Team Results Document
MakeSensing

University: NOVA School of Science and Technology (FCT NOVA)

Team members:

André Luís Caetano Piteira

Anastasiia Subach

Beatriz Carvalho Nobre

Beatriz Sofia do Carmo Machado

Chiara La Guidara

David Alexandre Figueiredo Alves

Diogo Filipe da Cruz Martins

Lara dos Santos Gonçalves

Mariana Duarte Pimenta Resende

Matilde Anaís Carneiro Martins de Abreu

Nuno Maria Reis Ferreira

Ricardo Miguel Oliveira Mafra

Simão Manuel Oliveira Caracho

Sofia Hassane Ribeiro

Tomás Emanuel Neca Adão Miranda Mingates

Supervisor:

José Ricardo Ramos Franco Tavares

Coaches:

Tomás Pinto e Cruz de Oliveira Pinheiro

Rui Alberto Garção Barreira do Nascimento Igreja

Ana Sofia Barradas Dalot

11th of August 2023

SensUs 2023
Traumatic Brain Injury

1. Abstract (max. 200 words)

Our team project, is a simple, yet effective electrochemical biosensor that was designed to be easily read by any professional, while simultaneously being able to give accurate predictions on the presence of brain trauma. Our biggest distinction is who we are focusing our attention to, namely the patients that suffer from milder, or intermediate cases of traumatic brain injury. If this disease is already named the "silent epidemic" for severe cases, consider how undetectable it is for milder cases. It is absolutely crucial to give a reliable option to humans who have not being injured enough to justify being exposed to radiation. A solution that is simple and quick to perform as not to take much time out of our agendas. That is the purpose of our project and that is exactly what we are going in detail in this document.

2. Biosensor system and assay

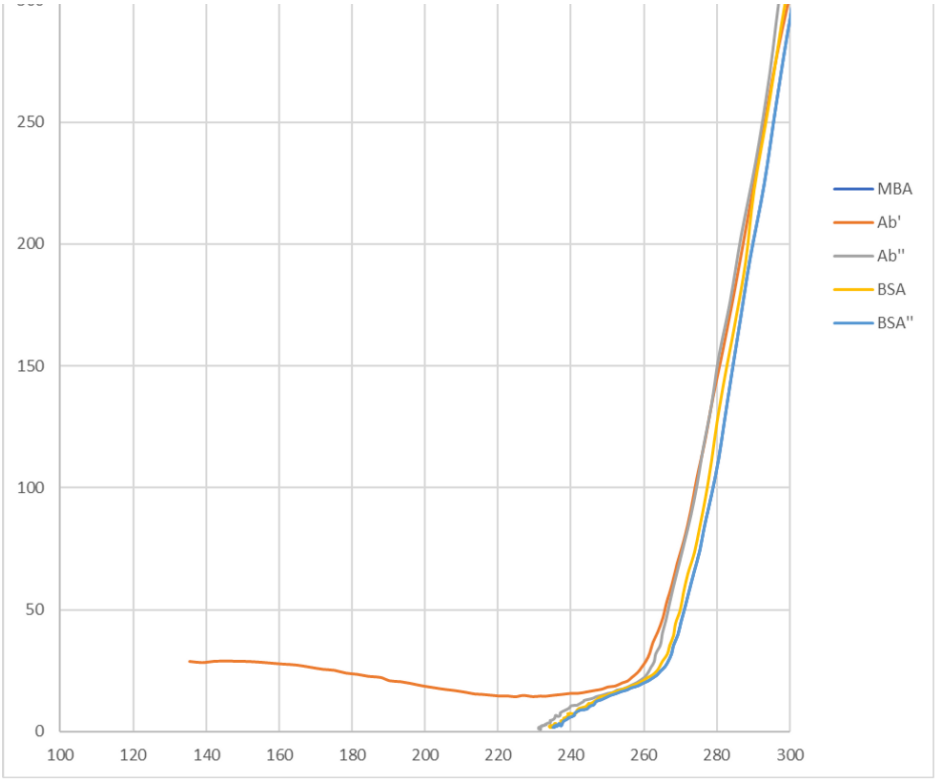
In order for our sensor to detect the antigen (GFAP), we opted for anti-GFAP monoclonal antibodies from mouse(IgGl), capable of recognizing the following sequence from the GFAP protein: 1AGFKETRASERAEMME16. (Hytest, n.d.)
These antibodies are bonded covalently to a conductive surface to which we apply a current, in order to measure resistance changes. Once the Physical/Chemical properties change, so will the resistance. By looking at the impedance curve, imaginary component against the real, we can identify the change in resistance by performing the EIS technique.(Lourenço, 2022)

To ease the identification of said changes to healthcare professionals that may have read the results from our sensors, we've adapted it to a commercial product by visualizing the Rct line (Lourenço, 2022), which is given by the intersection of the linear regime of the curve right after the hump. This method is highly practical as without any rigorous mathematical method or elaborated programs we can assess if there has been changes to the system properties. Given that we are adding protein to our sensor, that is being captured by the aforementioned antibodies located at the surface, it is to be expected that the resistance increases. By other words we are expecting the value of Rct to increase.

