Therapeutic Mechanical Horse Project
Scope of Work (SOW)

October 13, 2022

Sponsor:

Jack's Helping Hand

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Abstract

This Scope of Work document defines our senior project's goals, research, specifications, and management for our team of engineers from Cal Poly, San Luis Obispo. Our team has taken on the designing and manufacturing of a therapeutic mechanical horse simulator to assist our nonprofit sponsor, Jack's Helping Hand (JHH), with their Little Riders program. This program uses equine therapy to help children with disabilities, but while the program is overall very successful, sometimes children enrolled in Little Riders are intimidated by or have difficulty getting onto or riding a real horse. Thus, our goal is to build a safe, inviting, mechanical horse that the children can use as a stepping-stone to get comfortable mounting and riding a real horse, and to fully participate in equine therapy. We plan to do this by creating a self-propelled mechanical horse with a locking system for safe and easy mounting and dismounting. In order to make riders more comfortable we will emphasize safety and appearance by making the structure difficult to tip, have no exposed pinch points or sharp edges, have a high factor of safety to prevent mechanical failure, and have lifelike horse appearance. In addition to this, the final product needs to be reasonably transportable so that we can get the product to JHH's location. Once it is at that location, it needs to be simple to maintain and not get corroded or otherwise seriously damaged by any environmental conditions. From our research we found that an existing product, The Equicizer, meets many of our and our sponsor's criteria. Thus, we will further research and reference this product as we enter the design phase.

1 Introduction

Jack's Helping Hand is a local, non-profit organization that provides children with special needs physical therapy and programs to improve and enrich their lives [10]. Sponsors Leslie Orradre and Bonnie Burt (chairwoman and event coordinator, respectively) reached out to Cal Poly in order to expand upon their Little Riders program. The program provides therapeutic riding to the children, helping them improve core strength, balance, coordination, and confidence [1]. Therapeutic riding is a physical therapy that utilizes riding a horse to improve physical abilities [2]. The Little Riders program comes alongside a few drawbacks and limitations. Two of the biggest concerns are the wear on the JHH lesson horses and the various levels of experience of the riders. To make therapeutic riding more accessible, JHH has partnered with our team to create an alternative way to provide the experience of riding a horse to those who may benefit from such an approach. Our team consists of Zachary Barnishan, Carson Roff, Broghan Martin, and Lydia Barnes, all mechanical engineering majors with manufacturing concentrations. Taking up the mantle of the past Mechanical Horse Senior Project teams, we have been tasked with designing and fabricating a more accessible and usable way to provide JHH with alternative, mechanical equine therapy.

Henceforth, this document will outline our current design and research processes, going over current design ideas, and outlining our understanding of the project's challenges and sponsors' needs.

2 Background

2.1 Stakeholder's Needs and Wants Research

As a part of establishing our background knowledge, we needed to understand the needs and wants of our stakeholders. Our primary stakeholder is our sponsor, Jack's Helping Hand, and the secondary stakeholder is the children for which JHH provides therapeutic riding. The first step in this process involved meeting with JHH's point of communication, Bonnie Burt. Via this initial meeting, the sponsor's needs regarding size constraints, weight constraints, budget sources and movement profiles were clarified. To specify, Mrs. Burt requires a device that is around 100lb, can support a maximum of 175lb, supports a rider up to 6', resides within a footprint of 2’ by 4’, has a saddle at 36” above the ground, is water, dust, and rust resistant, and safe for those using and performing maintenance on it. This meeting gave us a holistic picture of the level of complexity and aesthetic appeal that our end product would need in order to be an effective tool. Ultimately, it was not possible to meet directly with our secondary stakeholders—the children who would be utilizing equine therapy—due to confidentiality agreements. Fortunately, Mrs. Burt was able to provide feedback she had received from the children on the basis of the previous senior project. With these desires in mind, we could move into looking at existing solutions before developing our own.

2.2 Current Products and Solutions

The second leg of our background research entailed performing research into what products already exist as mechanical aids or alternatives to therapeutic riding. Three categories of device clearly emerged with varying levels of complexity.

