Final Report

SkateLab Presents - Stattrak Wheel Pro Edition 2.0

Anders Law, Liam Scott, Jackson S. Dallas

University of Georgia

TXMI 4160

Dr. Sharma

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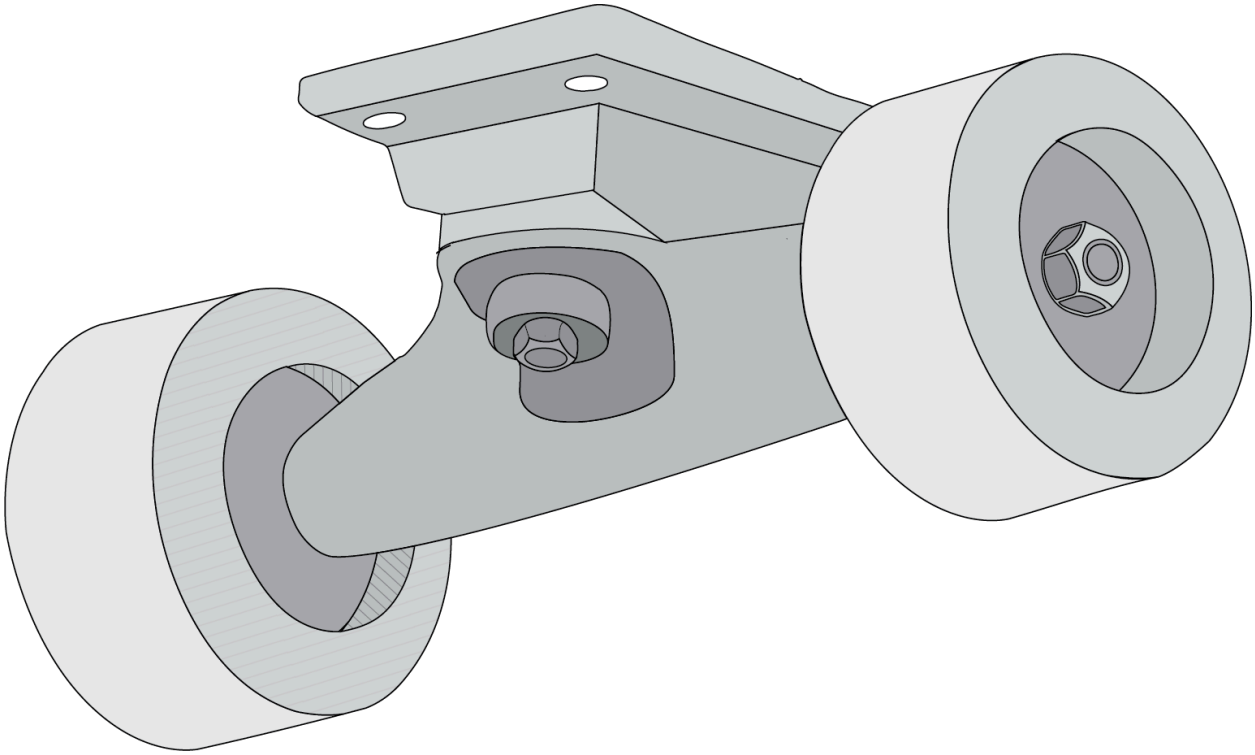

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I. Introduction

Skateboarding was born on the West Coast of the United States in the early 1950s, but has since grown into an internationally recognized competitive sport. Technical and practical elements of the sport remain an artform, yet become increasingly scrutinized as more participants garner exposure and invest in the competitive aspects of skateboarding. Despite the technical intricacies of the sport, quantitative empirical measurements derived from real time data are rarely considered in scoring competitors at a professional level. *Stattrak Pro Wheels* address the current gap in the market and facilitates the success of amateurs and professionals alike. Contemporary statistical monitors provide a cutting edge solution that can be seamlessly integrated into any board at an acceptable price point; applications of our product range from interior measurements, number of attempts, and trick identification. The reliability of our product is ensured through durable construction and consistent manufacturing.

II. Mission Statement

At Stattrak, our mission is to revolutionize skateboarding by bridging the gap between art and analytics, providing cutting-edge statistical measurement tools that seamlessly integrate with existing products on the market. Our commitment empowers amateur and professional participants with reliable, real-time data, to enhance performance and scoring metrics in the skateboarding industry.

III. Customer Needs

A. Target Markets

i. Primary - Professional Skaters

1. Competitive Events - Olympics / SLS / XGames

   Competitive Skateboarding Events such as the Olympics, Street League Skateboarding, and XGames have yet to comprehensively standardize judging criteria for the sport. The subjective nature of scoring professionals requires judges to rely on a level of intuition in order to rate the performance of competitors, who balance creativity & consistency in their profession. Skateboarding grows increasingly popular as it becomes more mainstream; there is an urgent need to reduce the subjective input during evaluations. Establishing consistency as a prerequisite for performance through quantitative measurement is a necessity for future competitive events.

2. Professional Athletes

   Professional athletes emphasize consistency throughout practice and performance. The unique styles of each professional contribute to the diversity of a sport, often influencing the future of the scene itself as they gain popularity. These athletes seek a consistent experience during training sessions; while their competition and partners may suffice in the early stages of their careers, professionals have yet to find a company that can record their individual performance quantitatively. Additionally, this product prevents distractions and improves focus in private training environments.

ii. Secondary - Amateur Skateboarders & Retailers

1. B2C Businesses

   Multinational retail corporations (i.e. Walmart), sporting goods store (i.e. Academy), wholesale centers (i.e. Costco), & sports manufacturing subsidiaries (i.e. Spitfire) all engage with their markets with a large selection of sporting goods. These companies rely on this strategy as a prerequisite for sales; by offering the most popular or premium products offered by each sport, these companies are able to serve the needs of their consumers more readily. In order to

maintain this status quo, companies will ultimately indicate our Stattrak Pro V.2. Wheels as a necessity for skateboarding goods.

2. Individual Direct Consumers

   Professionals all start as amateurs - in order to separate the wheat from the chaff, we offer our product as an additional mechanism for improvement on their journey towards competitive skateboarding. Our product is tailored to address the specific challenges faced by recreational participants interested in exceptional training today for assurance in the professional skateboarding environments of tomorrow. Additionally, this product has potential to reduce the concerns of guardians that might otherwise prevent youth from participation

iii. Tertiary

1. Academics Environments

   Many physics classrooms have a multitude of different tools and items to conduct experiments that are relevant to class material. Two of the most important elements in the physics curriculum are velocity and force. This wheel can measure both of those elements with the applied technology inside. It could be sold and marketed to educators as a tool to catalyze experiments which are currently being done on old, unreliable technology that's hard for the students to use. Because the wheels connect to an app students can very easily see the data they are collecting in order to use it in the classroom or for lab reports.

2. Engineering R&D Applications

   Researchers and engineers for organizations such as NASA and Virgin Galactic to name a few have an apparent need for a product that can accurately measure changes in altitude, direction, and velocity for a variety of reasons. Our product offers the conceptual alternative to the expense of current quantitative methods utilized by these programs. As technologies become increasingly advanced within the manufacturing industry, such organizations have already begun to contemplate the opportunity cost of quantity versus quality (especially as evidenced by SpaceX in the aviation and space industries).

B. Lead User Identification

The main lead users for our product are competitive events and the participating professionals themselves. These markets are deeply embedded in the roots of skateboarding as a profession; these segments are acutely aware of the culture and historical background of skateboarding, and are highly knowledgeable of contemporary and future skateboarding trends. The small details and overall statistics of our wheels can provide the pro's a huge advantage in the competitive scene, meaning they will be early adopters to get a "head start" on other professionals that do not have them. Professional skateboarders also have money, because by their very nature they get paid. Being a professional skateboarder is a job, so they will have the funds to purchase our wheels. They also have sponsors, people that invest in them and have a stake in seeing them succeed. Skateboarding sponsors are likely to send professional skateboarders, a.ka our lead users, the Stattrak wheel as a way to help ensure their success.

