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Master Thesis

Make the bot speak your language

Leveraging new technologies in a low resources environment to help rural communities market their products

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"We must dare to invent the future"
Thomas Sankara

Abstract

Western African countries have seen a huge increase in internet and smartphone use, however the digital gap is ever present between rural and urban areas. Many farmers in remote communities do not yet have access to those new technologies, often due to low literacy and digital literacy skills. The research builds on the foundation of voice-based technologies introduced in West Africa in 2011, which used simple phones and automated voice calls to improve rural communication. It examines the current relevance of these earlier approaches and investigates how they can be adapted to today's technological environment. To achieve that, two projects are used as case study: Project Sumbala in Burkina Faso which aims to empower Burkinabé women through entrepreneurship for sustainable forest products and a related initiative in Mali focusing on the cultivation and commercialization of artemisia for malaria treatment. The ICT4D 3.0 method is applied to build a voice based system to address their unique challenges. An interactive voice system was designed and developed using AI text-to-speech technology, implemented on the popular messaging platform Telegram. The system is tailored to meet the needs of users with low digital skills, facilitating access to market information and fostering better communication. By placing human-centered design at the forefront, this research contributes to the broader discourse on technology's role in rural development. It offers insights into creating adaptable, user-friendly solutions that can bridge the technological gap and improve livelihoods in resource-constrained environments.

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Introduction

Technology keeps progressing with constant hardware and software innovations. Nowadays, most everyone in the Global North have access to smartphones and use them proficiently with internet access. However, this is far from being the case everywhere in the world. Internet is penetrating more and more countries from the Global South and use of smartphones increase exponentially. However, in rural areas, many people are still unfamiliar with the potential that communication technologies can bring to their lives.

Connecting people from remote villages can help them access and share more information. As many rural people are farmers and produce various nutritional products, an improvement in their practice as farmers could mean enhanced food security. This is an active challenge that West African countries are facing; one that the United Nations are officially tackling in their Sustainable Development Goals: zero hunger (Goal 2)[1].

In 2011, voice-based technologies were first introduced in West Africa through different initiatives (1) (2) for farmers. They relied on simple phones and automated voice calls as it was the available technologies at the time in a low resource environment. The systems deployed were well adopted and proved to effectively improve communication in rural communities. Nowadays, more than 10 years later, women in these rural communities are starting to have smartphones, access to internet and most everyone is on social media. However, overall accessibility of those systems remain a challenge due to the low literacy rates in rural areas, as smartphones are used mostly as text-based solution. This issue is exacerbated by the lack of translations in smaller languages, reducing again the accessibility for people who do not speak more common languages like French or English in West Africa. Lastly, cost is a huge barrier for many people as they cannot afford to buy the newest technologies, especially if they would not know how to use it.

[1] `https://sdgs.un.org/goals`

Recent developments in ICTs such as AI progressing at exponential rates bring about the question of how useful they can be in improving accessibility for people in resource-constrained environments. Initiatives are taken to bridge the gap between mainstream and smaller languages. Communication solutions freely available incorporate speech seamlessly in their systems through asynchronous voice messages for example. Culture is evolving with technological progress.

That is why this research focuses on helping rural communities of developing countries access and develop their skills through new and available technologies. It also questions the usefulness of the old approaches, if they are still valid in the current context and how they can be adapted. The research is structured around the research question: *How can (digital) technologies (such as AI) be leveraged in a rural low-resource context for improving communication and access to information?*

Voice based technologies have been tested in African countries around 2010 when phones became more mainstream but least connected people from rural areas were forgotten about. More than 10 years later, a new technology paradigm has risen, namely smartphones with the use of Internet and ever progressing AI technologies. Those innovations have potential to empower people from remote communities in their daily lives. However, they have yet to be concretely implemented. Therefore, this research aims at establishing the feasibility of those solutions in the specific rural West African context and provide some guidelines for future implementations.

1.1 Background

West African countries still face issues regarding food security and gender inequality. Those are important pillars of a society and need to be addressed for long term well-being of the countries. Some aspects of those multi-faceted challenges can be improved through the use of new technologies. This research takes as case study the trade of forest products in Burkina Faso to examine the extent at which ICTs can be leveraged to improve trade in rural areas of the Global South.

Trees are great providers for the communities who live nearby. In many West African countries, there is a tradition of foraging different products from forests for food, medicinal or rituals. They are called Non Timber Forest Products (NTFPs). The Center for International Forestry Research (CIFOR) classifies NTFPs as including fruits and nuts,

vegetables, fish and game, medicinal plants, resins, essences and a range of barks and fibres such as bamboo, rattans, and a host of other palms and grasses [1].

NTFPs present a wide range of benefits for the communities in which they are traded. First, they provide a source of income for people living alongside a forest. They can collect, possibly transform and then sell them to make a profit. In Burkina Faso, NTFPs are usually traded by women (3), which gives them an opportunity to increase their household's earnings and gain some independence. Moreover, NTFPs are proved to be factors in improving food security, nutrition and health in households which uses them (4). Finally, the trade of forest products play in role in encouraging forest conservation (5). Indeed, when people spend more time in the forest and exploit its resources, it gives them incentives to keep it prosperous. In Burkina Faso, this goal is aligned with the aim of regreening part of the country, by supporting the development and managing of forests.

Women are key actors who collect NTFPs in Burkina Faso and are able to generate income from them. However the exploitation of NTFPs is under used. People are aware of the existence of NTFPs and their use is common but it is less common to buy them. Therefore, people who want to sell NTFPs have difficulties to find clients.

1.2 Two projects from West Africa

1.2.1 Project Sumbala

This thesis is part of the SUMBALA project. This project is spearhead by the Web alliance for Regreening Africa (W4RA) which is a trans-disciplinary community for research and action focus on sustaining local farmers' activities for regreening in Western Africa. Burkinabé women can be key actors for cultivating forest products, if given the chance. That is why the project SUMBALA is focused on supporting women's entrepreneurship to build innovative local food systems. Funding comes from the Dutch Ministry of Foreign Affairs and Nuffic, the Dutch organisation for internationalisation in education. They aim at promoting digitization in rural areas and encourage joint research with West African countries.

To achieve their goals, W4RA is partnered with Babafla, a company specialized in technology in the Global South and a local NGO: Réseau MARP [2] which aims at developing community actions for sustainable development. The project is carried out in close collaboration with cooperatives of women who sell NTFPs as they are the main recipient of

[1] `https://www.cifor.org/publications/corporate/factSheet/NTFP.htm`
[2] `https://reseaumarpbf.net/`

the action. Partners in this project also include radio stations which bring knowledge in advertising and communication methods.

1.2.2 Artemisia

This thesis was also implemented for a second project, this one in Mali. It will not be discussed as much as project Sumbala, because it was not as central to the research, however it is considered a use case for the solution that is developed down the line.