The first category that emerged were athletic devices that had been designed for developing core strength. These devices were focused less on the accuracy of mimicking a true equine motion profile, and more focused on providing a core workout for the user. A good example of this was found on Amazon under the title “TECHTONGDA Electric Horse-Riding Abdominal Exercise Machine,” pictured in Figure 2.1 alongside its overall dimensions [3]. This product is a saddle-like surface atop a column that rocks back and forth in a rough approximation of a horse running. Although this category of product does not fulfill the stakeholders’ wants due to it being motorized and not self-propelled, the core-strengthening aspect remains a trait that can be referred to for our product’s design. Core strength is a major benefit of therapeutic riding, so keeping motions that encourage abdominal exercise is a priority [1].

Figure 2.1 The TECHTONGDA Electric Horse-Riding Abdominal Exercise Machine [3].

The second category that emerged involved devices that had specifically been developed to replicate the motion of a horse as closely as possible. Horse motion profiles are complicated as they incorporate many degrees of freedom. Over the years, there have been many attempts at categorizing this motion through mechanical means. The earliest example our group found was a patent from 1893 which attempted to use gears to mimic natural motion [6].

Since then, years of research has gone into creating mathematical models of animals. The first large advancement we found was a journal article on “The Dynamics of Quadrupedal Walking” [8]. This journal article helped to lay the foundations for some of the initial methods, which were improved upon in a later “Trotting Horse Model” [7]. These two journal articles helped to quantify movement, which was the first step in creating a machine that accurately recreates the motion. Later, in 1999, a standalone horse simulator was built in the French National Equestrian School [9] for use in replicating obstacle course maneuvers and fully replacing a physical horse. Racewood Equestrian Simulators later made a more advanced simulator, which was used to train equestrian athletes [5].

In more recent years, additional studies have been performed using updated sensors to account for inertial imbalances between the horse and rider [14]. These sensors, in conjunction with advanced camera technology, has allowed a new wave of devices to come to market for specific use in therapeutic riding applications.

The most advanced example of physical therapy applications is the MiraColt, depicted below in Figure 2.2 [4]. The MiraColt is a saddle-like surface upon a column. However, instead of a simple reciprocating motion, the base encases a cam system. This product was developed with tangential relation to a patent filed for Baylor University as part of an overarching research project into hippotherapy [11]. It is also very similar to an earlier patent for hippotherapy which neglected the use of cams [18]. This complex system provides six degrees of freedom for the saddle to move and accurately mimic the gait of a horse. Extensive research and simulation were done for the MiraColt to accomplish this.

Figure 2.2 The MiraColt with visible internal mechanisms [4].

While the exact mechanism is not obvious, from the videos posted on their website, Racewood Equestrian Simulators must use a similar actuation system to create an accurate equine motion profile. The only detractor from these devices is that the body of the horse tends to be one solid piece which moves as a block. This might be solved in the near future with new products as a patent was filed in 2016 for a hippotherapy device which utilized articulating links to more precisely model the back of a horse [16]. While impressive, and within the field of therapeutic riding, these products are lacking in the aesthetics required by JHH and cost much more than allotted by our budgetary constraints. They also tend to be driven by motors, which is not preferable as our device needs to be self-propelled.

Fortunately, we were able to locate a patent for a device which was not actuated by motors. While it is comparatively simple, this device uses springs to create a mobile platform within a frame [15]. This platform has a handle that can be used by an attendant to maneuver the seat in a rough approximation of equine motion. Furthermore, the profile of motion would be more akin to a playground animal on a spring.

Although this approach does not mathematically capture the movement of a horse, value was found in the self-propelling attribute that comes with utilizing springs.

The final category involved hippotherapy-specific devices that focused on the aesthetics of a horse. The primary example of this is the Equicizer pictured in Figure 2.3 [17]. This product resembles a giant rocking horse with a fluffy stuffed animal look. It has no motors, and the user simply rocks back and forth atop it to move the apparatus. While it does not mimic equine motion very closely, it improves core strength just like traditional therapeutic riding. After speaking to Mrs. Burt, this product was the closest to what JHH ultimately wanted.

Figure 2.3 The Equicizer Classic [17].

Even with the patents found for products, research articles on horse movement, and existing products related to therapeutic riding, there are certainly more solutions to this problem that our team did not dig up.

