Design, development, and prototyping of bike chain & gear mechanism cleaning product.

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Confidential Technical Report
on behalf of:

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1. Aims and objectives

Aim of this project is to design, develop, and prototype a new Chain & Gear Mechanism Guard for cleaning bicycles.

2. Problem statement

John S. Allen (2015) states that chain maintenance is one of the most controversial aspects of bicycle mechanics. Chain durability is affected by riding style, gear choice, whether the bicycle is ridden in rain or snow, type of soil in the local terrain, type of lubricant, lubrication techniques, and the sizes and condition of the bicycle's sprockets. Because of the many variables, there are very little controlled experiments under real-world conditions. As a result, everybody's advice about chain maintenance is based on anecdotal "evidence" and experience. Experts disagree on this subject, sometimes bitterly. Halfords (2015) is the one of the largest Bike supplier in UK. They recommend that cleaning bike's chain regularly improves the performance of the bike and it can last longer. It prevents the build-up of grease and dirt in the chain, meaning you can change gear more smoothly, and also helps prevent wear to bike parts, saving you money on repairs or replacements in the long run. They supply bike chain cleaning kits (2015). This includes bike degreaser, liquids, sprays, brushes and specifically built kits. These current products are designed for cleaning bike chains using cleaning liquid and can be used only in a garage environment or outside. There is a requirement for designing a new chain cleaning product which can also be used in living spaces.

Professional bikes might cost from £1000 to £10k, depending on the weight, material used, and design features. Although low cost bikes are stored in garages/outside, these professional bikes are normally stored in safer places and are often stored at home in a corridor or utility room. Professional bike users regularly maintain these bikes. Unfortunately, especially while spraying or oiling the chain, users must be very careful not to spray the brake disc parts and also the floors or walls of the home. Therefore there is a need for a new product to address these issues.

3. Introduction

Sentini Marine managers Gareth Bransby and Jon Lee have contacted to the University of Huddersfield, Enterprise and Innovation Centre to find a design solution to their initial ideas and find a low cost manufacturing method for their Bike chain cleaning product They were introduced to the Product Design team and after an initial meeting Dr Unver and the team agreed to carry out design and development work and a Santander Voucher is awarded.

The chain and drivetrain are typically the dirtiest parts of any bike, and this dirt is bad news for bike longevity and performance. Specifically:

- Increased rate of chain wear.
- Reduced flexibility of chain links.
- Added wear on derailleur assemblies and drivetrain cogs.
- Impaired shifting performance.

Initial Research by Sentini Marine Ltd showed that although there are few products for cleaning the chain of a bike, there is no product for spray cleaning and also spray oiling for preventing spray particles reaching to the brake disc or other bike parts or the remnants of chain oil dripping on the floor.
The team from Sentini marine produced a simple product prototype using a plastic sheet and craft knife to demonstrate their ideas and do initial testing. After successfully demonstrating the idea they asked for professional help from the University's Product design team. They have written a brief stating the

requirements including designing and developing prototypes and identify a low cost manufacturing method.

3.1 Research into Review and Blogs: Is a chain cleaning device needed?

BikeRadar (2015) and Londoncyclist Review (2015) reviews are helpful to identify whether these kits are effective. But the result of the review is not clear as both positive and negative reviews are posted some of which can be seen below:

> *"The Park Cyclone doesn't actually immerse your chain in degreaser however - there's a fill line on the side of it which the brushes pass under but the chain doesn't. As chains don't really stretch as such - just wear the pins inside the rollers, it's the dirt that's hidden that will accelerate the wear most. Wiping the surface therefore isn't going to prolong the life of a chain and so I'm personally happy to use my own Park Cyclone on a regular basis, along with the occasional proper deep clean by removing it and soaking in degreaser in a jar. Ensuring proper lubrication of each pin is very important after the clean chain is properly dried obviously. I lubricate each pin and then lubricate again after allowing penetrating and wiping through a rag to remove excess. Seems to work well for me anyway"*

> *"I have a chain cleaning tool and don't really use it. Now I just have a removable link so I can take the chain off and clean it properly. My home brew "cleaning system" consists of an old jar half filled with white spirit and old pair of underpants. Simply drop the chain into the jar, replace cap and give it a good shake. Take the chain out and wipe over with underpants - simples, a nice clean chain instantly. Just let the chain dry out before oiling to make sure the residual white spirit doesn't thin the lube."*

Another Review by Kailas Narendran (2003) in MIT reviews Park Tool Chain Gang Cleaning System. The review is relatively positive but questions remain about the floor becoming wet. This review is useful and support development of this product.

> "*But in addition to cleaning your chain, the scrubber belches large amounts of cleaner all over the floor. The scrubber brush isn't too effective, as the bunch of bristles is really fat and has a hard time fitting between the rear sprockets. The cleaner does a decent job, but so does some dilute dish washing soap."*

> *"I do have to give the Park Tool people credit for being honest. In the instructions, they say you can use either their own brand of ChainBrite Cleaner, or dilute dishwashing soap. I can't say that one really works better than the other; they claim ChainBrite Cleaner works better in the long run. But using either is better than using none, the practice of most bicyclists. Given all the salt and sand that gets dumped on the sidewalks and streets in Boston and Cambridge, chain cleaning is important if you want any lifetime out of your commuting lifeblood (i.e., your bike). As you ride, street sediments build up, and rapidly increase wear on your chain, rear cassette, and derailleurs, which are pretty expensive to replace".*

> *"A friend of mine commutes over six miles per day. As a result of regular cleaning, she's put well over 1,500 miles on her drivetrain and it still has a ways to go. Cleaning your bike's drivetrain is an imperative. This setup from park tool is useful, but not imperative. I found the Cyclone Chain Scrubber to be the only really useful member of the trio. I found the scrubber for as low as $22 online".*

3.2 Bike Chain cleaning and Maintenance

REI (2015) shows the methods currently used for cleaning a bike chain. They recommend on a regular basis, the entire chain needs to be checked by lifting the rear wheel off the ground and slowly rotating the pedal, inspecting individual chain links for dirt build up, rust and/or tight links. They recommend to check for adequate lubrication by listening for squeaks while riding. If you find either condition, your chain needs at least a spot-cleaning.