According to the World Health Organisation, Mali has had 7.7 millions cases of malaria [1] for a population of under 22 million people[2]. That is almost 30% of the Malian population has suffered from Malaria and it caused 19 933 deaths in a year. Pharmaceutical treatments for malaria exist but they are too costly for most of Mali's inhabitants. A more affordable solution has been introduced from China: artemisia (6). This plant's leaves can be dried and prepared in a tea and it proved highly effective in treating uncomplicated malaria. Small farms in Mali can easily cultivate this plant and commercialise it for its health benefits.

The Vrije Universiteit's Centre for International Cooperation is currently collaborating with Malian farmer organisations to help build resilient food systems that depend on shorter food supply chains. Part of this project includes encouraging farming practices of smallholders farms, in addition to helping young people and women start their farming activity. In the present use case, this research aims at providing solutions for young and women farmers to advertise their production of artemisia plants and tea.

1.3 Research

West Africa is located in the Global South, therefore it consists of developing countries. Access to digital technologies in those countries has been slower than those of the Global North. The disparity is known as the digital gap. In the last few years, the use of smartphones and internet has widely spread in Western African countries, effectively bridging part of the digital gap. However, there remains disparities inside each country between urban and rural areas. Indeed, people from cities are getting used to smartphones for social media, ordering online and other activities. However, people who live in more remote villages have less access to smartphones and internet, often have low literacy skills, and thus

[1] https://www.afro.who.int/sites/default/files/2023-08/Mali.pdf

[2] https://perspective.usherbrooke.ca/bilan/servlet/BMTendanceStatPays?codePays=MLI&codeStat=SP.POP.TOTL

struggle to have access and use smartphones which are mostly text based. This research focuses on the struggles of those rural communities to integrate those new technologies into their daily lives. Its author recognizes the importance of putting humans at the center of development in order to implement usable and durable solutions.

The digital divide is still ever present between urban and rural areas and this thesis project aims at considering the specific challenges people from rural communities encounter when trying to adapt to new technologies. Through iterative development cycles and close contact with the future users, it is possible to build a solution that can answer some of their needs while being adapted to their skills. This research is focused on two specific use cases for farming in rural areas. Its overarching goal is to inform future projects on what design decisions could be taken to build systems relying on modern technologies for people who are not used to using modern technologies, and how they can be leveraged to fit low resource context for people with low digital skills.

ICTs can be a huge drive to progress, by helping communities connect to each other, increase their knowledge and be innovative. In the case studies of this project, the goal is for farmers and women to gain more autonomy through improved communications and thus income. Down the line, it means that it could really contribute to increase people's well-being.

The direct contribution of this research is an interactive voice system, implemented on a popular voice messaging application: Telegram. It takes the form of an automated chat bot. The bot enables users to enter quantities of their products for keeping track of stocks. Moreover, it creates automated advertisement messages to broadcast either on the radio or through messaging applications. It is entirely designed using speech technologies so that a user with low literacy skills can aptly use the system. Moreover, the bot leverages new technologies like AI text-to-speech models in order to efficiently connect with the user in their native language. It serves as a proof of concept for future voice based systems developed for smartphones.

Validation in the field with users from Burkina Faso and Mali aims at understanding the effectiveness of such automated systems to improve business endeavours for low income people in remote areas. Using novel technologies such as bots on messaging apps and AI models in fields where they were previously never implemented is a big step to boost research in those new avenues. The immense potential that new technologies present for sustainable development in Global South countries needs to be explored more in order to have a true impact on rural areas.

1. INTRODUCTION

Connecting people who are otherwise disconnected from the rest of their country contributes to bridging the gap between urban and rural areas. With the constant progress of technology, helping people effectively use devices that are in everyone's hands give them more autonomy and agency to navigate this connected world we live in. The women from Burkina Faso and smallholder famers from Mali stand to improve their digital skills but more importantly increase their profits. Access to more skills means for them access to opportunities for growth in their sector as they can learn to leverage technologies in their own ways for their own benefits. They can better support their future through better income, thus furthering their investment in their well-being, family and career.

This research fits within the framework of the United Nations' Sustainable Development Goals [1]. Namely goal 1 (no poverty) by trying to increase poor communities' income; goal 2 (zero hunger) by improving nutrition through the trade of NTFPs which are can be highly nutritional; and goal 5 (gender equality) because NTFP trade is mainly carried out by women and boosting their income will help bridge the gender gap in revenue.

This study shows the enthusiasm that new technologies and progress generate in rural areas. Indeed, even if the solution designed is not perfect for its users, they actively collaborate with the researchers to build a solution tailored to their needs and abilities. This process will not end with this thesis, as the ICT4D movement is still actively involved with those communities.

The field of ICT4D (Information and Communication Technologies for Development) focuses on bringing ICT to less developed countries in order to further some communities' development sustainably (7). In the last 20 years, ICT4D has met a soaring success. Indeed, as technologies develop in the global north, there is a growing enthusiasm aimed at helping the global south with the same technologies. Many initiatives are taken to further development in less developed countries, and they more often than not include ICTs.

A popular methodology for developing ICT4D solutions is the ICT4D3.0 method (8) which centers the users in the whole development process in order to have a system which best fits the targeted community's needs. It has proved successful with projects such as RadioMarché (1) or Tibaŋsim (9). These solutions were implemented with the available technologies at the time which are mainly GSM phones and over phone lines. This research proposes a novel approach to ICT4D solutions which integrates the next steps of ICT: smartphones and the internet. As a result, this thesis establishes new standards for the ICT4D3.0 method and can be seen as its evolution, the ICT4D4.0 method which uses the more recent technologies to reach West African countries.

[1] `https://sdgs.un.org/goals`

2

Research approach and methodology

After establishing information about the background of this research and its general setting, this chapter goes in depth about the structure of the study, meaning its purpose and accessible resources and finally the methodology that the author carried out.

2.1 Research goal and questions

Throughout this paper, we will focus on the case of commercialization of NTFPs in Burkina Faso. Because NTFPs can be beneficial to the community that trade them, this research aims at improving the marketing of NTFPs through Information and Communication Technologies (ICTs). Indeed, Burkinabé now have all access to a phone or a radio (10), even in rural communities. Therefore, an ICT solution can be designed to improve their lives. The results will be used to expand on the ways of helping remote communities improve their communication processes through the use of available technologies.

In order for ICT4D projects to be successful, there needs to be an extreme awareness of the context in which they operate. Indeed, this includes correct understanding of the future users, especially their needs, skills and current environment. To achieve this, a good research design and method is necessary.

This research was not carried out in isolation from the Netherlands. Indeed, it is key to make contact with different local persons who can provide insight into their lives. The research approach focused on getting in touch with as many people as possible who could reflect about the conditions of the case study. This includes the Burkinabé women who are the future users, but also people who are in close contact with them and have a broader view of their unique challenges. It is important to the author to gather different perspectives to grasp the context in an effective way.