2.3 Technical Challenges

Throughout the process of building anything, there are going to be technical roadblocks, setbacks, and challenges. This is especially true of a student team with limited access to the manufacturing equipment used in industry. Problems of safety become a concern which is why standards are created. The standards we are looking into are ASTM F963 – 17 and ASTM F2275-10 which concern toys and fitness equipment respectively [12] [13]. Fortunately, this project is purely mechanical due to the requirement set by JHH of a self-propelled apparatus. This means that concerns regarding safety in environments where electrical and mechanical systems must interface with each other are less of a concern [19]. Our team is fortunate enough to have two student shop technicians, who will ensure access to the tools that exist on campus and possess the training required to use them. The most difficult part of this project seems to be creating a realistic looking horse exterior and making that exterior comfortable to sit upon. It presents a unique challenge since it is outside the realm of our engineering degrees and more in-line with a creative field. There are clear solutions in the realm of comfort since we can use a saddle [20]. It is likely that a purchasable solution exists to satisfy the aesthetic requirements of our project but if not we will create an appropriate substitute.

3 Project Scope

This project aims to meet the needs of JHH in the form of a self-propelled therapeutic riding and training mechanical horse for children with disabilities that either need functional and mental training before riding a real horse or need access to therapeutic riding in a safer and more controlled environment.

3.1 Boundary Sketch

Figure 3.1 illustrates which aspects of the overall system our team plans to be able to work on. The aspects of this system that our team cannot/will not affect are the step block, ground surface conditions, the volunteer from JHH, and the rider. All of what our team will work on is contained within the dashed lines. This includes the appearance of the apparatus, overall transportability, how motion is constrained and generated, rider safety, and the addition of reigns and a saddle.

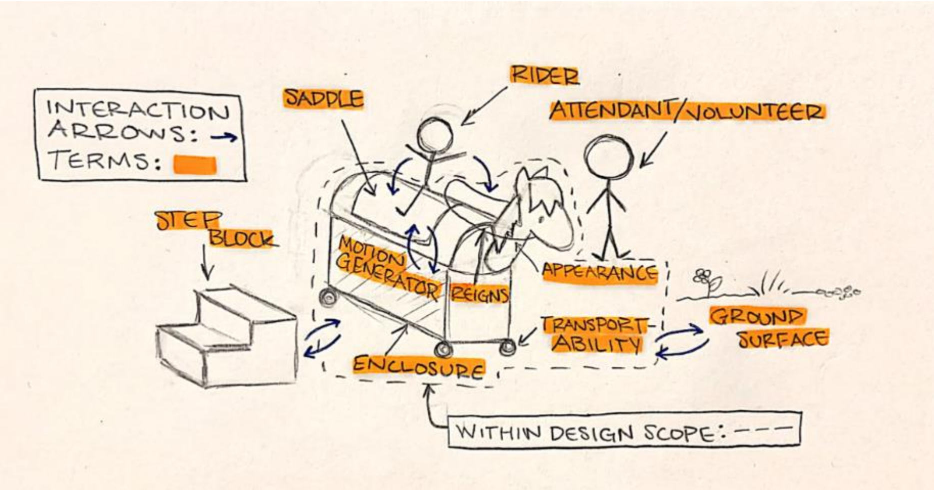

Figure 3.1 Boundary sketch illustrating the scope of this design and its interactions.

3.2 Summary of Stakeholder Wants/Needs

JHH requires a piece of equipment capable of getting special needs children and teenagers accustomed to a horse for therapy in a safe and gradual manner. In order to properly design and fabricate this equipment we need to have a complete understanding of the requirements that will be asked of it. The design must be mobile enough to be transported from Cal Poly to the JHH assisted riding barn. It must be safe in that there are no concerns for the wellbeing of the users that will be riding the mechanical horse. The design should provide adequate comfort during then riding practice that reflects that of a horse's saddle. A close approximation of equine motion should be facilitated through the motion of the mechanical horse during riding procedure. This motion should in turn be self-propelled by the user that is riding the mechanical horse i.e. the use of motors or external propulsion is not within scope. In order to gauge the relative importance of all of these factors, we created a small table to depict where each factor stands on a scale of 1-10.

