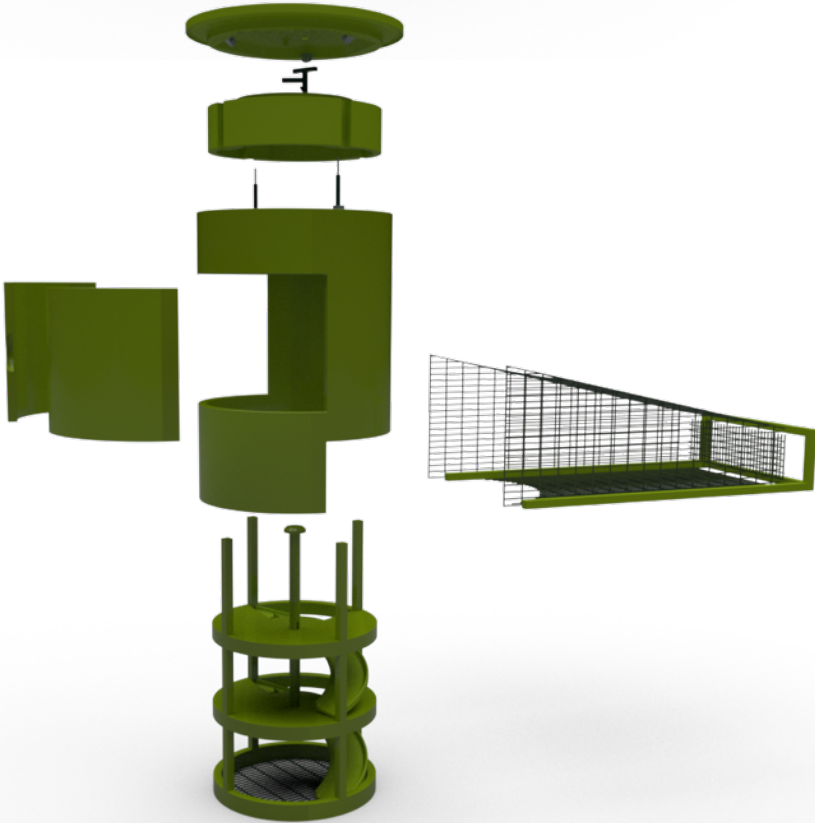


Figure 44 - CAD Render of Exploded View

17.12 Engineering Drawings

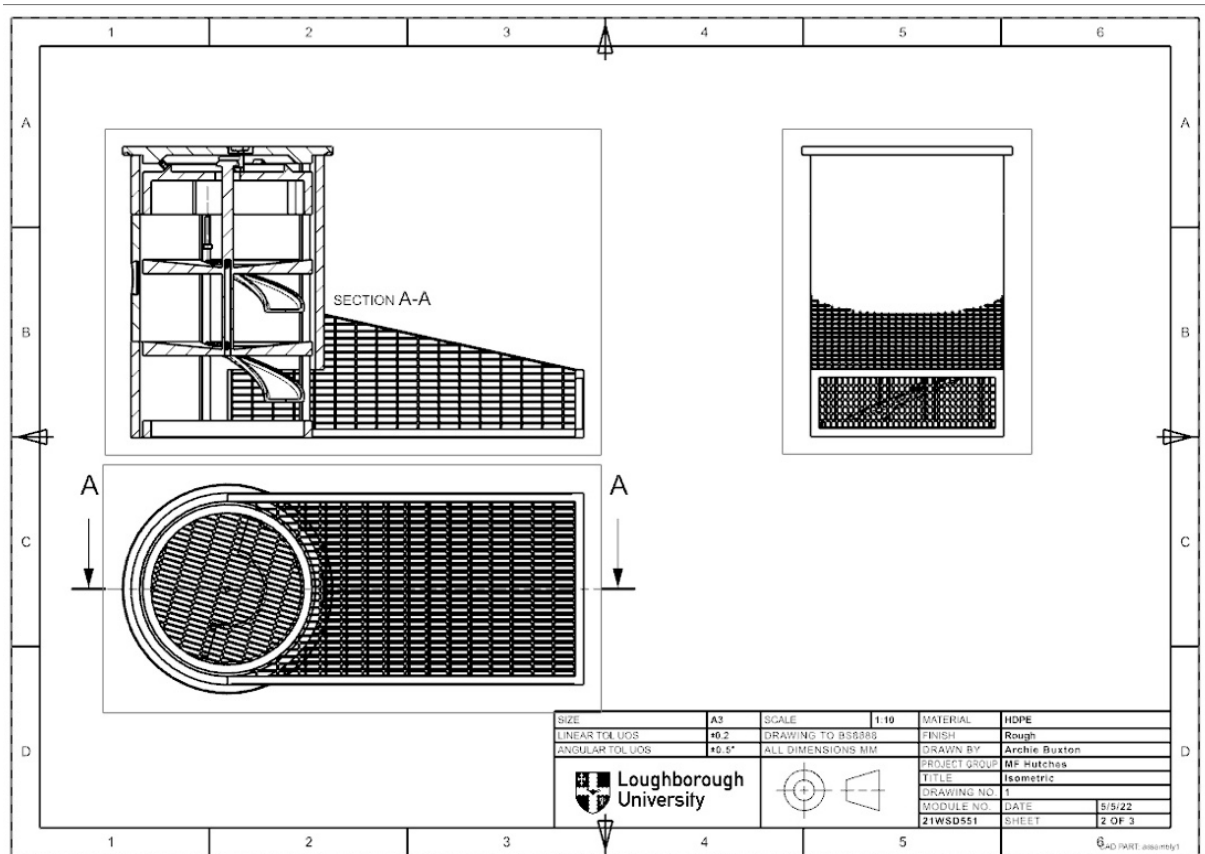


Figure 45 - Engineering Drawing, Over view

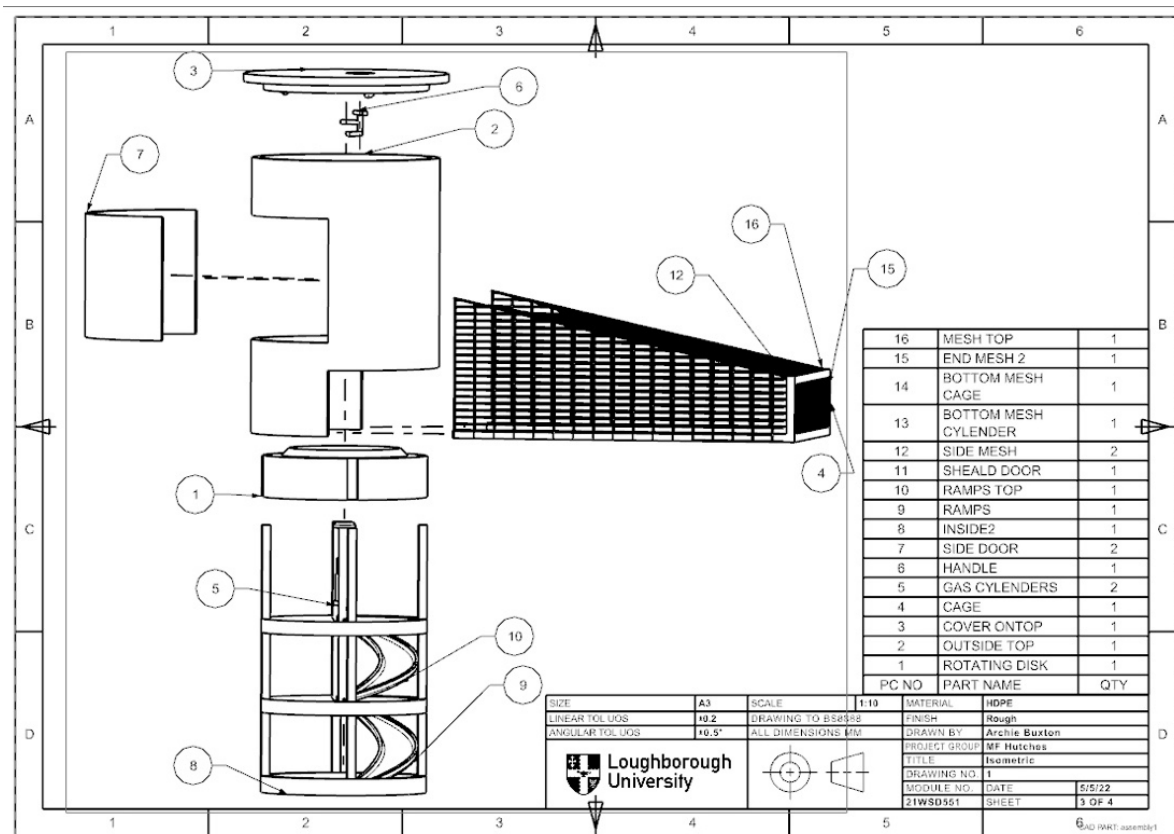


Figure 46 - Engineering Drawing, Exploded View

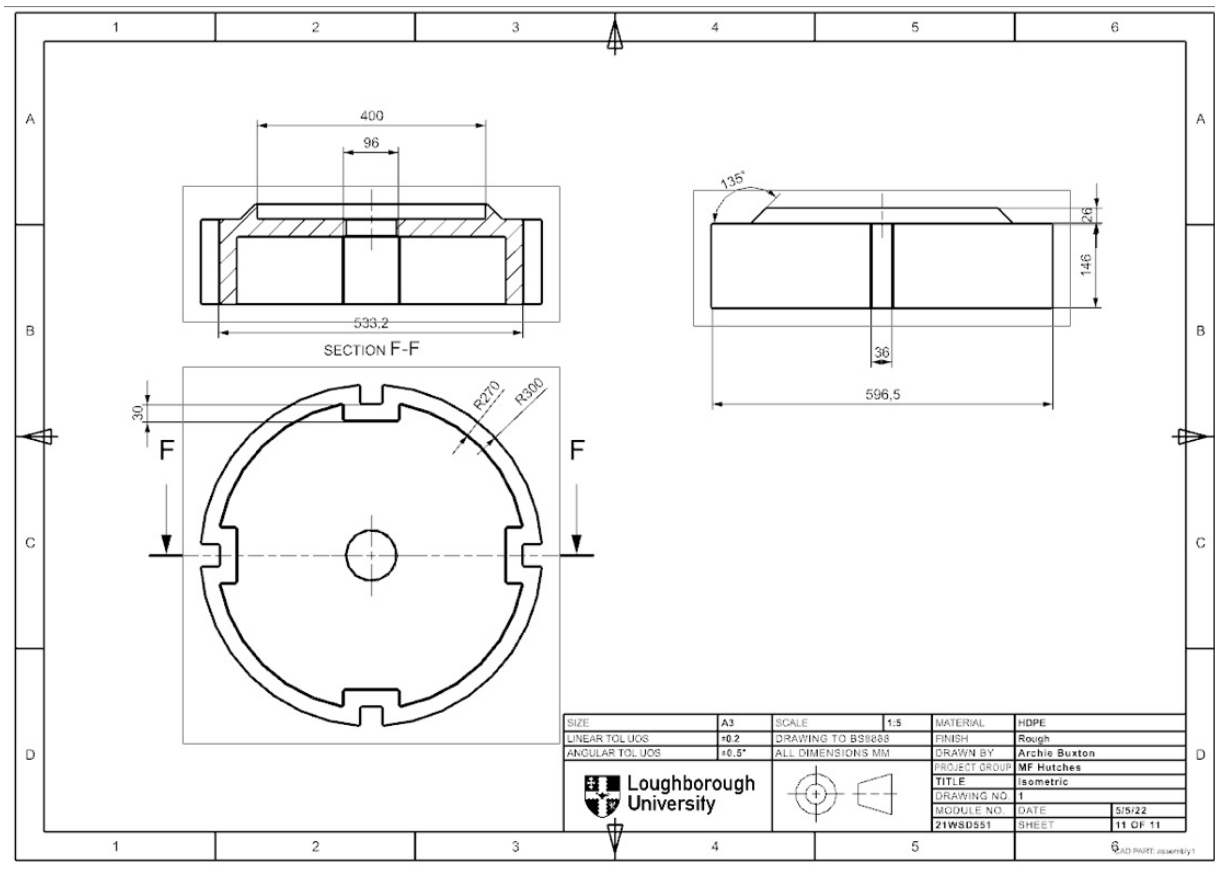


Figure 47 - Engineering Drawing, Rotating Disk

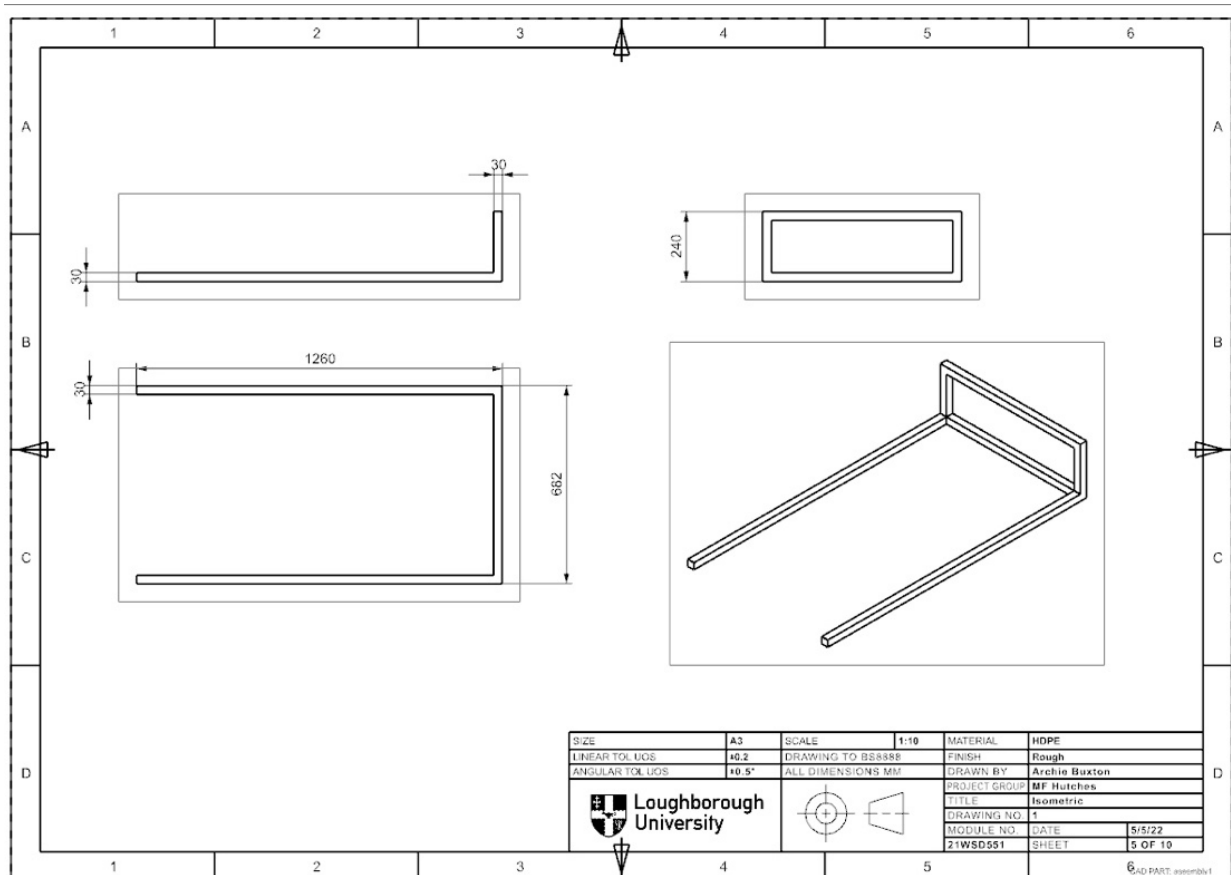


Figure 48 - Engineering Drawing, Cage Support