C. Summary of Data Collection

i. Interviews

The primary method for research will be one on one interviews. The interviewer will have a list of questions they will ask the respondent and can take notes based on the answers. The notes will then be organized and assumptions can be made when reviewing the combined responses. The interviewers can also take note of body language to deduce things the customer may feel very emotional towards, whether it be a positive or negative response. Interviews will be conducted at whatever location is most convenient for the interviewee. This could be a skatepark, restaurant, or even at UGA. By being willing to interview people at different locations, we are likely to get a well rounded group of differing individuals who can give us feedback on our product. In the event of an in person interview not being possible, we will use Zoom or another online video call service. In-person interviews will be prioritized in order to note the nonverbal cues correlated with the product and other relevant factors. The interviews targeted individuals with connections or experience with skateboarding; the surveys were sent out en masse to generate additional feedback and a larger pool of responses. One-on-one interviews were conducted either in-person or through a Facetime call, wherein two group members were present. One group member

conducted the interview while the second took notes on paper. The group conducted nine one-on-one interviews; each member accepted responsibility for conducting three interviews. Targeting the secondary market was the main focus for our surveys, as the primary market cannot be reached for contact. Questions were formatted as open and closed response answers to collect qualitative and quantitative data. Here is an example of the questionnaire:

1. Do you enjoy skateboarding? If so, in which ways? (Skating, watching skateboarding content, enjoy the overall vibes of skaters, etc)
2. How do you think skateboarding could be improved?
3. How do you feel about more technology being implemented in skateboarding?
4. How do you think competitive skateboarding should be judged? Based on what criteria for example?
5. Do you think (yourself if you skate/skateboarders in general if you don't) would benefit from technology within a skateboard that can track and quantify skateboarding?
6. What elements of skateboarding do you think would be beneficial to track?
7. Rank from least to most important the following elements associated with landing a skate trick: Speed. Style. Landing Impact. Trick Difficulty. Number of Attempts. Obstacle.
8. What general feedback do you have for a skateboarding wheel that employs sensors to measure speed, impact, and number of attempts for skate sessions?
9. How often do you repair or replace skateboard components?
    - ___ Once a month
    - ___ Once a year
    - ___ As needed
    - ___ Never
10. Rank the following in terms of importance:
    - ___ Tread Adjustment
    - ___ Wheel Durability
    - ___ Wheel Performance
    - ___ Aesthetic Customization

___ Ease of Maintenance

___ Replacement Time & Effort

In order to convert the interviews into parsable data, answers from open response questions were reworded to fit into similar themes that popped up across interviews. From there each statement could be quantified and ranked based on how many times it came up in interviews. These could later be converted into need identification statements. Some of the questions from the interviews had interviewees rank criteria. To turn this into data each criteria was given a score and ranked accordingly based on its average placement in the interviews.

ii. Surveys

The survey was created using Google Forms and distributed using social media and other peer-to-peer platforms so as to facilitate the ease of access and interaction. The total number of people who responded to the survey was 14. Targeting the secondary market was the main focus for our surveys, as the primary market cannot be reached for contact. Questions were formatted as open and closed response answers to collect qualitative and quantitative data. Data from the Google Forms is automatically displayed in graphs. The graphs can show percentages of surveyants who selected different options and rank them based on the largest number. Displaying the data in a graphical form makes it much easier to read and draw conclusions from. Out of the 61.5% said that they enjoy skateboarding. This is a good sign for our data, as it is important to have people that enjoy what the product is for. It is also good to have some other opinions from outside perspectives. When asked if amateurs could benefit from the implementation of technology in skateboarding, the majority of respondents chose the “Yes” option. This implies the general public sees technology as a catalyst for progress as a beginner in skateboarding, as opposed to a barrier. When asked if professionals might benefit from technology added to skateboarding the compiled data from interviews and surveys shows that an overwhelming amount believe in the utility of tracking technology in the competitive arena. This shows that even though there may be some skepticism to adding technology to skateboarding within the industry, more casual skateboarding enjoyers would not be opposed to a modernization of skating. When asked during interviews and surveys how often you replace skate parts, more than half of participants indicated “as needed;” the second

largest pool responded "rarely or never." This means that an amateur skater who buys our wheels would have them for life and someone who skates more often would rebuy our wheels every time they break down. This can be good for business since if they like our wheel they will have to keep buying it from our company.

D. Data Organization

In order to convert the interviews into parsable data, answers from open response questions were reworded to fit into similar themes that popped up across interviews. From there each statement could be quantified and ranked based on how many times it came up in interviews. These could later be converted into need identification statements. Some of the questions from the interviews had interviewees rank criteria. To turn this into data each criteria was given a score and ranked accordingly based on its average placement in the interviews. Data from the Google Forms is automatically displayed in graphs. The graphs can show percentages of surveyants who selected different options and rank them based on the largest number. Displaying the data in a graphical form makes it much easier to read and draw conclusions from. Notes from observations and content analysis were simply written down and later converted into needs statements. Things that appeared more times were ranked higher.

E. Needs Statements

Needs statements were created based on the responses from the interviews and surveys.

Figure 1. Needs Identification & Interpretation

Promt	Interview Answer	Interpreted Need Statement
How do you think skateboarding could be improved?	I think skateboarding should be easier for beginners to get into.	The technology is easy to use.
What feedback do you have for a wheel that employs sensors to measure speed, impact, and number of attempts for skate sessions?	The wheels can’t be super complicated to install.	The wheel is simple to install.
Aesthetics & Familiarity	The wheels should feel the same as the wheels I use now.	The wheel construction allows for skating.

	I would want the wheels to fit on my current setup.	The wheels are compatible with current truck sizes.
	The wheel can't look corny. (*Survey)*	The wheels look aesthetically pleasing
Data Collection & Utility	I'm not very good with math and numbers and stuff like that.	The data is easy to understand.
	I don't wanna wait a long time for the data.	The data uploads quickly to an application.
	I want to be able to flex on my friends if I get a good result.	The data is easy to share with other people.
	I definitely went faster than my friend, but there's no real way to know. (*Observation)*	The data is comparable with that of other users.
	The technology should be accurate everytime I use it.	The data is consistently accurate.
Quality & Durability	The technology also needs to be able to withstand how demolishing skateboarding can be.	The technology in the wheel withstands the destructive forces of skating.
	I rarely replace components unless I have to. (*Survey)*	The wheel is durable.
Accessibility	Skateboarding is already expensive.	The wheels are affordable for the target consumer's economic demographic.
	I don't want to carry around extra tools just to skate. (*Observation)*	The wheels should be attached using common tools.
Professional	Custom skateboards are permitted with exception to stickers and straps. (*Content Analysis)*	The wheels allow for full range of movement during performance.