Table 3.1:

Wants/Needs	Weight (1-10)
Mobility	4
Safety	10
Comfort	7
Facilitate equine motion	7
Self-propelled	9
Water-rust resistant	8
Dust resistant	8
Horse-like appearance	5
inexpensive	5
Ease of Operation	9
Mountable	10
Age 6-16 Riders	10
Include reins and saddle	9

3.3 Functional Decomposition

Figure 3.2 provides a breakdown of our project goals as simplified functions that must be accomplished by our final design. Our main function is to provide equine therapy practice for the children at JHH. This will be accomplished by providing functions in the four main categories: mental and physical improvement, safety, facilitation of motion, and transportation. By transportation, we mean the ability for our project to traverse the ground in an easy manner when it is being moved from storage into an ear for active use. By facilitation of motion, we mean that our project while be constructed in a manner that the passenger on top of the mechanical horse provides the energy for motion through their own actions and can therefore stop moving whenever they wish. Safety is exactly what is sounds like, no bodily harm should befall anyone within our specifications who rides on our horse. Mental and physical improvement describes the therapy imparted by using our device in conjunction with expert instruction given by JHH. With these functions and their subcomponents met, we should be able to provide a piece of equipment that is able to meet and exceed the needs of JHH.

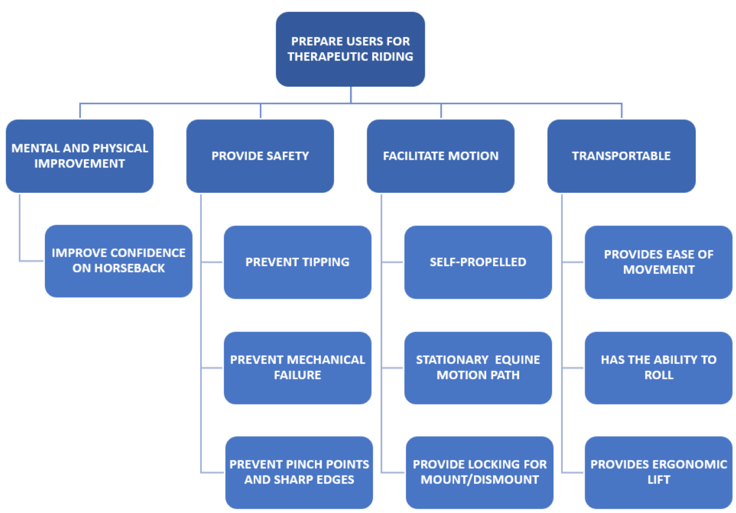

Figure 3.2 Functional decomposition depicting what our design must be able to do.

3.4 Deliverables

Table 3.1 below summarizes the key milestones for this project and the date at which they are expected to be completed.

Our final product to be delivered to Jack's Helping Hand will include the physical equipment that will be used in practicing for therapeutic riding. The equipment functions as a mechanical horse and will aid in understanding and practicing the motions of mounting and dismounting a horse as well as practicing hip motion and motor skills that are required to maintain safe riding posture. This physical equipment will be delivered alongside printed instructions for the safe operation and maintenance of the mechanical horse.

4 Objectives

4.1 Problem Statement

Jack's Helping Hand requires a device that provides an alternative way to experience equine motion and practice therapeutic riding for users with physical and mental disabilities. The device must be self-propelled, transportable, and allow volunteers to easily use the apparatus to provide therapeutic riding.

4.2 Quality Function Deployment Process

The Quality Function Deployment (QFD) in Appendix A provides a way to establish and quantify customers' needs, competitor data, and engineering specifications. The QFD allows us to focus directly on things that are most important to the scope of the project and the sponsors. By using the relationships between the variables of customer needs and engineering specifications, a rough idea of where energy should be spent can be extrapolated from the QFD.

4.3 Engineering Specifications Table

In Table 4.1, the target specifications are listed alongside their risk level and compliance method. An engineering specification is a specific number or attribute goal that the product will be designed to meet or exceed a statistically acceptable amount of time. For our project, that means all of the time since we are only building one mechanical horse. The key idea is that a specification can be measured in some way to see if the product meets what is required or not. The specifications are not listed in any particular order of importance, but this table is useful to prioritize time and energy in meeting the high risk requirements. In this context, in order to be a high risk requirement, that requirement must have the worst consequences were it to be left unfulfilled. Most of these specification descriptions are self explanatory, such as the weight requirements and rider weight restriction. However some of the specifications are more esoteric so they will be clarified. By appearance survey, we mean that the aesthetic appeal for the horse is acceptable. Since aesthetic appeal cannot be directly quantified, we needed to turn that requirement into a survey so that it can be measured. In a similar vein, the Use Survey is a survey measuring how easy each user found the horse to use.