Another resource shows how to clean and lube your bike's drive chain. It is easy to clean the muck build up on bike's drive train. Bike radar (2014) recommends a 10 step guide which take just under one hour to complete to get rid of the grit from a drivetrain. This will not only improves shift quality, but extends your bike's longevity too. BikeRadar (2014) recommends the following steps:


Image: Courtesy of BikeRadar

There are plenty of safe degreasers and chain cleaning devices on the market to bring that chain back to life though. A chain cleaner is recommended as its enclosed nature avoids mess and gets the chain sparkling. Also using a little degreaser and a rag or brush to scrub the jockey is recommended. The sprockets may be cleaned by flossing with a strip of rag or a special cog brush and degreaser also the grit from the chain rings should be brushed.

Images: Courtesy of BikeRadar

When all the parts are cleaned, they recommend to used water to rinse to ensure the degreaser won't contaminate the lube and use a soft rag to wipe the chain completely

They recommend to apply lubrication only when the chain is clean and dry and prefer to lubricate the chain as little as possible to prevent drops.

The lubrication should have two key properties to any chain lubricant:

- Minimize the accumulation of dirt, because dirt accelerates wear.
- Be durable, because lack of lubricant also increases chain wear.

4. Literature Review and Current Product Review

4.1 Cyclone Chain Scrubber

Park Tool's Cyclone Chain Scrubber is designed to use modern non-petroleum-based degreasing agents, and it works well with dish-washing detergent and water especially if the bike is ridden in the mud and wet. The Park Tool's Cyclone Chain Scrubber (2015) is the mechanized chain wash of the cycling drivetrain for around £15.

Cyclone Chain Scrubber Cleaner

The Cyclone's plastic body separates into two halves so that it can be installed over the chain without the need to remove it from the bike. The body is filled with cleaning fluid to a level mark on the transparent body and, after securing the Cyclone over the chain, the home mechanic holds the handle while turning the cranks. The first of three roller brushes scrubs the side-plates of the chain. The links then pass through a pair of vertical brushes that scrub the inside of the chain and finally, the chain passes through a gap in a foam element that removes most of the degreasing liquid and returns it to the device's reservoir. Cyclone Chain Scrubber Review (2015)

4.2 Weldtite Chain Degreaser System

Weldtite Chain Degreaser bicycle cleaning system is sold for around £15 and is used for cleaning. Chain Degreaser Machine (2015), Effortless Chain Cleaning Video (2015) all show how the cleaning system works.

Weldtite’s dirt wash

Shayn Audane states Weldtite’s dirt wash citrus degreaser is intended primarily for chains but it is quite useful for clearing gunge and grime from other components including derailleurs. Review by Shayn Audane Sep, (2009) recommends to use Latex gloves to prevent effects of the fluids used on the skin.

4.3 Muc-Off X-1 Chain Cleaning Device

This device quickly and easily removes grease, grime and chain oil with 6 rotating brushes Making chain cleaning a breeze with the X-1 chain cleaning device. This compact chain cleaner is a small, heavy duty construction with replaceable brushes and scrubbers. It is aimed at effectively prolonging a bike chain's life by regularly cleaning and lubricating. The X-1 chain cleaning device is an easy way to clean bike chains with a good scrub. This device is sold around £15.

Muc-Off X-1 Chain Cleaning Device (2015)

4.4 Finish Line Pro Chain Cleaner

Finish Line began innovating chain cleaners in 1988 when its patented rotating brush design set the standard. They claim a bicycle chain could be thoroughly cleaned in a minute or two without taking it off the bike. Quick, efficient and easy to use.


Finish Line's proprietary rotating brushes are still utilised in the third generation unit. However, the exit angle has been changed from 90 degrees to 47 degrees, which virtually eliminates drips and spills. An additional row of scrapper pads have been added for enhanced side-plate cleaning. A large magnet has been added to attract and hold magnetized wear particles and is located at the bottom of the chain cleaner. New shock quality plastic prevents shattering when dropped. For cyclists who are serious about keeping their drivetrain in race-ready condition, Finish Line's Pro Chain Cleaner is a valuable piece of equipment that will make this tedious task much easier. FinishLine Cleaner (2015)

4.5 Multi-Function Bicycle Chain Cleaning Machine Tool Set

Another product for chain cleaning with a wiper sponge VeloChampion Chain Cleaner. This system uses a 4 roller brush system and combined with the large wiper sponge to extend the lifespan of the chain. It is also a split case design. The split design means chain removal isn't necessary and hand held operation is easy with a refill hole on top to allow cleaning fluid to be added.

VeloChampion Bike Chain Cleaner

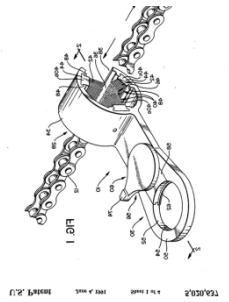
4.6 Chain Pig Chain Cleaner

Another mechanical chain cleaner has been developed by Pedro http://pedros.com/. They have improved the design with the ability to be used hands-free. The drag-free derailleur hook provides simple use and hands-free operation, while a reservoir holds your cleaner or degreaser. Pedro's claim is that the Chain Pig chain machine provides a "simple, efficient, and effective way to clean your chain without making a mess or wasting valuable degreaser." This product is under £10 and used for the chain cleaning of bicycles.

5. PATENTS:

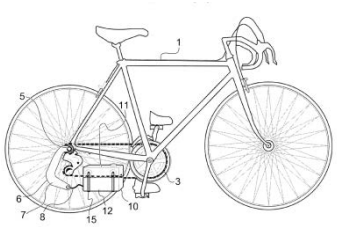
5.1 Bicycle chain lubricating and cleaning apparatus and method US 5020637 A

http://www.google.com.au/patents/US5020637



A lubricating and cleaning device adapted to be mounted to a pressurized can of lubricating oil and used to lubricate and clean a drive chain of a bicycle or motorcycle. The device has a generally cylindrical housing with an open slot to receive the chain. A plurality of brushes are positioned within the housing to engage the chain. A tube extends from the pressurized container to the housing to transmit the lubricating oil to one of the brushes so that the chain can be lubricated.