F. Needs Hierarchy

Figure 2. Needs Importance Ranking

#	Customer Needs Statement	Importance
1	The data is consistently accurate.	5
2	The data is easy to understand.	4
3	The technology is easy to use.	3
4	The technology in the wheel withstands the destructive forces of skating.	3
5	The wheels are compatible with current truck sizes.	2
6	The wheels are affordable for the target consumer's economic demographic.	2
7	The data uploads quickly to an application.	1
8	The wheel is simple to install.	2
9	The wheel is durable.	6
10	The wheels look aesthetically pleasing.	4
11	The wheels allow for full range of movement during performance.	4
12	The data is easy to share with other people.	1
13	The wheel construction allows for skating smoothly.	3
14	The data is comparable with that of other users.	2
15	The wheels can be attached using common tools.	1

On a Scale of 1-5, 1 is scored as being the least important and 5 is scored as the most important

IV. Searching

A. External Search

i. Material Durability

1. Metal - The first skate wheels were derived from roller skates and made out of metal. The specific metal was steel. This offered lots of durability but fell short in other areas such as grip and weight.
2. Polyurethane Plastic - Frank Nasworthy invented the polyurethane wheel in the 1970s and it has been the standard in the industry ever since. It offers adequate grip and weight but can differ in strength based on its makeup. There are many different compositions of the polyurethane wheel each with their own unique qualities. The following strengths are based on competing brands Spitfire and Bones which both produce skateboard wheels. The numbers represent durometers which is a standardized way to measure the hardness of plastic. Refer to Figure 2 for specific design elements.
3. Silicone - Silicone wheels have been used in a variety of industries due to their weather resistant, vibration dampening, and low cost of manufacturing. Compared to polyurethane wheels, these offer a higher level of grip and vibration dampening and have better performance in rainy environments. The flexibility of silicone is comparable to that of rubber, though slightly less so. It offers a slower and smoother ride compared to the experience of using polyurethane wheels.
4. Rubber - Bike tires are very different from skateboarding but often ride in the same spots. Rubber is also used in car tires which go through many miles of use and carry tons of pressure. Rubber wheels are also used in longboarding for more mountainous terrains. They offer lots of grip and strength but are harder to navigate in the smoother parks and street spots.
5. Sources - The information from here was taken from multiple skateboarding blog websites and reviewing existing products. The websites include SkateDeluxe which is a skateboarding specific blog and IQS Directory which is geared towards industrial design.

Figure 3 - Polyurethane Plastic Ratings	
Rating	**Function**
78a - 92a	These are the softest polyurethane wheels and therefore the least durable. They are good for rougher surfaces but will degrade quickly.
93a - 95a	These are just a slightly harder version of the previous wheels that still have a good grip due to their softness.
96a - 99a	These are the most popular amateur wheels due to balanced grip and high strength for a variety of surfaces and uses.
100a / 83b - 84b	These are the hardest available polyurethane wheels currently on the market and are preferred by more experienced skaters. They have lots of strength and can go very fast but suffer on rougher surfaces and can be slippery.

ii. Movement Profiles

1. Radial - These wheels have a wide surface area, with a rounded edge that can help when skating transitions. They are also especially good with grinds. Radial wheels, as the name suggests, are shaped like a radius. While transition and grinds is a style we hope our wheels can work for, it isn't as built for tricks and street skating as other wheels.
2. Conical - Conical wheels refer to the wheels whose edges have a conical shape, making sure solid ground contact is made for good sliding and bonus control. This is another transition based wheel, with grip being a big selling point. These are also a popular type of wheel, mainly for park skating.
3. Classic - The classic wheel shape is the best all around to serve as a solution. It can effectively perform tricks, grind, has good traction, and even function in transition. They come in different sizes, normally from size 50 to 60. 52 through 54 will likely be the most popular sizes, with it being a good middle ground for park and street skating. For reference, other sizes and their uses are provided below.
4. Sources - The information used in this Movement section was taken from skateboard blogs and information guides from leading skateboard wheel sellers. The websites include basement skate, a skateboarding blog, and skate warehouse, a skateboard retailer.

Figure 4 - Profile Technical Sketch References

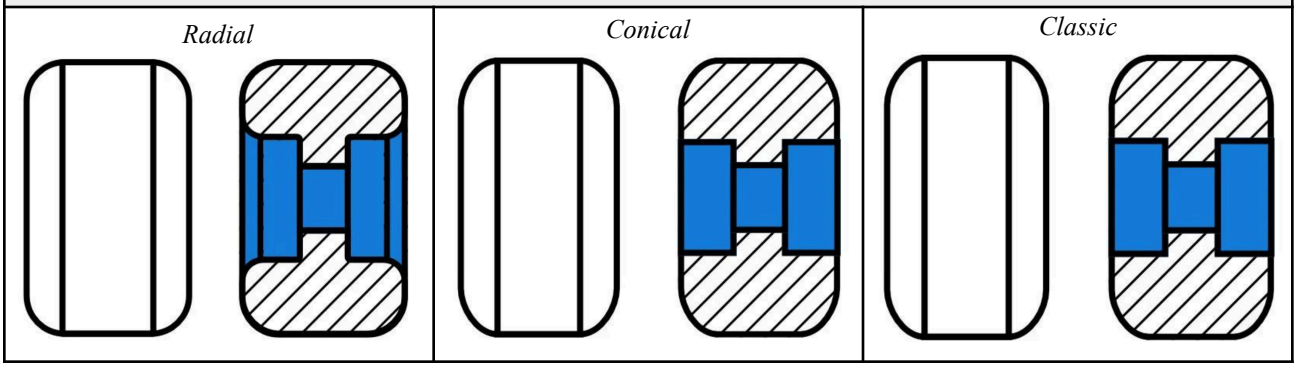
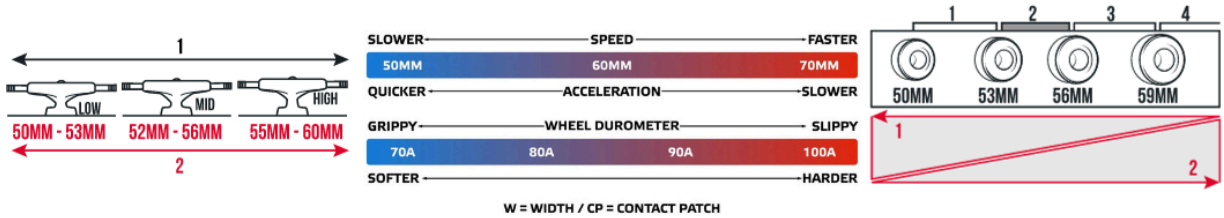


Figure 5 - Diameter Technical Sketch References



50 - 52mm	***53 - 55mm***	***56 - 60mm***
These are very suited towards tricks, but can struggle with rough environments. They are smaller, so they pick up speed quickly	These are the best wheels for beginners, as they can do tricks, skate parks, and handle rough terrain. A good all around wheel.	These are made for cruising and speed. They can also be seen in transition at skateparks.

iii. Sensor Tracking

1. Linear Speed - There are many different sensor options for measuring the linear speed of an object available on the market currently.
    a. Cable Extension - This type of sensor uses a spooled cable and a string to measure linear velocity. Because it has to be attached to something it would hinder skateboard movement and should not be used with the product.
    b. Magnetic Induction - The magnetic induction sensor works by attaching a magnet to the rotating object alongside a stable mounted magnet which can then sense how many rotations the moving magnet makes over a period of time. This technology could realistically be implemented inside the wheel or trucks.
    c. Microwave, Optical, or Laser - These types of sensors use waves shot at an object in motion which are then reflected back and measured using the doppler effect to find a speed. It could not be implemented in the wheels and would have to be a separate component or product.
    d. Radar - Similar to the previous technology this sensor would have to be placed away from an object to measure the speed so it is not realistic to apply.
    e. Ultrasonic - This sensor works similarly to the previous as well but instead of radio waves or microwaves it uses sound waves at a pitch too high for humans to hear.
    f. Sources - The sources used for finding these sensors were an industry blog and various existing products on the market.

2. Impact/Number of Attempts - There are a few different technologies that could be implemented in the wheel to measure impact force based on products available in the market today. The number of attempts can be calculated using a force sensor which tracks the amount of times there is a force sensed within a predetermined session.
    a. Strain Gauge - A strain gauge sensor converts force into a change in electrical resistance which can be converted into a measurable quantity. They are highly accurate, versatile, and reliable.

b. Load Cell - This works by sending electrical signals proportional to an applied mechanical force. It is larger than the other mentioned technologies and can only measure force at a singular point.
c. Force Sensitive Resistors (FSR) - The FSR works by creating a conductive grid which can measure force over a broad area. These are very thin and therefore minimally invasive. A downside is that they are not very accurate.
d. Sources - The sources for finding the impact sensors were once again an industry blog and then an analysis of the existing technologies on the internet.

