CBI Challenge Based Innovation

Moving Healthcare AI

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TABLE OF CONTENTS

1. INTRODUCTION

The project aimed to contribute to the solution of the United Nations' *Sustainable Development Goals* (SDG). Under the supervision of *Challenge Based Innovation* (CBI), *Idea Square* (CERN), and the collaborating universities, our group focused on the third Sustainable Development Goal, and more precisely, universal healthcare coverage and access to quality essential healthcare services.

Our multidisciplinary and multinational team comprises master's students from *UPC, IED, and Esade*, all based in Barcelona. The diverse fields of study include designing, engineering, and business. In less than three months, our group faced many challenging moments to create and finally present an artificial intelligence (AI) based solution for the given Sustainable Development Goal.

2. METHODOLOGY

The course provided us with some guidelines to follow, which our group complemented with our own methods. The methodology part intends to present our approach with the given guidelines.

The main timeline of the project followed the steps displayed on the roadmap (figure 1): *understand, empathize, define, ideate, prototype,* and *test*. These steps were divided into two phases: problem space and solution space. The roadmap gave our group something to start with and to follow later on. It helped us stay on track and on time with the project deadlines and mid-course deliverables. Therefore, the following chapters of the report are divided according to the roadmap.

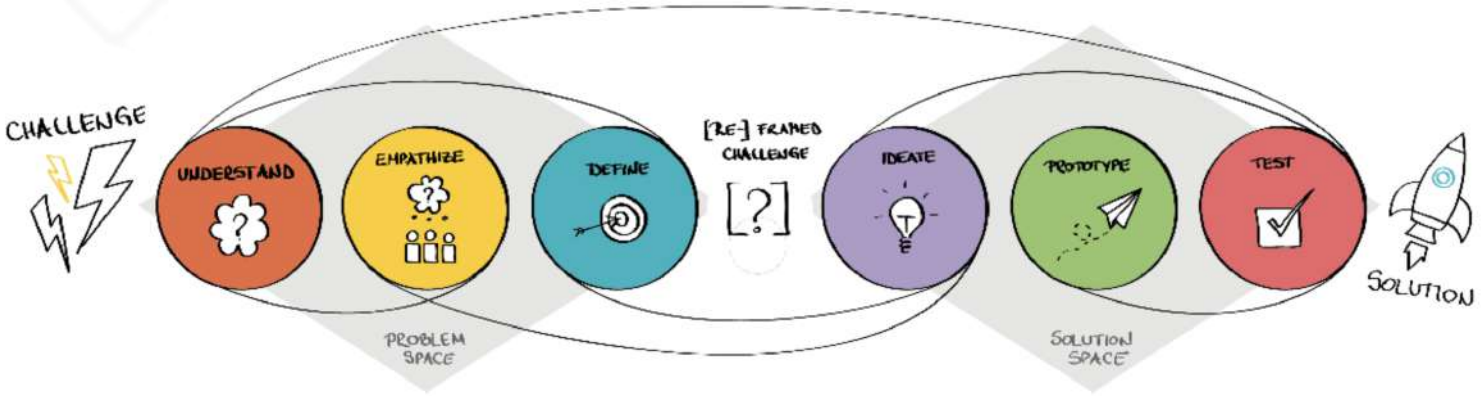

Figure 1: The roadmap

We used different techniques to understand the issue better, but the whole process was dominated by design thinking. The group decided to use the *top-down* analysis to funnel down the case to find a more specific sphere for which we can provide a solution.

After grasping the roots and understanding the issue, we initiated the solution phase. The course helped us ideate and finalize our solution with continuous coaching sessions and providing tools. Our group tried to

challenge the idea from different perspectives; therefore, we pivoted our product and service several times to achieve a feasible solution.

In the report, our group will elaborate specifically on the different tools, techniques, and frameworks used during the course and our project. These helped us question viability in the various steps and kept the project on track.

3. THE PROBLEM

One of the most critical aspects of innovation is defining the problem. Needless to say, understanding the problem precedes it since if you cannot understand the problem, you will never be able to solve it. In the case of CBI4AI, we were given the core principles but had to extract definitions of unfamiliar terminologies, construct hypotheses, and ideate to converge on the problem statement.

3.1.Issues under the third Sustainable Development Goal

Figure 2: The third SDG

Achieve universal health coverage, including financial risk protection, access to quality essential healthcare services, and access to safe, adequate, quality, and affordable essential medicines and vaccines for all (Figure 2).

Coverage of essential health services (defined as the average coverage of essential services based on tracer interventions that include reproductive, maternal, newborn, and child health, infectious diseases, non-communicable diseases, and service capacity and access, among the general and the most disadvantaged population). The proportion of

the population with large household expenditures on health as a share of total household expenditure or income.

3.2. Ideation for problem mapping

The team's ideation started with intense brainstorming (Figure 3) in IdeaSquare (Geneva, Switzerland). Using creative tools, we got an initial approach to understanding the different factors playing a role in the mentioned SDG.

Figure 3: Ideation as a team

The brainstorming resulted in several different ideas. Later, we organized it into a structured table (Table 1). The team created categories and reevaluated the points according to the newly created topics. As a result, we were able to progress and started to funnel the issue to a narrower environment. Our categories gave an initial idea about the different stakeholders.

Table 1: Result of brainstorming

	Technology	Supply Chain/ Logistics	Human capital	Cost	Finance	Governmental/ Societal	Education
Health care services	*Adoption* of new technology is slow and met with resistance Increase health care *coverage* by using technology The dilemma of *trust* in new health technology by customers	*Insufficient number* of clinics & hospitals *Inefficiency* in service; long waiting time, indirect tasks, outdated *standards* for a good service of logistics	Doctors might be *too far away,* especially in rural areas with low population density Lack of *accessibility* Increasing the *number* of medical staff	Low spending on *sustainability* to reduce cost *No money* for equipment	*Influence* of big companies lobbying, public advocacy)	Lack of *resources* in the public industry Availability of *social safety net* *Accessibility* of utilities (water, electricity, internet) Growing *population* Increasing *inequality* *Government spending* preferences	Lack of *knowledge* *No access* to health education Improving the *quality* of medical education
Health care products	Create a *standard model* for an AI in environments where different technologies and techniques are used	Production is at the mercy of any *supply chain disruption* *Time & cost* of logistics to reach new ideas The distribution of supplies can create a *gap* between supply and demand	*"Brain drain"* effect	*Hockey stick* effect *Profit* orientation *High R&D* costs	Stakeholders' *interests*: volatility & company value Generally low *ESG* rating in the pharmaceutical sector	*Patent* issues Lack of *regulations* (e.g., opioid crisis)	

3.3. Persona

Creating a persona (Figure 4) also helped us empathize with the problem owners. We want to achieve the same result by sharing the created persona.

Figure 4: Persona

Name**:** Ramesh Kumar

Age: 39

Location: Uttar Pradesh, India

Pain points:

- I am suffering from tuberculosis, but the closest medical support I can get is 10 km away. I don't have a vehicle to take me there, nor do they have an ambulance.
- Lack of medical support.
- Lack of infrastructure.
- Lack of health knowledge.

Goals:

- Improve the quality of infrastructure.
- Increase the level of health education.

