Hurdle Mover

Athlete Designed

Designers

Colin Recar

Manan Sharma

Element A

Problem Identification & Justification

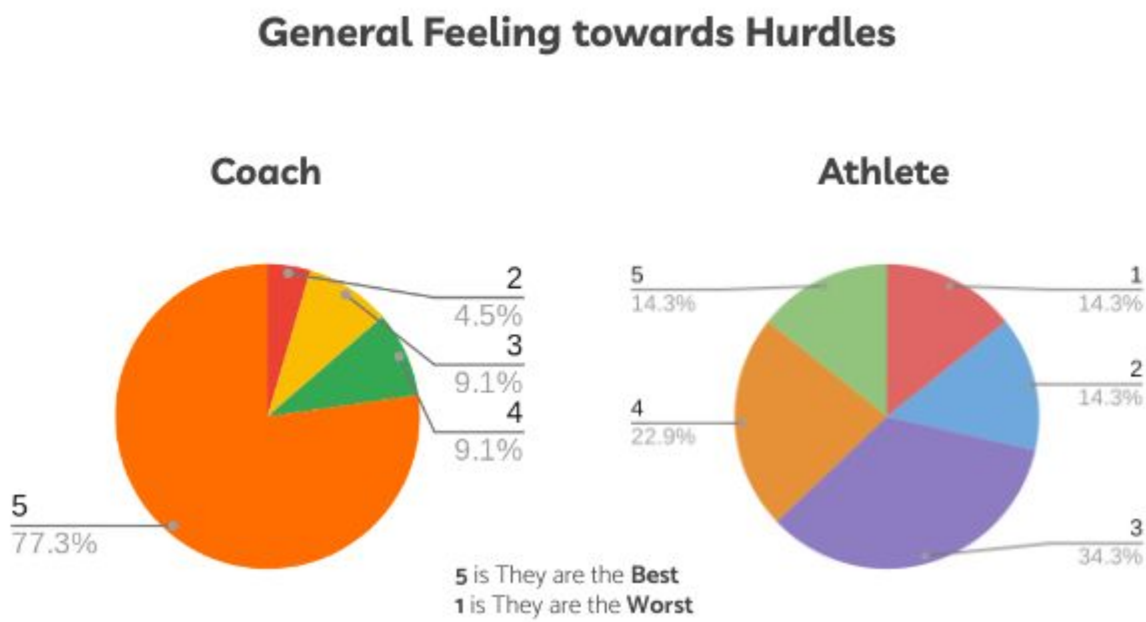
Problem Statement and Justification

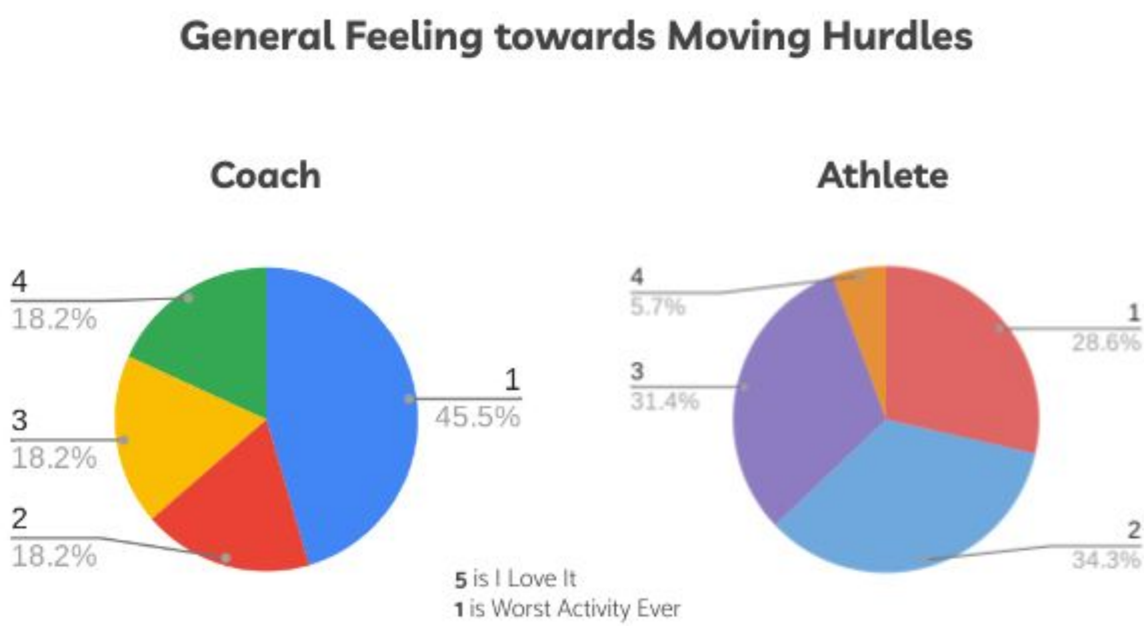
- Problem Statement
  - Oftentimes during the track and field season, high school track athletes are forced to move 100+ hurdles around the track complex. This often takes 10-20 minutes because athletes are only able to comfortably carry two hurdles at a time. As a result, this cuts into the athlete’s practice time, therefore potentially decreasing their ability to perform in competition. Therefore, there is a need to identify and design a mechanical solution that allows high school track athletes to quickly and efficiently move large numbers of hurdles. More specifically, a solution that allows us to move four or more high school rocker hurdles.
- Identify Stakeholders
  - Users- High School Track Field athletes, coaches, and groundskeepers.
  - Manufactures- AAE Sports, Stroops
- Justify Problem
  - This is a problem worth solving because the time it takes athletes and coaches to move hurdles around the track and field complex, severely cuts into practice time, potentially decreasing the performance of athletes in competitions.

Research and Survey Summary

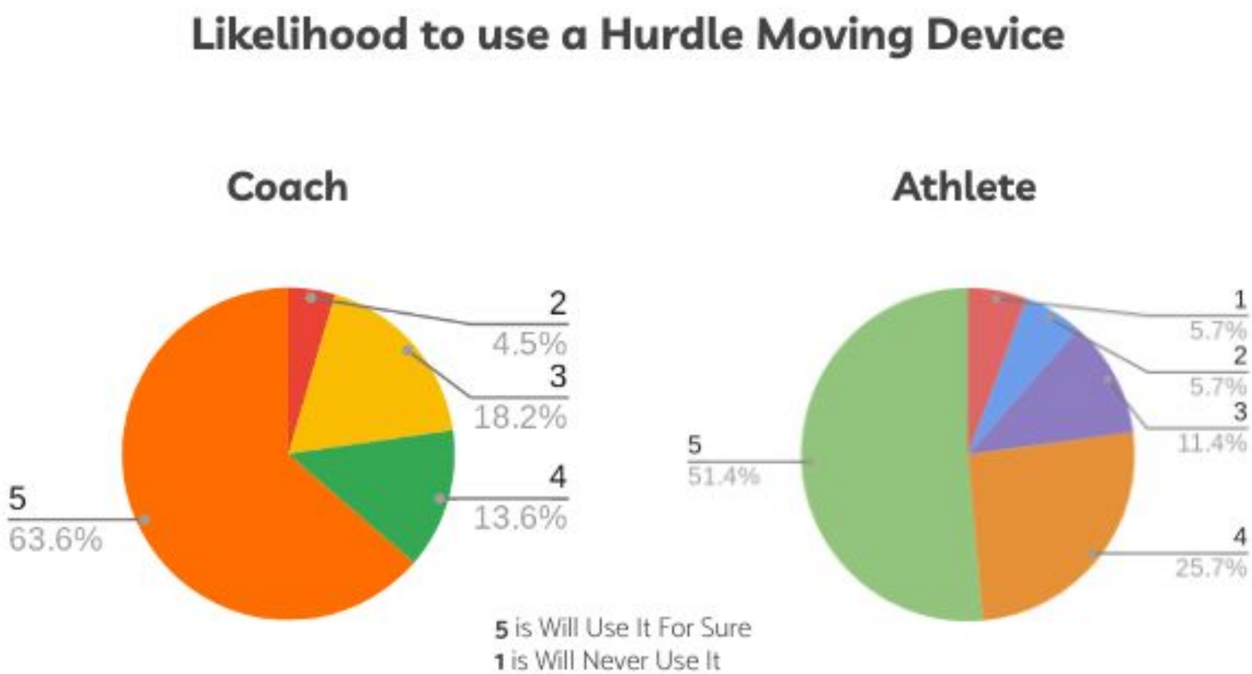
- Most of the existing hurdle-moving devices are designed to move professional and college 90-degree hurdles, not high school rocker hurdles.
- About 64.8% of coaches and athletes dislike or strongly dislike moving hurdles. This is out of the 54 athletes and coaches surveyed.
- About 66.6% of coaches and athletes spend 10 to 20 minutes a practice moving hurdles.
- About 77.8% of coaches and athletes would or would likely use a device that allowed them to move more hurdles at once.
- Other major thoughts were:
    - Awkward to move.
    - Can be very time-consuming, especially during meets.