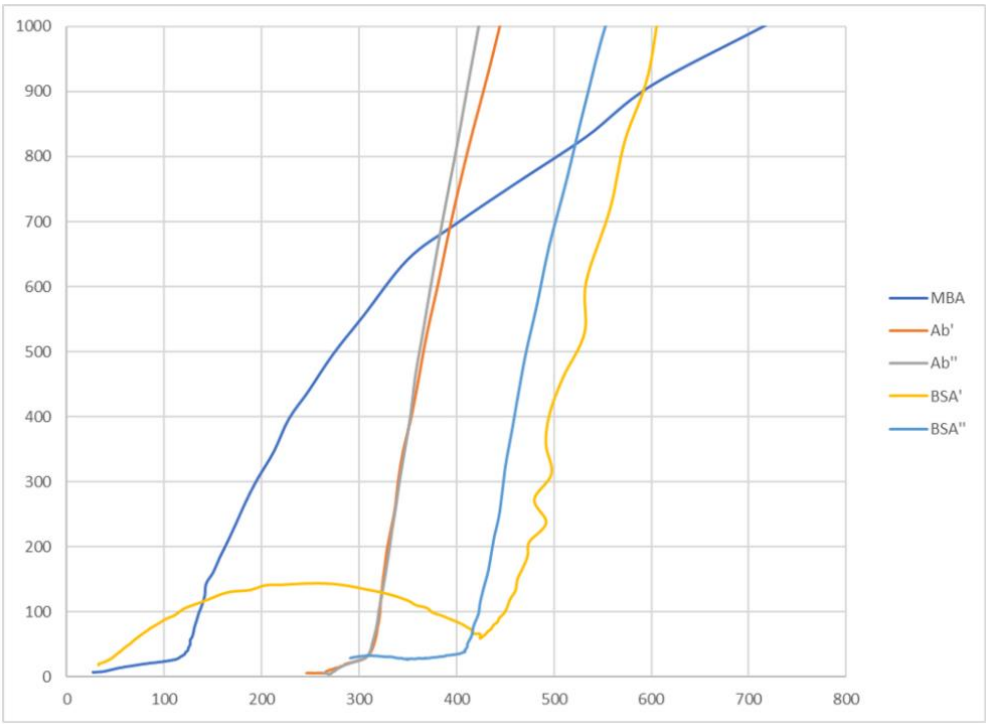
3. Technological feasibility

In respect to the feasibility of our device it must be stated that even though we did manage to develop a functional electrochemical sensor, there are some inherent problems associated with it. For instance, the system is extremely fragile since we did not optimize the process enough for the system to be stable. In addition, we have come to realize that there is an unexpected small increase in resistance overtime that appears to be random, occurring in seemingly unrelated situations.

We suspect that the design EIS setup is not the most precise, even though, from our advisor's experience, this technique has shown to be highly sensitive in other occasions. With that in mind, in the near future we would like to experiment with cyclic voltammetry as it might be better for this particular type of sensor. We believe that the transduction system is capable enough to support a highly sensitive biochemical assay and we also have ideas on how to improve the flow of the sample onto our device. From our results, presented below we are inclined to believe that our sensor is sensitive enough to perform well in blood plasma. However, we are eager to find out in Eindhoven!



The figure above shows one of our best sensors, where we can see that the resistance does increase slightly as the curves become steeper. However, after 2 cycles, we can see that there is close to no difference which suggests that the shift is negligible.
To make contrast, below is our best sensor, where the measurements where indeed successful.

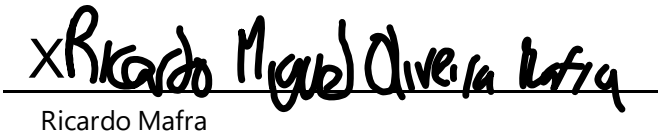


The reason for this is that at each modification step we see a disparity in the steepness of the curve, which suggests that the changes were not negligible.

4. Originality

The devices built were exclusively developed by students in our team. We intended to manufacture as many components as we could to have the highest degree of freedom in regard to creativity. The only component we did not fabricate was the potentiostat, as we understood that we wouldn't have the time or funds to fabricate and fine tune our own. Instead, we used the PalmSens4 from PalmSens.

While professors and our Supervisor Ricardo Franco gave plenty of pointers on which methods or techniques are more adequate, they still allowed us to be fully independent. We did end up following the advice of Tomás Pinheiro in various instances in regard to our prototype, given his experience in electrode manufacturing.



Ricardo Mafra
Team Captain

Diogo Martins
Team Co-Captain

The Team MakeSensing is presenting a GFAP biosensor with the following parts:

- An immuno-bioreceptor of anti-human GFAP monoclonal antibodies supplied by HyTest

- An electrochemical transducing system in which the bioreceptors are covalently immobilized on a gold nanoparticle (AuNPs) covered LIG (Laser Induced Graphene) printed electrode
- A detection system based on EIS (Electrochemical Impedance Spectroscopy)
- Testing was with recombinant GFAP antigen supplied by HyTest.

The innovative aspects of these system are:

1. The use of simple immobilization chemical techniques to link the antibody to the surface of the electrode
2. The proposed LIG-AuNPs electrodes can be easily mass produced in the reproductive a manner with no need for clean rooms or expensive facilities5
3. EIS is an easy implementable and powerful technique to measure antibody-antigen binding

The novel ideas were conceived by the Team and thoroughly discussed with the Advisors.
The Team recognized/selected the novel ideas.
The ideas were adjusted by the Team with expert technical help by PhD student Tomás Pinheiro.
The ideas were scientifically tested by the Team.