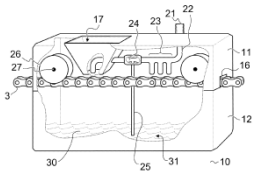
5.2 Bicycle chain cleaning and lubrication techniques US 8636114 B2



This invention relates generally to techniques for cleaning and lubricating the sprocket chain of a chain drive mechanism, and more particularly to a technique that uses compressed air both to clean the chain and then to apply a thin coating of lubricant. The present invention is useful for cleaning and lubricating, in situ, the sprocket chain of a chain drive mechanism of the type found, for example, in motorcycles and bicycles. For convenience, the invention will be described in the context of a bicycle chain drive.

5.3 Bicycle Chain Cleaner and Lubrication Apparatus, US 20120180821 A1

Very similar to the previous one by the same person.



This invention relates generally to devices for cleaning and lubricating the sprocket chain of a chain drive mechanism, and more particularly to a device that uses compressed air both to clean the chain and then to apply a thin coating of lubricant.

6. PRODUCT DESIGN & DEVELOPMENT

6.1 Sentini Marine original concept design

Sentini Marine's original idea was for a screening device to create a barrier between the chain and cog set of multiple sprockets attached to the hub of the rear wheel and the disc brakes attached to the other side of the wheel. Another distinguishing property of the original barrier device is to capture any spillage of cleaning products or oil in a deep pocket feature at the bottom of the device.

6.1a Version 1

Figure 1: Version 1 test by Sentini Marine

Figure shows early cardboard mock-up suffers disadvantage of a deep 'V' cut out to allow fitting around the hub.

6.1b Version 2

Figure 2: Version 2 test by Sentini Marine

Sentini Marine's plastic sheet mock-up has eliminated the 'V' cut out to a simple split line at the top of the device and introduced tabs to secure the device around the spokes. Here the folded pocket at the bottom of the device is better secured with tabs.

6.1c Version 3 - Sentini Marine initial prototype

Figure 3: Version 3 test by Sentini Marine

This image shows 0.8mm thick Polypropylene sheet mock-up. In this view from the left hand side of the bicycle the disc brake is visible.

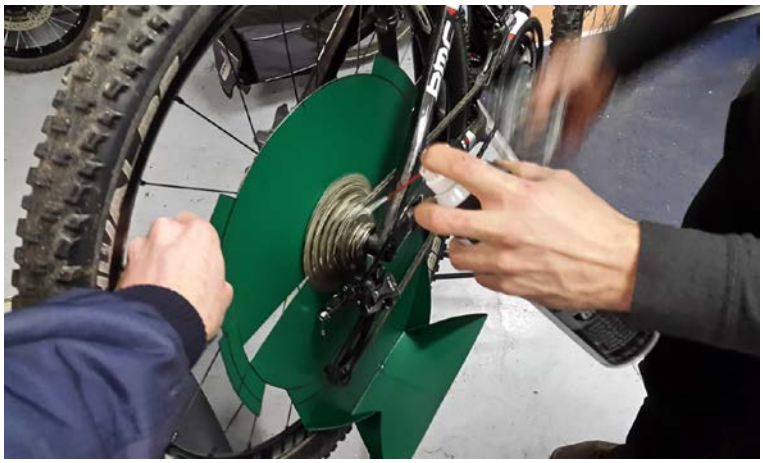


Figure 4: test by Sentini Marine

This mock-up version has moved the split line from the top of the device to the left of the device. The reason for this is to try and eliminate spray cleaner or spray oil from passing through the device and reaching the disc brakes.

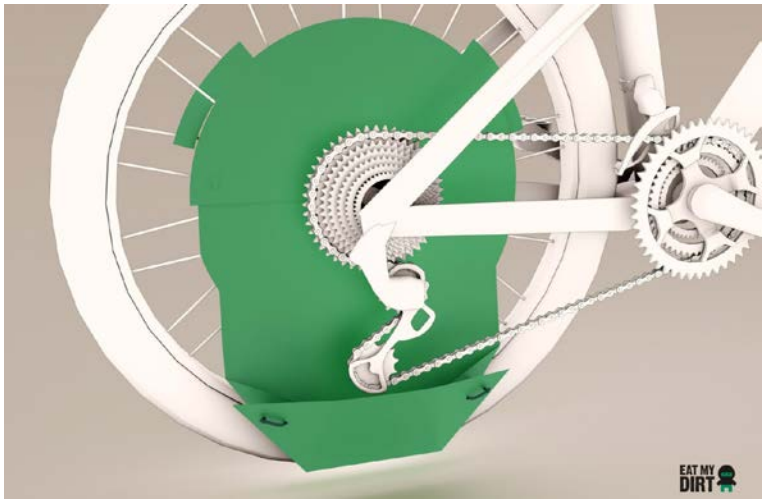


Figure 5: Version 3 - CAD visual.

This version has also been extended in length to allow the device to be used on a wider range of bikes with longer, deeper reaching rear derailleurs. In this view it is also clear to see the tabs that allow the device to be secured to the wheel spokes.

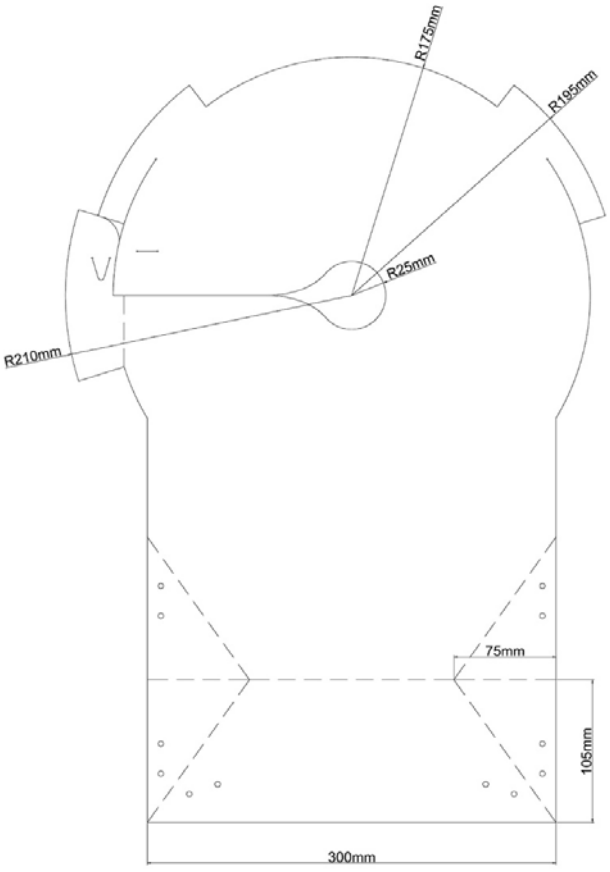


Figure 6: Version 3 - CAD plan view.