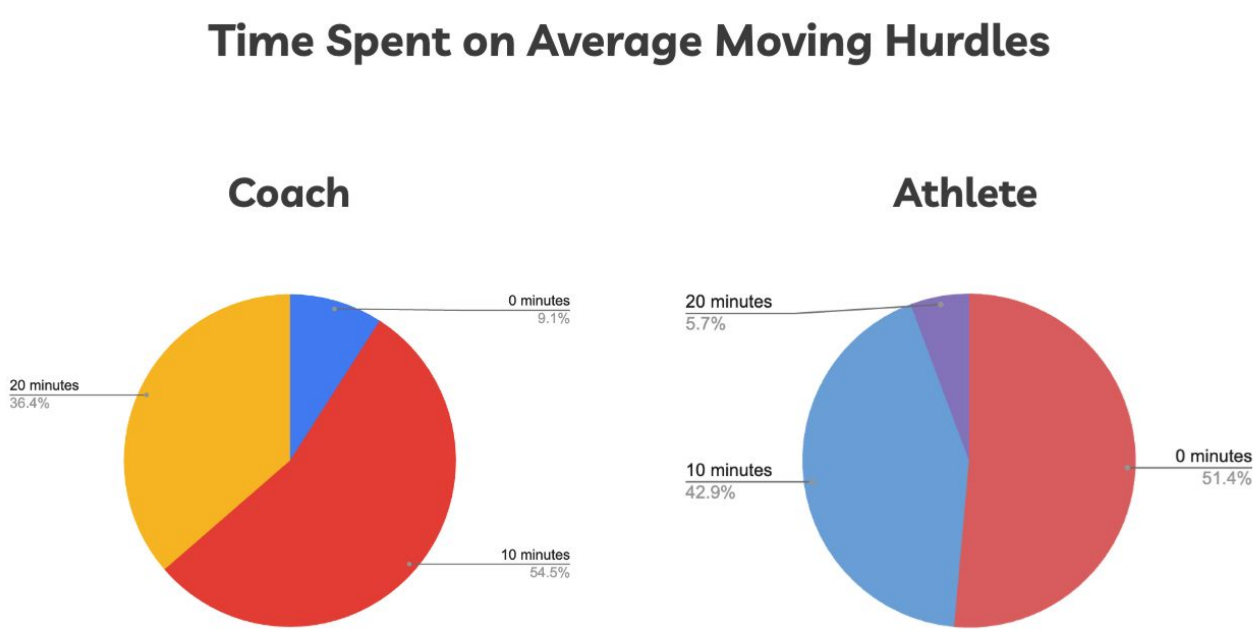
Survey Results





Survey Results





Element B

Documentation and Analysis of Prior Solutions

Documentation and Analysis of Prior Solutions

Name: Gill Hurdle Porter

Cost: $575

Pros:
- Specifically designed to move hurdles.
- Mobile, not really limited to pavement or the track.

Cons:
- Only really effectively works with college/heavy hurdles.
- Hurdles aren't really securely hold on cart.
- Still have to manually load hurdles on the cart.
- Student operators could easily fail to use it properly.
- Expensive.

Name: Gill Hurdle Cart

Cost: $800

Pros:
- Specifically designed to move hurdles.
- Moves 8–10 hurdles.
- More stable than the porter.

Cons:
- Only really effectively works with college/heavy hurdles.
- Hurdles aren't really securely hold on cart.
- Won't easily roll on turf due to caster wheels.
- Expensive.

Documentation and Analysis of Prior Solutions

Name: Forearm Forklift

Cost: $30

Pros:
- Easily storable.
- Cheap.
- Simple
- All terrain, though stairs might be a struggle.

Cons:
- Requires two people to use or some modification to be used by one person.
- Capacity is limited to the physical strength of the users.
- Probably not the easiest to set up or move.
- Hurdles must be stacked on top of the straps first.

Name: Forklift

Cost: $15,000

Pros:
- Can pick up the hurdles straight off the track.
- Self-powered.
- Can really move as many hurdles as you can fit on it.

Cons:
- Kind of overkill for moving hurdles.
- Can only pick up a first few hurdles before they need to be stacked on the forklift.
- Students probably shouldn’t be operating this.

Documentation and Analysis of Prior Solutions

Name: Hardwood Dolly Mover

Cost: $60

Pros:

- Ideal platform for moving hurdles.
- Could be used for other things as well.
- Fairly cheap.

Cons:

- No good way to push.
- Wheels probably won't work well on dirt or mud.
- No good way to push
- Rocker hurdles, which don't stack well, probably won't stay on the dolly.

Name: Platform Cart

Cost: $75

Pros:

- Fairly cheap.
- Can move a lot of hurdles at once.
- Good, wheels for lots of mobility.
- Multiuse functionality.

Cons:

- Have to stack the hurdles on a quite elevated platform.
- Kind of big for a hurdle mover.
- Could easily get quite heavy.

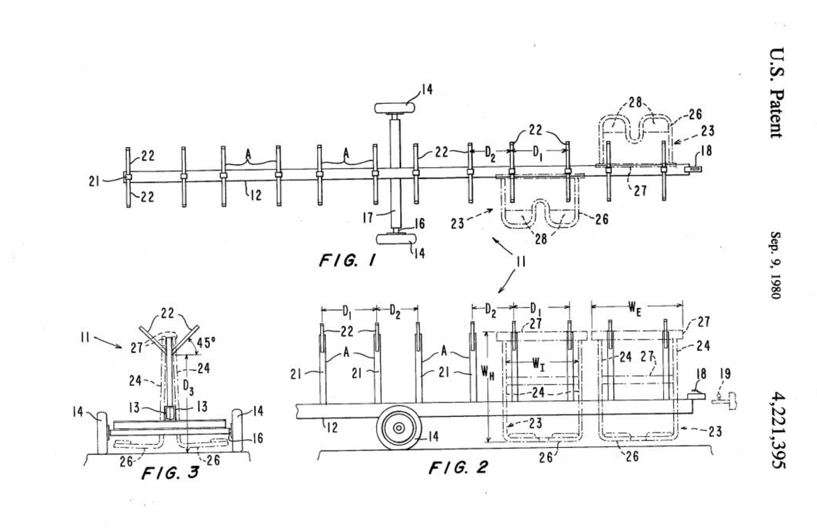
Documentation and Analysis of Prior Solutions

Name: Dolly Cart

Cost: $50-100

Pros:
- Easily move over lots of terrains.
- Weight capacity isn't a major limiting factor.

Cons:
- Would have to be modified to hold hurdles.
- Depending on wheels, it might not roll well on the turf.
- Depending on how it is modified to carry hurdles, it might not be able to hold a lot of hurdles.



Name: Hurdle Hauler

Cost: Unknown, probably expensive.

Pros:
- Dedicated hurdle mover.
- Can move any type of hurdles.

Cons:
- Requires golf cart or cart to use.
- Still manually loaded.
- Quite big for our purposes.
- Expensive.
- No true way to precisely replicate it.

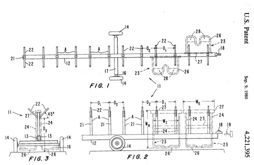
Element C

Solution Design Requirements

Design Goals

- Must be able to move between four and eight hurdles at one time.
- Must be highly portable, and able to move over a variety of surfaces.
- It must be easily replicable.
- Cost under $100 to produce.
- We shall have a deliverable prototype by February 26th.
- Must be able to move both the rocker and 90 degree hurdles.