Assinado por: **JOSÉ RICARDO RAMOS FRANCO TAVARES**
Num. de Identificação: BI07355636
Data: 2023.08.11 21.59.56 GMT Daylight time

X CHAVE MÓVEL

Ricardo Franco
Team Supervisor

5. Translation potential

5.1 - Introduction

In this section of the TRD we are going to go over our business plan in detail, from our customer segments, where we define our main target consumer, to their needs and pains. What follows ispaying close attention to the value proposition and how to capture value. Furthermore, we also assess our key resources, activities and partners. Lastly we'll go over a financial analysis on cost, price and also a market assessment.

5.2 - Stakeholder desirability

5.2.1 - Customer and stakeholders

As a B2B2C company, we have both business customers (B2B) and end-consumers (B2C). Our business customers are healthcare establishments: hospitals and medical centres, which seek improvements in the health and well-being of their direct customers. Incidentally, these establishments are eager to acquire new technologies provided that clear benefits are shown either by easing current problems or by empowering facilities, offering them new efficient and trustworthy tools. Concisely, these health systems need an alternative to CT/MRI scans, one that provides reliable results faster, leading to immediate follow-up care, and one that doesn't require centralized expensive equipment.

Our end customers can be split into 2 distinct customer segments: emergency patients and non-emergency patients. The former are victims of harsh head traumas likely to be diagnosed with some form of TBI. Their needs consist of immediate or prompt follow-up care, and reliability of the result given. As for the latter, these are victims of moderate, or light head traumas that are less likely to be diagnosed either due to lack of physical evidence or by lack of awareness. For this reason, they should have an alternative to CT scans which, if not utterly urgent, possess large waiting lists, where top performers in health services such as the Netherlands may still take up to 4 weeks to provide a hospital specialist diagnosis.(OECD, 2020) For this reason, providing awareness and possible treatments to previously unaware victims of TBI is of uttermost importance, since it is expected to have a serious impact on their productivity and mental state.(Khan et al., 2003; Schuchat et al., 2017; Seifert, 2007)

By incorporating non-urgent patients as a separate customer segment, we can increase the number of individuals who benefit from our TBI rehabilitation services. This approach enables us to maintain our focus on addressing the central problem of the "silent epidemic" of TBI while expanding the reach of our services to a wider customer base. We plan to offer a solution that gives swift, yet reliable results to healthcare establishments, that may or may not have access to CT scans.

5.2.2 - Value Proposition

Since our goals are largely aligned with those of our business customers, we have primarily focused our value proposition on meeting the needs of our end customers, more specifically on non-emergency TBI patients, mostly constituted of milder cases of TBI (mTBI), who are more likely to stay undiagnosed due to less noticeable symptoms and less likelihood of being detected under imaging modalities. This is of utmost importance, forasmuch TBI is causing a silent epidemic.(Dewan et al., 2019) There has been strong proof of the potential costs of undiagnosed cases of mTBI, mostly due to loss of productivity. (Seifert, 2007; Stein et al., 2006)

However, it is worth noting that healthcare establishments can also benefit from our product. For instance, by providing another alternative to CT/MRI scans, there is no longer the need to solely rely on these imaging modalities to perform diagnosis for TBI. Firstly, this relieves healthcare establishments from the financial burden of these imaging techniques, either from the cost of acquiring or operating them (Shobeirian et al., 2021). Meaning that smaller and more modest medical centres that lack expensive equipment will be empowered, distributing pressure between more establishments. Secondly, it allows better integration with digital systems such as Electronic Health Records (EHR) from Validic™, easing access to patient data to healthcare professionals, personalized medicine, and many other benefits from those technologies. (Campanella et al., 2016) Finally, due to a faster response, our product will make immediate follow-up possible, which has shown to be a highly desired issue to be solved in most establishments. (Seabury et al., 2018)

(See figure 1 in the Annexes – B2B customer value proposition diagram)

As for non-emergency patients, our solution provides a fast and reliable response without the need for them to queue for CT/MRI scans, which will generally imply long waiting lists, especially for non-severe cases that will have to compete with other severe cases of TBI, or other prioritized diseases such as cancer. As an example, and one of the

best health systems worldwide, the Netherlands, it may take two to four weeks to obtain the results of an imaging technique such as CT, but overall waiting times can go up to 90 days.(OECD, 2020) Even if patients are willing to wait, it is not feasible for most potential victims of TBI to undergo intense radioactive techniques to be proven negative. Our sensor only requires a blood sample to produce a result, avoiding potential allergies to contrast agents or radiation. Additionally, as it is not dependent on physical evidence, but rather the presence of certain indicators in patients' blood, there won't be false negatives due to the lack of visible evidence. Although it should be noted that no diagnosing method is perfect, and nor is ours. There are and there will always be false negatives, as much as we optimize for that.

There are also gains created from our product. For instance, given its fast analysis, it enables the victim to spend less time inside healthcare establishments, and more resting. Unlike imaging methods, our sensors produce a quantitative measurement, allowing us to relate results to degrees of injury severity, which in turn leads to personalized or severity-based rehabilitation plans. Not only that but also, by diagnosing cases of mTBI there will be a vast list of benefits to those victims, from a psychological and social acceptance standpoint but also productivity(Stein et al., 2006) , as we've stated before. Lastly, by supporting healthcare establishments of any size with the tools to diagnose TBI, patients will benefit from point-of-care (PoC) medical centres much closer to their residences.