Different resource persons are also necessary to understand the technological context and what resources are accessible in an environment where said resources might be very constrained. Moreover, this research heavily relies on people who can speak and write in both French, to communicate with the author, and in the local language, to give accurate and reliable translations for the system.

The rural populations targeted present some challenges in the fact that are largely illiterate and even though they possess a phone, people are mostly using them to communicate by call or voice memos. This research carefully develops a user-centered system which puts usability first. Indeed, for the solution to be useful in the long term, it would need to be adopted by as many women as possible to maximize its impact. And because they are not as used to technology as the author is, centering the users' needs in the entire developing process is essential for a useful project.

The development of the system described in this paper is articulated around the main research question: *How can (digital) technologies (such as AI) be leveraged in a rural low-resource context for improving communication and access to information?*

In order to best answer the research questions, some sub-research questions are devised to guide the process and ensure a useful output for future works.

1. What is the state of the art of infrastructure in rural regions?
2. How can users be involved in the remote developing process of a voice interactive system?
3. How is the use of smartphones facilitating the access to information in low resource, rural context?
4. What architectural and user designs make an application usable in low literate context?
5. What current technologies can provide a cheap and effective solution for automated communication?
6. Is the ICT4D3.0 method still relevant for developing ICT4D projects?

2.2 Methodology

The research is carried out in an iterative process of designing, by going back and forth with users and experienced people in order to identify a system structure which efficiently helps

them. This research applies the framework for developing ICT services in low resource environments as seen in (8), called ICT4D3.0. It consists of five phases, to enable the system designers to properly understand how to implement a system that is most usable in their context. They are presented below.

1. **Context analysis:** This phase aims at understanding the context of the future users of the solution. It is essential to get in contact with them in order to understand their reality, grasp what unique challenges they face and what their skills are.

2. **Needs assessment:** This phase focuses on the general needs of the users that could be answered through ICTs, what could they benefit from? It can range from improved communication or to access to very specific information that they cannot access otherwise, for example.

3. **Use case and requirement analysis:** This phase is more precise in terms of user needs. It devises specific solutions to certain problems that could be made in the context. Multiple ideas can be presented to the users and they pick one to focus on, based on its relevancy to the problem at hand and the different stakeholders involved. The requirement analysis is done to ensure that the system's qualities encompasses the needs and restrictions of its environment correctly.

4. **Developing, testing and deploying:** This phase is for the developing period of the solution. It consists of going back and forth with the users to make sure it is usable.

5. **Sustainability analysis:** This last phase is essential because it evaluates the long term viability of the solution. It assesses its business feasibility, for example how expensive is it to keep it running and who bears those costs.

Historically, ICT4D projects are paved with failures due to a misalignment between the technologies and their target users. The ICT4D3.0 framework puts the users in the center of the project development in order to avoid further mismatch. This research follows the steps as specified and it is reflected in the structure of the thesis.

This method was developed more than 10 years ago, with the current technology of the time in mind. As per the sub research questions, this research aims at questioning and validating this method with field work. Indeed, with the advancing ICTs that we now have access to, this thesis aims at proposing changes in the method to adapt it to the state of the art technology in West African countries.

2. RESEARCH APPROACH AND METHODOLOGY

This chapter has established the steps that the author takes and how they will be carried out in order to develop a system adapted to its future users' needs and how this research is novel for the ICT4D field with a new approach to using available technologies.

3

Context analysis

To begin this research, a thorough context analysis is described in this chapter. It includes background on NTFP trade in Burkina Faso, as well as the political insecurity that has riddled the country lately and finishes by delving into the specific context of women dealing NTFPs, as they are organised in specific structures called cooperatives.

In order to truly grasp the context of NTFPs trade in Burkina Faso, the author met (online) with some of the heads of the cooperatives involved in project Sumbala to get in touch and exchange around their challenges during a workshop in Ghana in November 2023. Moreover, the author interviewed different people, including Amadou Tangara, an ICT4D expert based in Mali, and Jean Arnaud Sawadogo, a radio station operator who closely collaborates with cooperatives. They have first hand experience which the cooperatives of women selling NTFPs. The author also had access to the trip reports of a workshop that took place in November 2023 for the project SUMBALA (Sustainable women's entrepreneurship to build innovative local food systems). This workshop was held in Ghana with Burkinabé women in attendance to describe how they carry out the production and sale of NTFP. It was a precious resource to understand their goals and how they currently operate. Project Sumbala aims at improving and increase the trade of NTFPs to promote the benefits mentioned previously. Unfortunately, due to the language barrier and lack of internet connection, it was impossible for the author to interview furthermore some of the women themselves for this thesis to carry out the context analysis. However, she was part of a WhatsApp groupchat with the cooperatives and asked them a few questions by text.

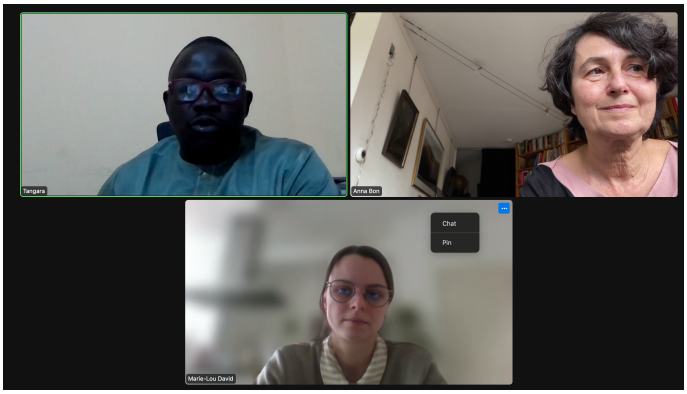

Figure 3.1: Zoom interview with Amadou Tangara (top left), Anna Bon (top right) and Marie-Lou David (bottom)

3.1 NTFP trade in Burkina Faso

The NTFPs traded in Burkina Faso usually include honey, shea nuts and its derivatives, African locust beans that can be used for food or medicinal purposes, neem oil and many other products. The women gather raw materials in the woods and can sell them as is, for example shea nuts, or they can also transform them to sell another type of product, e.g. shea butter. Their harvest and thus the products they offer depends on the season and the weather conditions, therefore they are used to diversifying the products they offer.

There are considerable income disparities between men and women in Burkina Faso. This issue is exacerbated in the rural context. Indeed, rural women have less opportunities to access income. They rely on the production of NTFPs and small farming activities. For them, NTFPs could be a key source of income. Amadou Tangara cited a previous project RadioMarché (1) which helped women to increase their NTFP sales in Mali. When interviewing the women after the project was implemented, some expressed that they gained more independence and autonomy because they did not have to ask their husband for money anymore. This shows the validity of NTFPs as source of income for rural women.