Past and Current Solutions Matrix

	Cost	Complexity	Efficiency	Durability	Mobility	Capacity	Total
Straps 	4	4	3	2	3	2	18
Hurdle Hauler 	1	1	2	4	3	4	15
Hurdle Porter 	2	3	3	4	3	4	19
Hurdle Cart 	1	2	3	4	2	4	16

4 - Cheapest
1 - Most Expensive

4 - Simplest
1 - Most Complicated

4 - Most Efficient
1 - Least Efficient

4 - Most Durable
1 - Least Durable

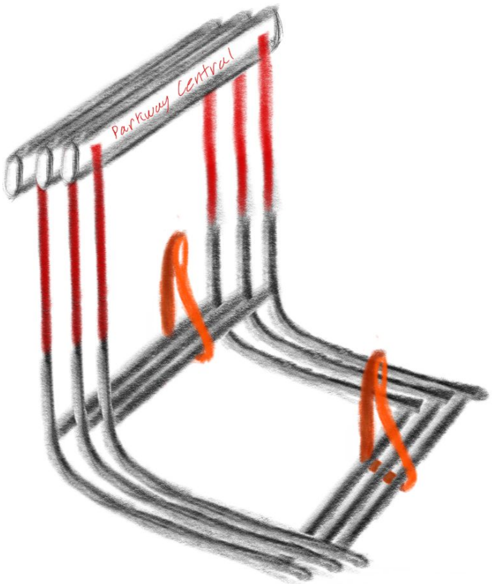
4 - Most Mobile
1 - Least Mobile

4 - Largest Capacity
1 - Smallest Capacity

Element D

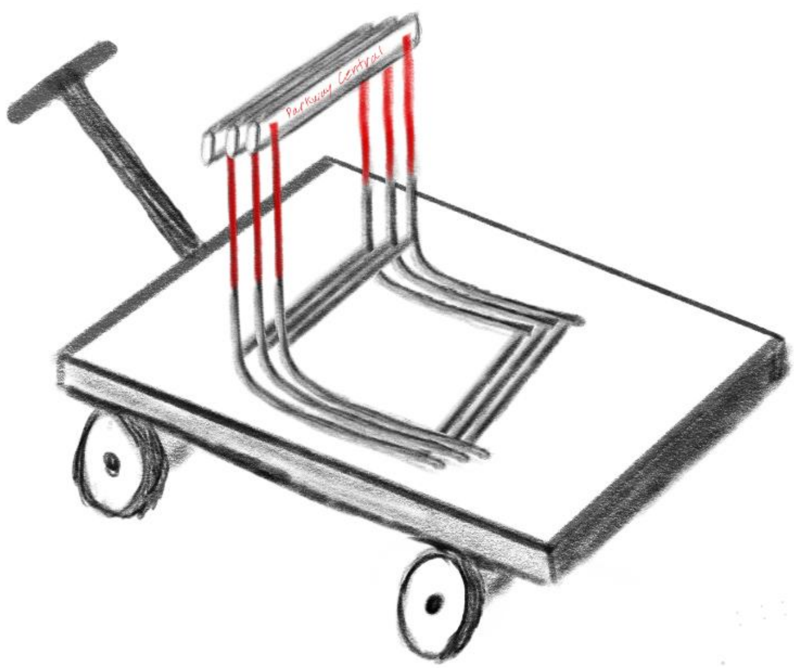
Design Concept Generation and Analysis

Strap/Rope Design



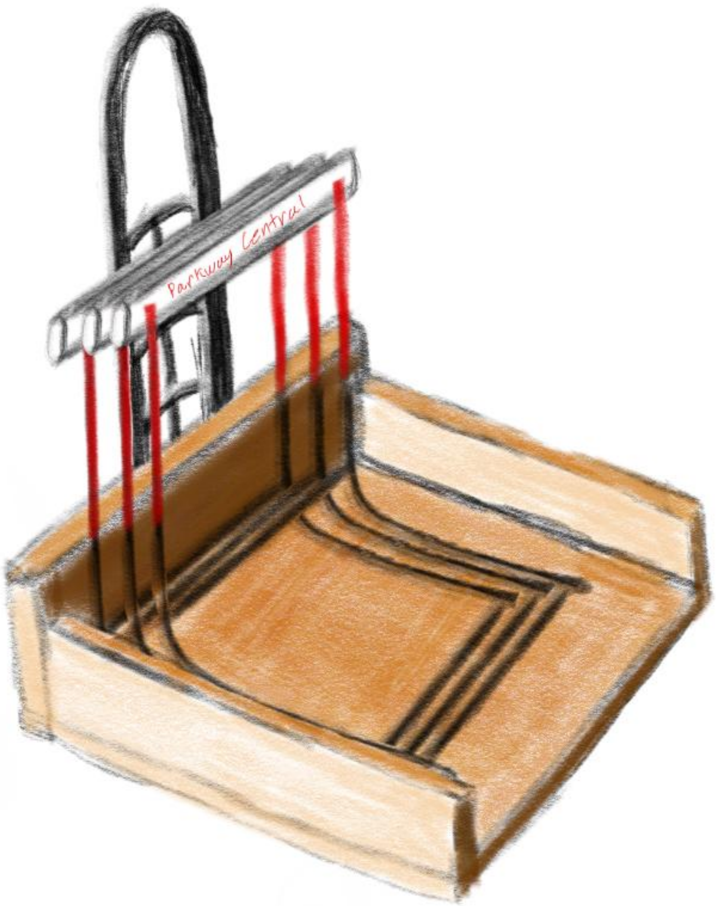
This is a hurdle mover that is composed of two straps, one wrapping around each of the crossbars of the hurdles. This design makes it easier for a person to pick up more hurdles at once by eliminating the limitation of not being able to comfortably wrap one's hands around more than the crossbars of two hurdles. However, the number of hurdles moved at once will still be limited by the muscular carrying strength of the user.

Cart Design



This design is composed of a cart on which the hurdles are placed. It completely eliminates the limitation of a person only being able to lift 3–4 hurdles at once due to their weight. Instead, wheels reduce the effort and strain on the user, allowing them to move more hurdles at once. However, it does require the hurdles to be lifted and placed high off the ground, in order to be stacked on the cart. This is something that might prove to be less than ideal for some users, and could prolong loading and unloading times.

Dolly with Attachment Design



This design is composed of a dolly on which a platform attachment is placed in order to carry and move hurdles. It once again completely eliminates the limitation of a person only being able to lift 3–4 hurdles at once due to their weight. Instead, utilizing wheels reduce the effort and strain on the user, allowing them to move more hurdles at once. However, unlike the cart, it is smaller and more compact, allowing for easier maneuvering in tight spaces. Additionally, it is not terribly far off the ground, especially in comparison to the cart, which would make loading and unloading easier. On the other hand, the dolly would likely be less capable at crossing muddy or squishy terrain, when fully loaded due to the fact that all the weight is spread between two tires. Additionally, controlling the dolly, when fully loaded, could prove to be harder and take more strength/control than some users will want to use.

Design Concept Matrix

	Cost	Complexity	Efficiency	Durability	Mobility	Capacity	Total
Traditional	4	4	1	3	4	1	17
Rope System	3	2	1	2	4	2	14
Dolly System	2	3	3	4	3	4	19
Cart System	1	3	4	4	1	4	17

4 - Cheapest
1 - Most Expensive

4 - Simplest
1 - Most Complicated

4 - Most Efficient
1 - Least Efficient

4 - Most Durable
1 - Least Durable

4 - Most Mobile
1 - Least Mobile

4 - Largest Capacity
1 - Smallest Capacity

Design Concept Analysis

Solution Decision:

- The design idea we chose was the dolly with an attachment for the hurdles to sit on.

Why This Design?

- We selected this design because it was the highest ranked in our decision matrix, it was also a combination of the ideas we came up with separately.

How will it solve the issue?

- The dolly with platform attachment solves the issue of only being able to move two hurdles at a time, by introducing a platform on which a multitude of hurdles can be stacked. Additionally, this design allows for easy loading and unloading, as the device is pretty close to the ground and doesn’t require the hurdles to be lifted high. Lastly, the wheels of the both allow for a continued ability to move over a variety of terrains, while also reducing the effort required to move large numbers of hurdles.

Plan of Action

- Going forward, we plan on really diving into the design of this concept. It will likely some thought and prototyping will have to go into make the mechanism for attaching the platform to the dolly. Additionally, the dolly will need to be engineered to support the weight of all the hurdles without breaking, which could prove challenging due to the nature of how it will sit on the dolly. In terms of timeline/order, our first steps will be to design the platform, and then we will tackle attaching it to the dolly. After all this, we should be ready for testing. Depending on how initial testing goes, we might have to go back and add a way to secure the hurdles to the platform.

Element E

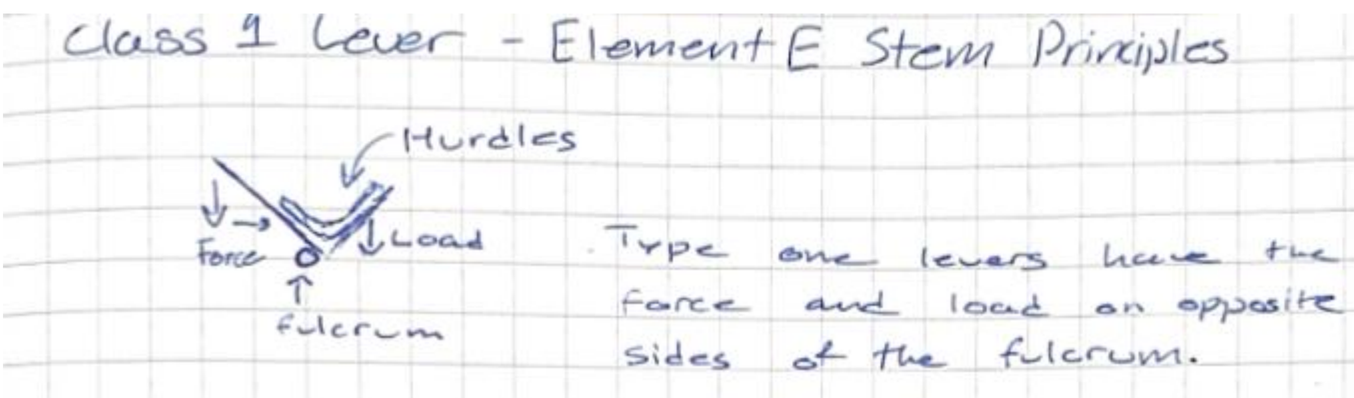
Application of STEM Principles and Practices