3. Trick Landed - Identifying the trick landed with a sensor is hard but not impossible. Based on gyroscopic motion sensing technology and calculated motions assigned to tricks in a database the app could theoretically identify a trick which would prevent arguments over the nuances of certain tricks.
    a. Internal Gyroscope - Gyroscopes are used in many industries as a way to measure and maintain the forces acting on an object in motion. In the past, these technologies were expensive to produce and maintain, however recent developments afford a variety of options at various price points. Additionally, these technologies have since become smaller than the original models, and highly accurate as well.
    b. Optical Encoders - Optical encoders are often used in robotics; they provide highly accurate data on the number of rotations an object goes through. A potential downside of optical encoders is that they require a specific setup and may not be applicable to all models.
    c. Inertial Measurement Units (IMUS) - IMUS are highly calibrated devices that provide comprehensive data on the inertial movement of an object, including rotations and number of flips. These devices are often used in drones and other such technologies that require precise, real time data measurement.

iv. Supporting Technology

1. Power Source
    a. Wireless Charging - Wireless charging works by using a magnetic copper coil to induce a current. We could wrap the coil around the inside of the wheel. The skateboard would be put on a pad to charge, and would have no hassle of

wires or batteries. It would also allow the wheel to be completely closed off on the outside, meaning a stronger composition and less chance for foreign particles. Though effective, this is the most expensive option for us to produce.

b. Battery - A battery charged wheel would be an effective way to keep our wheel charged. While changing out batteries might be annoying for the consumer, they would appreciate not having to keep the wheel charged. Changing out the batteries once every 5 months would make sure the consumer never forgets to charge their wheels. A weakness is that some consumers see having to pay for batteries as a way of the seller ‘cheaping out’, which is not how we want our product to be seen.

c. USB - A charging port and cord would fall in with many tech products, in the sense that a charging port is a very common way to run tech products. This is a strength because it is something customers have come to expect. Most people are used to using and own USB chargers. So while standard, this option comes into problems with the wheel being exposed. There would have to be a way to close off the port, and the port itself could get damaged while skateboarding. This could make the wheel unusable as a tech product.

2. Data Storage

a. Bluetooth - Bluetooth is the chief option of transmitting data from the wheel to the consumer's phone. There will be a board that receives the trick and speed information, and bluetooth will send it out to the consumer. This means the consumer doesn’t have to remove anything, and will be instantaneous.

b. Removable Chip - Removable chip, while less practical for casual skateboarders, would be ideal for a competition setting. This would focus on recording the statistics, not on sending them out, meaning there is less room for mistakes and technical malfunctions. After a run, the organizers would remove the chip, plug it into a computer, and review the statistics for comparison.

c. Sources - The sources for inspiration of different chargers and data storages came from tech blogs, who review and discuss pros and cons of both. These

sites help introduce new solutions, and introduce potential problems. We also looked at STEM websites explaining how certain technologies work that we were unfamiliar with.

B. Internal Search

i. Durability

Members of the group have experienced wheels of many different constructions throughout their lifetimes. The idea for rubber wheels arose from interest in driving cars and riding bikes and possibly implementing the materials used in those activities. Similar to spokes on a bike wheel it could be possible to use similar methods to reinforce the strength of these wheels. Members who skate also agree though experience that harder skate wheels from the current industry ride better and last longer.

ii. Movement

Members of the group have personal experience riding various products with various types of wheels, including skateboards. Based on experience conical wheels work well with roller blades to give speed and align with the movement for this activity but seem too thin to work well for a higher impact event like skateboarding. Generally the wheels for skateboarding currently work well and don't have many issues. It seems best based on this not to stray too far away from the current shape of skateboard wheels but instead focus on the technological aspects.

iii. Sensor Tracking

Some members of the group have experience working with welding and creating technological circuits for achieving a specific goal. They have pointed out that when put together the wires and technology can take up lots of space, which in this case the wheel does not have a lot of. From this experience it is suggested to prioritize smaller sensors that could fit within the wheel.

iv. Supporting Technology

Members of the group have varying skill levels with technology. Technology for the wheel was talked through by relating the wheel to other technologies on the market, which helped brainstorm unconventional ways to help power the wheel and make it

perform. Once a solution was brought up, it was used as a springboard for coming up with even more ideas.

C. Competitive Benchmarking

Professional Skateboarding is a highly competitive athletic field that lacks the concrete analytics seen in other sports industries. Our product would provide an innovative, discreet method of quantifying results in such arenas, and serve to add an additional element of intrigue or interest to professional skateboarding. By comparison, other competing products do not accomplish the goal of fulfilling customer needs. To start benchmarking data, we first looked at competing wheels' consumer perceptions. By seeing what our consumer values, we can implement these characteristics into our wheels as well. While a statistics tracking wheel is not sold by any of our competitors, the physical needs of the wheels we are competing against are very similar. Meeting and exceeding quality expectations for Stattrak wheels is crucial, as they can not succeed if they are a hindrance to skateboarders. We paid special attention to reviews relating to durability, ease of install, and feel while riding. We ranked our competition's product on a scale of one to five, based on how well they handle the need. The examined products are below, and ranked in *Figure 5* in the appendix.

Spitfire Formula Four Wheels

Bones STF Wheels

OJ Hardline Wheels

Power Peralta Wheels

After looking over *Figure 5*, we compared what consumers thought of the product to the actual specifications and features listed by the companies. After comparing reviews from customers and features from companies, it became apparent that what companies claimed their product would do did not always match up with consumer perceptions. These product specifications were collected from company websites, while consumer perceptions were collected from reviews across different stores and marketplaces.

i. While all companies made claims against flat spots, consumers complained about almost every brand.

ii. While some consumers cared about graphics and appearance, it wasn't a selling point for companies or consumers.

iii. While most wheels do well at first, consumers took issue with weaknesses after long term use.

V. Concept Generation

A. Specifications

After needs statements were created and ranked they needed to be assigned a metric of measuring them in the product. Some needs can be quantified, such as affordability and upload time. The applicable metrics in that circumstance are price in USD and time in seconds. Other needs are subjective and can only be measured based on qualitative user feedback, some examples being data understandability and wheels aesthetic look. Other needs operate on a simple binary yes or no as to whether they pass a certain qualification test, such as data can be shared and wheels can be attached to current truck models.