NTFPs are found and traded in rural areas. This means that the women come from remote villages, not necessarily connected to a road. Finding clients can be challenges in such situation. NTFP traders often went to weekly markets in neighboring villages to be able to sell their products. However, the clients were the ones fixing the prices, often at a disadvantage to the sellers. Unfortunately, the public is still unaware or uneducated about all the benefits that NTFP consumption could represent. This represents a loss of income for the women and can be explained by the lack of education around the quality and benefits of NTFPs. After the RadioMarché project which advertised NTFP qualities on

the radio, it was observed that clients were willing to travel further and to pay the prices fixed by the women for NTFPs. In some cases, the price for the product has doubled because the women regained control over it. This underlines the importance of raising awareness around NTFPs and their advantages, which can be achieved with the help of ICTs. However, as raised by Jean Arnaud Sawadogo, many rural people are also unable to afford NTFPs which are deemed superficial. He cited as an example soumabala which can be used to make a sauce, and is considered a luxury.

People from urban areas seem to appreciate NTFPs and would be interested in buying them because they are considered of higher quality than mass produced products. In the city, people generally use social media to find interesting products and can get them delivered directly to their house by motorcycle. In the case of NTFPs from rural areas, this process is more complex to carry out. Indeed, the women do not all have access to a smartphone and internet, therefore, they cannot advertise their products on social media or they do not know how. Moreover, they come from remote villages, so the delivery is not as fast and easy as from inside the city. According to Amadou Tangara, the bus network is extensive, even in the countryside, and generally, a bus will stop close to the villages. One can put packages in the bus, give the contact of the person picking it up and at the destination stop, the driver will check that the right person has picked up the correct packages. This is a reliable method for delivering packages from one destination to another without having someone traveling with the products, besides the bus driver.

3.2 Political insecurity

In 2022, two coups d'état took place in Burkina Faso, generating a lot of political insecurity (11). Since the start, thousands of people have been displaced, having to leave their homes in order to escape the escalating violence by religious extremist groups and the military state (12). As a result, traveling has become unsafe, especially in the northern and eastern part of the country. More people are in need of extra income to survive but the insecurity makes it more difficult to travel and sell products in some regions. Furthermore, the phone lines can sometimes be disconnected by armed groups. According to our interviewees, the situation seem to be getting safer in 2024, but they still consider it unstable.

3.3 Women cooperatives for NTFPs

In accordance with the Organization for the Harmonization of Business Law in Africa (OHADA), women selling NTFPs organize themselves in cooperatives. In the following section, we go in depth about the organization of such cooperative and the challenges they encounter.

3.3.1 Organization

A cooperative gathers women from the same or neighboring villages which want to produce and sell NTFPs. This framework facilitates administrative implementation and enables the women to sell in bulk to clients. The production of individual women can be small, but by gathering in cooperatives, when approached by a client who wants a large quantity of a certain product, they can adequately meet the demand. Thus, they make more profit. Each cooperative often focus on offering one or two types of NTFPs.

The cooperatives have varying size, which typically can be between 20 and 100 members. In the case of the Sumbala project, the typical size is of around 30 women. When a woman moves to a new village, she will usually join the local cooperative. At the head sits a board of directors, elected democratically every two or three years. The board comprises a president, sometimes a director of communication, of organization and other members depending on the hierarchy decided by the cooperative. One person is appointed as contact for potential clients, who is responsible for relaying the demand to the cooperative and concerting with everyone to try to meet the demand.

Every member has a phone, but it is not necessarily a smartphone. The women possessing smartphone and having access to the internet are fond of using WhatsApp as a method of communication. Everyone is also accustomed to using mobile money services which essentially acts as an online bank for many people in Burkina Faso (13). The cooperative women like to use mobile money because they do not have to carry cash on themselves which can be unsafe. Moreover, they are familiar with the system, know how to navigate it and they trust it because their relatives from cities often use this method to send money. Even though, many women have low literacy skills, they still know how to read numbers and type them into a phone.

3.3.2 Challenges

The following challenges for cooperatives have been identified during the interviews.

- **Marketing**: The cooperatives have difficulties in reaching new clients and advertising the NTFPs they have available.
- **Societal traditions**: As explained by Jean Arnaud Sawadogo, in some regions of Burkina Faso, women traditionally hold a quiet role in society, where they do not often speak up and let men take public space. He observed that for some cooperatives in Passoré, it is difficult to advertise themselves because they fear the judgement of others for appearing and speaking publicly, something they are not used to.
- **Storing system**: They have no storing system or storing management system in place so they cannot yet group their stocks in one place to facilitate meeting bigger demands of clients. This generates delays when gathering everyone's stocks and means that they can lose on business.
- **Inventory management**: In the same vein, the members of one cooperative can be spread out in different villages, so it is difficult to keep track of the quantity of product each member has.
- **Setting prices**: The cooperatives struggle with pricing their goods, especially when they are not aware of the market prices of NTFPs in other areas of Burkina Faso.
- **Predicting production and demand**: It is difficult to predict the production that the exploiters will have for one period because it depends on the weather and quality of the raw material. The women have a hard time responding correctly to the market, meaning producing enough but not too much, also because they face fluctuating demand. Furthermore, if a demand is too big for a cooperative, they have to decline it.
- **Lack of treasury funds**: To be able to make NTFPs, cooperative members might need initial investments. However, microcredit rates are too high for them. Their way of obtaining liquidity is by each investing 200CFA per week, the member who needs money can borrow it from the common fund and reimburses it with an interest between 1 and 5%. The money from the loan stays in the cooperative, so other members can also reuse it.
- **Unequal methods of production**: There is no archive or resources to reference the production process used when processing NTFPs. This creates a disparity in the production processes, especially when new people arrive and use their own methods.

Therefore, the quality of products in one cooperative can differ, depending on which member made them.

- **Middlemen**: Middlemen sell NTFP from rural areas in cities. They add no value to the products and only reduce the margins that the women would make on the sale of the product. They also jeopardize the quality of the products, in order to sell more at a lower cost, for example by diluting honey or mixing multiple types of butter but only showing the higher quality label.

Overall this chapter explores the setting in which the research takes place. It enabled the author to isolate important challenges that the cooperatives face and those will be the basis for designing the system as well as the skills that the women present and the available communication structures that they have.

4

Needs assessment

This chapter aims at understanding who the actors of the system will be and how they can concretely benefit from a digital system. The goal of conducting needs assessment is to capture what ICT solution could potentially help its users. In the case of ICT4D, people are from remote areas where they are not aware of the range of capabilities from ICTs. This takes into account future users' hardware and digital skills.