Solid black lines indicate the cut line on the sheet material and the dashed lines indicate the folds.

At this stage 2 holes were used to for cable ties to secure the folded pocket at the bottom of the device as can be seen in Fig.5.

6.2 Software Tools

At this stage of the project the University of Huddersfield team Dr Ertu Unver and Robert Silkstone intervened and took over the design and development of the project using a variety of software tools including Solidworks 3D Modelling, Adobe Suites, and laser cutting.

SolidWorks is a solid modelling computer aided design (CAD) and computer-aided engineering (CAE) software that runs on Microsoft Windows platform. The SolidWorks is part of the Dassault Systèmes based in Vélizy, France. Currently SolidWorks is used by over 2 million designers and engineers at more than 165,000 companies worldwide.

6.3 Material Analysis

Polypropylene (PP), also known as polypropene, is a thermoplastic polymerused in a wide variety of applications including packaging and labelling, textiles, ropes, thermal underwear and carpets, plastic parts and reusable containers of various types, laboratory equipment, loudspeakers, automotive components, and polymer banknotes. An addition polymer made from the monomer propylene, it is rugged and unusually resistant to many chemical solvents, bases and acids.

Polypropylene sheeting is a non-woven plastic polymer fabric used in a wide variety of packaging, promotional, and protective applications. The lightweight and durable polypropylene material is used to make extruded and heat-moulded plastic items. Pressing the polymer into thin sheets creates an effective and inexpensive shield against most liquids and chemicals. Many disposable nappy companies use polypropylene sheeting to form a final barrier against moisture leakage. Sheeting made of polypropylene can often be recycled into new plastic materials.

In this study a range of thickness and material tests were carried out for identifying the thickness for stability changing from 0.8mm to 2 mm. 0.8mm thick Polypropylene was chosen due to its properties, cost, and wide availability for prototyping and mass manufacturing.

6.4 3D Modelling, Prototyping and Testing

6.4a Version 4

At this stage the previous Version 3 was translated into the Solidworks CAD program. Firstly the design was initially refined to soften the edges with appropriate radiuses both for aesthetic reasons and user comfort. Further to this the opening to fit around the wheel hub has been enlarged and tapered wider to ease applying and removing the device. The split line has been moved from the left to the right hand side of the device to test if it is easier to apply the device. Also on version 4 single holes are used replacing the cable tie fixing solution with snap fit rivets to secure the folded pocket at the bottom of the device See Fig.8.

At this stage it was determined through testing that the tabs intended to grip the wheel spokes are sometimes irrelevant and cumbersome depending on the wheel design, number and position of the spokes and could be removed from the design and further evaluated. Further still the replacement of cable ties for snap fit rivets was successful making it much easier to assemble the device. One major failing of this design was the folding of the 0.8mm thick polypropylene sheet. In Fig.7 it can be seen where 4 red fold lines intersect. At this intersection the material will split and break. A recommendation for version 5 was to try another method perhaps smoothing the line with a radius and interrupting the fold lines before they reach the intersection.

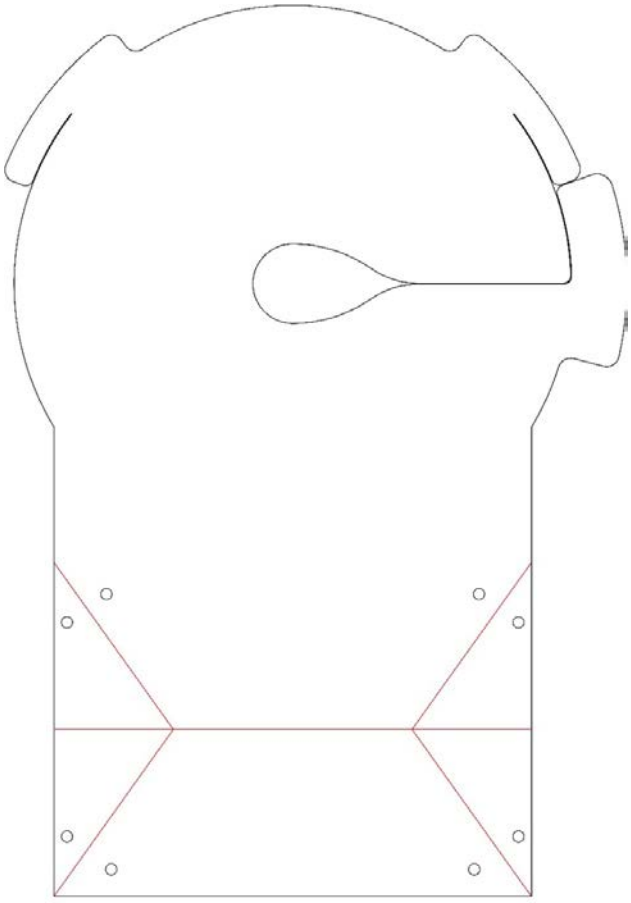


Figure 7: Version 4 - CAD plan view.

Figure 8: Snap fit rivets

Solid black lines indicate the cut lines on the sheet material and the red lines indicate the folds.

6.4b Version 5

At this stage the tabs have been removed from the design and a stepped split line has been introduced in order to locate with the wheel spokes. The red fold lines have been modified to include a radius and prevent the sheet material splitting, see Fig.10. The design is also reversed for the laser cutter allowing a greater scoring effect when the material is folded on the back of the device.