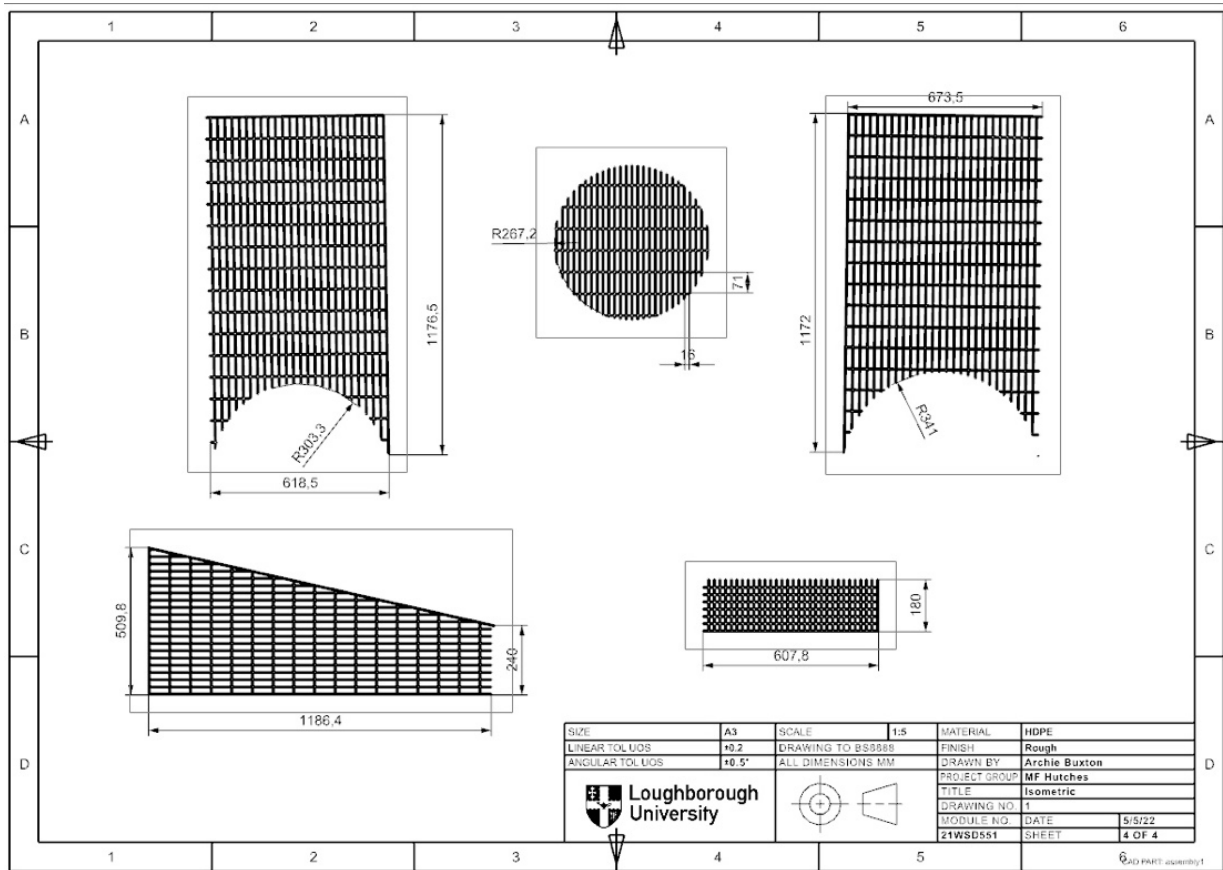


Figure 50 - Engineering Drawing, Cage Mesh

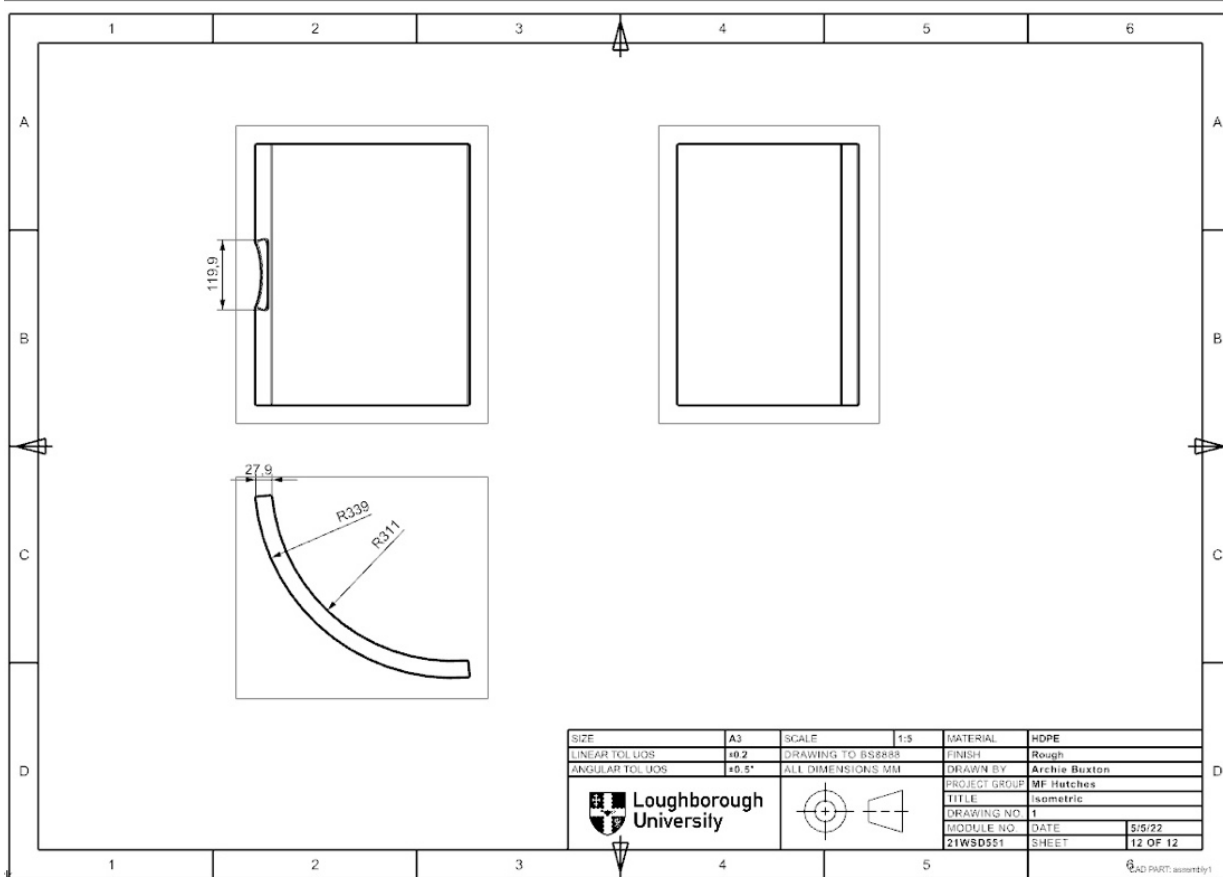


Figure 49 - Engineering Drawing, Side Door

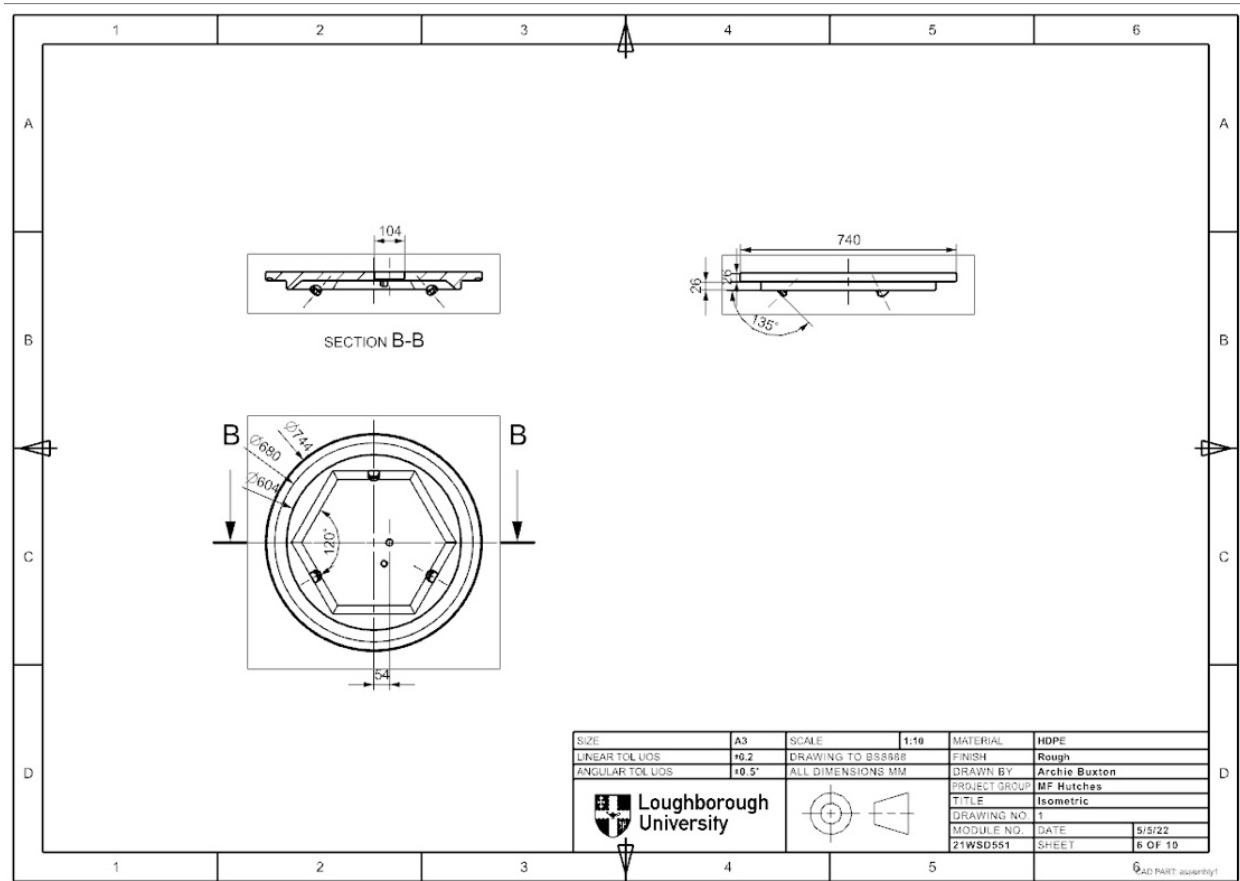


Figure 52 - Engineering Drawing, Lid

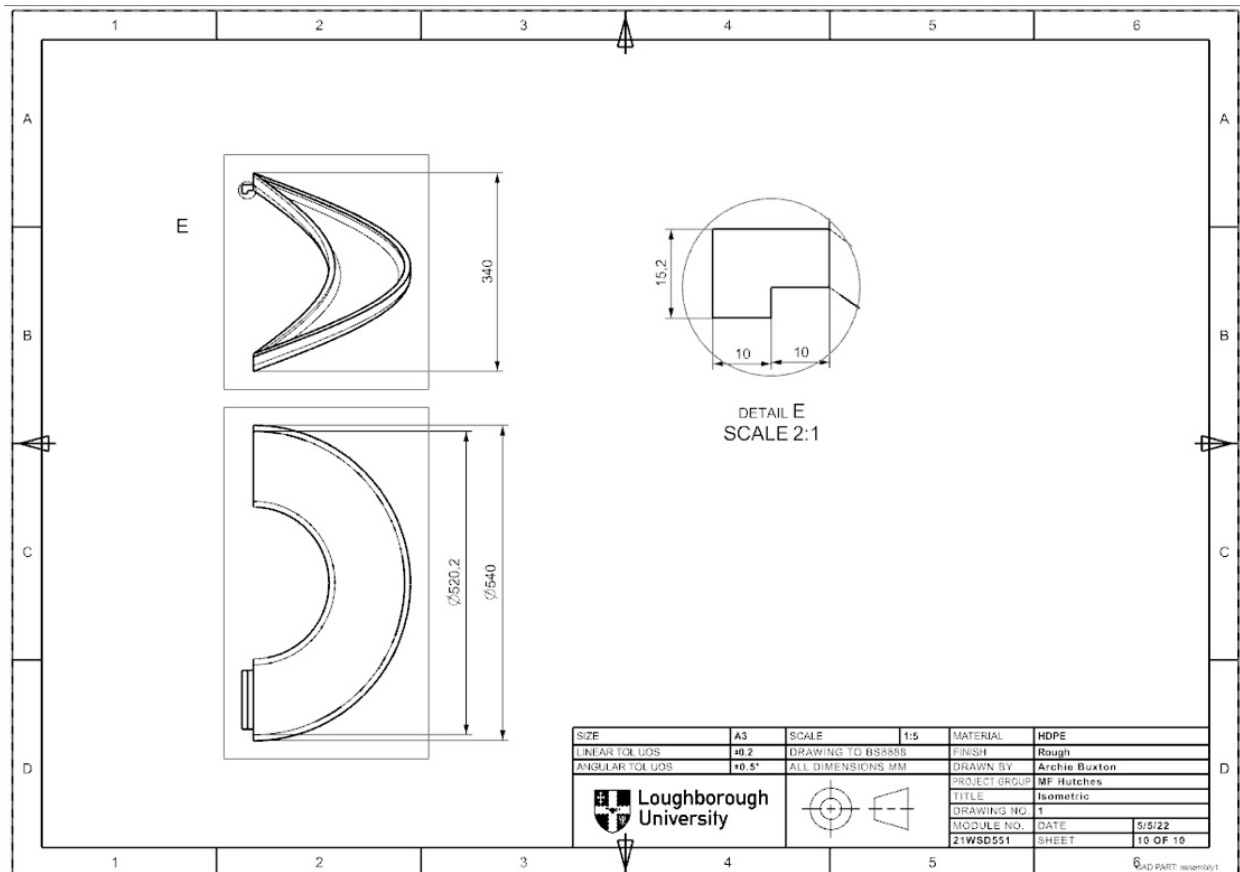


Figure 51 - Engineering Drawing, Ramp

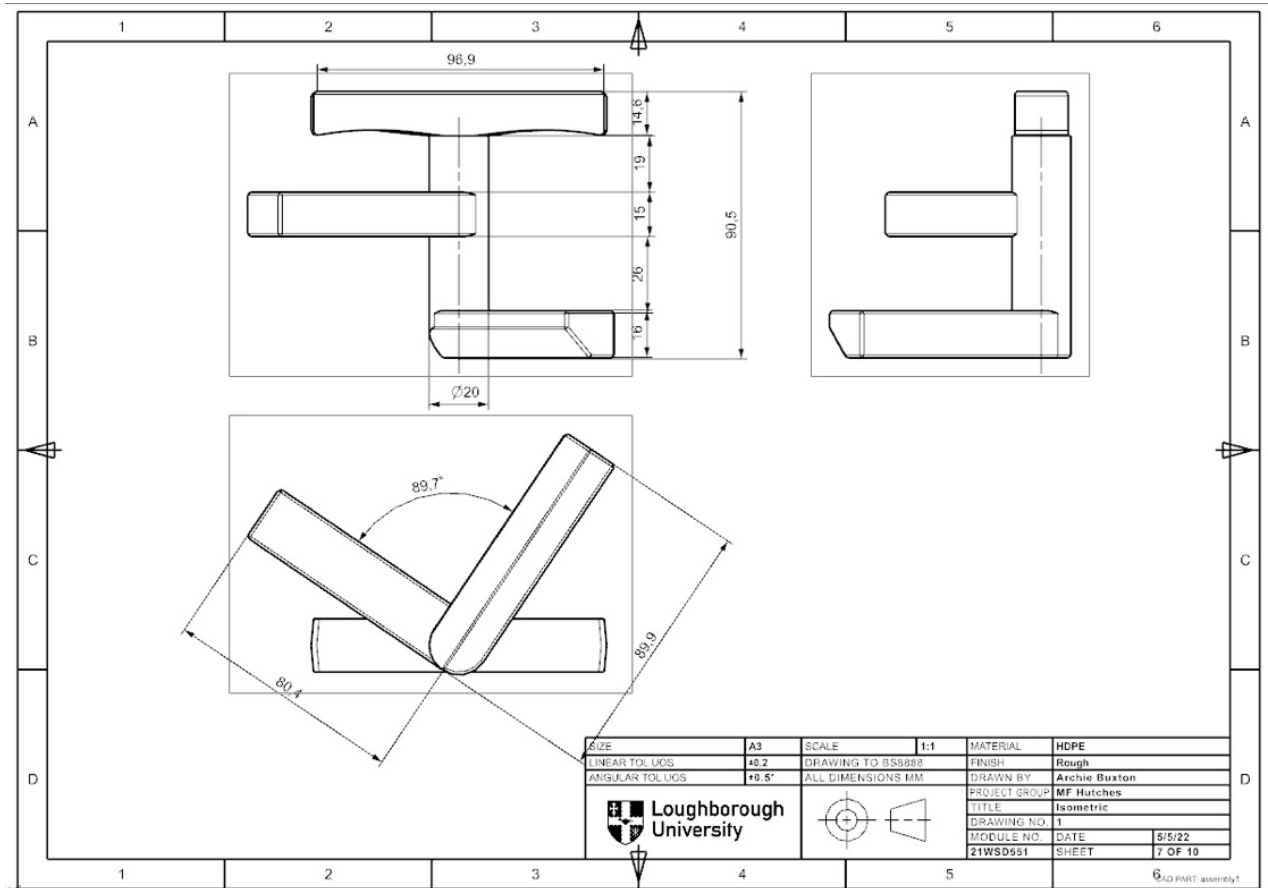


Figure 54 - Engineering Drawing, Handle

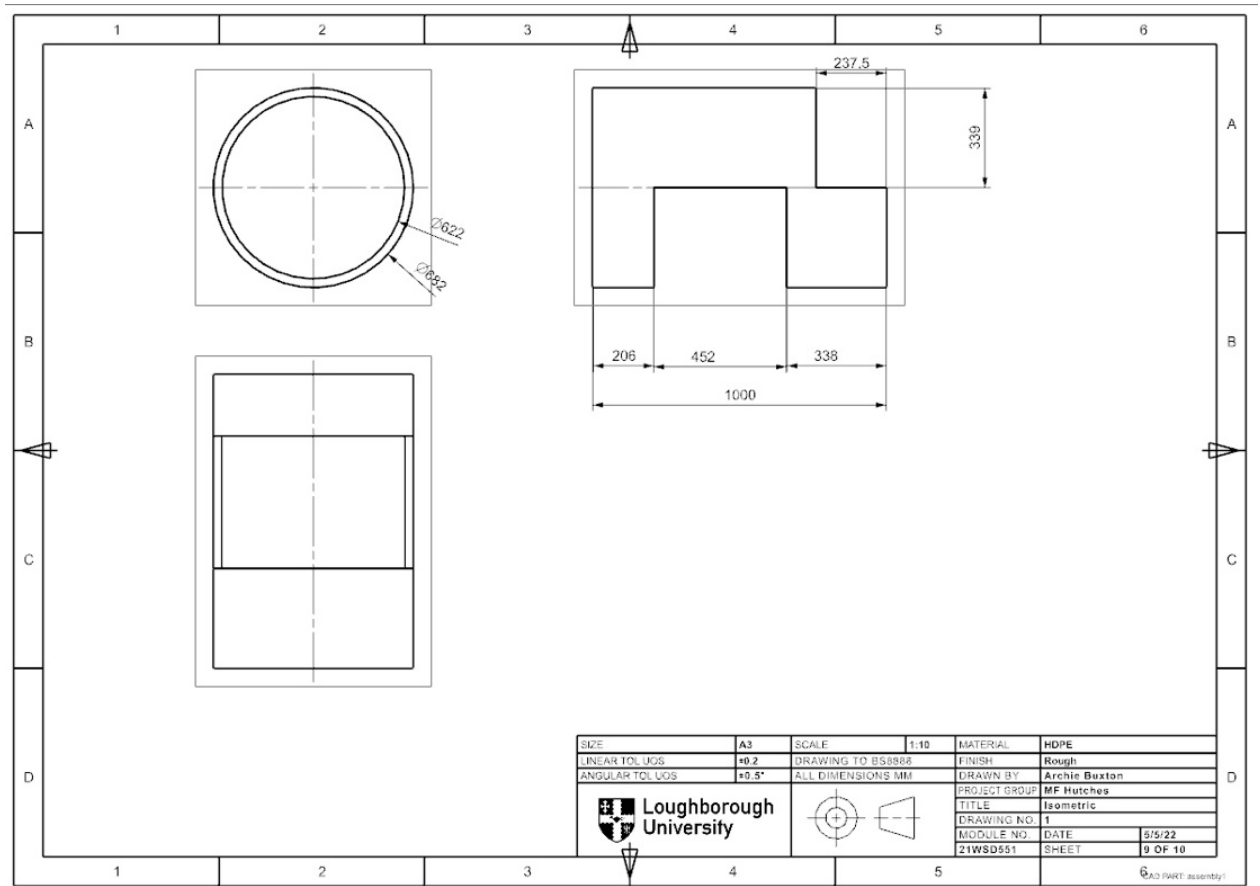