4.1 Stakeholders

The cooperative infrastructure is extensively described in Chapter 3 because they are central to this research. They constitute the main stakeholder for this project. For more clarity, the author made the distinction between cooperative organisations which represent the board of a cooperative and their members. This is to reflect the fact that they have different goals for the system.

4.1.1 Cooperative organisations

The organisation or board of a cooperative have for main goal to effectively manage their members, stocks and finances to make a profit. Indeed, one of the advantage of grouping themselves was to be able to aggregate production and thus attract more clients for sales. However, managing stocks and finances can prove to be difficult without an efficient information system in place. The operational goal of a cooperative organisation is to trade more NTFPs, which can be helped by attracting more clients, supporting members, or through more effective management stocks or finances. They also have a need to be more connected to the NTFP market in general, especially other cooperatives dealing in similar products, in order to have a better understanding on setting prices.

4.1.2 Cooperative members

A member of a cooperative aims at selling their products to increase their income and therefore independence. This can allow them to support their family. They are also looking for support from the cooperative, in learning new skills, building a community and a reliable network to sell their goods.

4.1.3 Radio Stations

Radios play an essential role in rural West African communities. They are the main method for information dissemination, as having a radio does not need much electricity and signal reception (8). Radio stations are heavily involved with the SUMBALA project. As privately operated organisations, they aim at making a profit through airing advertisements. They are also invested in raising awareness around environmental issues. Indeed, they have multiple programs centered around protected plants, organic farming and tree maintaining. NTFPs can be very beneficial for preserving nature, therefore stations have an interest in promoting the use of NTFPs as their cultivation helps conserve and develop forests.

4.1.4 NGOs

Non Governmental organisations (NGOs) are also part of this project, as they often act as facilitators for community development actions in their region. This is the case of the NGO Réseau MARP [1]. They are implemented in Burkina Faso and they focus on helping participatory approaches for projects around (i) food security, (ii) natural resource management and climate change, (iii) decentralization, (iv) training and networking of innovative farmers, (v) promotion of microfinance, (vi) disaster risk management. They are involved in helping Burkinabé women trade more NTFPs because it is heavily linked to (i), (ii) and (v).

4.2 Technical needs

After a discussion with an ICT solution expert in West Africa, Amadou Tangara, several needs have been identified which can be answered through the use of ICT. They are presented in the following section.

[1] `https://reseaumarpbf.net`

4.2.1 Knowledge sharing

In remote areas, where the internet connection is sparse and people do not all have smartphones, communication can be difficult. In this case, it can take place at different scales. The smallest scale is the struggle for members inside one cooperative to share their stocks, decide where and how to meet. One need for a cooperative is to have access to a way to reach all members easily at one time. It would make it easier for them to collaborate on sales and trade. ICTs in that case can be used to connect members through a voice application that surveys them on what their stocks or availability are for example. As they all have phones, this could be achieved.

On a bigger scale, cooperatives struggle to make themselves known to potential clients. Indeed, people are becoming more and more connected to social media but the cooperatives are lagging behind, which causes them to lose out on potential clients. ICTs can be used in multiple ways to improve advertisement to people who are already present. This could be on social media for example. There is a need for more advertisement and this can be achieved through communication technologies.

Lastly, an important part of knowledge sharing is to learn more about one's craft. ICTs can be leveraged to enable a nationwide sharing of best practices in terms of collecting and producing NTFPs. A forum could be helpful for everyone in the NTFP community to share their experience and learn from others. This approach has been tested previously in various countries for farming and it proved to be beneficial to farmers because it improved their skills and strengthened community feelings (14)(15).

4.2.2 Knowledge base

In addition to sharing information with other people, ICTs are also a really good way to store information for future use and to build a knowledge base for one's organisation. In the cooperatives' case, it could prove very useful to document their process in order to harmonize them and easing newcomers into their practices. Another way to leverage a knowledge base for them would be to record the demand for certain products over time to try to predict and answer it the most accurately possible. Keeping records is an essential part of examining one's operations to improve them.

On a bigger scale, one can imagine a nationwide knowledge base for prices, where each cooperative can record the latest prices they sold goods at. This could help every cooperative to ensure that their prices are coherent with the rest of the offer on the market. Currently, cooperative boards have no real access to price history for what they are selling

and some are struggling to determine the ideal price of their products. A price knowledge base that they could access at any time and update would alleviate this problem.

This chapter covered the goals of the different stakeholders for this project. Furthermore, it highlighted their general technical needs. For the rest of this research, it is essential to keep in mind the need for improved communication whether it is among a community or outside of it.

5

Use cases and requirement analysis

Once the context and the needs of the future users are well understood, specific use cases can be designed and presented to the relevant stakeholders for selection. In order to properly develop one of the use case, non-functional requirements are decided on. They are all presented in this chapter.

5.1 Use cases

From the context analysis and needs assessment, multiple use cases emerged. They are described in the following section, and the system's main functionalities will be derived from the use cases.

5.1.1 Radio advertisement

Current situation: Potential buyers of NTFPs are often unaware of the offer that the cooperatives have. The cooperatives currently do not advertise the products they make and it is difficult for the general public to find them if they want to buy specific products. Moreover, in some regions of Burkina Faso, women can be shy to appear on the radio and make their voice heard to their close community.

Key idea: Broadcasting on the radio reaches many people in Burkina Faso. Having a system that automatically generates messages on the radio to advertise the products that the local cooperative offers and who to contact to get them, would increase the business of said cooperative. It also alleviates the fear of certain women to be a public figure on the radio.

Actors: In Table 5.1 are shown the different actors of this system and their respective goal.

Actor	Operational goal
Cooperative	Advertise their products to sell them
Radio station	Play advertisement in exchange for money
Potential clients	Listen to the radio and potentially buy NTFPs from local cooperative

Table 5.1: Actors and their goals for the use case of radio advertisement

5.1.2 Processes database

Current situation: Members of cooperatives have all their own way of processing NTFPs. This creates heterogeneity in the quality of the products they offer, especially if multiple members group to meet a bigger demand. When a new member joins the cooperative, there are no set process in place to teach them, thus, everyone employs different techniques.

Key idea: The key idea is to create an application that acts a database for each cooperative to store and access their processes. This will help the uniformization of methods inside one cooperative. When a new member joins, the other members can teach her their ways of doing things using the database as a resource. This can also help sharing techniques between cooperatives so they can uplift each other and learn more.

Actors: In Table 5.2 are shown the different actors of this system and their respective goal.

Actor	Operational goal
Cooperative member	Record and access process of making an NTFP
Cooperative coach	Train new recruits with the help of recordings
Cooperative	Exchange with other cooperatives about processes of fabrication

Table 5.2: Actors and their goals for the use case of processes database

5.1.3 Stock and meeting survey

Current situation: Members of one cooperative are geographically split, sometimes

living in different villages. Communication can be difficult between all the members. This is especially a problem when a client approaches the cooperative with a bigger demand, the point of contact has to call everyone individually to be aware of the stock available. This delays the sale. The process of organising a meeting is similarly complex because there is no centralised method of communicating with every member.