Figure 6. Marginal & Ideal Values

#	Metric	Units	Ideal Value	Marginal Value
1	Margin of Error	%	<0.5%	0.51-1.25%
4	Breaking Point	Newtons	500	350-499
6	Price	USD	$40	$41-70
7	Upload Time	Seconds	3	4-10
8	Time to Install	Seconds	300	301-600
9	Distance Until Worn	Miles	500	300-499
11	Tricks Completed	%	99%	95-98%
13	Friction Force	Newtons	0.5	0.6-3

Figure 7. Metrics & Units

#	Need Statement	Rank	Metric	Units
1	The data is consistently accurate.	5	Margin of Error	%
2	The data is easy to understand.	4	User Feedback	Subjective
3	The technology is easy to use.	3		
4	The technology in the wheel withstands the destructive forces of skating.	3	Breaking Point	Newtons
5	The wheels are compatible with current truck sizes.	2	Fit Test	Binary
6	The wheels are affordable for the target consumer's economic demographic.	2	Price	USD
7	The data uploads quickly to an application.	1	Upload Time	Seconds
8	The wheel is simple to install.	2	Time to Install	
9	The wheel is durable.	6	Distance Until Worn	Miles
10	The wheels look aesthetically pleasing.	4	Consumer Reviews	Subjective
11	The wheels allow for full range of movement during performance.	4	Tricks Completed	%
12	The data is easy to share with other people.	1	Share Test	Binary
13	The wheel construction allows smooth skating.	3	Friction Force	Newtons
14	The data is comparable with that of other users.	2	Comparison Test	Binary
15	The wheels can be attached using common tools.	1	Tool Test	

On a Scale of 1-5, 1 is scored as being the least important and 5 is scored as the most important

Figure 8. Metrics to Needs

		Metrics													
		1	2	3	4	5	6	7	8	9	10	11	12	13	14
#	Need	Margin of Error	User Feedback	Breaking Point	Fit Test	Price	Upload Time	Time to Install	Distance until Worn	Consumer Reviews	Tricks Completed	Share Test	Friction Force	Comparison
1	The data is consistently accurate.	•													
2	The data is easy to understand.		•												
3	The technology is easy to use.		•												
4	The technology in the wheel withstands the destructive forces of skating.			•					•						
5	The wheels are compatible with current truck sizes.				•									•	
6	The wheels are affordable for the target consumer's economic demographic.					•									
7	The data uploads quickly to an application.						•								
8	The wheel is simple to install.							•							•
9	The wheel is durable.			•					•						
10	The wheels look aesthetically pleasing.									•					
11	The wheels allow for full range of movement during performance.										•				
12	The data is easy to share with other people.											•			
13	The wheel construction allows smooth skating.								•				•		
14	The data is comparable with that of other users.													•	
15	The wheels can be attached using common tools.														•

B. Alternative Concepts

Three concepts were developed with the intent of maximizing the variety of possible ideas and solutions for the given problems and subproblems. The solutions arose through internal and external investigations. The three concepts are as follows:

i. Concept one is a conical wheel with wireless recharging made of soft material. This will use the removable chip for data with cable extension, load cell, and optical encoder sensors. The goal of this wheel is to try all the most experimental and unorthodox technology in an attempt to subvert the norms and come up with a radical solution.

ii. Concept two is the classic wheel design with a hard polyurethane material and battery charging. This will use the bluetooth data chip with strain gauge, magnetic induction and IMU sensors. The goal of this concept is to stay truest to how skating currently is equipped with the easiest to use and most accurate technologies.

iii. The third concept is a radial wheel made with rubber material and usb charging. This will employ the removable chip to store data with FSR, radar and internal gyroscope sensors. The goal of this concept is to make the most diverse performing wheel that could possibly be used in a variety of environments and situations.

C. Concept Screening

All three of the alternative concepts were first compared in a concept screening matrix. The criteria for judging was based on the needs statements from previous stages and problems discovered in this one. They are as follows:

i. *Durability* - The wheel needs to withstand lots of impact force and friction and should last for an extended period of time before wearing down.

ii. *Skates Smoothly* - The wheel should move effortlessly through multiple environments and any added technological components should not hinder skating ability.

iii. *Ease of Wheel Control* - The wheel needs to have enough grip that the skater can feel in control of the board's overall motion, such as changing speeds or directions.

iv. *Aesthetic Similarity* - Skaters are known to have a certain look so the wheel must appear visually appealing and not differ too much from current models.

v. *Modern Truck Compatibility* - This is essentially a binary category but it is crucial that the wheel can be used with current hardware.

vi. *Data Accuracy* - The data from the sensors should be consistent and accurate.

vii. *Data Relevancy* - The data obtained from the sensors should be useful for skaters to draw relevant conclusions about their performance and techniques.

viii. *Ease of Obtaining Data* - The data should easily be transferred to a platform that can visualize it for skaters to see.

ix. *Technology Durability* - Similar to the overall wheel the technology also needs to withstand the various destructive interactions that come across while skating.

x. *Adequate Power Life* - Skate sessions can last for many hours at a time so the power source needs to have an extended life with a single charge.

xi. *Ease of Charging* - The power source should be simple for the user to recharge after sessions requiring minimal effort and maximum speed.

Concept Screening Matrix				
Criteria	Concepts			
	1	2	3	Baseline Spitfire
Durability	-	.+	.+	0
Skates Smooth	.+	-	-	0
Ease of Wheel Control	.+	-	-	0
Looks Aesthetic	.+	.+	-	0
Compatible with Modern Trucks	0	0	0	0
Accurate Data	-	.+	-	0
Relevant Data	.+	.+	.+	0
Easy to Obtain Data	-	.+	-	0
Durable Technology	-	.+	-	0
Adequate Power Life	-	.+	.+	0
Ease of Charging	.+	-	.+	0
Sum +	5	7	4	0
Sum -	5	3	6	0
Sum 0	1	1	1	11
Net Score	0	4	-2	0
Rank	2	1	3	2
Continue?	Y	Y	N	N

The baseline for comparison was a Spitfire wheel which is one of the most popular and average wheels currently in the skate market. A 0 indicates the concept performs equal to the baseline while a + or - means the concept performs better or worse in a criteria than the baseline respectively. The scores are explained as follows by category:

i. *Durability* -
    1. Concept 1 (-) The soft material and thinner shape makes this concept wear down to an unusable state at a faster rate.
    2. Concept 2 (+) The hard polyurethane and classic wheel design don't wear down as quickly as the spitfires soft material.
    3. Concept 3 (+) A radial wheel shape has the largest surface area which combined with a thick rubber material takes a while to wear down under the duress of skateboarding.

ii. *Skates Smoothly* -
    1. Concept 1 (+) Soft material and a thin surface area allow for quick, smooth skating.
    2. Concept 2 (-) The harder polyurethane does not skate as smooth as its softer counterpart.
    3. Concept 3 (-) The rubber has lots of friction so it does not skate as smooth.

iii. *Ease of Wheel Control* -
    1. Concept 1 (+) Soft material gives a strong grip on the surface allowing lots of control.
    2. Concept 2 (-) Harder material is more slick and has weak surface grip.
    3. Concept 3 (-) The rubber gives a strong grip but the radial shape makes it hard to shift in any direction.

iv. *Aesthetic Similarity* -
    1. Concept 1 (+) The conical shape has a sleek appeal to the eye.
    2. Concept 2 (+) The classic wheel shape is what skaters are used to and fits their aesthetic desires.
    3. Concept 3 (-) The radial wheel looks very bulky and the rubber gives off a cheap, unprofessional vibe.

v. *Modern Truck Compatibility* -

1. Concept 1 (0) The wheel will go around a normal bearing so therefore will fit a modern truck.
2. Concept 2 (0) The wheel will go around a normal bearing so therefore will fit a modern truck.
3. Concept 3 (0) The wheel will go around a normal bearing so therefore will fit a modern truck.

vi. *Data Accuracy* -

1. Concept 1 (-) The sensors used in this wheel are generally used for different types of impacts and therefore may not provide very accurate data for this purpose.
2. Concept 2 (+) This concept utilizes all the most accurate available technologies that work within similar applications to how they are used in this concept.
3. Concept 3 (-) The sensors for this wheel are used more to find data from an external POV and may lack the high level of accuracy required for the product design.

vii. *Data Relevancy* -

1. Concept 1 (+) Compared to the spitfire wheel which cannot find data any possible numbers found will be relevant. Technically these sensors are made to find speed, force, and motion detection.
2. Concept 2 (+) Similar to concept 1 these sensors are all able to find the data sought after for the design and bring more to the table than the basic Spitfire.
3. Concept 3 (+) The sensors in this wheel are also equipped to find the necessary information that skaters desire.

viii. *Ease of Obtaining Data* -

1. Concept 1 (-) The cable extension sensor requires a long setup process and could be a hazard while skateboarding so this data is difficult to obtain. Having the data stored on a removable chip also makes it a hassle to get the data in a visible environment to be of any use.