Although, despite our efforts, the prototype as it stands doesn't achieve the value proposition in its entirety, namely in regards to sensitivity and packaging. Our product is also lacking a dedicated platform that will process the measured values, presenting them in a user-friendly way, and there is no support for machine learning predictions. On the other hand, the device does produce a result within 10 to 15 minutes, it is extremely simple to operate, and the processes chosen are compatible with industry scale manufacturing.

It is not our intention to substitute powerful techniques, such as the aforementioned imaging modalities, but to offer a much-needed segregated alternative focused on patients and victims that are unlikely to undergo such diagnosing methods. Above all, we are driven by the possibility of improving the lives of many that are unaware of TBI. We can argue against other competitors such as portable NIR scanners (InfraScan Inc., 2023) or many other similar devices in a sense that many of these are designed for military purposes, thus they target customers with significantly different needs from ours. Those devices are typically not cheap, thus not useful for diagnosis of a large volume of patients, and, in addition, the portability is not as necessary in our case, as our devices are intended to remain inside local medical centres. There are also other devices that were successful in the research phase such as a neurochemical sensor(Tageldeen et al., 2020), which is meant to be a wearable device with high sensitivity. For this same reason it is not a direct competitor for our main customers, milder cases of TBI. This is because, a wearable device that provides constant monitoring is intended for patients that are already diagnosed with TBI. Not to mention that this device is invasive given that it requires surgery to attach a cranial bolt, which contrasts with our non-invasive approach.

To put it simply, by targeting the population with milder cases of TBI we can distinguish our products from the competition. This strategy also allows us to choose a technology that is currently not under any patent.

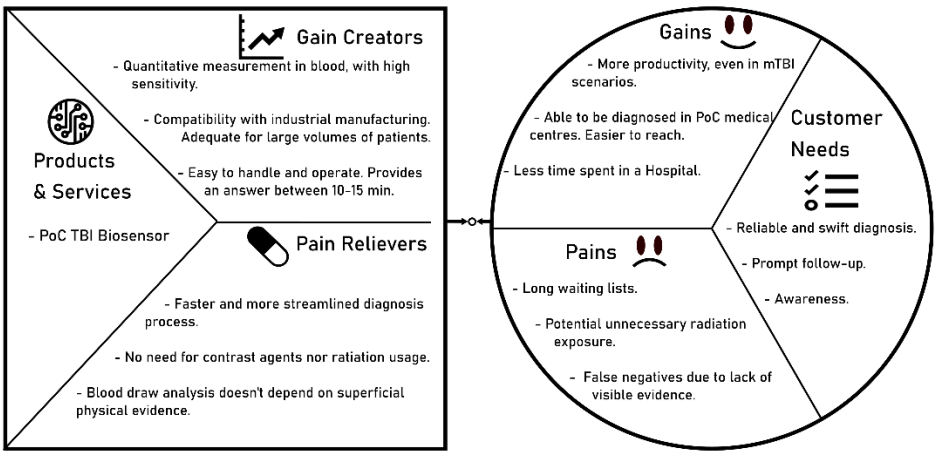


Figure 1 - Value proposition - Value Proposition Canvas for B2C customers.

Lastly, to retrieve as much monetary compensation as possible from our product, we will begin by assessing what is the cost per unit of our sensors, compute the initial investment required to start producing devices, and from there we will have an early estimate of what the price of the sensor should be to achieve a breakeven point within an acceptable

range of years in this industry (below 10). As our product targets a very distinctive customer from other competitors, we will keep in mind the price of PoC biosensors for other diseases as pointers for what the price of ours should become down the line.

5.3 - Business feasibility

5.3.1 - Key resources

Given the current size of our project and its small scope objective: the SensUs competition, our key resources are the skilled team members that constitute our team, mainly our professors that possess a large amount of know-how to distribute amongst the students. As it stands, our teams possess students that are either starting or finishing a master thesis on subjects such as in electrochemical biosensors, biomaterials and nanomedicine, machine learning, electronics, pathology, and many others in the biochemistry field. For this reason, we are sure that we can develop a commercially worth prototype in due time as each member attains more experience.

In the medium term, foreseeing a finished prototype, we will need to have at least one person with at least one year of work-experience with In-Vitro Devices (IVDs) to assure that we comply with the CE directive. The reason for this is that, for us to commercialize any medical device in Europe, we must apply for the CE certificate under Regulation (UE) 2017/746 (EUR-Lex, 2023). To be approved we will need to conduct a performance report, following the general requirements of safety and performance in Annex I, which require an elevated control of quality. For this matter, one other key resource to have an IVD approved by the EU we need to hire a quality assurance engineer to comply with aforementioned standards. Naturally, in the long-term a full team of quality management and control would be key for us to be able to keep improving our devices from customer's feedback, while making sure we are always under the EU standards for IVDs, renewing our licence to commercialise this product.

5.3.2 - Key activities

One key activity we must accomplish to the best of our ability is the manufacture of a product that is reliable and produces results according to the high standards of healthcare establishments. On top of this aspect, we must assure the quality of the sensor does not compromise its reliability and that there must be enough redundancy built-in the sensor, or a maintenance policy that assures repair within a defined small interval of days, independently of distance to the customer.