Key idea: The key idea is to create an application enabling the administration of the cooperative to quickly survey the stocks available of each member or to consult them on their availability for a meeting.

Actors: In Table 5.3 are shown the different actors of this system and their respective goal.

Actor	Operational goal
Cooperative member	Quickly make their stock or availability known
Cooperative administration	Centralise the stock or availability knowledge of the cooperative member

Table 5.3: Actors and their goals for the use case of stock and meeting survey

5.1.4 Web shop for urban people

Current situation: People living in urban areas have no means of knowing about the NTFP offer in rural areas and of ordering them. However, they would be interested in buying them because the products are perceived as high quality goods when they are handmade. This represents a loss of business for cooperatives.

Key idea: City dwellers have for the most part smartphones and are used to finding different products on social media. Therefore, the idea would be to create a web shop advertised on social media, which presents the NTFPs available at a certain cooperative. The web shop would give the clients the opportunity to order goods directly from the internet, they can pay with mobile money that the women in cooperatives trust, and the women can ship the products on the bus.

Actors: In Table 5.4 are shown the different actors of this system and their respective goal.

Actor	Operational goal
Cooperative	Register their products to sell them
Client	Order NTFPs

Table 5.4: Actors and their goals for the use case of a web shop

5.1.5 Artemisia advertisement

Current situation: Farmers in Mali are starting to grow artemisia for its health benefits. However, they struggle to sell all of their products. This is probably due to the facts that many people are not aware of the benefits that artemisia has for curing diseases like malaria.

Key idea: Similarly to the first use case, using radio to broadcast messages would be useful in creating awareness of artemisia benefits and of farmers selling them. This would increase the potential client base of the farmers and help them make more sales.

Actors: In Table 5.5 are shown the different actors of this system and their respective goal.

Actor	Operational goal
Artemisia farmer	Sell artemisia products
Client	Hear about benefits of artemisia products and potentially buy some
AOPP	Defending interests of small-scale and family farmers

Table 5.5: Actors and their goals for the use case of a web shop

5.2 Key quality attributes

A key part of designing a system involves identifying the qualities it needs to fulfil in order to be useful for its users. From the context analysis, emerged three main quality attributes. The attributes described in the following section are essential for the solution developed to be successful. They will drive the selection of the use case and furthermore the design decisions. They are summarized in Table 5.6 and explained furthermore in the rest of the section.

Name	ID
Financial viability	QA-FINANCE
Usability	QA-USABILITY
Language accessibility	QA-LANG

Table 5.6: Main quality attributes of the system

5.2.1 Financial viability

ID: QA-FINANCE

Description: The system is affordable for every stakeholder. This includes members of cooperatives who do not have the means to maintain an expensive system. Therefore, it should be as close as possible to free for them, while creating added value, so that the system stays viable in the long term.

Rationale: This project benefits from funding from the Dutch government and universities, so we have the initial investment to create a solution. However, the funding will stop eventually but the project should be affordable enough for all parties that when the international actors pull out of it, it still can function. Indeed, this project aims at improving the marketing of NTFPs, and if done successfully could improve income of poorer rural Burkinabé communities. A previous project, RadioMarché, was implemented in Mali and proved useful but it was too expensive to keep it running when the funding stopped. Ultimately, the goal here is to generate long-term and sustainable impact in Burkina Faso, so financial viability is essential for success.

5.2.2 Usability

ID: QA-USABILITY

Description: The system is easy to install and use for every stakeholder. The main stakeholder of our system is the women in the cooperatives who sell NTFPs. It is important that the system is simple to use, straightforward and developed with people from low (digital) literacy background in mind. Thus a user-centered development (16) will be used in order to develop an application that best corresponds to the abilities of its users.

Rationale: The ICT solution developed in this project is destined mainly for women who have low literacy and digital literacy skills. They are averse to change and might struggle to adopt a new system if they do not understand it well. For the application to

be successful, it is essential that the system is correctly adapted to its users and to limit its learning curve.

5.2.3 Language accessibility

ID: QA-LANG

Description: The system supports multiple languages most relevant to its users. In our case, it must include French, Mooré, Dyula, Bissa and Fula.

Rationale: More than 60 languages are spoken in Burkina Faso so not everyone will have one language in common. The language accessibility of the system is necessary for it to be adopted by as many people as possible.

6

Developing, testing, deploying

Once the context analysis is concluded, we can go about designing the solution. It is important to correctly plan out and consider the expectations from the system. Moreover, this chapter maps out the functionalities of the solution, to also showcase what it will not be able to perform. The following chapter expands on the system. First, a use case is selected from the ones which emerged during the context analysis. Then this chapter goes in depth about the designing phase of the system, its development and finally deployment.

6.1 Use case selection

This research is part of the Sumbala [1] project which aims at empowering women to build innovating local food systems. Burkinabé radios are an important actor of this project as they provide support in the marketing of NTFPs with their knowledge of communication technologies and strategies. Therefore, when looking at the five use cases we identified for this research, we wanted to select a use case which involved the radio. This is only valid for use case 1. Moreover, the radios have signed a convention to help cooperatives with their marketing strategies. As radio workers or people from réseau MARP are more proficient technology users, they can support the women in the cooperatives in navigating the system.

In addition to implementing use case 1, we saw the opportunity to combine it with use case 3 in order to design a real pipeline between surveying stocks available and directly generating a communiqué about said stocks. This solution would relieve two needs of cooperatives, the one for more organized way of collecting information and the one for

[1] https://w4ra.org/2023/12/06/sumbala-lesprit-dentreprise-durable-des-femmes-au-burkina-faso-projet-dem

easier communication. For a better understanding of how the system is expected to work in the typical use case, a scenario is pictured in Figure 6.1.

Use case 5 is a special case because it came later in the thesis project. It was presented to the author when she already had started developing the prototype. It was decided that the current chosen solution could fit the needs of Artemisia farmers. This chapter is mostly dedicated to the design of the solution for NTFP cooperatives because they will be it primary recipient. However, everything will be translated in Bambara for Malian users and adapted to the Artemisia use case for further testing.

The first step to use the system is for each cooperative member to input their available stocks of NTFPs. When the cooperative administration wants to be advertised on the radio, they can trigger the generation of a communiqué in relevant languages. The communiqué is then sent to their local radio station which can broadcast it on allocated time slots. When the radio listeners hear the communiqué, they are made aware of the cooperative and can contact them if they are interested in buying some products, thus generating profit for the cooperative.

6.2 Functionalities of the system

After establishing the general scenario of the system, it is important to consider what functionalities will it be expected to perform. The functional requirements are listed in Table 6.1.