3.4. Stakeholder Mapping

We continued analyzing the problem by identifying the main actors and stakeholders playing a role in the issue. To have an idea about the different levels and weights that contribute to the problem, we used the framework provided by the course (Figure 5).

Key Actors:

1. Pharma manufacturers
2. Supply chain participants
3. Medical operators
4. Regulators
5. Governments
6. General Public
7. Legislators
8. NGOs
9. Customers
10. Educational institution
11. Intergovernmental organizations
12. Social media

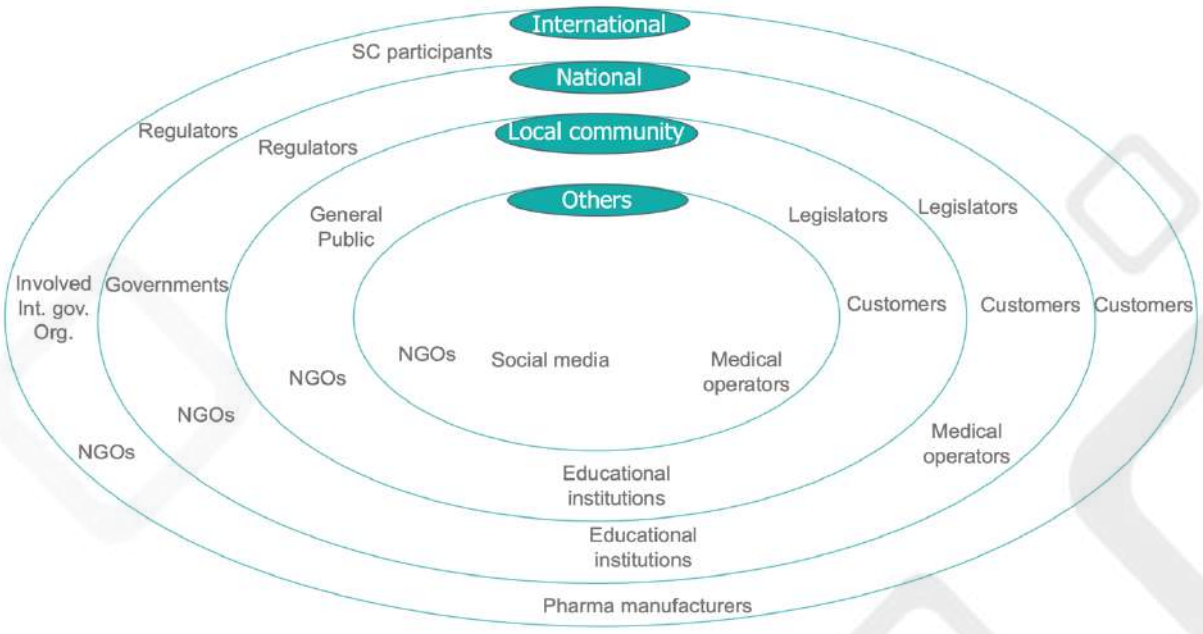

Figure 5: Categorizing the different stakeholders

3.5. Quantitative Analysis

After leaving CERN IdeaSquare, our group deep-dived into the topic to unbundle all the crucial details behind the issue. We needed to approach it with research from different aspects. Therefore, we tried to have some key takeaways from statistical data (Figures 6 to 11), but we also needed to catch the humane side of the issue and tried scenario analysis. Reading testimonials and stories about the subject helped later to identify the people who we wanted to target with our interviews.