STEM Principles:

- Wheel and Axle
    - One principle that had a critical impact on our design, was the wheel and axle. A large problem with moving hurdles, asides from only being able to comfortably grasp two hurdles at once, is the weight of the hurdles. Each hurdle weighs about 20 pounds. As a result, if a person could grasp an infinite number of hurdles, the max number of hurdles the average person could lift would be 3-4 due to the weight of the hurdles. Consequently, by implementing a wheel and axle system, we can distribute the weight of the hurdles between the two wheels. Therefore, reducing the amount of weight carried by the operator. Additionally, wheel and axle designs reduce the amount of friction between the ground and the object being moved, which in our case would reduce the effort required to move the hurdles on the dolly system. Also, the wheel and axle system, which will employ large, treaded tires, will continue to allow the hurdles to be moved across most terrains, while reducing the effort required to move them. This is something that not all movement systems, like caster wheels and ball wheels, allow for.

STEM Principles:

- Lever
  - Another simple machine that was critical to our design is the lever, specifically a class 1 lever. Once again, this simple machine is to reduce the effort required to pick up and carry a large number of hurdles. Allowing one to move a larger weight in hurdles than they could carry with their two hands. In the case of our design, the fulcrum is the wheels of our dolly. The baseplate and platform act as the load for the lever. Finally, the handle of the lever is the handle of the dolly. Since the handle of the dolly is much farther away from the fulcrum than the load, one has to apply a smaller force on the handle of the dolly in comparison to the force the load is applying on the baseplate. This is due to the principles of torque (T=Frsin(theta)). As one gets farther from the fulcrum, the amount of force required to move the same load decreases. Ultimately, this is how the principles of a lever fit into this design.



STEM Principles:

- Loading
    - The design also had to incorporate the principles and ideas of loading into the design. For instance, the hurdles each weigh about 20 lbs, so eight of those hurdles would be around 160 lbs. As a result, we had to create a design that could support this weight and transfer it to the baseplate of the dolly without breaking. This is especially necessary because most of the hurdle's weight isn’t located directly over the baseplate. As a result, we needed to design a system of beams that could support the plywood, as well as function as a means of transferring the weight of the hurdles to the dolly. We ended up designing a system similar to that of a floor joist system to support the load of the hurdles, as floors are incredibly efficient at transferring/distributing loads. Therefore, allowing us to maximize strength, while working a bit to minimize weight.

STEM Principles:

- Materials
  - Dolly
    - We choose to base our design around a dolly because it can hold a lot of weight, and are designed to withstand repeated loading. Furthermore, dollies, especially metal ones, have excellent durability. Allowing them to resist all measures of weather and physical deterioration. Additionally, due to the construction, dollies are fairly resistant to temperature fluctuations, with the only consistent issue being with the inflatable tires on some dollies. These might require to be aired up after major fluctuations.
  - Wood
    - We selected wood to be the basis of our platform attachment for a few reasons. It is much stronger than anything we could 3D print. Additionally, it is much cheaper to fabricate this device out of wood, than say plastic or metal due to the size of the platform we need. It is also more accessible to get in the sizes we require, without having to pay extra premiums for custom cut pieces (likely have to do this with metal). Furthermore, while wood isn't quite as durable as metal or plastic, when painted or treated it can be quite durable, as well as weather resistant. In addition, the wood, when connected together in a joist like design, should be able to withstand the repeated loading and unloading. As in most use cases, the wood is only temporarily withstanding the full load as the dolly is raised up and let down. Ultimately, when cost, accessibility, and strength are all considered, wood was the best option.

STEM Principles:

- Materials
  - Plastic Parts
    - We decided to make the pieces that attach the platform to the dolly out of PLA plastic. This type of plastic has widespread availability and comparable properties to other 3D printer plastics. While it isn't the strongest or toughest plastic, it is a middle of the road plastic that gives one good strength with relatively low cost. Furthermore, it can withstand a fair amount of temperature fluctuation without terrible detriment. Additionally, due to the layering nature of a 3D print, it takes a lot of abrasions and impacts before it has a detrimental effect on the part. Also, while chemicals could have a major impact on our 3D printed parts, the places where they will be used are going to have a low risk of actually coming in contact with these chemicals. Finally, while sunlight is known to damage 3D prints, most of our 3D parts will be located in places where they won't be constantly exposed to sunlight for long periods of time (namely the bottom of our device). For all these reasons we went with a PLA plastic for our plastic parts, as it will withstand the test of time.

Source:
Barrett, A. (2020, June 9). Advantages and Disadvantages of PLA. Bioplastics News. https://bioplasticsnews.com/2020/06/09/polylactic-acid-pla-dis-advantages/

STEM Principles:

- Materials
  - Straps/Rope
    - All reinforcing and connecting straps are going to be made of nylon (specifically paracord and nylon straps). This is due to the high tension strength and durability of nylon, along with its relative low cost. It can withstand abrasions quite well, compared to some rope materials. Additionally, and most importantly, it can withstand constant loading and unloading, and be able to do it quite often. Furthermore, it is largely unaffected by temperature fluctuations and sunlight, making it perfect for our application in our outdoor device. Finally, nylon has excellent strength in tension, which is how it will be loaded in our design, making it perfect for our application. In fact, a .238 mm thread of nylon can support 8 lbs in tension before breaking. Therefore, for our purposes, nylon is the best option for the ropes and straps incorporated within our design.

Source:
WGBH EDUCATIONAL FOUNDATION, & Materials Research Society. (2010). DEMONSTRATION Breaking Point : Testing Tensile Strength. https://www.pbs.org/wgbh/nova/assets/education/making-stuff/stuff-toolkit-stronger-demo.pdf

Roles and Responsibilities

Responsibility*	Primary	Secondary
Document Control*	Colin	Manan
Recorder / Note Keeper*	Colin	Manan
Communication Expert*	Colin	Manan
Researcher*	Colin	Manan
Timeline/Scheduler*	Manan	Colin
CAD Expert	Manan	Colin
Prototype Planning	Colin	Manan
Prototype Construction	Manan	Colin
Testing Methods	Manan	Colin
Data Collection	Manan	Colin
Presentation Planning	Colin	Manan
Presentation Visual Aids	Manan	Colin
Final Project Documents	Colin	Manan

* Indicates responsibility for this will apply throughout the entire design project.

Timeline

Element A: Problem Identification & Justification – December 15th

Element B: Documentation/ Analysis of Prior Solutions – December 22nd

Element C: Solution Design Requirements – January 12th

Element D: Design Concept Generation and Analysis – February 9th

Element E: Application of STEM Principles and Practices – February 16th

Element F: Consideration of Design Viability – February 23rd

Element G: Construction of a Testable Prototype – March 8th

Element H: Testing and Data Collection Plan – March 15th

Element I: Testing Data Results and Analysis – March 28th

Element J: Documentation of External Evaluation – April 12th

Element K: Designer Reflection on the Process – April 12th

Element L: Presentation of Designer's Recommendations – April 12th

Element F

Consideration of Design Viability

Design Viability

The proposed product design comprises a dolly equipped with a platform attachment, specifically designed for the transportation of hurdles.

Advantages:

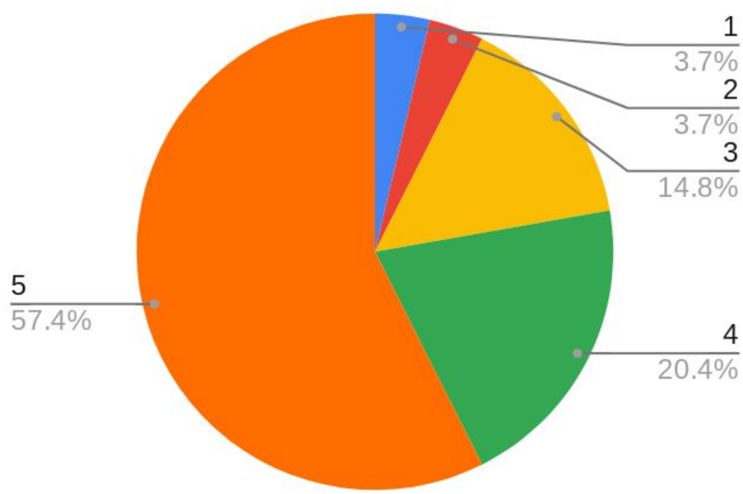
- **Enhanced Efficiency:** By utilizing a dolly with a platform attachment, users can significantly increase the number of hurdles they can transport at once. The design mitigates the limitations posed by the weight of hurdles, allowing users to move multiple hurdles simultaneously.
- **Reduced Physical Strain:** The incorporation of wheels in the design reduces the physical effort and strain typically associated with manually lifting and carrying hurdles. This feature enhances user comfort and minimizes the risk of fatigue or injury during transportation.
- **Compact and Maneuverable:** Unlike traditional carts, the dolly with platform attachment boasts a smaller and more compact form factor. This characteristic allows for easier maneuvering, particularly in confined or crowded spaces where larger carts may struggle to navigate effectively.
- **Optimized Loading and Unloading:** The dolly's lower height, especially when compared to bulkier carts, simplifies the process of loading and unloading hurdles. As a result, users can access and manage hurdles with greater ease, hence streamlining the process.