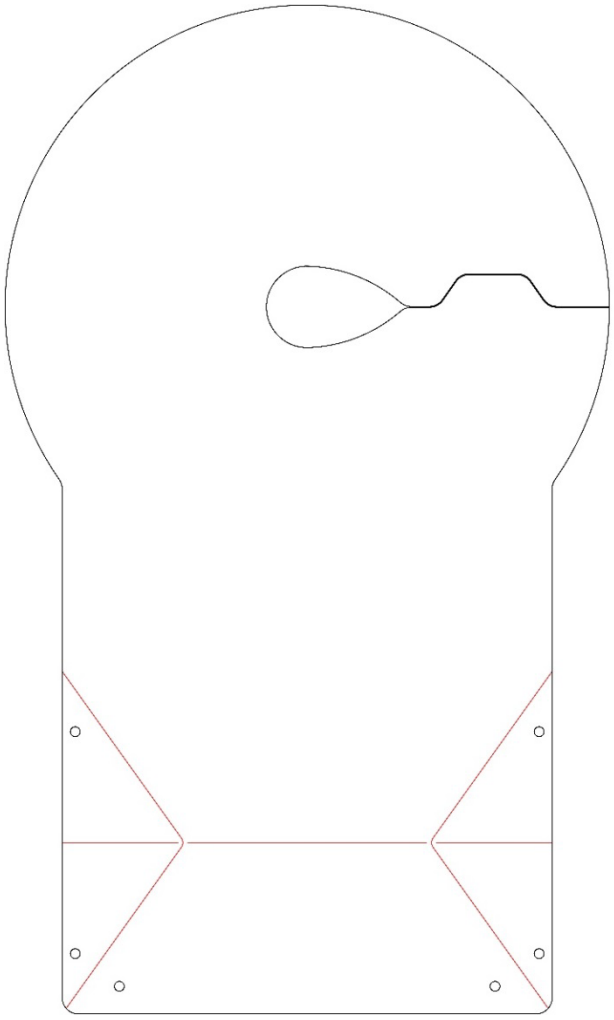


Figure 9: Version 5 - CAD plan view.

Figure 10: Close up of laser scoring fold.

Solid black lines indicate the cut lines on the sheet material and the red lines indicate the folds.

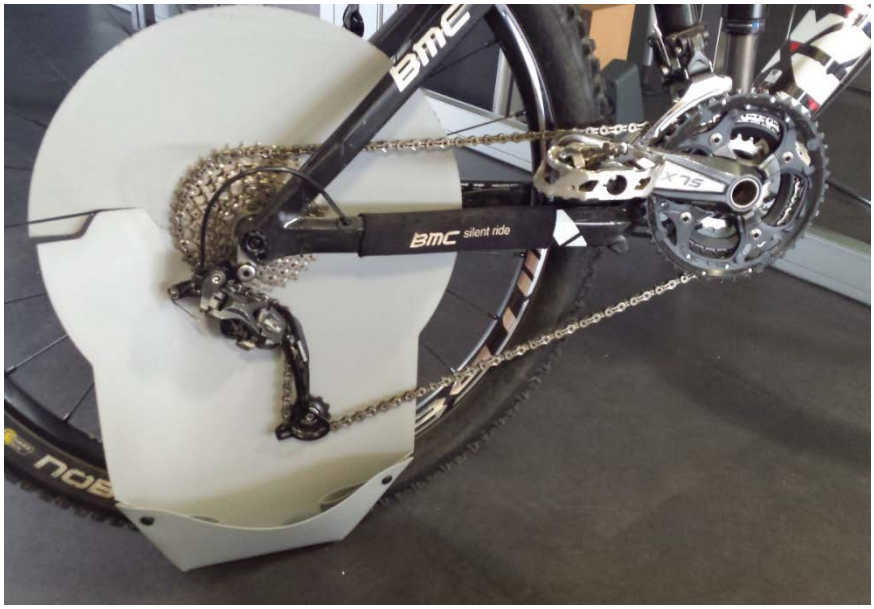


Figure 11: Version 5 under testing showing the split line hooking over the spokes.

The snap rivets can also be seen securing the folded pocket that captures the cleaning and lubricating fluids.

Figure 12: Version 5 folded pocket close up showing the excess material of the fold.

At this stage it was determined that the removal of the spoke tabs was successful but the re-profiled split line needed to be adjusted and the tab within that profile made smaller – see Fig11. Further still the excess sheet material once the folded pocket is assembled can be obstructive to cleaning out the pocket once it has been used. Recommendations are to remove some of the material from the design in the fold area and also to further iterate versions of the split line profile.

6.4c Version 6

At this stage it was determined that this design had been optimized as far as it could be but the overall consensus within the team was that further research and experimentation could be done with a 2 piece design to enhance the fitting and removal function of the device.

Figure 13: Version 6 folded pocket close up showing the reduction of the excess material of the fold.

The design of version 6 has a new smaller tab incorporated into the split line profile that makes securing the device around the spokes easier. Further still the reduction in the folded pocked material make cleaning out the device much easier.

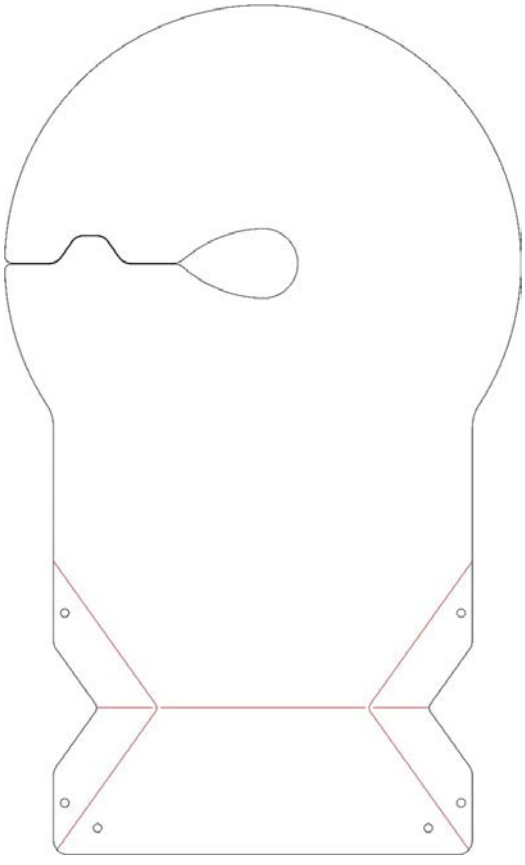


Figure 14: Version 6 - CAD plan view.

'V' shaped cut outs reduce the excess material in the folded pocket as can be seen in Fig.13.

Smaller tab can also be seen in the split line profile.