2. Concept 2 (+) These sensors are all small and could fit within the wheel while also acquiring the data to upload externally. The bluetooth chip makes it easy to get the found data to any application later developed for displaying data.
3. Concept 3 (-) This concept also uses the removable chip which makes data difficult to make any use of. The sensors are also all external and would require setting up over and over again each time the skater moves spots.

ix. Technology Durability -

1. Concept 1 (-) The cable extension over time will wear down very quickly and the other sensors are fragile and liable to break quickly.
2. Concept 2 (+) Strain gauges are able to take lots of impact force based on their design and use in other industries. The IMU sensor is used in drones which are made to be durable in case of a crash. Magnetic induction sensors are also strong due to their construction.
3. Concept 3 (-) FSR sensors are very thin so therefore will break down quickly.

x. Adequate Power Life -

1. Concept 1 (-) Wireless charging is quick but doesn't last for a long time since the technology required to make it possible takes up space that could otherwise be batteries.
2. Concept 2 (+) The batteries' power life depends on where they are sourced but there are removable batteries that can last a long time and those will be prioritized for use in this product.
3. Concept 3 (+) The usb charging is similar to the wireless charging but employs longer lasting batteries.

xi. Ease of Charging -

1. Concept 1 (+) Wireless charging requires the user to simply place the wheel on the charging station making it very easy.
2. Concept 2 (-) Replaceable batteries require deconstruction and reconstruction in order to take out and put in batteries which takes the longest time and most effort for the user.

3. Concept 3 (+) USB charging is similar to phones and computers which most people deal with already and won't find it difficult to do a similar task with this concept.

D. Concept Scoring

Concept Scoring Matrix					
Criteria	Weight	Concept 1		Concept 2	
		Rank	WS	Rank	WS
Durability	0.25	3	0.75	5	1.25
Skates Smooth	0.1	3	0.3	2	0.2
Ease of Wheel Control	0.05	3	0.15	2	0.1
Looks Aesthetic	0.025	4	0.1	3	0.075
Compatible with Modern Trucks	0.025	3	0.075	3	0.075
Accurate Data	0.2	3	0.6	4	0.8
Relevant Data	0.1	3	0.3	4	0.4
Easy to Obtain Data	0.05	3	0.15	5	0.25
Durable Technology	0.1	3	0.3	3	0.3
Adequate Power Life	0.05	3	0.15	4	0.2
Ease of Charging	0.05	3	0.15	1	0.05
Total Score		3.025		3.7	
Rank		2		1	
Develop?		N		Y	

The first and second concepts were then put head to head in a concept scoring matrix to find the best solution. The criteria were the same as before but this time weighted differently based on their relative importance. Durability and accurate data were given the highest weights while aesthetics and ease of use were weighted on the lower end. The wheels were then given scores 1-5 where 3 was an average score for comparison purposes. The wheel deemed to be closer to a baseline was given a score of 3 while the under or over performing wheel was given a 1-2 or 4-5 respectively. For the most part concept one acted as a baseline with concept two generally performing better or even across the board with a rare underperformance in ease of control and charging. The scores with explanation for each concept are as follows:

i. Durability -

1. Concept 1 (3) Because the soft material is close to the average wheel already in use this concept served as the baseline score.
2. Concept 2 (5) Compared to a soft polyurethane baseline the hard polyurethane scores higher due to its longer life cycle.

ii. *Skates Smoothly* -

1. Concept 1 (3) This concept was the baseline again because of its material which skates with a similar smoothness to average wheels currently on the market.
2. Concept 2 (2) The hard material offers more durability but less smoothness on rougher surfaces which overall makes it score slightly below baseline.

iii. *Ease of Wheel Control* -

1. Concept 1 (3) Similar to the first two criteria this concept is the baseline again since soft material has more friction and allows the skater to feel a solid amount of control.
2. Concept 2 (2) The hard material has less friction so it will slip more and have less control.

iv. *Aesthetic Similarity* -

1. Concept 1 (4) The intriguing conical shape has a slicker look compared to the chunkier classic wheel design.
2. Concept 2 (3) This concept has the classic skateboard wheel shape so it will serve as the baseline.

v. *Modern Truck Compatibility* -

1. Concept 1 (3) Both concepts base the wheel around a normal skateboard wheel bearing so they are both on par as a baseline.
2. Concept 2 (3) Both concepts base the wheel around a normal skateboard wheel bearing so they are both on par as a baseline.

vi. *Data Accuracy* -

1. Concept 1 (3) This concept defaults to a baseline position since the other concept exceeds a normal level of accuracy.
2. Concept 2 (4) This concept utilizes all the best sensors available on the market so it cannot be a baseline and score higher than the other concept by default.

vii. *Data Relevancy* -

1. Concept 1 (3) Sensors and gauges used to gather data do an adequate job of obtaining relevant data that can be pulled from the wheel.
2. Concept 2 (4) This concept utilizes the best technology on the market to capture all relevant data so that it can be transferred.

viii. *Ease of Obtaining Data* -

1. Concept 1 (3) Relative to the second concept this concept defaults to a baseline due to its more average time and effort required to obtain the data.
2. Concept 2 (5) This concept scores very high because the sensors use bluetooth to automatically transfer data to an application making it very simple for the user to see and utilize how they please.

ix. *Technology Durability* -

1. Concept 1 (3) All the sensors in both concepts are very similar in construction and size so will likely have a similar durability while skating.
2. Concept 2 (3) All the sensors in both concepts are very similar in construction and size so will likely have a similar durability while skating.

x. *Adequate Power Life* -

1. Concept 1 (3) This concept is similar to modern technologies which also use wireless charging and have average battery lives so it serves as a baseline.
2. Concept 2 (4) Because a swappable battery doesn't need other components to make it usable like wireless chargers it allows for larger battery cells and longer life.

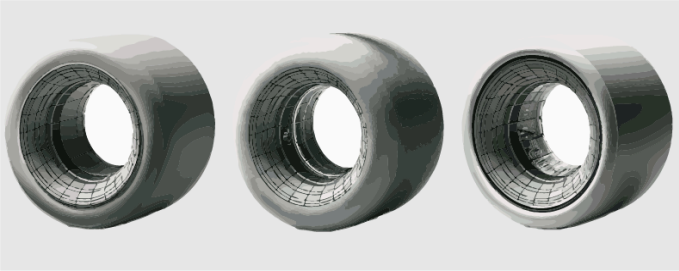
xi. *Ease of Charging* -

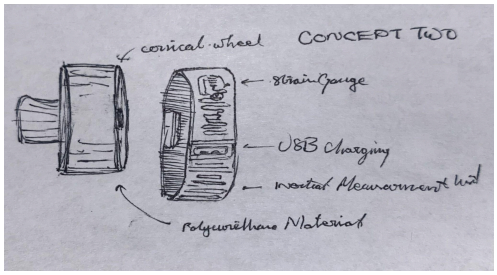
1. Concept 1 (3) Wireless charging is already utilized often in the modern market so it serves as a baseline for the average charging experience.
2. Concept 2 (1) Swappable batteries are obviously a more difficult charging process so this concept cannot be a baseline and must score very low.

VI. Detailed Drawings and Specifications

A. Design Specifications

From the selection process in the last stage gate concept two was deemed to be the best option and will be utilized for components in this stage. Concept two is the classic wheel design with a hard polyurethane material and USB charging. This will use the bluetooth data chip with strain gauge, magnetic induction and IMU sensors. The goal of this concept is to stay truest to how skating currently is while being equipped with the easiest to use and most accurate technologies. For the first run the wheel will only come in the classic off-white color and in a single size of 60mm. They will weigh .81 lbs.