Considerations:

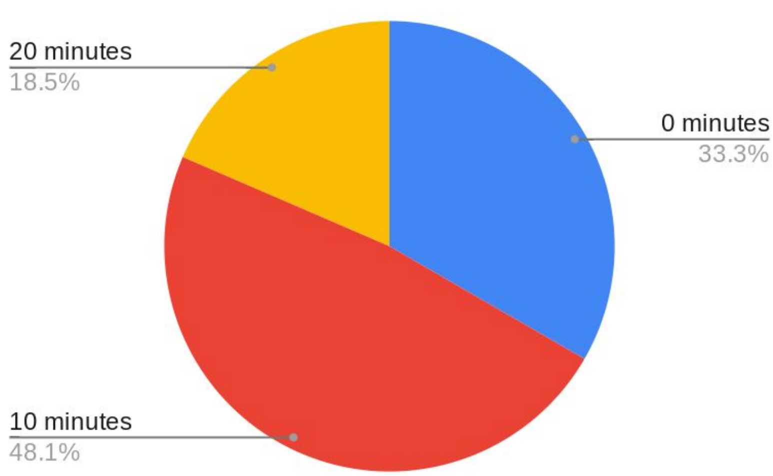
- **Weight Distribution:** Careful consideration must be given to the distribution of weight on the platform attachment to maintain stability during transportation. Proper balance ensures safe handling and prevents potential accidents or tip-overs.
- **Durability and Materials:** The dolly and platform attachment should be constructed from durable materials capable of withstanding repeated use and environmental factors.
- **Maneuverability on Various Surfaces:** The design's effectiveness may vary depending on the surface conditions encountered during transportation.
- **User Training and Safety Protocols:** Users should receive training on the proper usage and safety protocols associated with the dolly and platform attachment. Clear instructions and guidelines will minimize the risk of accidents and ensure optimal performance.

Design Viability

- The viability of our design is further supported by the data we collected from our initial survey research. According to our collected data, the vast majority of athletes would use a hurdle moving device, which can be seen in the graph below. Please note: the scale is 1-5, with 5 being very likely to use the hurdle moving device.



- Also, a large majority of respondents replied saying they spend 10–20 minutes moving hurdles a day, which significantly cuts into practice time of the athletes. A pie chart illustrating a breakdown of the responses is featured below.



Material List

Name	Material	Quantity
2x8 Lumber	Wood	1
2x6 Lumber	Wood	1
1x3 Lumber	Wood	4
4x8 Sheet of ¼” Plywood	Wood	1
Wood Screws	Metal	1 Package
Dolly	Metal and Rubber	1
PLA 3D Printer Filament	Plastic	1 Spool
Paracord	Nylon	60’
3’ or longer Nylon Tie Down Straps	Nylon	2

***For a more in depth analysis of materials and why we choose what, please see Element E’s section on materials.

Build Requirements

- Process
    - The basis of our building process will be a wood fabrication utilizing wood screws and brackets. In terms of tool requirements, we will need a saw (preferably a circular and/or jig), drill, impact driver, and 3D printer (for printing brackets and other attachment devices).

- Programs
    - We will be using Fusion 360 for all of our CAD modeling, including to make the drawings for our design and the 3D printed parts.

- Tools and Other Resources
    - We will need access to computers, as well as a track and field complex, in order to test our design.

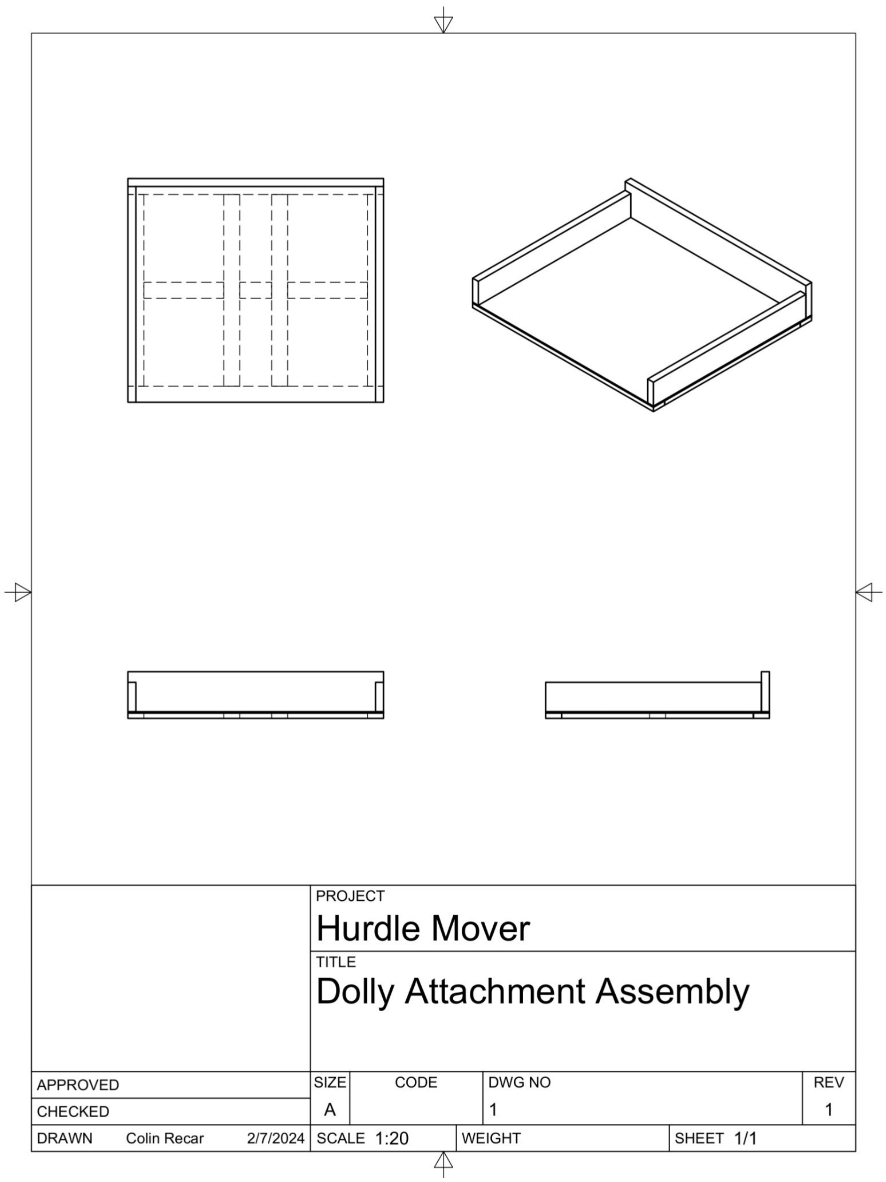
- Price and Sizing
    - For the purposes and design requirements previously outlined, we will need to have a hurdle mover large enough to move 4-8 hurdles at once, which will give the device a footprint of 4’ x 3.5’. Additionally, the ideal cost of a prototype would be less than 100 dollars for the hurdle moving attachment.

- Realism
    - All of our design decisions were made based on feedback we gained from others, as well as are our own personal experiences. Additionally, we have prioritized functionality and cost, at times to the detriment of the device's looks and weight. We really honed in on the fact that we wanted our design to be able to hold 4-8, while being easy to operate and move. Furthermore, we really wanted a device that ideally would compliment existing equipment at a track, hence, the connection to a dolly. Finally, as an added benefit, our device should be able to help move other objects (i.e. water coolers, blocks, cones), as well as hurdles due to the design we settled on.