Figure 53 - Engineering Drawing, Outside Structure

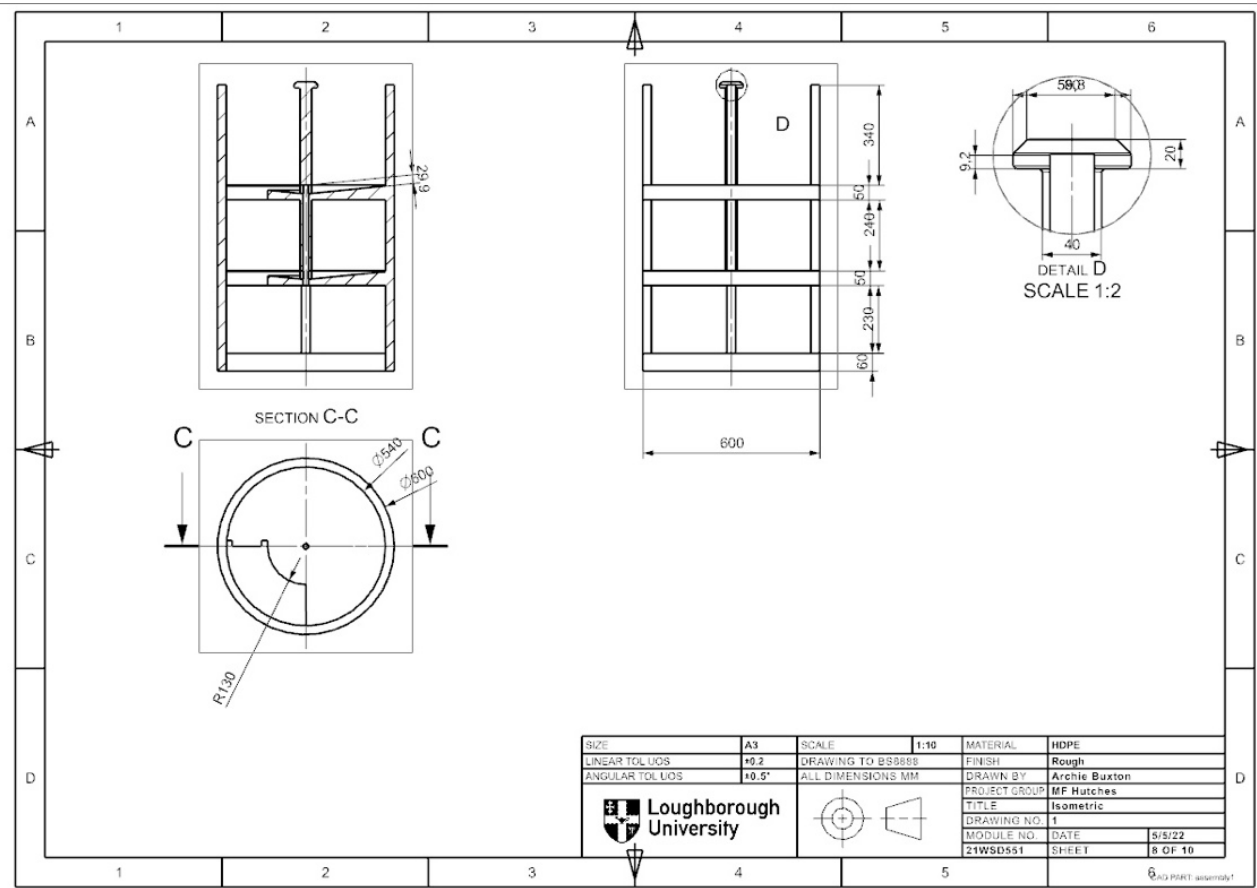


Figure 56 - Engineering Drawing, Inside Structure

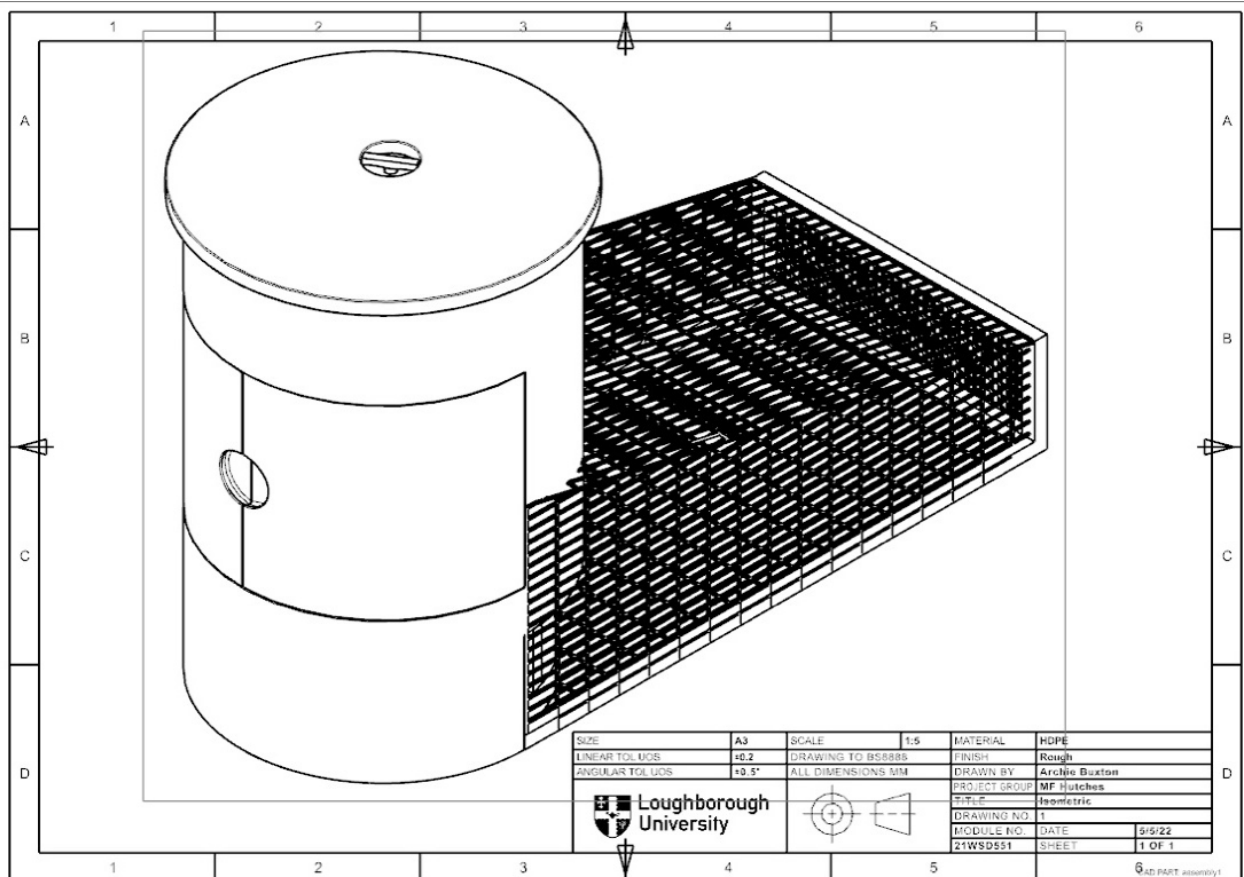


Figure 55 - Engineering Drawing, Overview

17.13 Ethics approval for user testing

The following is the confirmation of ethics approval to run user testing on the full-scale model manufactured at Omlet this can be seen in section 8.2.2.

Research & Enterprise Office