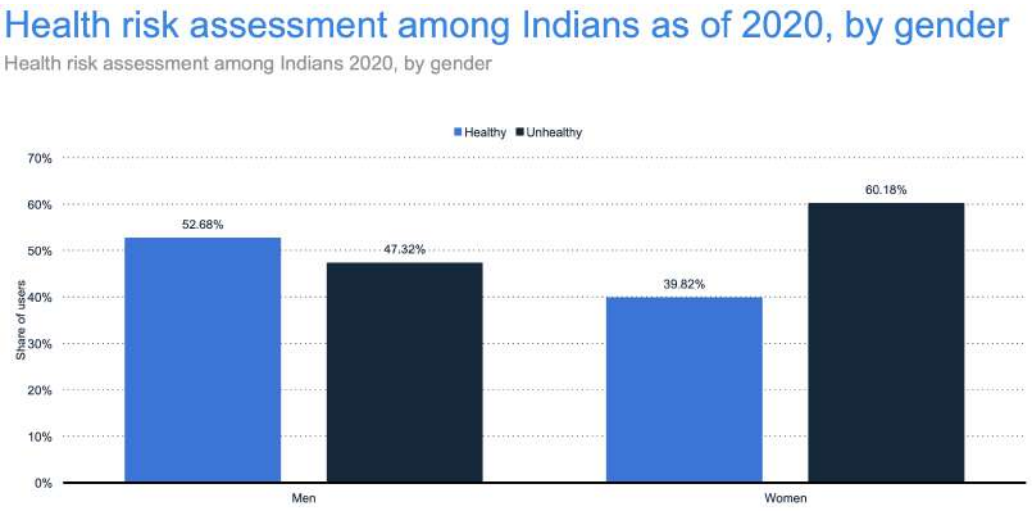

Figure 6: India: health risk assessment by gender 2020 | Statista, 2022

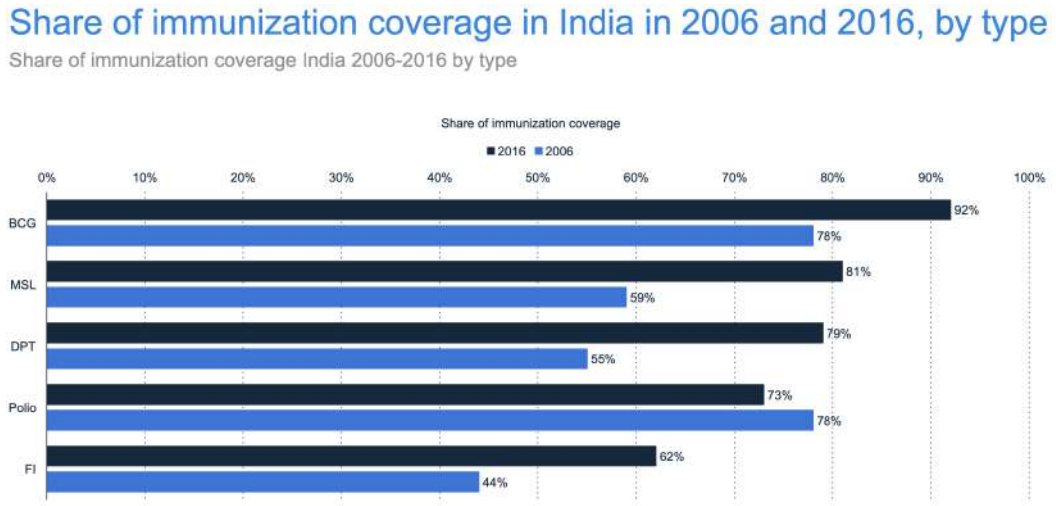

Figure 7: India - share of immunization coverage by type 2016 | Statista, 2022

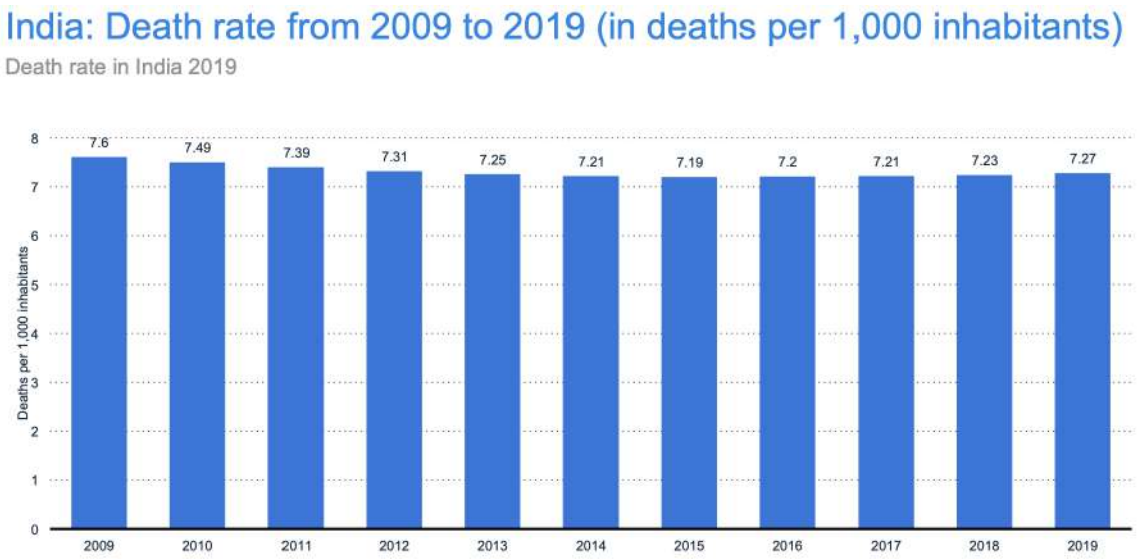

Figure 8: India - death rate 2009-2019 | Statista, 2022

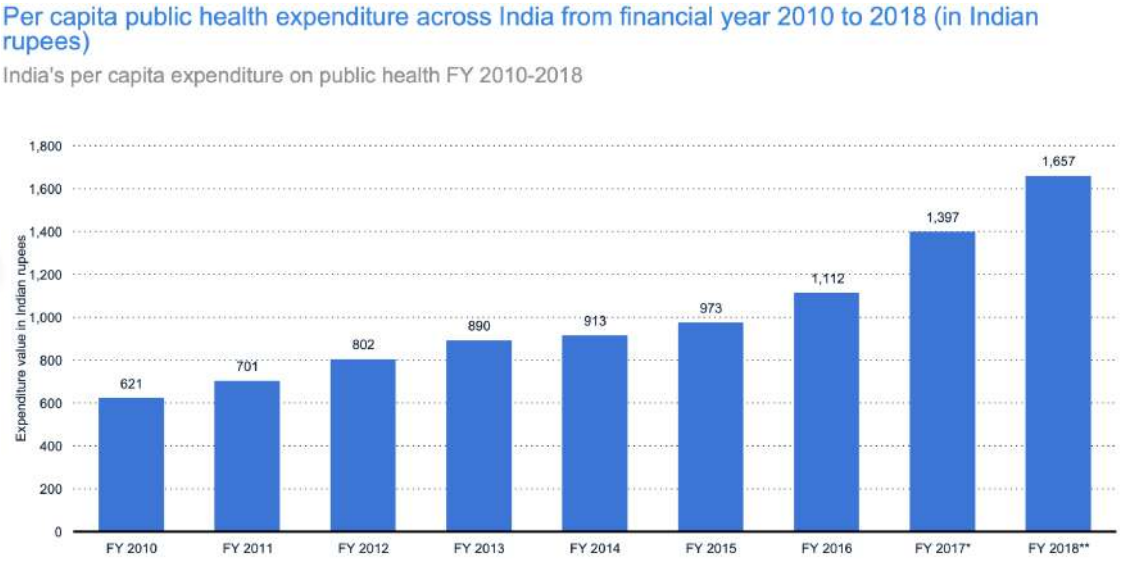

Figure 9: India: per capita public expenditure on health 2018 | Statista, 2022

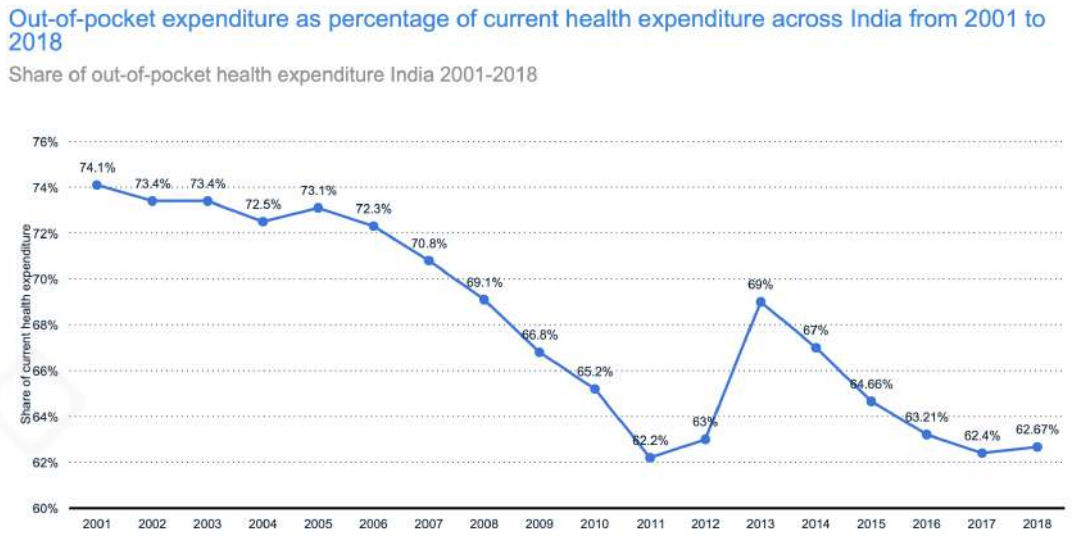

Figure 10: India: share of out-of-pocket health expenditure 2018 | Statista, 2022

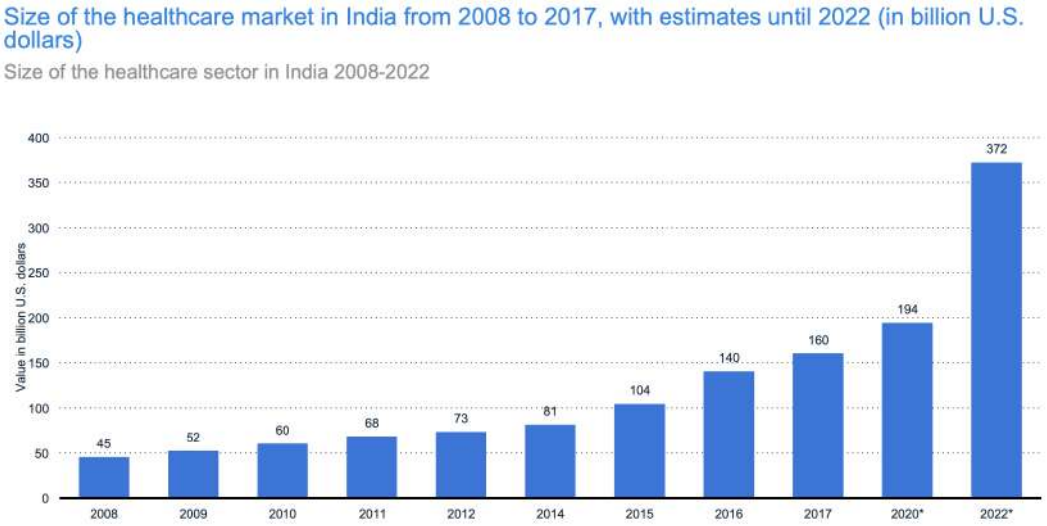

Figure 11: India: healthcare sector size 2022 | Statista, 2022

Key takeaways from the statistical analysis:

1. <u>World</u>
   a. *The overall accessibility* of health care is a major worldwide problem
   b. Health care takes a significant portion of *out-of-pocket expenditures*
2. <u>India</u>
   a. India's *private health care sector* is highly developed, but the *public sector* is lagging behind
   b. The Indian government has been investing heavily in health care
3. <u>AI in Healthcare</u>
   a. AI in Health care is a new trend that has shown *rapid growth* in recent years
   b. AI is still new to the health care industry; therefore, the *implementation is challenging*

3.6. Qualitative Analysis

From online articles, we were able to gather essential insights to narrow our problem statement.

1. *Harvard Business Review – Building Health Care AI in Europe's Strict Regulatory Environment (Lin, 2022)*
    - Startups are multiplying in the healthcare AI domain: Nabta Health (Dubai), ExactCure (France), Owkin (France, US)
    - European Environment – Data privacy regulations, strict laws
    - In centralized healthcare systems, patients' data is distributed across many databases, which makes the training data hard to get
    - US and China are relatively less regulated environments, making them more opportunistic for a green field strategy
    - The main problem is the disconnection between private and public health systems. Therefore, there is no significant data pool
2. *McKinsey Global Institute – Transforming healthcare with AI (Spatharou, Hieronimus, and Jenkins, 2022)*

    The article highlighted barriers to applying AI further in healthcare:
    - Quality and suitability of solutions
    - Changing skills of healthcare workers and education
    - Data quality, governance, security, and interoperability
    - Change management
    - Working at scale
    - Regulation, policy-making and liability, and managing risk
    - Funding

3.7. Final Problem Statement

"In many countries around the world, accessibility to medical facilities and hospitals is not guaranteed due to several issues. Some of these problems include inadequate services and medicines, shortage of medical personnel, and difficulty regimenting the facility in rural areas. For our job to be done, we focus on villages in *Uttar Pradesh, India*, and selected *malaria* as our pilot service."

3.8. Interviews

Desirability

To check whether we were solving the pain points of our stakeholders, we interviewed prospective customers. First, we interviewed Rana DS, Chairman of Ganga Ram Hospital, New Delhi, India. In this interview, Rana DS provided us with deep insights from his own professional experience. Many patients traveled from far villages to the city to get better medical care. Some of the most common diseases include Malaria, TB, and Diabetes. At Ganga Ram, state of the art blood test center allows them to detect malaria within two days, but it is only accessible to people who come to their hospital. Currently, their popularity is the biggest weakness; they always have 100% occupancy, meaning many people who need medical help cannot get it. For Ganga Ram, opening any new hospital is a matter of sentimental feeling or board direction rather than statistics.

Then, we interviewed the former State head, Mr. B. Prasad to draw out the concerns of the public sector and the status quo of resource allocation for medical impact in Uttar Pradesh. Currently, the government body looks at the annual death toll, population, and per capita income to make decisions regarding the allocation of medical resources. From the

interview, we were able to gather that these data points are annual and don't paint the complete picture. Another problem the public officials face is a centralized structure of information to resolve any conflicting information.

Viability

To check the viability of our idea on the value chain. To check if our business model fits and ensures it contributes to the stakeholders, we interviewed Eva Vidal, Professor at UPC, who has collaborated with Doctors without Borders in the past. She has worked on different projects, including the digitization of medical records of people in underdeveloped countries to improve the speed of access to medical care. She helped us understand the ground-level work NGOs like Doctors without Borders do and how new technology is adapted to their work. She helped us understand how there is currently a need for new technology that helps with logistics.

She also highlighted the importance of consideration of non-market players in the political and social aspects. She was pleased with our solution of tackling accessibility as, in her experience, outbreaks can be stopped with proper allocation of personnel, medicine, food, and sanitation.

Feasibility

For the final test, we focused on checking the technology's feasibility and objectively assessing the capabilities to ensure a competitive advantage. For the same, we interviewed Albert Oliveras-Vergés, Professor at UPC. His current research interests include non-linear image and signal processing, mathematical morphology, and non-linear processing and its applications

to biological signal processing. He was able to guide us through the various aspect of launching our own AI service and the essential features required to make our project stand on its own core capabilities. With his help, we were able to validate our idea of combining MULITIMAL, an ATTRACT project, with current AI to offer the user a key differentiation factor.

We summarized the results of our interviews to which factors the outcome-focused the most (Table 2).

Table 2: Interview results

Interviews	**Desirability**	**Feasibility**	**Viability**
Rana DS, Chairman of Ganga Ram Hospital, New Delhi, India	Yes		
Balmiki Prasad, Former State head	Yes		
Albert Oliveras-Vergés, Professor at UPC		Yes	
Eva Vidal, Volunteer at Doctors Without Borders and Professor at UPC			Yes

4. THE SOLUTION

After analyzing and narrowing down the initial SDG to a final problem statement, we came up with a solution proposal for it. This chapter will present our final product and service, including the connection with *ATTRACT*.

4.1. Mission Statement

With our final problem statement, we created a mission that we should follow in any circumstances. It helps us focus on our goals and guide us throughout the whole project.

"Not everyone can obtain basic healthcare, so we are dedicating our work to helping patients gain access to it anywhere across the world, no matter how remote the location is. We bring the service you need to your location, thereby moving the world toward all-access healthcare."

4.2. Product and service description

We needed to find a service that directly contributes to the mentioned problem. After pivoting the idea, our group developed a viable service initiative.

Our idea is to create a service that detects the optimal locations for resource allocation in areas the service categorizes as high-risk areas. It is powered by its own AI engine, which uses a backend neural net, graph AI, and logistic regression to detect areas under significant risk precisely. The engine categorizes villages where malaria cases might surge in the coming months. The Moving Healthcare AI can accurately predict the needed medical devices, personnel, and medication in the mentioned

areas in each period. It also helps to determine the most efficient locations for portable hospitals.

ATTRACT contributes to our objective with the project named Multimal, which is a proposal to create a multiplex disposable graphene DNA-based sensor; in other words, an accurate diagnostic device capable of detecting and identifying Plasmodium species, including malaria. Multimal could provide our service with a more efficient and highly cost-effective solution for malaria prevention. Our contribution to Multimal's success is an infrastructure to target the affected areas effectively (Figure 12).

Figure 12: Click on the image to reach our explanation video

4.3. Business approach

In case our group wants to elevate MH.AI from a university project to a business proposal, we need to take into account the business dimension of the project. We will highlight the different factors that play a role in this dimension. As a business, we need to consider other market elements which play a considerable role in feasibility. Moreover, profitability is an essential variable to measure the success of a business, so we needed an idea of how and to whom we plan to sell our service.