Element G
Construction of a Testable Prototype

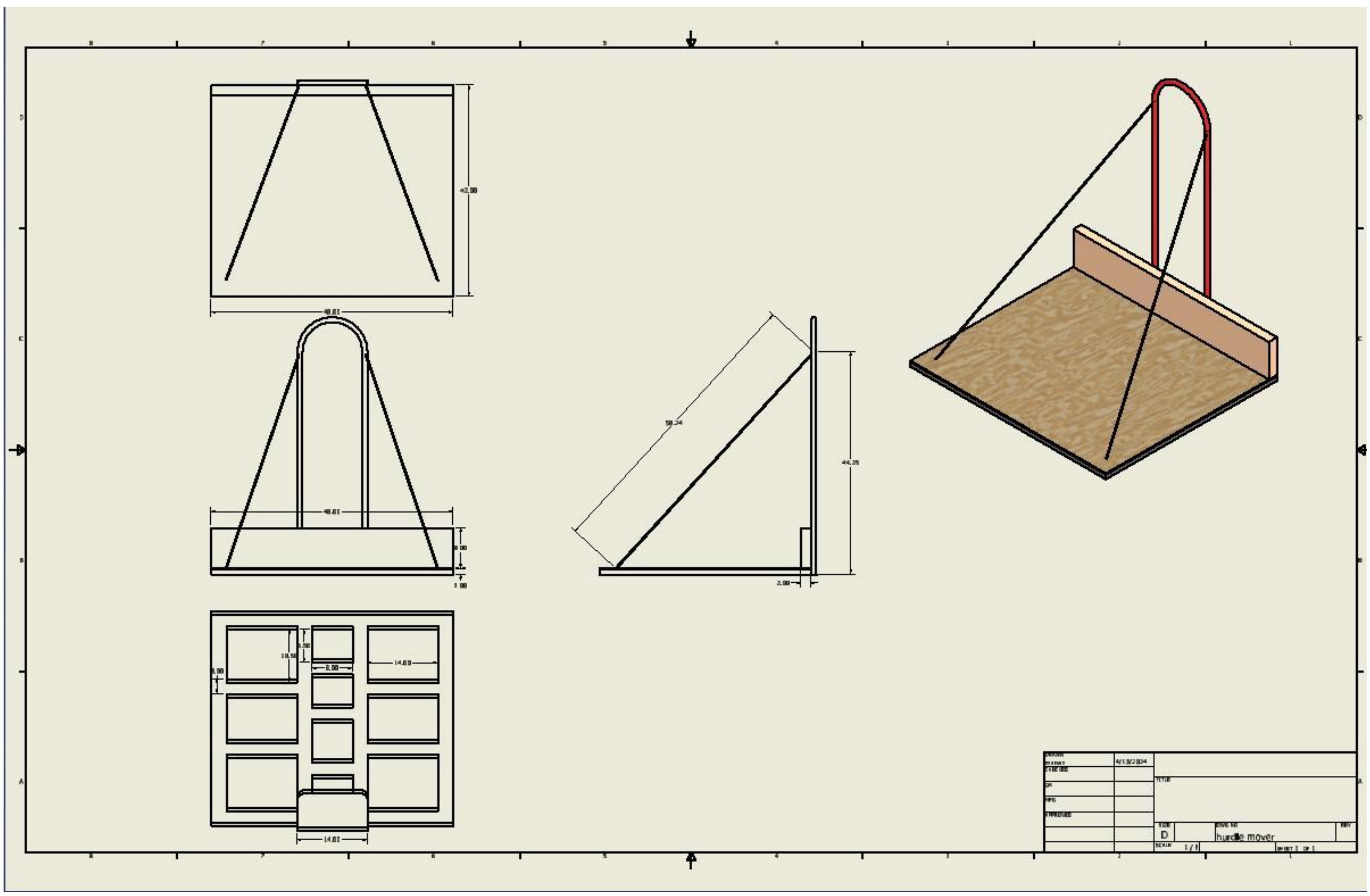
Sketches

We used CAD to model the platform and how it would be connected to the dolly. The first design included back and side supports as well as reinforcements beneath the platform for added structural integrity. The dimensions are based off the length and width of a high school hurdle with some extra room for error on each side. This would help in the loading and unloading of the hurdles during use.



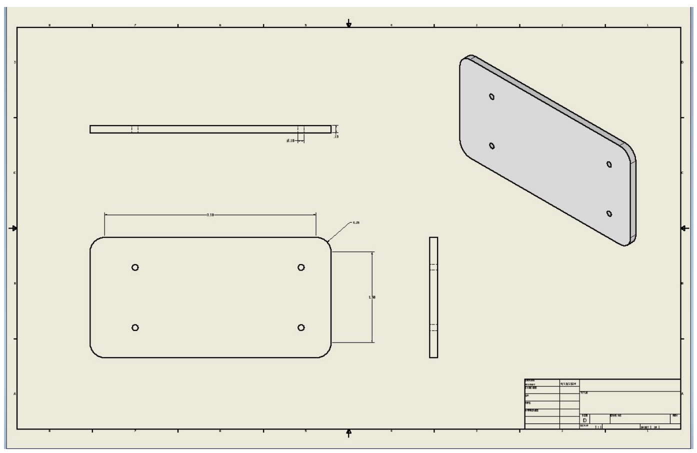
Sketches

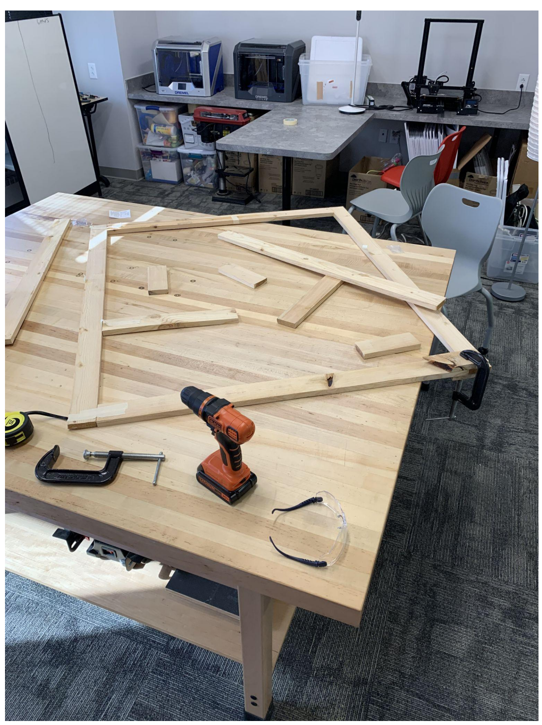
Our second design iteration did not have the side supports as we realized they were not necessary. Additionally, we added more reinforcement on the bottom to make it more stable and have the ability to withstand more weight. We also made the decision to add ropes to the platform tensioned back to the dolly to provide more lifting force with hurdles.

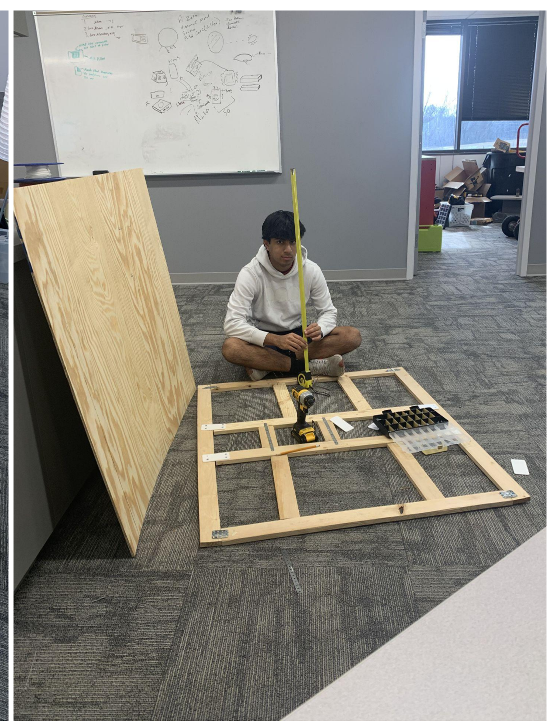


Development

We started by gathering the materials needed and measuring out each piece of wood and laying it out before we joined them together. To join the frame together we initially tried screwing a long screw through the 1x3 planks however that ended up splitting the wood. We decided to pivot and 3-D printed brackets that can be placed on an intersection of two pieces of wood and screwed there.