6.4d Version 7

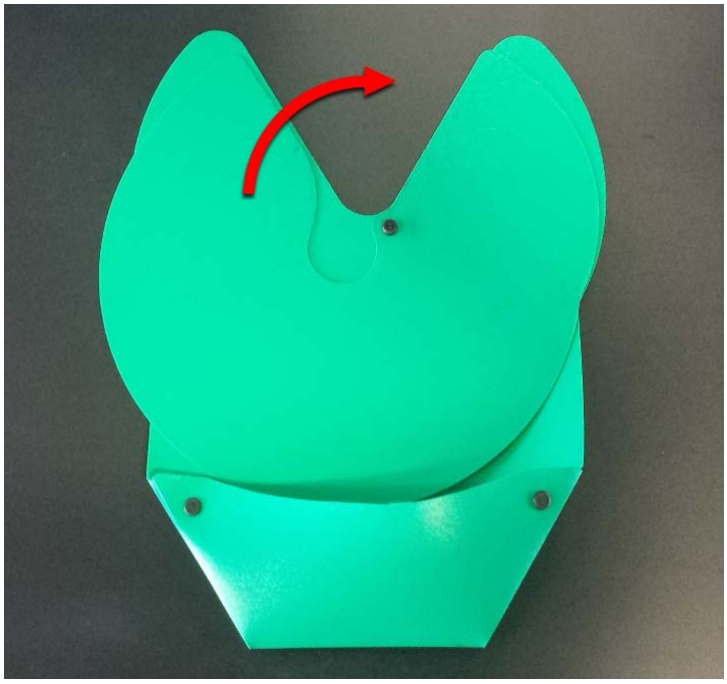


Figure 15: Version 7

At this stage of the project another strand of development was undertaken as it was judged that the product could be rethought as a 2 piece design. This 2 piece design was investigated in Version 7 using a pivot point to rotate a second piece of sheet material to form a cover once the device has been fitted.

This design reverts to the very first version 6.1a see Fig:1 in which a deep ‘V’ shape is used to locate the device around the wheel hub.

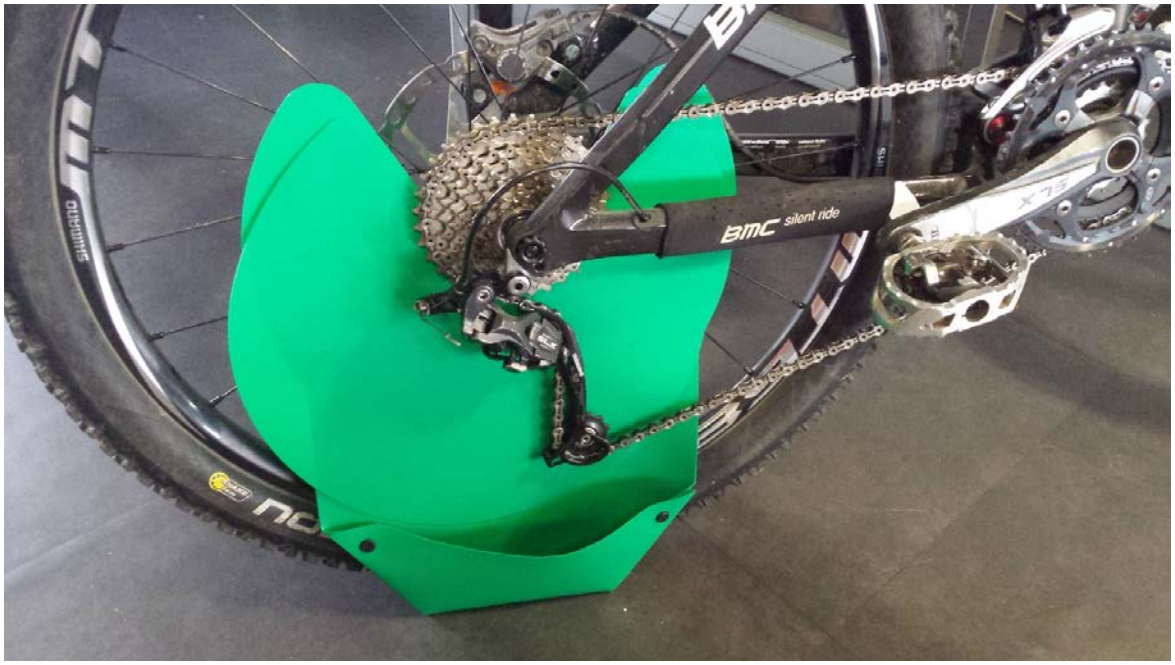


Figure 16: Version 7 open and being located on to the hub.

Figure 17: Version 7 closed to protect the disc brakes and ready for use.

Version 7 was evaluated and was judged to have potential to take forward for further development as it was so much easier to fit that the previous versions due to the wide V shaped opening. A modification needed in this version is the alignment of both parts that are slightly off centre and needs correcting as can be seen in Fig.17. Further still the second part that forms the cover is too large and can be reduced. Finally through testing it was proven the pivot point is too close to the centre of the hub and can on occasion interfere with the sprockets of the cog set causing the chain to stop spinning under maintenance.

6.4e Version 8

At this stage the 2 piece design was optimized to provide a smaller second piece to screen the brake disc. Also for aesthetic reasons a horizontal bottom was given to the part. This also works for the user to determine intuitively when the device is properly closed.