4.3.1. Target Market

It is essential to decide on a target market for a business. After defining the problem, it was clear who is our final beneficiaries, but we had to create a strategy for our targeted customers.

As our understanding of the problem developed, it became clear that India shows excellent potential; therefore, MH.AI focuses on Uttar Pradesh in India. The region of Uttar Pradesh suffers from several already mentioned problems. Still, the critical factor that plays a role in our business perspective is that the government systematically focuses on healthcare in the region. So it shows potential from the angle that the government has the will and the financial background to use our service and make healthcare in the area more efficient.

For diversification, we broadened our service to be accessible to both the private and public sectors. MH.AI understood that focusing only on the public sector carries an unnecessary and unwanted risk factor of becoming highly dependent on one player. After conducting the interviews, our team realized that the private sector is also present in lower-density areas, so we can diversify our service and make it available for both sectors. In later stages, MH.AI has to create tailor-made sales and marketing plans for players in both industries.

It is essential to mention some factors that played a role in the decision. The private sector in India is highly developed and works with a higher profit margin. They also plant facilities in less developed areas to increase their reach. The public sector, in that sense, is lagging, but the governmental spendings in India are focused on healthcare. With growing

funds, it is a clear potential to contribute to healthcare accessibility in the country.

4.3.2. Entry Barriers

Another vital factor after identifying the target market is awareness of the entry barriers. Considering the project from different aspects, we highlighted the most significant factors that we must overcome in order to create the service potentially.

- *Bureaucracy*: The level of bureaucracy in third-world countries makes market entry harder.
- *The gap between sectors*: There is a significant difference in development level between the public and private health care sectors.
- *Lack of investment*: The majority of investors have not recognized the value of impact investing.
- *High R&D cost*: The AI industry is generally defined by high R&D costs.
- *Data collection*: Collecting and transforming viable data is expensive and complicated.
- *Complicated learning system*: It is hard to find the correct base variables for an un or self-supervised learning system.

4.3.3. Revenue model

After considering various options for developing our revenue streams, we decided to go with the *subscription revenue model* (Figure 13).

It would work cyclically, as the customers, on both public and private end, have access to our service if they provide the necessary amount in each period.

To determine our *pricing strategy*, we would need further project development. It would be necessary to know the fixed and variable costs of the service to calculate the break-even point, then calculate the periodical

price tag on the service. The bottom is that it is hard to make a precise estimation of cost and profit without further development.

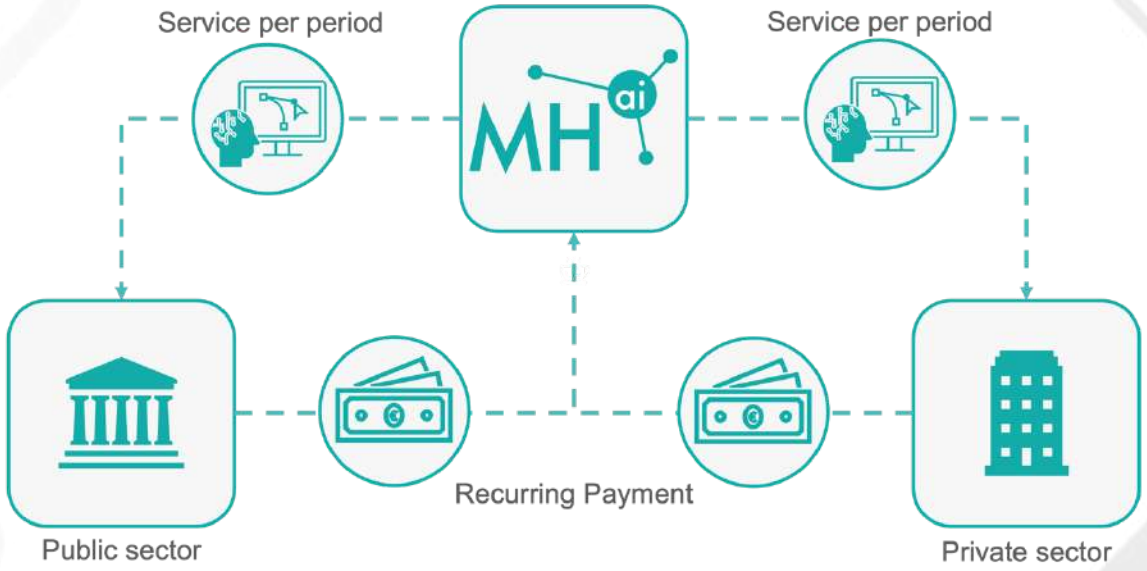

Figure 13: Subscription Revenue Model

4.4. Designing & Prototype

Visualization is crucial to selling an idea or a product; therefore, we leveraged the designing expertise in our group to create the service's visuals, including a first prototype.

We chose a clean and straightforward design that contributes to the image we want to achieve. As our primary goal is to help instead of profitability, our design gives a welcoming and clean feeling. Still, the message of simplicity is regularly attached to the tech industry, which we further developed with the geometric shapes.

4.4.1. Prototype

A prototype helps highlight the product's unique selling point because people would not have to rely entirely on their imagination. We created an interactive wireframed prototype for MH.AI using Figma. The figures (Figure

14-17) are snapshots from the interactive cross-platform prototype we presented in the exhibition on different devices.