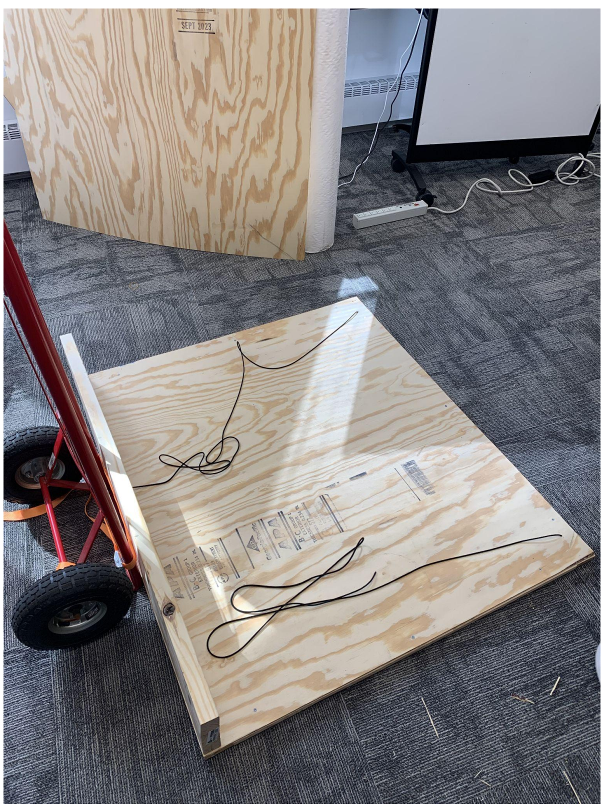






Development

After making the support frame, we laid the plywood surface on top and screwed that in. Next we attached a 2x8 to the back of the platform which will be used as our connecting point to the dolly. This back board also has straps attached to it which allows us to winch the platform to the dolly with a secure connection. Next, we added the ropes towards the front which act as tension for when we pull the dolly back. These are then tied towards the top of the dolly.



Development/Final Prototype

To finish the construction of our prototype, we had to adjust the position of the strap on the back to better attach to the dolly and secure it in place. Additionally, inserted more screws into the base as well as the back support to make the overall structure more sturdy. One main element of the hurdle mover is that it can be detached from the dolly and the dolly can be used for other applications.

Element H

Testing and Data Collection Plan

Weight Test

- Purpose
  - Identify how many hurdles our hurdle mover can safely and effectively hold.
- Pass/Fail Criteria
  - If the hurdle mover platform breaks in any way, we will consider the test a fail.
- Materials
  - Hurdle Mover
  - Dolly
  - Hurdles
- Test Overview
  - Throughout the hurdle movers use, it will be subjected to many loads. As a result, through this test, we will simulate the various loads by adding and removing weights from the platform.
- Procedure
  - 1) Set up the hurdle mover by attaching it to the dolly.
  - 2) Place 1 hurdle on the platform.
  - 3) Move the dolly for 100m.
  - 4) If the dolly passes the test with its current load, increase the load on the dolly by one hurdle.
  - 5) Repeat steps 3-4 until the dolly doesn’t pass with its current load or passes with a load of 8 hurdles.

Efficiency Test

- Purpose
  - Determine if our hurdle mover is more efficient in comparison to a traditional hurdle moving method.
- Pass/Fail Criteria
  - If the hurdle mover takes longer to move the hurdles than a traditional hurdle moving method, it is considered a fail.
- Materials
  - Hurdles
  - Hurdle Mover
  - Dolly
- Test Overview
  - The whole purpose of this design is to make the movement of hurdles more efficient. As a result, this test is to see if our design is truly more efficient than traditional hurdle moving methods.
- Procedure
  - 1) Set up the hurdle mover by attaching it to the dolly.
  - 2) Scatter 6 hurdles at the 100m Dash start line.
  - 3) Use the hurdle mover to move these 6 hurdles to the other side of the track, placing the hurdles on the breakline (using lanes 1-6). Start the stopwatch when one starts moving the first hurdle, and stop once the last hurdle has been placed. Record this time.
  - 4) Reset the hurdles in accordance with step 2. Then repeat step 3, only this time utilize the traditional hurdle moving process (your hands). Record this time the same way.
  - 5) Repeat steps 2-4 at least two more times, and average the resulting times for both methods before comparing.

Mobility Test

- Purpose
  - Determine if our hurdle mover is able to move over a variety of surfaces.
- Pass/Fail Criteria
  - If the hurdle mover gets stuck, isn't able to move forward, or becomes incredibly difficult to move, it fails the test.
- Materials
  - Hurdles
  - Hurdle Mover
  - Dolly
- Test Overview
  - Another large priority for our design was a design that could move hurdles, and other large objects, over various terrains. As a result, the purpose of this design is to test its ability to move over a variety of terrains.
- Procedure
  - 1) Set up the hurdle mover by attaching it to the dolly.
  - 2) Load the hurdle mover with 4 hurdles.
  - 3) Push the hurdle mover over various terrains, including track, turf, sand, grass, cement, and gravel.
  - 4) Record the results by making note of its ability to move over each terrain.

Element I

Testing Data Results and Analysis

Weight Test - Results

- Results:

Number of Hurdles	Pass/Fail (If fail, it is noted why)
1	Pass
2	Pass
3	Pass
4	Pass
5	Pass
6	Pass
7	Pass
8	Fail - We were unable to lift the platform of the hurdle mover off the ground and get it moving. There was no visible structural damage to the hurdle mover.

- Analysis:
  - The hurdle mover was successful in moving 7 hurdles, which makes it far more successful than the traditional hurdle moving methods. In other words, it could move about 2.3x - 3.5x more hurdles than traditional methods.

Efficiency Test - Results

- Results:

	Time using Traditional Methods	Time using Hurdle Mover	Difference (Traditional - Mover)
Participant 1	5 min 6 sec	3 min 58 sec	1 min 8 sec
Participant 2	4 min 50 sec	4 min 12 sec	38 sec
Participant 3*	4 min 37 sec	6 min 18 sec	-1 min 41 sec

*Participant 3 didn't receive any training or practice on how to use the device prior to beginning the test.

- Analysis:
    - With a well-trained user, we were able to move hurdles around the track and field complex much more efficiently than the traditional means for moving hurdles. However, with an untrained user, the hurdle mover was much more inconclusive about which method was faster.

Mobility Testing - Results

- Results:

Surface	Difficulty (5- Very Hard, 1- Very Easy)
Running Track	1
Concrete	1
Turf	3
Sand	4
Gravel	2
Grass	5

- Analysis:
  - In terms of mobility, the hurdle mover is fairly mobile. The dolly we were using did have some flatter tires, which could have impacted our results in the mobility test slightly. However, even with this, the mover was very easy to move over harder surfaces like gravel, running tracks, and concrete. The only surface that it really noticeably struggled a ton with was grass. It could have been because the ground was a bit soft the day we tested, but it was by far the hardest to push and control the hurdle mover on.

Analysis of Effectiveness

Overall, based on our testing, we conclude that our design is a moderately effective alternative to traditional hurdle moving methods. With a user trained in how to effectively operate and utilize the device, it can be incredibly effective in reducing the amount of time it takes to move hurdles around the track and field complex. However, once one also factors in the time it takes to bring the device to the hurdles, make sure it is set up correctly, and put it away, the time benefits become less certain. Additionally, the need for a properly trained user in order to reap the efficiency benefits is another major detractor from this design because it requires extra time to set aside, in an environment where time is already limited, in order to start reaping the benefits of the design. Also, due to these additional factors of the device, one won't start seeing the time reduction benefits till after many, many uses of the hurdle mover. Lastly, our hurdle mover really needs to be able to hold eight hurdles to really maximize its effectiveness on the track (in most scenarios eight hurdles are needed, one for each lane). For these reasons, we can say that our hurdle mover did achieve its main objectives, but there is still a lot of room for improvement, making it only moderately effective in the grand scheme of things.

Element J
Documentation of External Evaluation

Expert #1: Corey Feit

- Qualifications
  - Corey is an industrial designer who makes his living designing products for companies. As a result, he is very good at asking the tough questions that could make or break a design. Additionally, Corey is very proficient at considering designs from many angles (example: consumer, designer, and manufacturer's perspective).
- Evaluation
  - Questions:
    - Most of Corey's questions revolved around the physics of our design, as well as its usability and durability.
  - Suggestions:
    - A large concern of Corey's was the strength of our design. Our prototype was largely made of wood and only connected to the dolly in a few places. As a result, he recommended we reinforce it with metal L brackets in various places. Additionally, he recommended we increase the number of points connecting the platform to the dolly through various different means.

Expert #1: Corey Feit

- Suggestions Continued:
  - Corey also recommended that we add some type of icon symbols on our device to show how to use the device, as well as the possible safety concerns for our device.
  - Corey also suggested we design a way to secure the hurdles to the platform in some way. This way they don't fall off while going over rough terrain, or shift in a manner that makes the mover difficult/dangerous to operate.
  - Corey's final suggestion was to consider selling/producing the dolly and hurdle mover as a singular item. Customer's might not want to always take the time to hook up the hurdle mover to the dolly, so they might view it as more advantageous to buy a device that contains all the necessary components. Also, by eliminating the rope/strap connections we would be able to further eliminate weak points, strengthening our overall design.

Expert #2: Mr. Franck

- Qualifications
  - Mr. Franck is the engineering and construction science teacher at our home high school. He also used to coach track and field. As a result, he has a very high level of expertise in the areas in which our project is focused.
- Evaluation
  - Questions:
    - The majority of Mr. Franck's questions were directed towards why we choose the materials we did, as well as the hurdle mover's specific application to track and field. He also asked some questions about how this device could be used for other situations.
  - Suggestions:
    - One suggestion, Mr. Franck had, was to consider making it useable for more situations (to be able to move other items). Currently, the rope support system limits the size and shape of some items it can hold, so redesigning the support system would open up the possibilities of items this platform and dolly could move.