Loughborough University
Leicestershire LE11 3TU UK

T: 01509 222222
W: www.lboro.ac.uk



PROJECT TITLE: Moving Guinea Pig Cage Testing

PROJECT ID: 7988

Dear Archie

On behalf of the Ethics Review Sub-Committee I can confirm that the proposal 2022-7988-8671 has been given a favourable ethical opinion.

Please refer to the [COVID-19 FAQs](#) for the latest guidance on conducting studies involving human participants.

Studies can be moved online without requiring an amendment, unless this substantially changes the study in which case an amendment is required.

If in the future you wish to make any amendments to the study please submit an amendment using the relevant form. Guidance on amendments is available on our [website](#).

You are required to report to the Sub-Committee any incidents that have an adverse effect using the Adverse Events Report form in LEON.

This decision applies from the date of this letter until 08/05/2022 (date given within the form). If the study continues beyond this date you should submit an amendment request for an extension.

Kind Regards,

Jacqueline

on behalf of Ethics Review Sub-Committee

Figure 57 - Ethics Approval for Testing

17.14 User Testing Questions and Answers

These are the questions that will be asked to each person after they have interacted with the prototype. 25 People were chosen to take part in the testing of all heights. This also shows the answers to a few of the questions.

1. On a scale of 1-10, how easy did you find it to rotate the guinea pig cage, with 1 being very difficult, and 10 being very easy?
2. And why have you give that score?
3. On a scale of 1-10, how intuitive do you think it would be to move, with 1 being I don't understand how to use it, 10 being I knew how to use it before you even told me?
4. And why have you give that score?