In addition, we must be highly effective with our marketing to portray the importance and the benefits of being diagnosed to confirm or negate TBI, making sure that our end customers trust us enough to feel compelled to be diagnosed by a quicker and less known method when compared to CTs or MRIs. Our go-to-market strategy involves using advertisement to raise awareness of how common a mild- or moderate-TBI is, followed by demonstrating how easy and quick it is to be diagnosed. This way we can cultivate the habit to think of head injuries as serious threats that can be prevented from becoming worse in little to no time.

5.3.3 - Key partners

Given that in an early stage, we will only commercialize locally due to financial limitations, it is clear that the local medical centres and hospitals are our key partners. First and foremost, these are the only establishments that can expose our product to other patients at the start. Secondly, these partners are also potential bridges to other healthcare providers, helping us to expand. To establish a symbiotic partnership, we intend to demonstrate to healthcare establishments how solutions like ours can reduce a significant part of their waiting times and reduce how crowded central hospitals are. Considering how large the waiting times are in Europe, and how precious each minute can be for many patients, we are confident that even the slightest help will be worth investing in our products. From our discussions with Hospital Garcia de Orta (HGO), it became noticeable that there is such interest from central hospitals. In this particular case, we are building a partnership with HGO by first publishing a case study in collaboration with a team of doctors on the performance of our sensor. If the study proves to be successful, and we get statistically relevant data to back our claims, they agreed to form a partnership once the product is approved by the EU.

One other key partner, but at a medium-to-long term is Siemens Healthineers. A company to whom we have briefly presented our project and that were eager to hear more from us in the future whenever a functional was available. To collaborate with Siemens Healthineers, we must apply for their Digital Ecosystem. To be accepted we must have a digital solution that sparks the interest of Siemens and then we can invest to be part of the program. Upon being part of the program, we will have access to support from Siemens in growing our business, we'll be exposed to the entire network of customers in their ecosystem, which is a enormous opportunity for small businesses. Siemens also benefits from this, not only because they get paid by us, but also because they get one extra digital tool into their ecosystem which

attracts more customers. (Siemens, n.d.)

5.3.4 – Sustainability

When it comes to sustainability, we are aware of rising issue with electronic waste. For that exact reason, and to try to be as resourceful as we can, we've been using a technique that allows us to recover used sensors. This process consists of lowering the pH at room temperature, which breaks the crosslinking bonds between the antibody and the antigen (GFAP). From our experiments, the sensitivity is damaged, but the sensors remain functional.

In addition, as we've mentioned in the value proposition, our solution may help mitigate the overuse of CT and MRI procedures, as multiple studies have shown.(Naunheim et al., 2019; Shobeirian et al., 2021)

One other concept we kept in mind while designing our biosensor was to avoid as much electronic waste as we could. That is also why we have tried to find a way to decouple the antibodies from the antigens, so that we could at least keep reusing the electrodes. As it stands the packaging is not environmentally friendly, but it is in our plans to do so in the future.

5.4 Financial viability

5.4.1 - Costs projection

To assess the costs per use of our sensor we fetched the costs per unit/ml/area of each of the materials used, computed how much percentage of said unit was required for one sensor, and computed a weighted sum based on those percentages. The cost per sensor is ≈ 5.076 Eur.

Component	Amount	Cost (EUR)
anti-GFAP	100 µg	400
Gold nanoparticles	25 mL (4.5E8 particles/mL)	247
Horseradish Peroxidase	10 mg	106
Electrodes	300	270
Gold Salt Gold(III) chloride hydrate	500 mg	126
MBA	5 g	40
anti-IgG	2 mg	221
Total	300	4.7 per sensor

Material	Price	(A/mL/un.)	Preço/(A/mL/un.)	Qt(per sens)	Price(per sens)
Bench-top ECP device	10k				
Universal Laser System vls 3.50	15k				
Film	90.93	100	0.9093	0.08333333	0.075775
Silver Ink	472	400	1.18	0.2	0.236
Ink AgCl (reference)	219	200	1.095	0.05	0.05475
PBS	33.44	10000	0.003344	0.07	0.00023408
KCl	16.7	125	0.1336	0.07	0.009352
					0.37611108 per sensor

On the left table, we have estimated that the number of components in the middle column are enough for 300 sensors. We have also estimated the cost of our two main used tools, a standard laser system to be around 15 thousand Euros and the cost for a bench-top electrochemical deposition system from an established brand, with automated capabilities should cost around 10 thousand Euros.

5.4.2 - Sales price

From our perspective, even though we have already pre-established a partnership with a central hospital in one of the most populated cities in Portugal, we are expecting the first two years to sell a very low amount of sensors, as our marketing strategy requires awareness from other customers, something we can't expect to get from year zero. Thus, we expect the values in the first year to fluctuate between 10 sensors and 15 at best. On average, in the first year we expect to sell 128 devices. As for the second year we can see the number of healthcare providers to increase from one to at least 2 others, with whom we already have ties with. Nevertheless, we expect the number of devices sold to fluctuate more or less around the same values as we won't have invested much in advertisement until the end of the year. From our estimates we expect to sell 400 units. As more hospital and medical centres adhere to our product, we expect to sell around 889 units by the end of third year. If in fact the advertisement worked well, we plan to use part of our working capital to triple the amount of money spent on advertisement. We expect to have at least 10 healthcare establishments as regular customers, selling around 3810 units. In similar fashion in the fifth year we again increase in investment in advertisement, and we expect the expand to Spain in that same year, selling up to 63828 units.