Expert #2: Mr. Franck

- Suggestions Continued:
    - Another of Mr. Franck's suggestions was to make the platform of metal. This is something we had considered, but because of cost and material/tool availability, we decided to make it out of wood. However, if we were going to make it commercial, we would likely make it out of metal.
    - The other big piece of feedback we got from Mr. Franck was to keep it detachable, as many track and field teams use their dollies for several different purposes. As a result, especially for teams with limited resources, an attachment would be more beneficial and useful than and permanently fixed piece.

Element K

Designer Reflection on the Process

Project Reflection

Defining the Problem

From our experience, as track athletes we knew that pretty much every high school in the St. Louis area moved hurdles through people carrying them in groups of 1-3 around the track complex. We both feel like this method is inefficient and wastes valuable practice time. As a result, we conducted a survey of high school track athletes and coaches, in order to gather their thoughts on this style of movement, and confirm that there was truly a problem that needed to be addressed. Ultimately, through this survey we learned that over 50% of our respondents dislike or strongly dislike moving hurdles with the current system. A more through breakdown of this survey can be found in Element A.

Reflection

The survey data collected during this process, and our own personal experiences, really helped use to define and shape the problem we are going to solve. It also gave us our basic parameters and design criteria by which we were going to try and measure success. However, looking back we probably should have sent our survey to more people. While we did get responses from 54 people, the vast majority were within the Parkway School District, which all have very similar track and field setups. To have really gotten all the opinions and ideas we should have tried to incorporate athletes from more schools, whose setup might differ slightly. This probably would have refined our problem more, making our solution applicable to more groups.

Project Reflection

Research

After we defined our problem, we began to research, specifically looking for past or current solutions to the problem we were trying to solve. We were able to collect quite a bit of information about these types of devices from patents and manufactures websites. However, there aren't a lot of hurdle movers currently on the market, so we also took quite a bit of time to look at devices that were capable of moving objects of similar size and weight to a stack of hurdles. Throughout this whole process, we were making note of various things including cost and usability.

Reflection

This research, along with the survey data, would eventually form the basis of our initial inspiration for our design criteria and ultimately, our initial design sketches. Additionally, this research further confirmed the reality of our problem because throughout the research process, we found plenty of examples of the hurdle movers for college and professional hurdles. However, we were unable to find any currently sold hurdle movers for high school rocker hurdles.

Project Reflection

Developing Project Specifications

Our project specifications came from a variety of sources. Our survey data and our real world observations formed the backbone of many of our efficiency and capacity requirement. Our research into past and current solutions, led to our criteria that focused on moving high school rocker hurdles and being low of a cost, both originated from our research into other solutions. Lastly, our size requirements largely originated from the specifications of the hurdles being moved, and the footprint eight of them took up.

Reflection

These design specifications became really important as we were moving forward, as they served as the driving force behind many of our decisions and design concepts. At a few different points we had to adjust our design criteria slightly as we realized one point conflicted slightly with another, however, overall they largely remained unchanged. This allowed us to stay on track in building a solution that gave us our best shot at solving the problem at hand.

Project Reflection

Design Concept Generation and Selection

For this part, we each created 3-4 sketches of possible designs (We each had similar ideas, so we only put the three main designs in Element D). We then came together and discussed our various sketches. Ultimately, we decided to combine the ideas from a few of our sketches into one final design. As a result, together we created a final sketch that ultimately formed the basis of our final design.

Reflection

Overall, this step wasn't too hard for us because we both had similar ideas with where we wanted to take the project due to some conversations we had with mentors during earlier stages in the process. Additionally, once we created a matrix comparing our various sketches, our earlier thoughts were supported and confirmed. Nonetheless, it was a very important step because this sketch was the basis of the rest of our project. It was going to be the design concept that we were going to develop into a prototype. The prototype that we were ultimately going to test to see if it met our design criteria and solved the problem statement we developed in Element A.

Project Reflection

STEM Applications

Most of our STEM application research was done as we were slowly building our prototype. From an early point, we knew of most of the STEM principles that were going to be incorporated into our design due to its relative simplicity. However, we didn’t realize the complexity of some of these simple STEM principles (loading and materials), until we began working through the documentation of these principles. This was especially true for materials, as we used quite a few different materials in our project.

Reflection

This step really helped us to better understand how exactly our solution works, as well as the STEM ideas behind it. Additionally, the materials section in particular really helped us to pick the best materials for our project when we later started to plan for and construct our prototype (Elements F and G). Lastly, this research and documentation really helped us problem solve later as issues arose, as we had a very good baseline understanding of the STEM principles within our design.

Project Reflection

Prototyping/Testing

Once we gathered all of our materials, the construction of our prototype wasn't super complex or difficult. The biggest challenge we faced, was that some of our pieces of wood were kind of thin and would easily split when screwing pieces together. As a result, we had to design a 3D printed plastic bracket to connect the pieces of wood together, while minimizing the chances of splitting. After we built our prototype, we went into the testing phase. We ended up conducting three different tests on our prototype. The tests were a carrying capacity, efficiency, and mobility test. A detailed report of the results from each test can be found in Element I. However, the big takeaway was that our hurdle mover could move up to about 7 hurdles, and with a trained user was more efficient than traditional hurdle moving methods.

Reflection

It was during this part of the project that we were able to start seeing all of our work over the previous few months starting to come together. Additionally, we were able to see if the design concepts would actually be feasible to build, which are final design concept was, and see if it actually solved the hurdle moving problem, which initial testing showed it did. Lastly, if we had more time, there were definitely parts of our design that could have been refined in the initial prototyping process, as well as more testing that could have been done.

Project Reflection

External Feedback

For this part of the project, we got feedback from two different people, Corey Feit and Mr. Franck. Both of them gave us excellent feedback on our project, and gave us much to think about as we were moving forward in our project. Additionally, they helped us to identify many potential strengths and weaknesses within our project, especially those that would affect the usability of our product.

Reflection

The external feedback was incredibly helpful and informative. It really helped to drive our conversations about how we would change the design for the next prototype, and as a result became the basis of our Element L. Additionally, they both provide some helpful suggestions in the areas of marketability and usability, which we hadn’t previously considered.

Element L

Presentation of Designer's Recommendations

Designer’s Recommendations for Improvements

- Product Improvements
    - Materials
        - One of the biggest improvements we want to make to our hurdle mover is to make it out of metal. For our initial prototyping it wasn’t economically feasible nor did we have the tools on hand to make it out of metal. However, designing it out of metal would likely allow us to reduce the amount of material needed, and would likely allow us to make the platform lighter. Additionally, metal is much stronger and more durable than wood, which would also increase the longevity of the design in comparison to our wood prototype.
    - Connections
        - Another improvement we would like to make is how we connect the platform to the dolly. Currently, we are simply using a tie down strap screwed to the rear upright board of the platform to attach the dolly to the platform. However, we have come to notice that this never provides a super secure tie down, and often there is quite a bit of wiggle between the dolly and the platform. As a result, it would likely be beneficial if for the next iteration we designed some sort of rigid clamp or bracket by which the platform could be attached to the dolly.
    - Size
        - When we were originally designing the platform we designed it conservatively as the high school rocker hurdles never stack perfectly (they tend to spread out in a pile). However, during testing it became apparent that our platform was a little bigger than it needed to really be. As a result, with the next iteration we could probably make the platform smaller, especially in terms of its depth.

Designer’s Recommendations for Improvements

- Product Improvements
    - Instructions
        - One of Corey’s recommendations that we found incredibly helpful was the idea of putting icons or symbols illustrating the potential dangers of this device, as well as the basics in how to use it. This would definitely be something that we would include in the next interactions, as it would likely help an untrained user use the device better (something our first prototype struggled with).
    - Securing Device
        - The final product improvement that we would likely make in the next iteration, would be the implementation of a device to secure the hurdles to the platform. This would be especially helpful for a user when traversing uneven terrain, where the hurdles would be more prone to shifting and falling off the platform. Additionally, this would be a system that could be stored away on the platform if not in use, as to not interfere with the use of the hurdle mover.

Designer’s Recommendations for Improvements

- Project Improvements
    - Real World Testing
        - Real world testing would be highly beneficial for this project, as it would have really let us know if our prototype would have solved our problem. All of the tests we conducted, which pointed to our device solving our problem, were in extremely controlled environments. However, the real world is far from controlled, meaning that our hurdle mover could fail to solve the hurdle moving problem in the real world. As a result, leaving our prototype with a track team for them to test for a week or two, would have been highly beneficial in determining the success of our solution. Hence, why if we did this project again or continued to work on the hurdle mover, this type of testing would be a priority for us.