The categories are mapped to actors in Figure 6.2, for a visual representation of who does what in the system. It is important to note that the radio station is connected to all use cases related to the communiqué and the administration board. That is because the radio workers or people from réseau MARP are the ones who will use these systems day to day as the cooperative members and administration do not have the necessary skills to. This is further described in the following section. This representation enabled us to isolate the system into three main components who will manage respectively: the generation of the communiqué (purple), the administration board (red) and the stock survey (yellow).

6.3 Design decisions

Now that we can split the system into three components, responsible for different tasks, we need to compare options on how to best carry out those considering the quality attributes

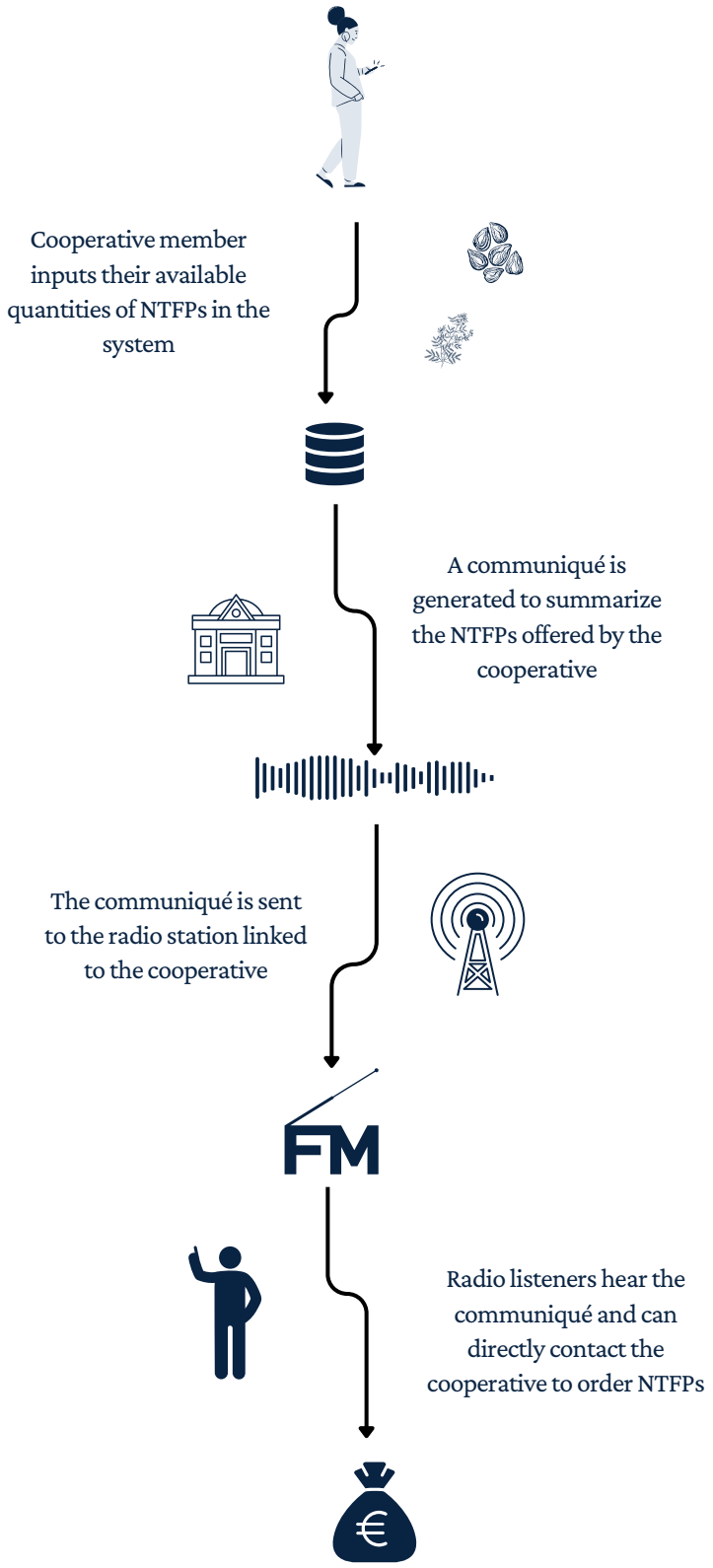

Figure 6.1: General scenario of the use of the system

Category	Name	Identifier	Description
FR-STOCKS	Input stocks	FR-INPUT-STOCKS	A cooperative member is be able to list the quantities they currently have available of key NTFPs.
FR-REG	Register member	FR-REG-MEMBER	A cooperative administration is able to add a member to their structure so that the system can contact them.
	Register NTFP	FR-REG-NTFP	A cooperative administration is able to pick their 3 key NTFP that they specialize in.
FR-CONSULT	Consult stocks	FR-CONSULT-STOCKS	A cooperative administration is able to consult the available stocks of the cooperative.
	Consult list of NTFPs	FR-CONSULT-NTFP	A cooperative administration is able to access the list of their registered NTFPs.
	Consult list of members	FR-CONSULT-MEMBER	A cooperative administration is able to access the list of their registered members.
FR-DEREG	Deregister NTFP	FR-DEREG-PRODUCT	A cooperative administration is able to delete a NTFP from their list.
	Deregister member	FR-DEREG-MEMBER	A cooperative administration is able to delete a member from their list.
FR-COMM	Add contact information	FR-EDIT-CONTACT	A cooperative administration is able to add and modify the phone number on which they want to be contacted for sales.
	Generate communiqué	FR-GEN-COMM	A cooperative administration is able to automatically generate communiqué from the system info on stocks.
	Send communiqué	FR-SEND-COMM	A cooperative administration is able to send a communiqué directly to radio stations for broadcasting.