Given that each sensor costs around 5 Euros to manufacture we have chosen the price of 20 Euros per unit. This price per unit, gives us a positive breakeven point by the end of the fifth year, with an Internal Rate of Return of 4%, meaning that there is a gain per euro invested.

5.4.3 - Market analysis

From our research we have found an estimate that per year 7.6 million of people are expected to suffer any degree of TBI in Europe.(Dewan et al., 2019) If we assume that the probability of having a TBI is equal between every European country, given that Europe has around 764 millions of humans, and Portugal has around 10.33 millions, we obtain that Portugal is 1.3520942% of Europe's population and thus out of those 7.6 million of TBI per year, Portugal is expected to have 102,759 injuries per year. This value should be roughly a decent estimate of our market size. It is also estimated that 80% of these are expected to be mild injuries, which suggests that around 80,000 patients would probably remain undiagnosed if no alternative to CT or MRI is in the market. And this is just in Portugal, as in Europe around 6 million of mild-TBI go unnoticed, so there certainly is enough room for our business to profit and grow.

5.4.4 - Revenue streams and business strategy

To clarify our revenue streams, and thus explain our business strategy we will go a bit further onto how we intend to generate profit out of this product. In the first 5 years, we want to focus on developing a biosensor with the aforementioned characteristics, following a volume-based strategy. By other words, we seek to generate profit by selling large volumes of cheap units, instead of selling less, but more expensive. This goes well with our design for the sensor and with out strategy to reach as many PoC locations as possible. If the devices were more expensive, we wouldn't be able to distribute them among smaller healthcare providers such as local medical centres. During these 5 years, we plan to expand as much as possible around Portugal, by making use of our already established partnership with HGO, but also to expand to Spain. On the side, we want to keep developing our digital solution that will complement our sensors, that is, software that can take the results from our sensors and make predictions in regards to what the patient could be experiencing in the next following days. We don't intend to release together with the sensor, to avoid spreading our attention in the beginning. If we focus on one product at a time, we can be more assured of its success. Not only that but, such a predictive model requires vast amounts of data that we do not possess in the first few years.

Once our prototype for the digital solution is ready to deploy, we want to collaborate with Siemens Healthineers, are previously discusses to further expand our solution to world. By then, we should be able to afford the investment required, while simultaneously being able to provide services of interest to Siemens. Once both products are deployed, we plan to follow the standard revenue model of companies in Siemens Network, subscription based.

6. Team and support

Our team was divided into 2 main groups of students: those responsible for the transduction system, and those for the biochemical assay. **Diogo Martins** was the main responsible for the former, while **André Piteira** oversaw the latter. Both mainly contributing to aiding the team captain, **Ricardo Mafra**, when completing the various assignments throughout the year, and planned and scheduled their respective team tasks. In June, **André** handed over his position to **Simão**, who by then was already getting the most experience in the lab. In the end, **Simão**, was by far the main contributor to the biochemical assay. **Simão** also worked with **Ricardo** in the beginning by contacting dozens of companies in search of funding. At his right hand there was **Nuno Ferreira**, who was mainly involved in research and development of our biosensor. He focused on the procedures regarding the conjugates.

In addition, **Nuno** also used his lab expertise to full fill paperwork to one of our partners, Hospital Garcia de Orta (HGO) with respect to sample collection, preservation, and preparation. **Mariana Resende** was also part of this process, while also assisting **Nuno** and **Simão** in the lab when possible. **Mariana** was mostly in charge of complementing **Beatriz Nobre**'s work on the Social Media team. Overall, **Mariana** contributed in every social media task, especially with entirety of our Instagram Takeover, which coincided with a period of unavailability for **Beatriz Nobre**. Yet, despite this, **Beatriz** worked hard to produce content with great quality throughout the entire year, including making most of the content for the Takeover. She was also part of the transduction team, where she assisted with most procedures.

In the transduction team, there is also **Tomás Mingates**, the student responsible for most of the work in the transduction team, from troubleshooting measurements to being in charge for the whole nanofabrication process. Just like **Nuno** was the partner of Simão in the lab, **David** and **Sofia** were always present to assist **Tomás** when fabricating the electrodes. Both, **David and Sofia**, were part of the Events and funding team, where they contributed with a plethora of ideas. **Sofia**, worked as the bridge between both departments, dedicating her time to being involved in both laboratories, thus overall having a large contribution to the entire sensor. Not to mention her contributions to the events and funding team. This team was coordinated by **Lara Gonçalves**, who created a GoFundMe campaign, pushed, and made happen several events for our team to gather funds. **Lara**, was also assisting **Simão and Nuno** in the lab when available. **Chiara**, together with **Professor Ricardo** led the researching phase early on. Sadly, she also had to leave Portugal earlier, meaning that she

had no opportunity to work in the lab with us. Nevertheless, she still helped us design the biochemical assay from afar.

Unfortunately, it was not possible for **Matilde, Beatriz Machado and Anastasia** to contribute much to the team as they faced personal problems. **Matilde** helped in the transduction lab early on and was always vocal when available to assist the team in whichever way she could.

At last, **Ricardo Mafra**, the team captain, worked oversaw every department and subgroup of the team, being mainly responsible for SensUs assignments and the business aspect of this project. **Ricardo** had no presence in the lab, as he was outside of Portugal. Instead, **Ricardo** oversaw **Diogo and André** in that regard, and pushed through the first critical phase in December, when looking for funds to cover the entry fee.