B. Material and Components Selection

After researching and analyzing multiple materials for the different concepts in the last stage gate it was decided that polyurethane would be the best for the main construction. This is the material that is already used in skate wheels and continues to be the best current available option. The mix of polyurethane in the wheel will be a harder one in order to increase the durability of the product. There are also a variety of technological components that give the product its primary utility. The components for this concept were chosen based on their viability in use as well as ease and accuracy. The sensor to track speed will be a magnetic induction sensor. This specific sensor uses a magnet that rotates around a base point and uses the number of rotations over a period of time to calculate a speed. The sensor to track force is a strain gauge which can hold up to lots of force and give consistent accurate data. The sensor to determine the trick based on rotation in space is an IMU sensor which is utilized in drones which have similar size to skateboards. The data is transferred through bluetooth to a connected application and device. This makes it easier for the consumer to get their data and frees up space in the wheel that would have been used to store the data. The charging method for this concept was originally swappable batteries but was switched to USB to increase the ease of use. Normally skate wheels

are sold in plastic wrap but this brand places some weight on sustainability and will use eco-friendly packaging that is made of recycled materials.

VII. Assembly Information

A. Manufacturing Steps & Application

After researching and analyzing multiple materials for the different concepts in the last stage gate it was decided that polyurethane would be the best for the main construction. This is the material that is already used in skate wheels and continues to be the best current available option. The mix of polyurethane in the wheel will be a harder one in order to increase the durability of the product. There are also a variety of technological components that give the product its primary utility. The components for this concept were chosen based on their viability in use as well as ease and accuracy. The sensor to track speed will be a magnetic induction sensor. This specific sensor uses a magnet that rotates around a base point and uses the number of rotations over a period of time to calculate a speed. The sensor to track force is a strain gauge which can hold up to lots of force and give consistent accurate data. The sensor to determine the trick based on rotation in space is an IMU sensor which is utilized in drones which have similar size to skateboards. The data is transferred through bluetooth to a connected application and device. This makes it easier for the consumer to get their data and frees up space in the wheel that would have been used to store the data. The charging method for this concept was originally swappable batteries but was switched to USB to increase the ease of use. Normally skate wheels are sold in plastic wrap but this brand places some weight on sustainability and will use eco-friendly packaging that is made of recycled materials.

i. *Material Selection* - The first step is to select all the components from the wheel to be sourced from third parties for construction. This includes the hard polyurethane as well as all the technological components.
ii. *Molding Wheel Components* - The polyurethane must first be molded into the classic wheel shape. This will be done at Gallagher Co.
iii. *Incorporation Sensors* - After the wheel is molded the first technological components that will be inserted into the wheel are the magnetic induction sensor and the strain gauge.
iv. *Integrating Motion Sensors* - The next sensor embedded into the wheel will be the IMU motion sensor.
v. *Data Node Configuration* - Once the sensors are in place a worker will insert and connect a bluetooth data transfer node.

vi. *Power Source Installation* - Next, the lithium battery will be added in to power all the technological components and make the wheel work.

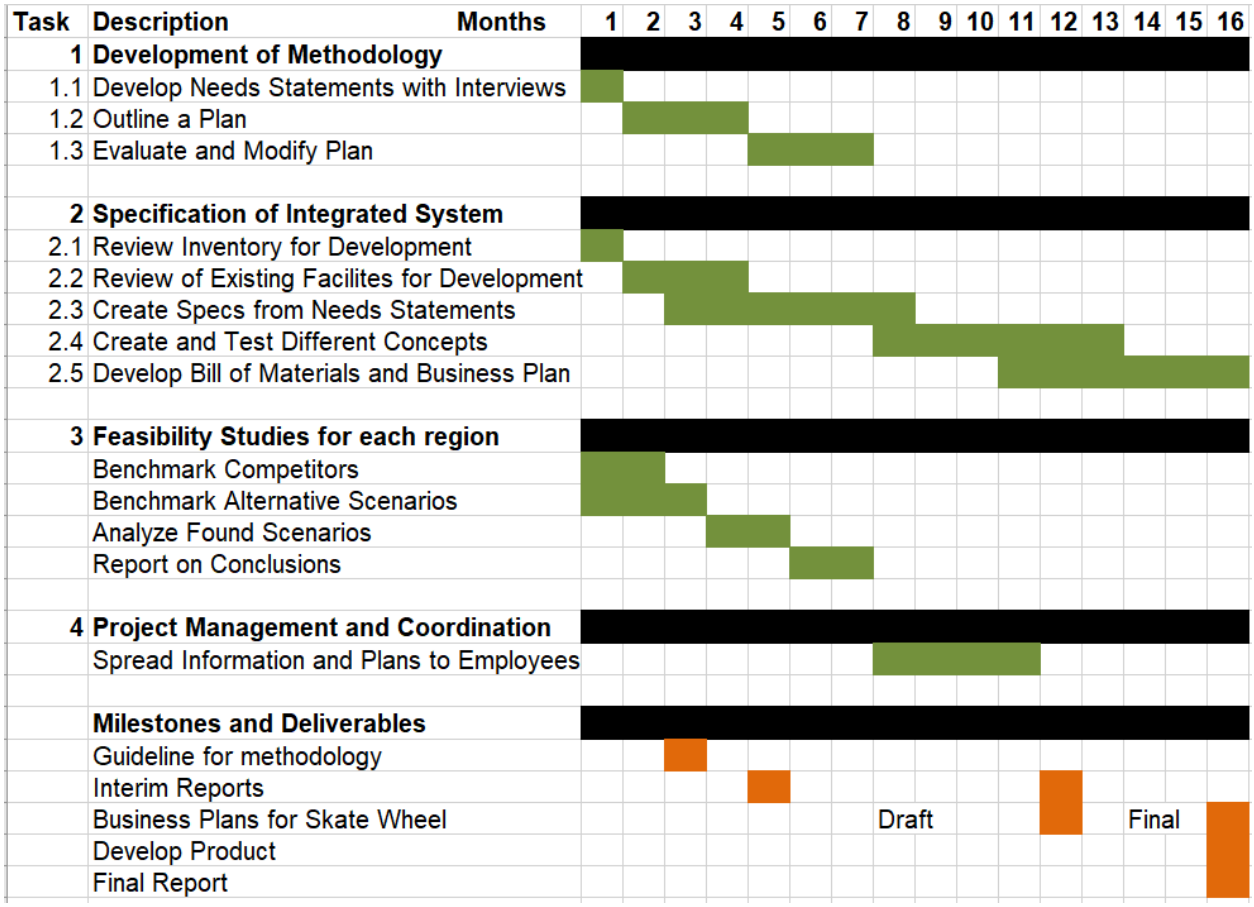
vii. *Final Assembly* - Fully lock down all the components with additional wires and soldering to make sure everything is connected and securely fastened in the wheel.

viii. *Quality Check & Testing* - Test the wheel to make sure it spins correctly and all the technology works as well as checking for any other major defects before packaging to be sold.

ix. *Packaging & Delivery* - Once the wheel is made and analyzed to be fit for sale it will be wrapped in plastic packaging and sorted into its correct shipping location.

VIII. Costs

A. GANTT Chart



B. Total Cost Analysis & Bill of Materials

The product has a variety of materials from molded plastic to advanced technologies and therefore will need a few different vendors. The vendors were chosen based on their reputation in the industry and product availability. The breakdown of vendors and cost for each component is as follows:

- Wheel - The wheel is supplied by Gallagher Corp which is located just outside of Chicago, Illinois. It will cost $6.10 dollars.
- Speed Sensor - The speed sensor is a magnetic inductor. It will be supplied by Mag Sensors. This company is located in Anaheim, California. It will cost $5.71 dollars.