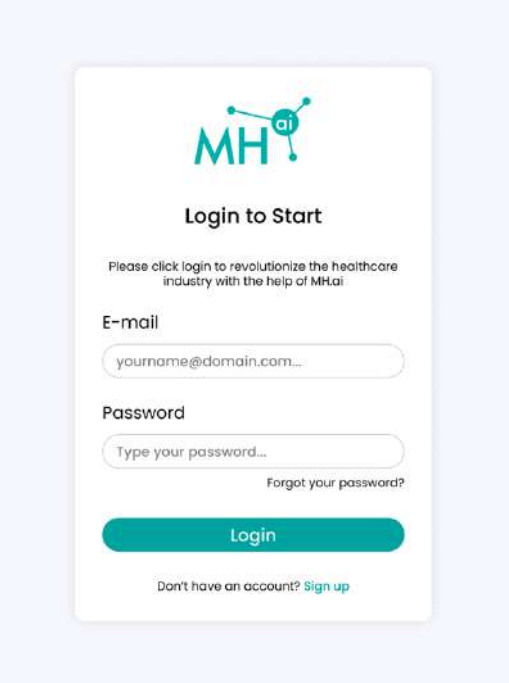

Figure 14: Prototype login page

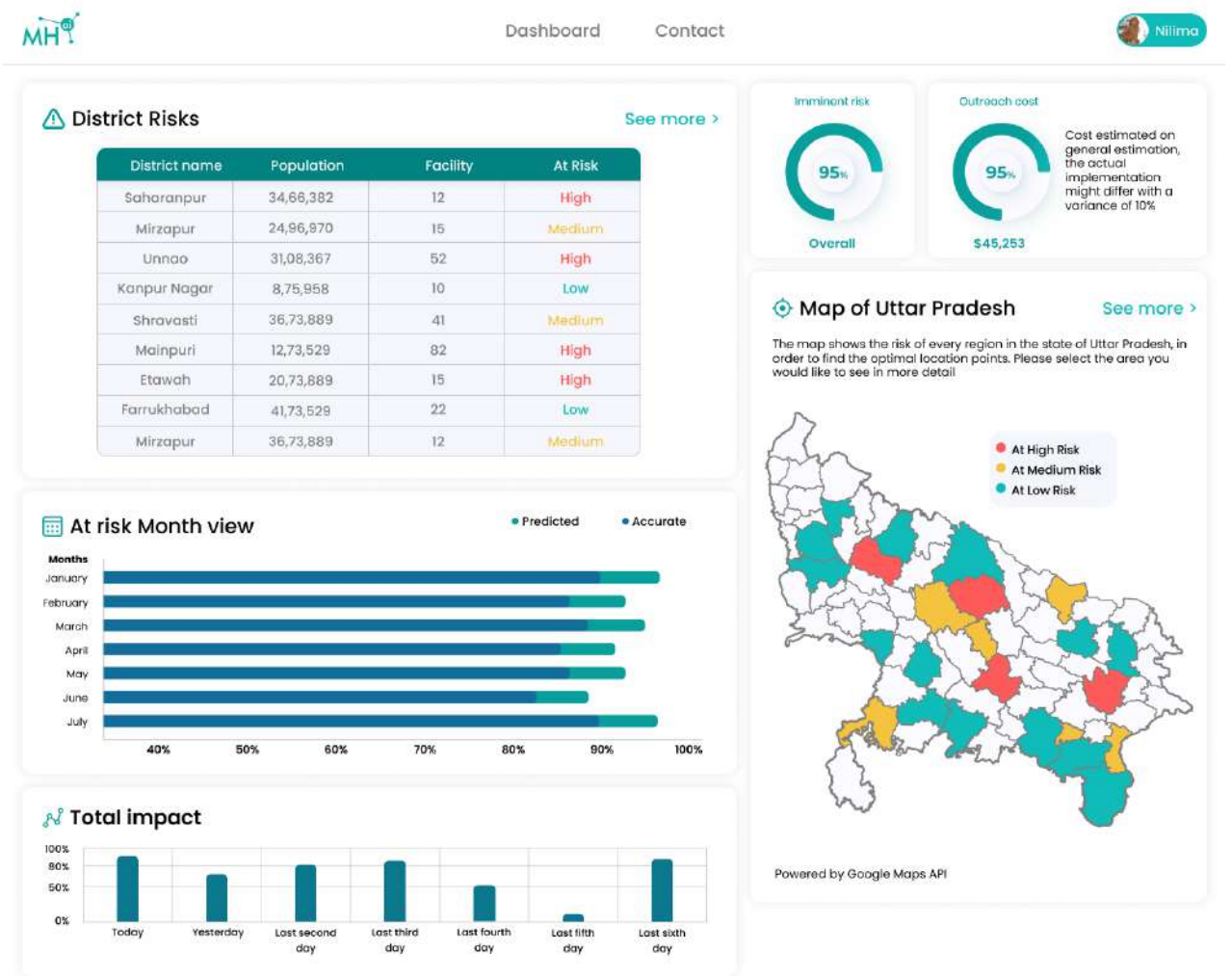

Figure 15: Prototype main page - Dashboard

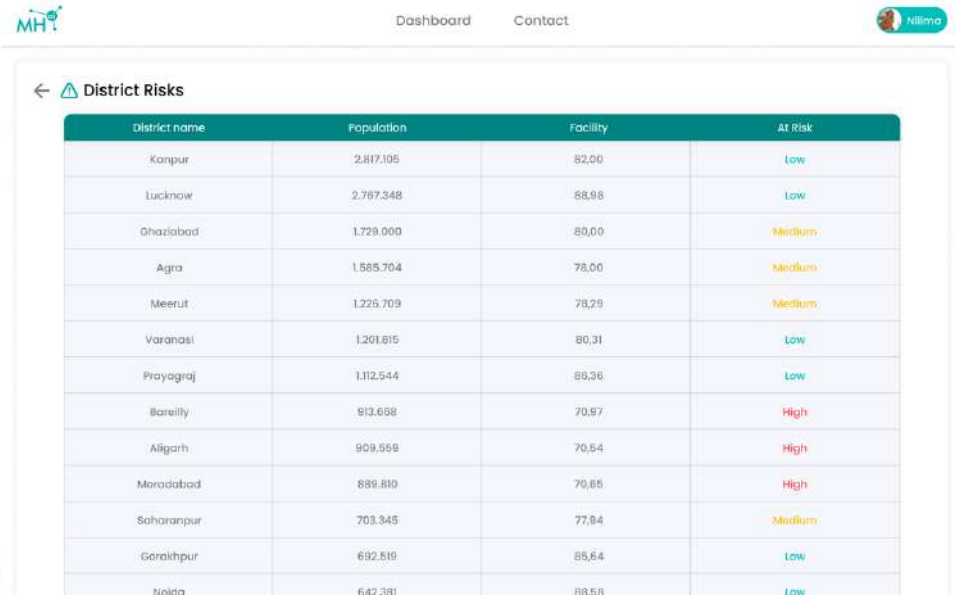

Figure 16: Prototype table

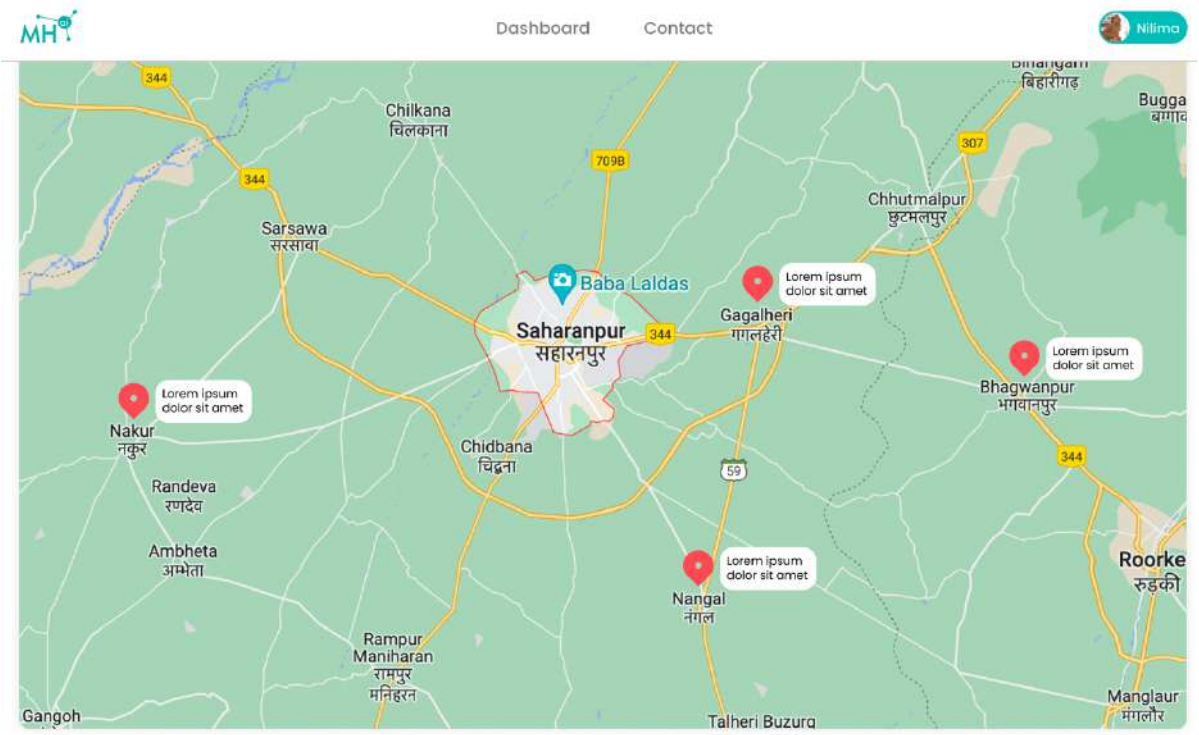

Figure 17: Prototype map

After the login page (Figure 14), the user reaches the dashboard (Figure 15) from where other subpanels, for instance, the table (Figure 16) and the map (Figure 17), are accessible. The prototype's goal is to give an idea to the users of what the service looks like when it is fully functional.