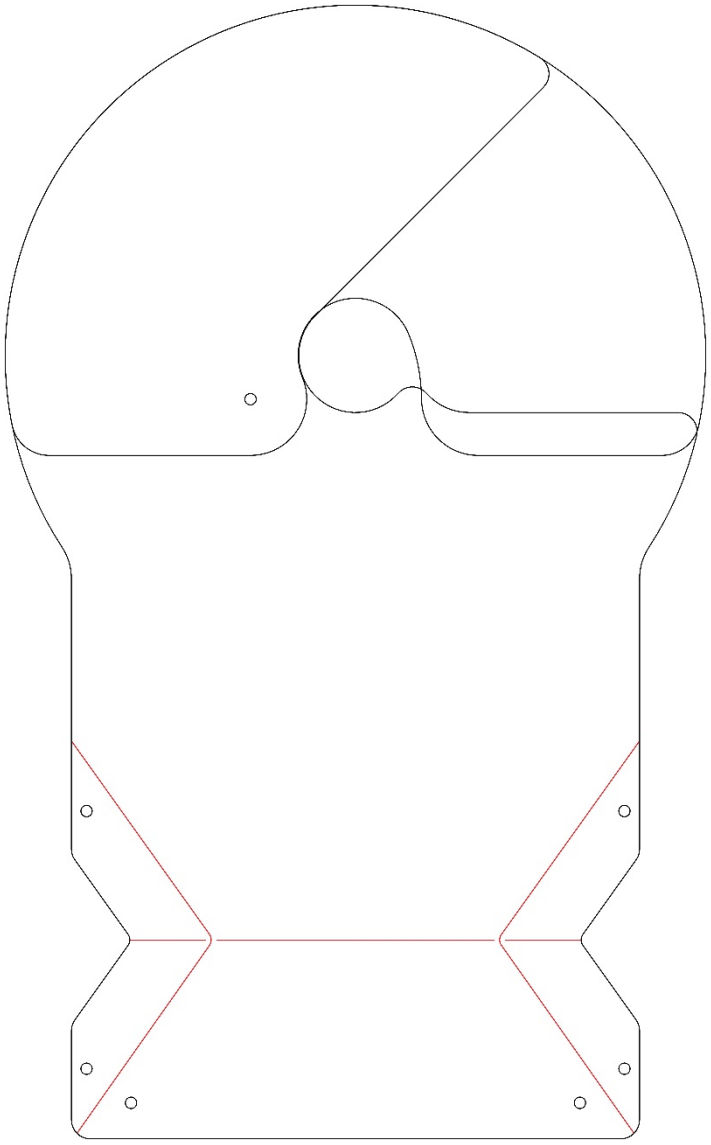


Figure 18: Version 8 - CAD plan view.

The 2 parts are overlaid on top of each other sharing the same pivot point.

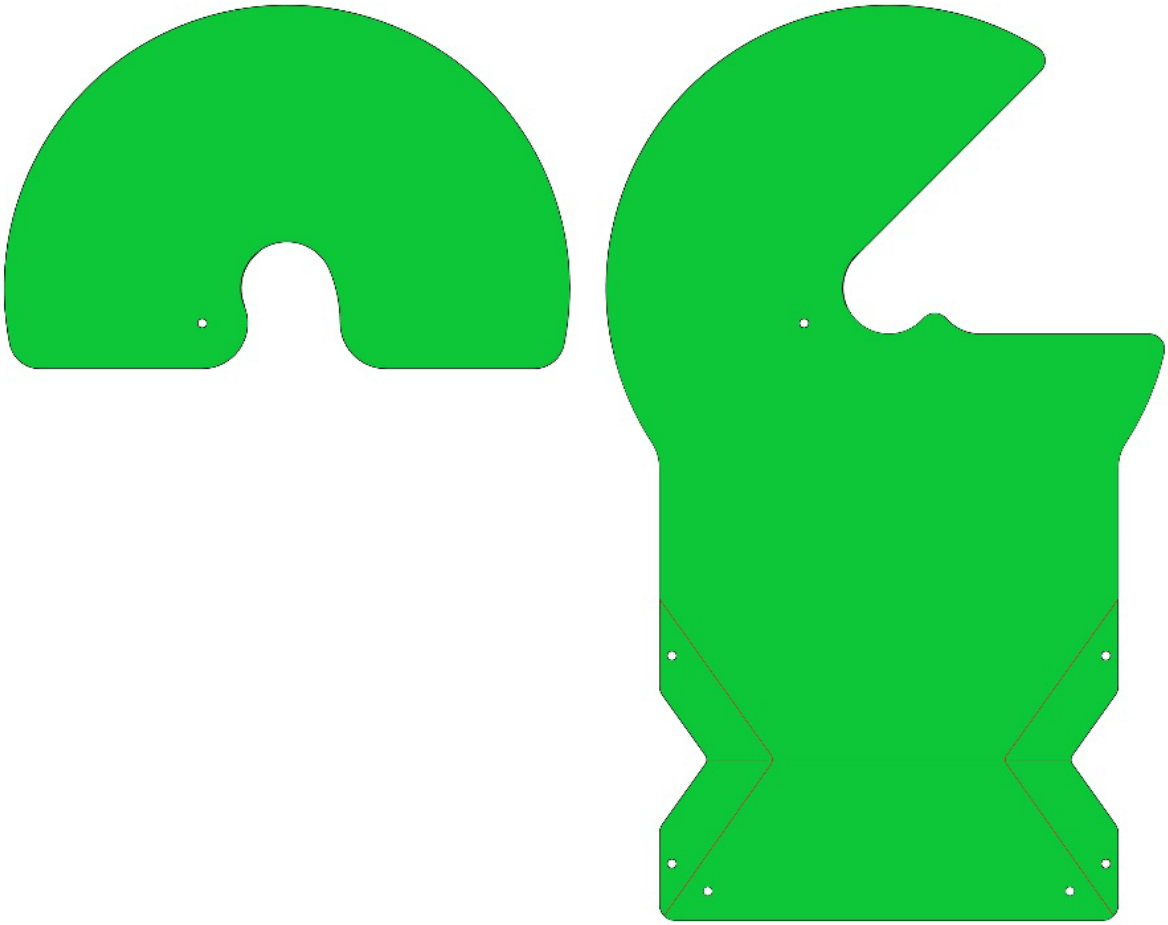


Figure 19: Version 8 - CAD plan view.

The 2 parts displayed side by side.

At this stage the design was changed to have the ‘V’ shaped opening to the main part on the devices left hand side. The reasoning for this was to further improve the ease of use and make the device as simple to fit and remove as possible. A further change was to add a raised nodule to the horizontal profile of the ‘V’ cut out on the main part. This was to further screen the hole as much as possible once fitted and also to better locate the device on the bicycle hub.

Figure 20: Version 8 being fitted.

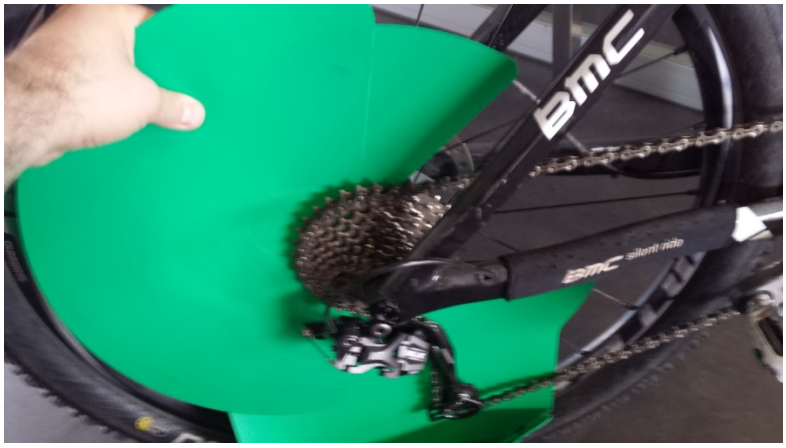


Figure 21: Version 8 with the main piece located and the second part being rotated to close and mask to V shaped opening.