Professor **Rui Igreja** was mainly present in the first month of the project providing valuable insights on how we should design a sensor. The PhD Researcher, Ana Dalot, mentored the biochemistry team in their first experiments with conjugated proteins. The main contribution came from Professor Ricardo Franco, who oversaw every paperwork procedure, helped us establish a partnership with our only partners, and supported the cost of the antibodies. Professor Ricardo, guided Simão and Nuno in their first days in the lab. Finally, Tomás Pinheiro is a PhD student that works with Rui Igreja, who accepted to substitute the latter to the best of his availability. Tomás was always nearby to answer questions from our team and helped overcome multiple difficulties.

When it comes to partners and sponsorships, our team managed to receive support from **LaborSpirit**, who provided our team with extra equipment, such as micropipettes and other lab equipment. **NOVA.ID** also agreed to open an account for us to receive funds from companies. Unluckily, we ended up not taking advantage of this partnership as we intended to. We also began a partnership with **HGO**, with the intention to perform a rigorous study using blood samples collected by volunteers. This would've been a great opportunity to fine tune our sensor as blood is a more challenging, but more trustworthy matrix to assess the performance of a biosensor. We haven't began said study, as our main contact in the Hospital required a sudden sick leave from work. As an important remark, Siemens Healthineers PoC director, was impressed by our project and was eager to hear more from us in the near future.

7. Final Remarks

Unfortunately, or fortunately, this wasn't the prettiest journey. Firstly, the two team captains and two other members, Ricardo, Diogo, André and Tomás, respectively, are currently finishing their master thesis. Furthermore, it is a fact that we had to fund most of this project and event fees by ourselves, as our university couldn't afford more than the initial team entry fee, and without the help of our supervisor we could've never bought the needed antibodies. To make matters worse, we were also not able to work the entirety of August, nor be able to bring our potentiostat to the competition.

Surprisingly, by shear-will and sacrifice from multiple members, coaches and our supervisor we were able to produce functional devices. Of course, we didn't do this on our own and so we'd like to thank our university for covering the team entry fee, and for providing us tools and space to work with. In particular, we would like to praise Professor João Paulo Borges, for his openness to hear about our project at 22h00 after a long day of meetings. For his kindness and swiftness to push the approval of the early funding of this project. Without the help of Professor João, we wouldn't have been able to begin this journey. In a similar way, we must applaud the assistance of Sara Monteiro de Oliveira, CEMOP's technical assistance, who helped us in the most critical of times, always in reach, helped us reach the director counsel in our university. Susana Rações, is another name we mustn't forget, she's the only reason why our team was able to have t-shirts representing our university.

We had heroes on the administration side, but also on the technical. Professor Ricardo Franco, our supervisor, was someone who provided frequent feedback, and made multiple call-to-actions that none of the team members will ever forget. He was utterly critical in this project, by leading us to experiment and develop the sensor mostly by ourselves, but most importantly by providing early guidance and proactiveness. Not to mention that Professor Ricardo is the reason why we heard about SensUs in the first place. Another hero in the laboratory was a PhD student, Tomás Pinheiro, who wholeheartedly plunged in this project to mentor us and shine some lights on what we should do. Tomás had no responsibility over this project, yet he went out of his way, while being overwhelmed with his own work to aid us.

Not to forget the entire SensUs organization who managed and organized such a large event as this one. We would like to thank Linn van den Aker and Floor van Veen, who helped us with the long list of questions and doubts we've kept on building throughout this year.

Lastly, and as the Team Captain, I must praise all the team members that didn't gave up, and even invested their own money to finance our project and get to Eindhoven, each and one of you, will always have a special place in my mind. Thank you.

8. References (no page limitation)

Campanella, P., Lovato, E., Marone, C., Fallacara, L., Mancuso, A., Ricciardi, W., & Specchia, M. L. (2016). The impact of electronic health records on healthcare quality: a systematic review and meta-analysis. *The European Journal of Public Health*, *26*(1), 60–64. https://doi.org/10.1093/eurpub/ckv122

Dewan, M. C., Rattani, A., Gupta, S., Baticulon, R. E., Hung, Y.-C., Punchak, M., Agrawal, A., Adeleye, A. O., Shrime, M. G., Rubiano, A. M., Rosenfeld, J. V., & Park, K. B. (2019). Estimating the global incidence of traumatic brain injury. *Journal of Neurosurgery*, *130*(4), 1080–1097. https://doi.org/10.3171/2017.10.JNS17352

EUR-Lex. (2023, March 20). *REGULATION (EU) 2017/746 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL*. https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A02017R0746-20230320

Hytest. (n.d.). *Glial Fibrillary Acidic Protein, Antibody*. Retrieved July 5, 2023, from https://shop.hytest.fi/product/glial-fibrillary-acidic-protein-antibody

InfraScan Inc. (2023). *Product Brochure - Infrascanner 2000: "The Power to Heal in the Palm of Your Hand."* https://infrascanner.com/models/

Khan, F., Baguley, I. J., & Cameron, I. D. (2003). 4: Rehabilitation after traumatic brain injury. *Medical Journal of Australia*, *178*(6), 290–295. https://doi.org/10.5694/j.1326-5377.2003.tb05199.x

Lourenço, C. N. (2022). *Development of a skin-like sensor for monitoring an inflammatory biomarker for wound care application*. FCT NOVA.