Table 4.1 Engineering specifications and related attributes.

Spec. #	Specification Description	Requirement/ Target	Tolerance	Risk	Compliance
1	Product Weight Requirement	100lbs	±30lbs	M	A, I
2	Rider Weight Restriction	175lbs	±10lbs	H	A, T
3	Rider Height Range	3'6" to 6'	-	M	A, T
4	Product Footprint	2' by 4'	±1ft^2	L	I
5	Load Factor	250lbs	Max	H	A
6	Saddle Height	36"	±0.5ft	M	I
7	Appearance Survey	10/10	-	M	I
8	Use Survey	10/10	-	M	I
9	Maintenance Schedule	Biweekly - Monthly	-	L	T
10	Setup Time	10 minutes	±5 minutes	L	I, T
11	Cost of Materials	$2000	Max	M	I

*Risk of specification: (H) High, (M) Medium, (L) Low
**Compliance Methods: (A) Analysis, (I) Inspection, (S) Similar to Existing, (T) Test

5 Project Management

With any long-term or complex project, it is easy to fall behind or get lost in the weeds of unnecessary details. To avoid these issues, a comprehensive project management plan is needed to keep the timeline on track and ensure a finished and functional product.

5.1 Design Process

The first aspect of our project management plan is to outline the general approach to the design process. In the context of this project, defining the problem we are to solve has been completed.

After we know what problem to solve, we will home in on details such as actuation methods to achieve the motion desired by JHH in the product. For example, this includes components such as springs or rockers. Once a good idea of the general method of actuation is solidified, we can start thinking about how large each component needs to be in order to properly ensure the safety of our users. That would include choosing and sizing the materials that our product will be comprised of. Perhaps a wooden horse would suffice, or perhaps steel tube will be needed for extra stiffness. Most of the analysis and modeling will occur in this step. Beam deflection will be calculated. Stress analysis will be done to make sure that the mechanical parts used do not wear at unacceptable rates, and similar calculations will ensure a product that functions long after this project has been completed.

At the conclusion of this step, material acquisition and fabrication can begin. This will likely require many hours in the shop where small problems will dictate operations day-to-day. Since a design has not been solidified, the specific manufacturing process remains undecided due to the amount of variation in the approaches that could be employed depending on the finalized design.

5.2 Milestones

The major milestones that will be completed before our PDR have been compiled in the table below:

Table 5.1 Deliverables Timetable

Milestone	Date
Scope of Work	10/19/2022
Concept Prototypes	11/07/2022
Preliminary Design Review	11/17/2022*
Interim Design Review	01/30/2023*
Critical Design Review	02/10/2023*
Final Product with Instructions and Safety Data	06/01/2023*

*Date subject to change

- Narrowing down our design selection. This is where the issue of actuation will be addressed.
- Creating a CAD model of what we intend to build. This will help us size parts relative to each other to make sure we are meeting size constraints.
- Building concept prototypes. This is where we take our ideas and make a small model to prove that what we made on the computer translates well to reality.

For a more detailed roadmap of our project, refer to the project Gantt chart in Appendix B.

6 Conclusion

This Scope of Work document is meant to serve as an agreement between our senior project team and those at JHH. We will work to adhere to the timeline detailed above and to meet the design specifications and sponsor requirements in order to develop a fully functional and safe final product. The product will be delivered to JHH by the end of Cal Poly's spring quarter, 2023. The next major deliverable, the Preliminary Design Review (PDR), will be presented on November 17th, 2023, which will document our concept CAD, prototypes, feedback, and refined CAD model.