Figure 22: Version 8 closed.

Figure 23: Version 8 modified adding a small locating tab to secure the second part in place.

Figure 24: Version 8 fully fitted and ready for use.

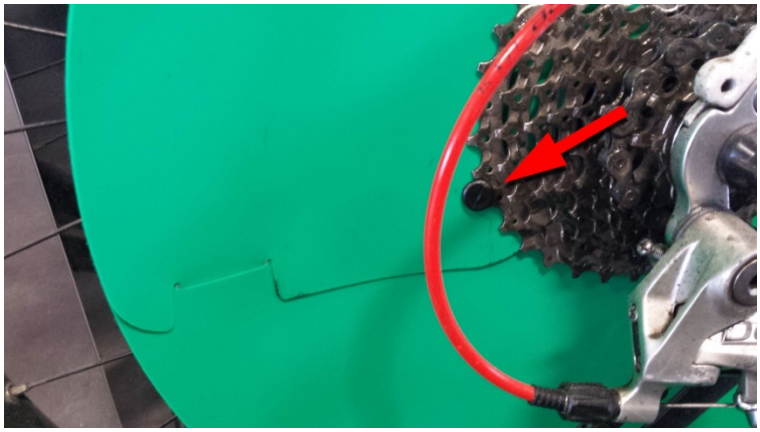


Figure 25: Version 8 tab.

Version 8 pivot point for is marginally too close to the largest sprocket. A recommendation is to further move the pivot a further 15mm away from the centre of the bicycle hub to aid the spinning of the chain and sprockets.

The design of Version 8 was largely successful despite the problem identified in Fig:25 to move the pivot point further from the centre of the hub. A further recommendation was to include a small locating tab to connect the main part of the device to the second part that forms the top piece as seen in Fig:25.

Finally one further recommendation was to see if it was possible to further reduce the diameter of the circular opening that locates around the wheel hub to create a tighter seal. As different types of bikes have different sized hub diameters could the device be adapted to meet hub diameters ranging from 45mm to 60mm?

6.4f Version 9

Version 9 was modified to move the pivot point further away from the centre of the wheel hub eradicating any clash with the largest sprocket as seen in Fig: 25. Further still dashed etch lines were added to indicate where the user can cut and trim to modify the device for bikes with larger hub diameters.

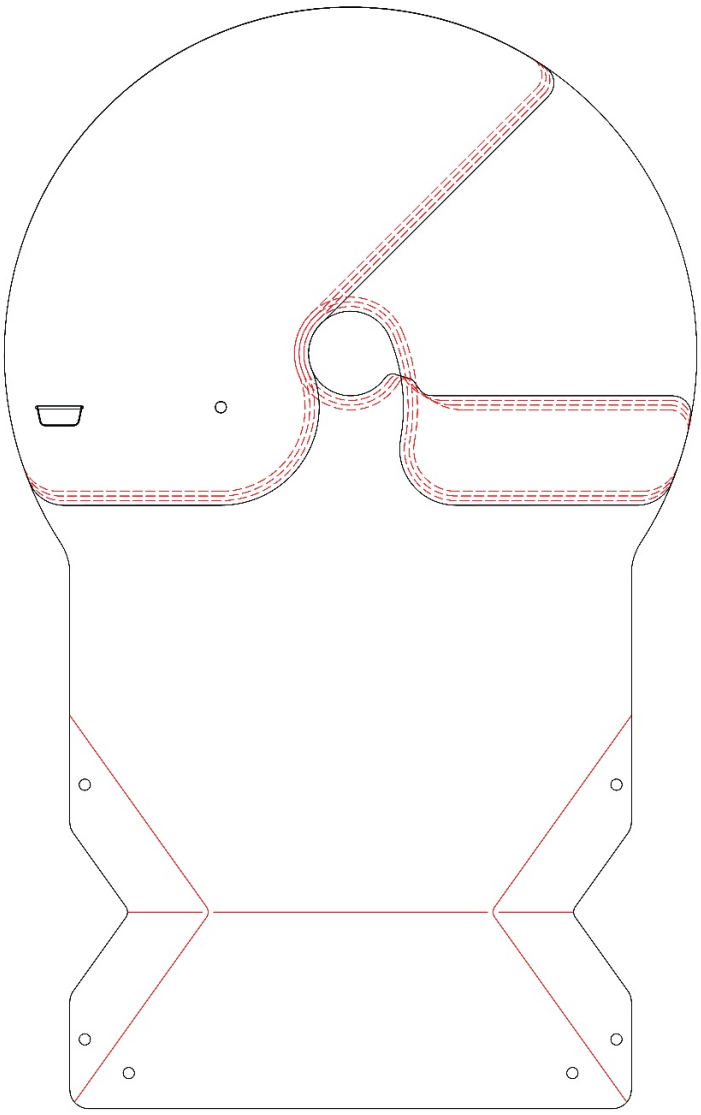


Figure 26: Version 9 - CAD plan view.

The 2 parts are overlaid on top of each other sharing the same pivot point. Red dashed lines indicate the cut lines the user can trim away to modify the device for larger diameter wheel hubs.

7. Findings and Conclusion

This project is supported by a Community Venture Fund (CVF). The purpose of the Community Venture Fund (CVF) is to develop new relationships between University of Huddersfield and the Community. The fund is an incentive to help identify potential projects arising from the University's knowledge/skills capable of supporting community regeneration and which test University ideas/research.

In this enterprising activity, this CVF financial support enabled the University staff to better understand the needs of potential community partners and enable it to develop a former foundation for partnership. The final design idea is currently being tested in a number of Companies and experts for suitability and market expectations and a joint patent application process is being underway. Further collaborative research on few other project are already been discussed with the company showing that CVF and Santander vouchers are very helpful for establishing the initial contact.

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