4.5. Artificial Intelligence perspective

In some countries, accessibility to medical facilities and hospitals is not guaranteed due to several issues. Our goal is to create a model based on variables that could potentially explain the outcome.

As we mentioned before, we use data from *Uttar Pradesh, India*, as our target for our experiment model.

Related works: (Ahmadi-Javid, Seyedi, & Syam, 2017), (Calvo & Marks, 1973), (Chan, Filos-Ratsikas, Li, Li, & Wang, 2021).

4.5.1. Models

Features

In this section, we will explain what features our artificial intelligence will have, where we will get the data from, and what techniques of Machine Learning we could use.

All the data below are numerical numbers.

- **Population:** Number of people who are living in Uttar Pradesh. Data available here
- **Location:**
  - Average Rural Area and Average Radial Distance Covered by Health Care Institutions in Uttar Pradesh: Data available here
  - Average Number of Villages Covered by a sub-center/Primary Health Centers (PHCs)/Community Health Centers (CHCs) and Number of Sub-Centers Per PHCs and PHCs Per CHCs in Uttar Pradesh: Data available here
  - Building Position of Health Sub-Centers in Rural Areas in Uttar Pradesh: Data available here
  - Building Position for Community Health Centres (CHCs) in Rural Areas in Uttar Pradesh: Data available here
- **Population density:** Population density is the concentration of individuals within a species in a specific geographic locale, data available here
- **Age groups:** number of people classed together as being of similar age, data available here
- **Data of the device:** Multimal will provide us with data regarding the number of people being tested and the number of people positive for each of the different variants:
  - Plasmodium falciparum (or P. falciparum)

    - Plasmodium falciparum (or P. falciparum)
    - Plasmodium malariae (or P. malariae)
    - Plasmodium vivax (or P. vivax)
    - Plasmodium ovale (or P. ovale)
    - Plasmodium knowlesi (or P. knowlesi)
- **Number of people who have died from malaria:** Number of deaths in India due to malaria; data are available here
- **Distance from healthcare infrastructures:** By using Google Maps API, we want to calculate the distance between different villages and the chosen location for our mobile hospital.
- **Mortality rate:** Number of Positive cases and deaths due to malaria in India; data are available here

4.5.2.Process

Pre-process

- Feature extraction engineering: Feature extraction is the automatic creation of new variables by extracting them from raw data. The purpose of this step is to automatically reduce the volume of data into a more manageable set for modeling.
- Pattern recognition: Pattern recognition is a data analysis method that automatically uses machine learning algorithms to automatically recognize patterns and regularities in data.

- Data cleaning: Data cleaning is the process of fixing or removing incorrect, corrupted, incorrectly formatted, duplicate, or incomplete data within a dataset.
- Data discretization: data discretization is a method of converting attribute values of continuous data into a finite set of intervals with minimum data loss.

Feature selection

- PCA for dimensionality reduction: PCA is a linear dimensionality reduction technique that converts a set of correlated features in the high dimensional space into a series of uncorrelated features in the low dimensional space.
- *Feature importance computation* is calculated as the decrease in node impurity weighted by the probability of reaching that node.
- Variance Analysis: Variance analysis can be summarized as an analysis of the difference between planned and actual numbers.

ML techniques

- Baseline performance, several algorithms tried: A baseline results from a fundamental model/solution. You generally create a baseline and then try to make more complex solutions to get a better result. If you achieve a better score than the baseline, it is good.
- Classification 1/0: rating from 0 to 1 for each location tried, where 0 means it is not a good location for our purposes and a 1 is an excellent location for our goal
- Logistic regression

- Random forest: Random forests or random decision forests is an ensemble learning method for classification, regression, and other tasks that operates by constructing a multitude of decision trees at training time. For classification tasks, the output of the random forest is the class selected by most trees
- Pre-pruning and Post-pruning: Pre-pruning or early stopping involves stopping the tree before it has completed classifying the training set and post-pruning refers to pruning the tree after it has finished. They are essential for avoiding the overfitting of our model.

4.5.3. Multimal's report

Light microscopy and rapid diagnostic tests (RDTs) are the main diagnostic tools used in the field for malaria diagnosis, whereas polymerase chain reaction (PCR) is used primarily for molecular diagnosis in sophisticated laboratories.

These methodologies are time-consuming, require skilled specialists/ interpretation, and show poor sensitivity for early/ asymptomatic malaria infections.

This project aims to develop a multiplex diagnosis device for all malaria species, which also allows the identification of asymptomatic patients by using non-invasive samples (saliva)

with an analytical performance at the same level as standard molecular approaches.

The combination of graphene-based sensors and DNA enhances its analytical response opening the possibility of detecting malarial DNA in biological samples (urine, saliva).

The disposable chip was designed with a layout of seven distinct regions of three sensors.

Each region has a specific DNA sequence that allows multiplex detection of all five malaria infections, the Plasmodium, and human control.

The current technologies for rapid diagnostics of malaria do not address the diversity of the infections, can only analyze blood samples where parasites or their metabolites are present in high concentrations and show poor sensitivity for early malaria infection

4.5.4. Output

The expected result is a set of locations with an evaluation for each of them, assessing whether it would be a good location in which to build a medical facility or place a portable hospital that could solve the problems described.

4.5.5. Technical Feasibility evaluation

To study the feasibility of our project, we had the pleasure of speaking with Albert Oliveras-Vergés and Ramon Bragós, professors at the Polytechnic University of Calanuya.

Albert Oliveras-Vergés has been personally involved in the battle against malaria given that he has several publications: *Oliveras-Verges, Maximum: "likelihood factor analysis in malaria cytokines analysis and modeling", 2009* and *Oliveras-Verges & Espel-Masferrer: "Elevated basal hepcidin levels in the liver may inhibit the development of malaria infection: Another piece towards solving the malaria puzzle?", 2008*.

Multimal: state of the art

Multimal is still in the testing phase but is getting good results.

Following the strengths of Multimal, researchers at the University of Florida created a paper reaction test that allows the detection of all the different variants of malaria by using a sample of saliva (Tao et al., 2019)

This latter innovation based on paper reaction could have a future and an even lower cost than Multimal.

Correlation between Malaria and environment variables

In the article (Gaudart, et al., 2009), the authors speak about the correlation between Malaria and environmental variables.