7 References

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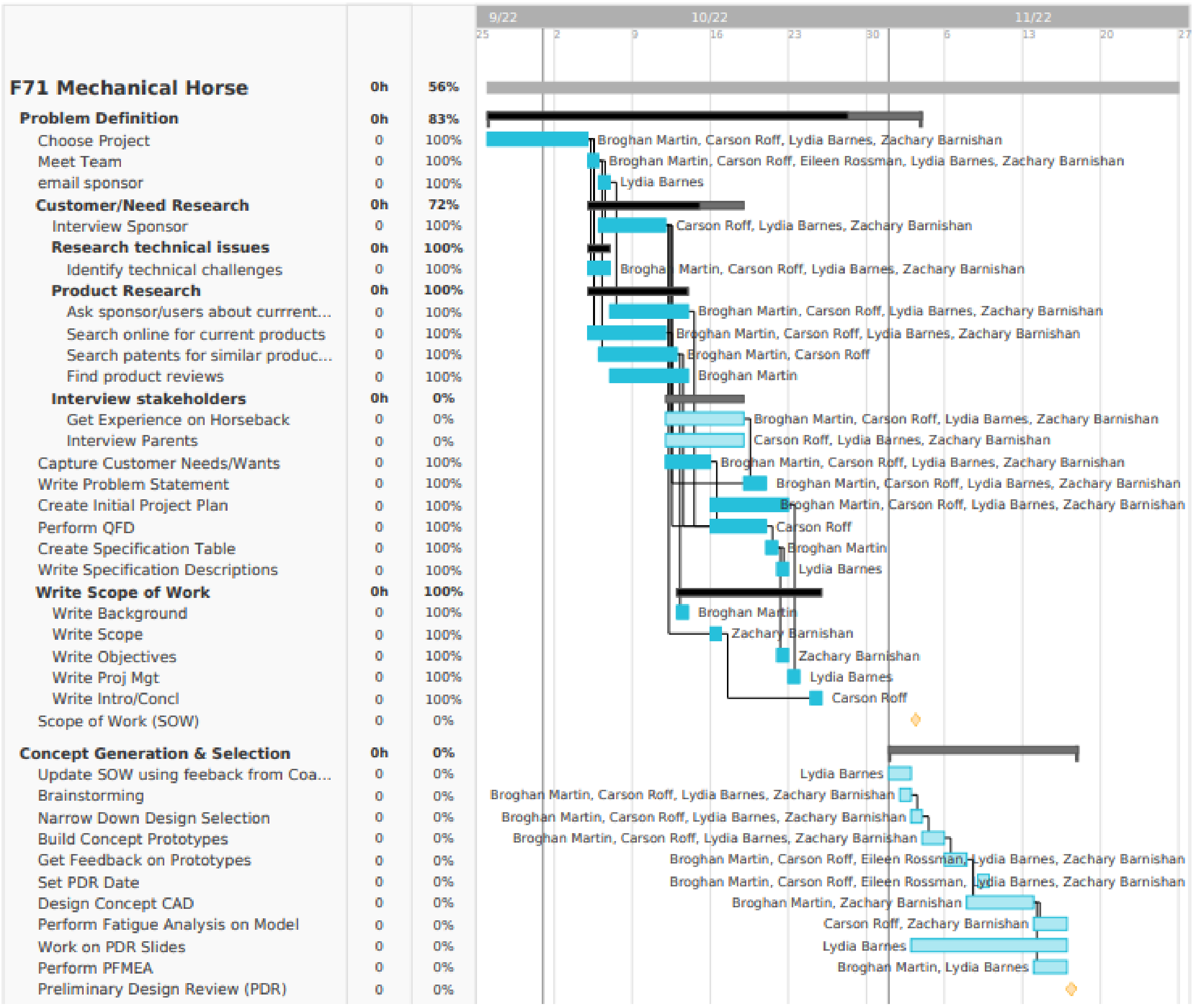
Appendix 1: Gantt Chart



Appendix 2: QFD House of Quality

Correlations	
Positive	+
Negative	–
No Correlation	

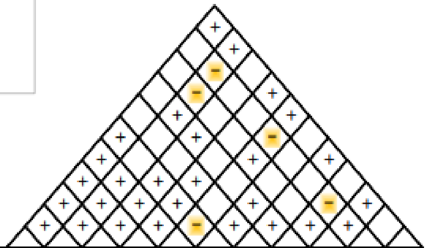
Relationships	
Strong	●
Moderate	○
Weak	▽

Direction of Improvement	
Maximize	▲
Target	◇
Minimize	▼

QFD House of Quality

Project: Musty the Mechanical Equine Therapy Machine FTK

Revision: A Date: 10/12/2022



	Column #	1	2	3	4	5	6	7	8	9	10	11
	Direction of Improvement	▼	◇	◇	▼	◇	◇	▲	▲	▼	▼	▼

WHO: Customers — NOW: Curr.