Naunheim, R., Konstantinovic Koscso, M., & Poirier, R. (2019). Reduction in unnecessary CT scans for head-injury in the emergency department using an FDA cleared device. In *American Journal of Emergency Medicine* (Vol. 37, Issue 10, pp. 1987–1988). W.B. Saunders. https://doi.org/10.1016/j.ajem.2019.04.037

OECD. (2020). Waiting Times for Health Services: Next in Line. *OECD Health Policy Studies*, 32–33.

Schuchat, A., Director, A., Griffin, P. M., Rasmussen, S. A., Leahy, M. A., Martinroe, J. C., Spriggs, S. R., Yang, T., Doan, Q. M., King, P. H., Starr, T. M., Yang, M., Jones, T. F., Boulton, M. L., Caine, V. A., Daniel, K. L., Fielding, J. E., Fleming, D. W., Halperin, W. E., … Schaffner, W. (2017). Morbidity and Mortality Weekly Report Traumatic Brain Injury-Related Emergency Department Visits, Hospitalizations, and Deaths-United States, 2007 and 2013 Surveillance Summaries Centers for Disease Control and Prevention MMWR Editorial and Production Staff (Serials) MMWR Editorial Board. In *Summ* (Vol. 66).

Seabury, S. A., Gaudette, É., Goldman, D. P., Markowitz, A. J., Brooks, J., McCrea, M. A., Okonkwo, D. O., Manley, G. T., Adeoye, O., Badjatia, N., Boase, K., Bodien, Y., Bullock, M. R., Chesnut, R., Corrigan, J. D., Crawford, K., Diaz-Arrastia, R., Dikmen, S., Duhaime, A.-C., … Zafonte, R. (2018). Assessment of Follow-up Care After Emergency Department Presentation for Mild Traumatic Brain Injury and Concussion. *JAMA Network Open*, *1*(1), e180210. https://doi.org/10.1001/jamanetworkopen.2018.0210

Seifert, J. (2007). Incidence and economic burden of injuries in the United States. *Journal of Epidemiology & Community Health*, *61*(10), 926–926. https://doi.org/10.1136/jech.2007.059717

Shobeirian, F., Ghomi, Z., Soleimani, R., Mirshahi, R., & Sanei Taheri, M. (2021). Overuse of brain CT scan for evaluating mild head trauma in adults. *Emergency Radiology*, *28*(2), 251–257. https://doi.org/10.1007/s10140-020-01846-6

Siemens. (n.d.). *Siemens Healthineers Digital Ecosystem* -. Retrieved July 11, 2023, from https://www.siemens-healthineers.com/nl-be/healthineers-digital-ecosystem/digital-ecosystem

Stein, S. C., Burnett, M. G., & Glick, H. A. (2006). Indications for CT Scanning in Mild Traumatic Brain Injury: A Cost-Effectiveness Study. *The Journal of Trauma: Injury, Infection, and Critical Care*, *61*(3), 558–566. https://doi.org/10.1097/01.ta.0000233766.60315.5e

Tageldeen, M. K., Gowers, S. A. N., Leong, C. L., Boutelle, M. G., & Drakakis, E. M. (2020). Traumatic brain injury neuroelectrochemical monitoring: behind-the-ear micro-instrument and cloud application. *Journal of NeuroEngineering and Rehabilitation*, *17*(1), 114. https://doi.org/10.1186/s12984-020-00742-x

9. (Optional) Appendix (no page limitation)

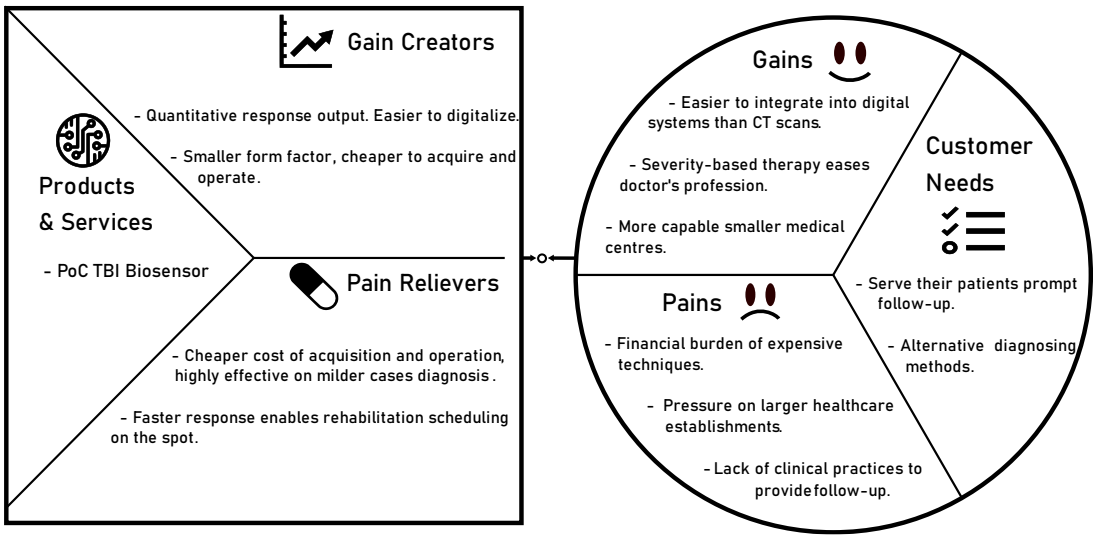


Figure 1 - Value proposition - Value Proposition Canvas for our B2B customers.