The risk of Plasmodium falciparum infection is variable over space and time, which is related to environmental variability. Environmental factors affect the biological cycle of both vectors and parasites. Despite this strong relationship, ecological effects have rarely been included in malaria transmission models.

In our case, we want to introduce the environment variables as a feature of our model; therefore, we want to use the previous work of these authors to incorporate this type of data inside our model.

4.6. Timeline

Future planning is an essential factor in transforming an idea into an existing service. MH.AI provides both short- and long-term plans and goals.

4.6.1.Short-term

Our short-term goals represent the necessary steps the project should achieve to become an active service and business. The steps on the timeline (Figure 18) display the milestones that MH.AI should reach in a startup form until reaching the market.

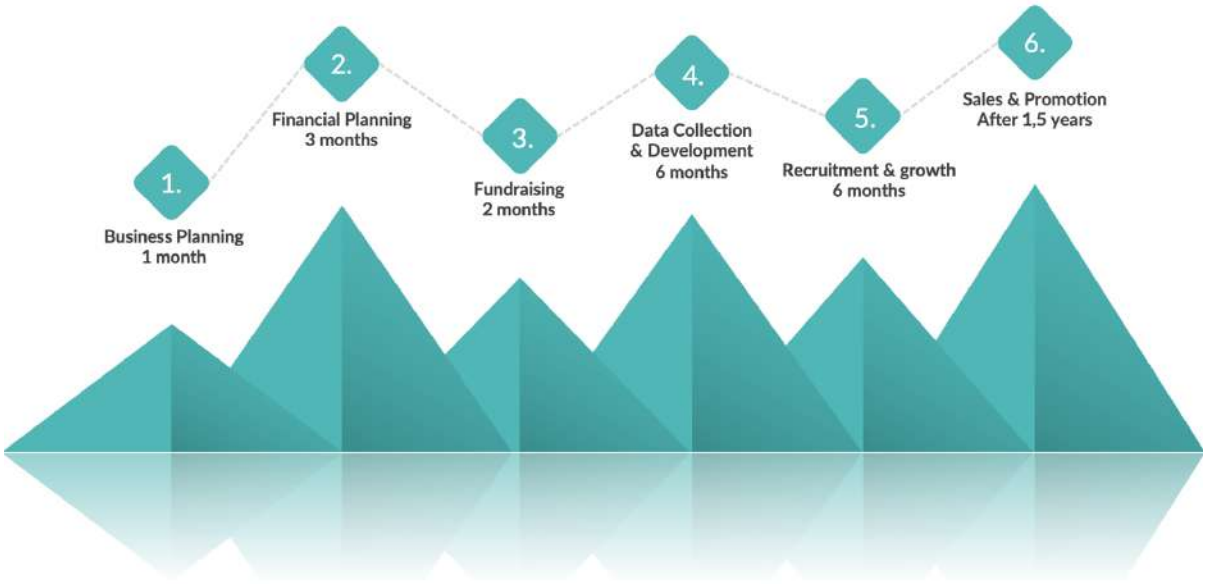

Figure 18: Short-term timeline

4.6.2. Long-term

A business is more than just an idea; it has many components. It is vital to form a vision that MH.AI can follow in the future to grow. Our growth plan is displayed on a matrix (Figure 19) on which one axis represents vertical growth, and the other is horizontal growth. Both are crucial in a company's lifecycle, and innovation is key for a startup.

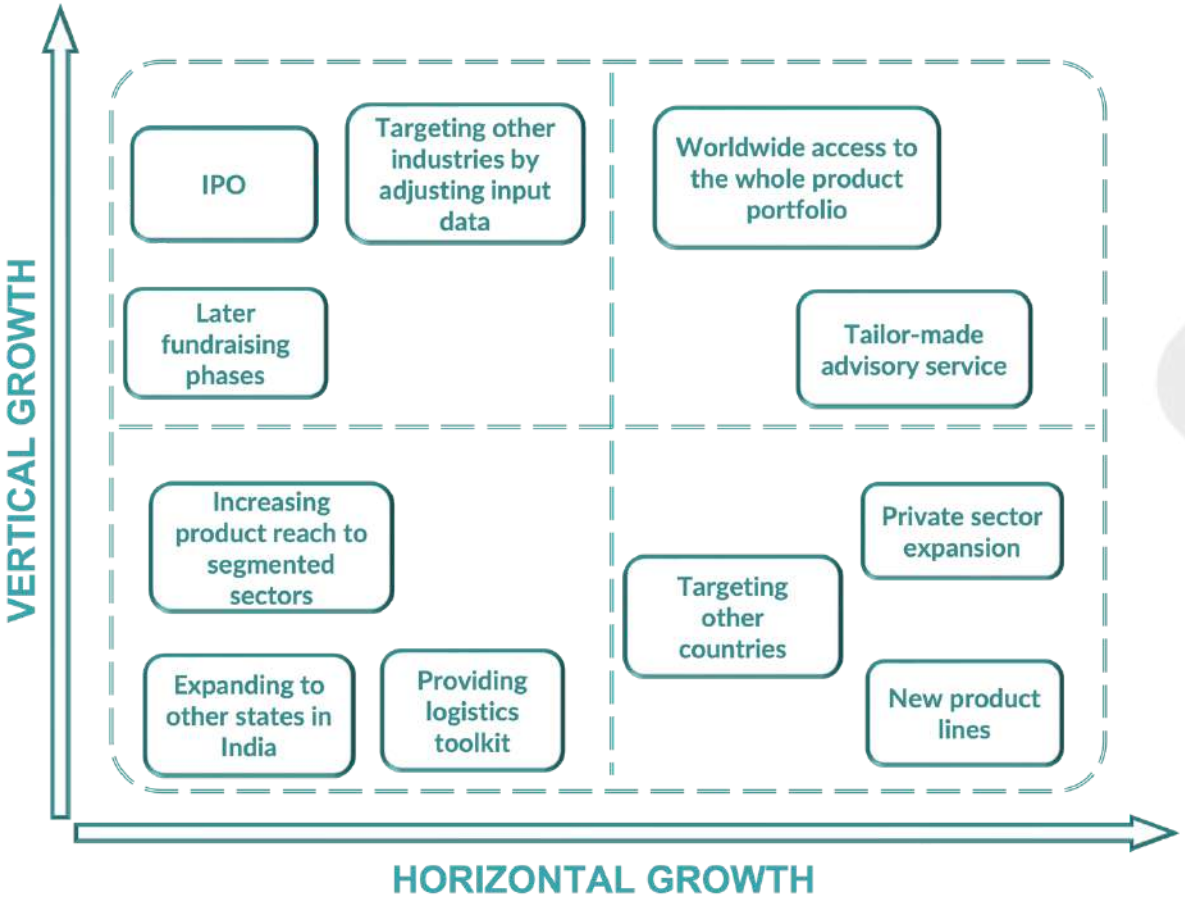

Figure 19: Long-term vision

5. SUMMARY

Throughout our project, we learned a lot and not just from the lectures but also from each other. It is an exciting experience to work in a multinational and multidisciplinary environment. As international students, we were expecting cultural differences as there are always some in global teams, but the multidisciplinary part simultaneously made the course challenging and attractive.

We overcame our differences and found a way to leverage every team member's knowledge and background. Therefore, we can proudly say that MH.AI is the result of the efficient collaboration of engineers, designers, and business students.

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