Row #	Weight Chart	Relative Weight	Bonnie	End User Lydia	End User Broghan	End User Zach	Maximum Relationship	WHAT: Customer Requirements (Needs/Wants) / HOW: Engineering Specifications (Tests)	Product Weight Requirement	Rider Weight Restriction	Rider Height Range	Product Footprint	Load Factor	Saddle Height	Appearance Survey	Use Survey	Maintenance Schedule	Setup Time	Cost of Materials	Last Year's Horse	Miracolt	Equicizer	Amazon's Gyrotron		Row #
1		5%	10	8	1	1	9	Mobility (2 Person Lift)	●	○	○	●	●	○	▽	●	○	●	▽	2	10	6	2		1
2		4%	10	2	1	3	9	Safety	●	●	○	○	●	●	○	●	○	▽	○	1	10	8	8		2
3		7%	8	4	6	8	9	Comfort	▽	●	●	○	○	●	●	●	▽	○	○	1	10	8	6		3
4		10%	7	10	9	9	9	Facilitate Equine Motion	●	●	▽	▽	○	●	○	●	▽	▽	●	3	7	7	2		4
5		8%	7	7	7	6	9	Self Propelled	▽	●	●	○	▽	▽	▽	●	○	●	●	4	3	9	2		5
6		2%	4	2	2	1	9	Water/Rust Resistant	▽	▽	▽	▽	▽	▽	○	▽	●	▽	●	6	9	7	5		6
7		3%	5	2	2	1	9	Dust Resistant	▽	▽	▽	▽	▽	▽	○	▽	●	○	●	2	9	7	5		7
8		10%	7	9	9	10	9	Horse-like Appearance	●	▽	▽	●	○	●	●	▽	●	▽	●	2	3	6	1		8
9		5%	9	8	2	1	9	Able to talk over	○	▽	▽	▽	▽	▽	▽	●	○	▽	▽	9	9	10	8		9
10		3%	10	1	1	1	9	Inexpensive	●	○	▽	○	●	○	○	○	●	▽	●	1	1	4	1		10
11		7%	10	2	7	8	9	Ease of Operation	○	▽	▽	○	▽	▽	▽	●	●	○	○	1	7	8	8		11
12		10%	10	9	9	9	9	Mountable	▽	▽	●	○	○	●	○	●	▽	▽	▽	1	9	7	9		12
13		8%	6	9	5	9	9	Age 6-16 Riders	▽	▽	●	▽	●	●	●	●	○	▽	▽	3	10	6	4		13
14		8%	8	6	7	7	9	Reigns	▽	▽	▽	▽	▽	▽	●	○	▽	▽	○	1	3	10	1		14
15		8%	7	7	7	8	9	Saddle	▽	○	▽	▽	▽	●	●	▽	▽	▽	○	9	2	10	5		15

		1	2	3	4	5	6	7	8	9	10	11
	HOW MUCH: Target Values	100 lbs	175 lbs	3'6" to 6'	2' by 4'	250 lb	36"	10	10	Monthly	10 Minutes	$500
	Max Relationship	9	9	9	9	9	9	9	9	9	9	9
	Technical Importance Rating	384	365	388	302	339	585	501	647	366	237	458
	Relative Weight	8%	8%	8%	7%	7%	13%	11%	14%	8%	5%	10%
Curr. Products	Last Year's Horse	1	3	1	1	3	1	1	1	1	1	1
	Miracolt	2	3	5	5	5	5	3	5	4	5	1
	Equicizer	1	5	4	3	5	5	4	4	4	5	0
	Amazon's Gyrotron	5	1	5	2	3	2	2	2	5	4	1
	Column #	1	2	3	4	5	6	7	8	9	10	11