5. On a scale of 1-10, how much do you like this concept, 1 being I don't like this idea at all, 10 being I love this idea.
6. And why have you give that score?
7. Would you buy this guinea pig cage if you had a guinea pig?
8. What did you think about the experience of rotating the cage?
9. Do you have anything else you would like to add?

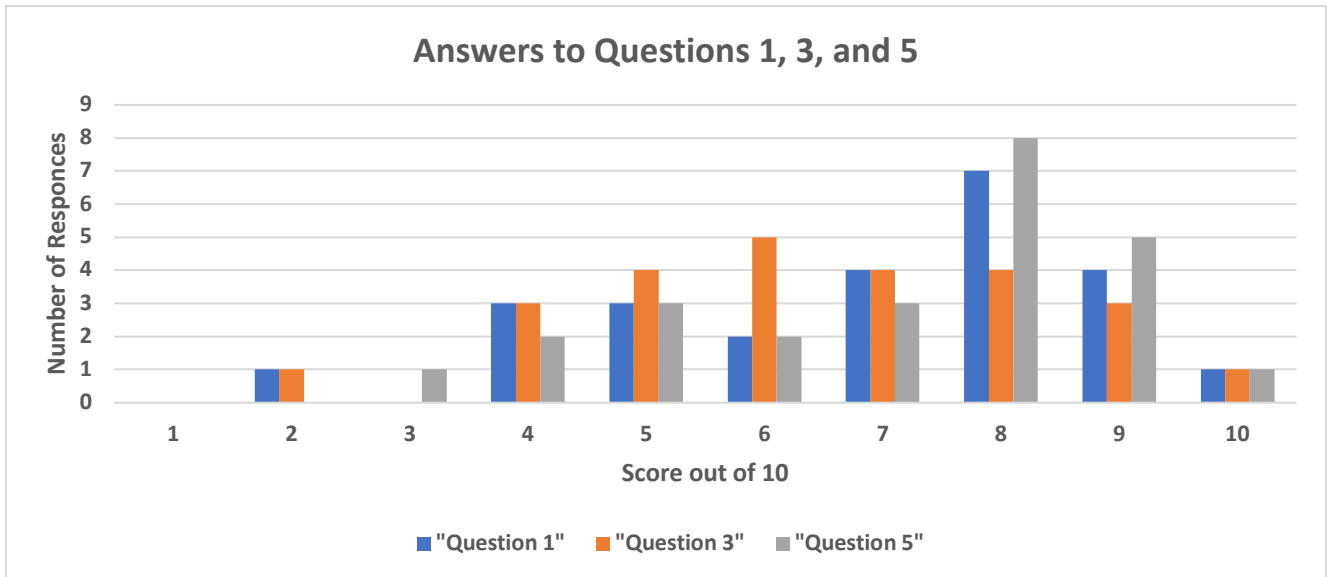


Figure 58 - Graph of Number of Responses against Score Out of 10 for 3 Questions