- Force Sensor - The force sensor for the final product was decided to be a strain gauge. The specific one used is sourced from RDP Electronics, a company based in Pennsylvania. It will cost $3.00 dollars.
- Motion Sensor - The motion sensor is an IMU, or Inertial Measurement Unit. It will be produced by Pepperl Fuchs based out of Twinsburg, Ohio. It will cost $4.50 dollars.
- Data Transfer Node - The data transfer device for the final product is a bluetooth sender. It will be supplied by Feasycom which is a China based company. It will cost $2.43 dollars.
- Power Source - This product will be powered by a lithium battery which can be recharged with a USB. The battery pack is sourced from Navico. The factory is located in Tulsa, Oklahoma. It will cost $7.07 dollars.

Besides raw materials and individual components there are other considerations to ponder while making product development decisions. They all fall under the umbrella of manufacturing and were decided as follows for each part:

- Patents - This is an original product idea so there are no patents preventing us from development. The technological components may have patents which is why we are sourcing them from a third party instead of making them ourselves.
- Machinery - The wheels will be premade by the polyurethane manufacturing so the company will not have to invest in wheel making machinery. The main tools needed for construction will be welding components. This includes torches, gas, and protective equipment. They will be needed to connect all the technological components together and into the wheel. Most of this equipment will be one time investments that will last for a few years. The gas however will be a recurring expense that will depend on how fast laborers can make the wheels. An average welding rig for a single laborer will cost about $1200. A rig will last about 3 years making the cost per week $7.70. If 5 wheels can be produced in an hour the cost per wheel will be 3 cents for the rig. At this rate of production gas will have to be replaced every 8 hours, or 40 wheels and gas costs $75. This means the cost of gas per wheel is $1.875.

- Factory - Each wheel will be crafted by specialty workers from Portland Manufacturing Co. in Portland, Oregon. We chose this factory because of their outstanding quality and efficient work.
- Production - Production will be done in batches. Each batch will take one week to make. This will help assess inventory and demand. There will be 25 workers, and they will get paid $17 dollars an hour, plus benefits.

As previously mentioned all the prices found in this stage of the process were for individual components from different sources. This was to come up with a rough estimate of pricing but due to a lack of experience in sourcing this does not accurately represent the actual costs that will be charged for the final product that could be found by a professional colleague or third party sourcing agent. This is important to know moving forwards as the prices used here for costing will be from the individual sourcers. The direct costs encompass the materials, labor, and overhead. Materials will cost $28.81. Labor will cost $17 per hour but each employee can make 5 wheels in an hour so that is $3.40 per wheel. Overhead will be 10% of the wheel price, or $2.88 per wheel.

The indirect costs cover marketing and distribution. Lots of money will be allocated to marketing the product since the industry is saturated and it will take a large buzz to break through that. It is also crucial that the consumer knows the capabilities of the wheel and how it is different from wheels already on the market. This will be achieved through a well-designed marketing campaign including social media advertisements and partnerships with professional skateboarders to promote the product. The estimated cost for this campaign is $25,000. While the initial investment is high it should pay itself back as consumers start to purchase the product. Once they do so the product will sell itself as consumers become the marketer and show off the product to their friends inadvertently. Costs associated with distribution include freight, storage, handling, and managerial. These costs will be accounted for and covered in the markup of the product.

Description	Vendor	Material	Min. Order	Material Cost	Unit Quantity	Unit Cost
Wheel	Gallagher Corp	Poly-Eurothane	4	$6.10	1	$6.10
Speed Sensors	Mag Sensors	Electrical Components	2	$5.71	1	$5.71
Force Sensor	RDP Electronics	Electrical Components	2	$3.00	1	$3.00
Motion Sensor	Pepperl Fuchs	Electrical Components	2	$4.50	1	$4.50
Data Transfer Node	Feasycom	Electrical Components	2	$2.43	1	$2.43
Power Source	Navico	Electrical Components	2	$7.07	1	$7.07
Labor	Portland Manufacturing Co.	Average Wages	N/A	$17	5	$3.40
Machinery	Portland Manufacturing Co.	Metals				$1.00
Shipping	Albertsons Distrobution Center	Cardboard				$5
Total Cost						$38.21

After totalling the costs for this product it will cost $38.21 to produce. This leaves plenty of room to mark up the product to customers to make profit without being out of the price range compared to similar competitors' wheels.

IX. Future Cash Flows & NPV

Values in Millions	Year One				Year Two				Year Three				Year Four			
	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
Sales					0.9	1.8	3.6	6.75	1.8	3.6	4.5	5.4	3	4	6	8
Units					10,000	20,000	40,000	75,000	20,000	40,000	50,000	60,000	30,000	40,000	60,000	80,000
Price					90	90	90	90	90	90	90	90	100	100	100	100
Total Revenue					**0.9**	**1.8**	**3.6**	**6.75**	**1.8**	**3.6**	**4.5**	**5.4**	**3**	**4**	**6**	**8**
Development	0.5	0.5	0.75	1												
Equipment			0.25	0.5												
Ramp-Up				1	0.75											
Marketing				2	1.5	0.75	0.75	0.75	1	0.75	0.75	0.75	1.5	1.25	1	1
Production					0.75	1	1.25	1.5	1	1.25	1.25	1.5	1.25	1.5	1.75	2
Total Costs	**0.5**	**0.5**	**1**	**4.5**	**3**	**1.75**	**2**	**2.25**	**2**	**2**	**2**	**2.25**	**2.75**	**2.75**	**2.75**	**3**
Period Cash Flow	-0.5	-0.5	-1	-4.5	-2.1	0.05	1.6	4.5	-0.2	1.6	2.5	3.15	0.25	1.25	3.25	5
Period Present Value	-0.4875	-0.4875	-0.975	-4.3875	-2.0475	0.04875	1.56	4.3875	-0.195	1.56	2.4375	3.07125	0.24375	1.21875	3.16875	4.875
Net Present Value	13.99125															

In four years the company will have a net present value of about 14 million dollars. This is with a 10% discount rate. The first year will take lots of losses as it will be a development period. After that the company will begin to increase production and sales to turn profits. Each year the sales will increase over time and peak in quarter four with holiday shopping. The net profit is calculated by summing the total present values from each quarter. These values were calculated by finding the difference between total profit and total costs. The first quarter sees sales of 10,000 wheels and the final quarter in the fourth year sees a peak at 80,000.

X. Summary & Risks

The market is very saturated and adverse to change but we believe we have the knowledge to penetrate skateboarding with an innovative and game changing product. Prior to this product there was no way to quantify skateboarding tricks. Because this is such a unique product we believe this diminishes the risk as there are no direct competitors. This product is very costly to make, so a risk of production is large losses if the market is not ready.

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XII. Appendix

Figure 9. Benchmarked Data

Imp.	Need	Spitfire	Bones	OJ	Power Peralta
5	The wheels fit an average skateboard	5	5	5	5
5	The wheels withstand hard use	4	3	2	3
4	The wheels are affordable	2	4	4	5
4	The wheels are comfortable to ride	5	4	4	2
4	The wheels do not develop flat spots	5	3	1	2
2	The wheels retain their graphic	2	3	3	3
2	The wheels are aesthetically pleasing	4	3	5	3
3	The wheels are the correct hardness	5	4	4	4

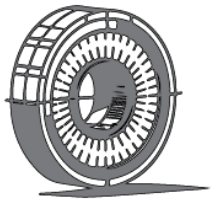

Figure 1

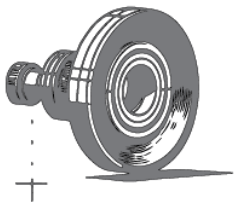

Figure 2

Figure 3

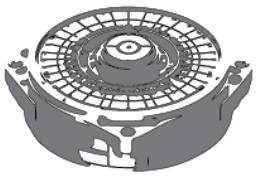

Figure 4