Table 6.1: Functional requirements of the system

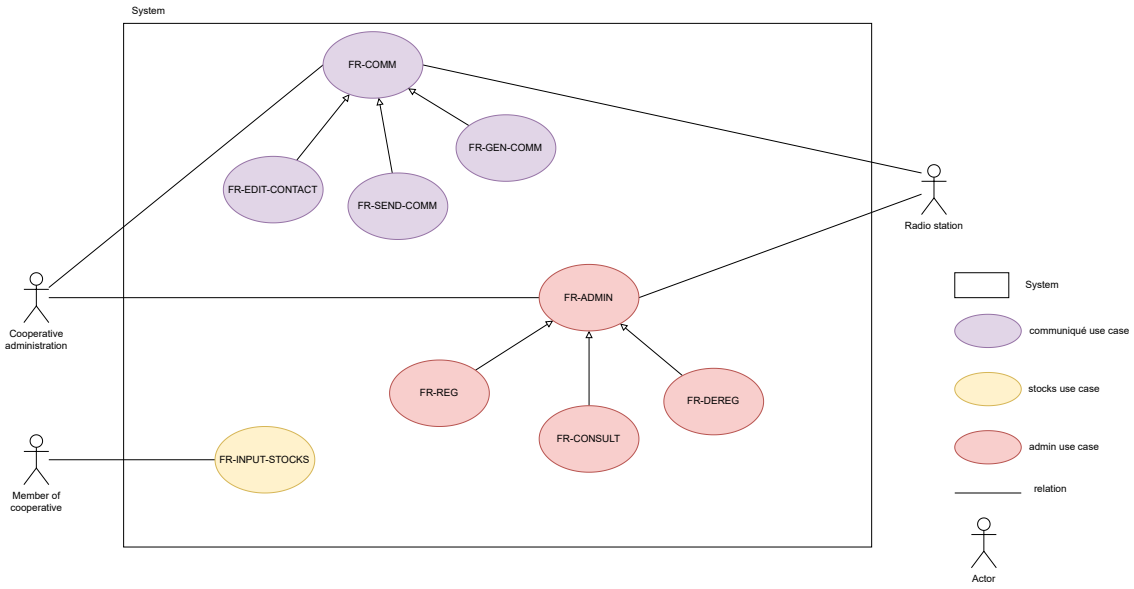

Figure 6.2: Use case diagram for the system

defined in section 5.2 during the context analysis. These decisions were helped with the expertise of Stéphane Boyera in designing similar systems.

6.3.1 Administration board

This component of the system is for the use of the administration to manage who can input stocks and what types of NTFPs they provide. However, the women making up the administration board might not be skilled enough digitally to navigate a system with so many possibilities. A way to circumvent that is to delegate the administration of the system to Réseau MARP. Indeed, they have more experience with ICTs and are literate. This simplifies the task of designing a usable system.

- **WhatsApp bot**: This option aims at communicating with an administration member through a bot on WhatsApp. This fulfills QA-USABILITY because the people in Burkina Faso are familiar with the app, they will have the necessary hardware and we will provide relevant languages for QA-LANG. However, in order to develop a bot on WhatsApp, the business API is needed and it is not free. Moreover, it would be a complicated system to navigate with 17 cooperatives and at least 10 members per

cooperative; it does not fulfill QA-USABILITY. This option is not decided, because it fails QA-FINANCE and QA-USABILITY.

- **Voice application**: This option makes use of a voice application instead of a bot. It fulfills QA-USABILITY and QA-FINANCE, however, other options can handle connection troubles and asynchronous messages as well as a large influx of information. Therefore, this option is not decided.

- **Web application**: This option makes use of a web application instead of a bot. It fulfills QA-USABILITY and QA-FINANCE because workers of réseau MARP know how to navigate a web site. Moreover, this option is more adapted to access a lot of information. Indeed, the NGO might manage multiple cooperatives, each with up to thirty members who each have different stocks. This information would be better displayed on a web page. Therefore this option is decided.

6.3.2 Stock survey

This component is centered around having cooperative members fill in and update their NTFP stocks. Choosing the appropriate method of collecting data is essential for this component to work well. Let us present the three main options and select one based on quality attributes.

- **SMS**: This option involves querying the member to update their stock via SMS. However, as most cooperative members are illiterate, they are not used to SMS technology and will struggle to input their stocks. This option violates QA-USABILITY, therefore it is not decided.

- **Voice application**: This option makes use of a voice application to avoid using text. It has been validated before on systems such as RadioMArché (1) or Avaaj Otalo (14), which proved to be quite efficient, therefore it would fulfil QA-USABILITY on condition of being carefully developed. Moreover, this solution requires funds to get access to a dedicated phone and maintenance, so it does fulfil QA-FINANCE. Due to the political instability in the country and the general patchy phone coverage, this option relies too much on phone lines. Indeed, once the call disconnects, all data is lost, so it might not be a very reliable solution, so it is not decided.

- **Bot on messaging application:** Online messaging applications such as WhatsApp are gaining a lot of traction in the world and especially in West African countries

Figure 6.3: Some cooperative women with the smartphone they just received

where it is now considered cheaper to use than pay for a mobile subscription if you have access to internet. Therefore, a bot developed on a messaging application would fulfil QA-USABILITY as it is a familiar application. Moreover, on applications like Telegram, developing a bot is completely free of charge, so this option fulfills QA-FINANCE. Finally, because the communication is done through messages, patchy internet does not prevent the bot from functioning. Telegram manages by itself messages sent without connection and stores them to send when the phone is back online. The conversation can take place over multiple days if needed without its flow and relevant information being lost in translation. Therefore this option is decided.

6.4 Prototype

Due to the political insecurity in Burkina Faso and the language barrier, no workshops took place with the cooperatives to test the working prototype during this research project. Therefore, the author chose to focus on implementing only some parts of the proposed solution. From the design decisions above, a relatively new technology was chosen: Telegram bots for interaction with the heads of cooperatives. This was settled on because (i) each cooperative has been given a smartphone with the Sumbala project (Figure 6.3) and (ii) they are familiar with messaging applications such as WhatsApp. However, the cooperative members have not interacted with a bot on such applications yet. This research proposes an interactive bot on Telegram in order to test its usefulness in a rural area of a developing country. The administration board will also be made for the Réseau MARP to be able to manage cooperatives.

6.4.1 Administration

In an effort to keep the system as usable as possible, it was kept extremely simple. From the context analysis, it was gathered that cooperatives typically focused on making few

key products. Therefore, to limit choices in the system, a cooperative can only keep track of up to three products from the following list, which was made after consulting the heads of cooperatives. They are deemed the most common types of NTFPs produced in Burkina Faso.

- Balanites juice
- Balanites leaves
- Baobab bread biscuit
- Baobab juice
- Baobab powder
- Herbal tea
- Honey
- Moringa powder
- Neem oil
- Shea butter
- Shea nut
- Soap
- Soumbala
- Zamenin

The products will be pre-entered by the réseau MARP, for each cooperative. Then each member can interact with the bot on Telegram to input their stocks of each product. Once they are done, a communique is automatically generated and sent to them so that they can share it either with a radio station to be broadcasted or to different group chats for advertisement.

The database and corresponding admin board have been implemented in Python using the Django framework (17). It was chosen for its efficiency in getting a project up and running, creating a managing interface for admin users and setting up a database. The database configuration is shown in the appendix, Figure 10.1.

6.4.2 Bot

A member accesses the bot through the Telegram application and can send any messages to get a reply. When messaging the bot for the time, it will ask for a phone number as they are not directly available through the Telegram API. If the number is in the system, the bot will give a list of the member's products and respective quantities. It will prompt the user for which product quantity to edit. As shown in Figure 6.4, the bot generates button with the corresponding products, and the user just has to click on the relevant one. Next they are prompted to write down the quantity of the product they currently have. It is solely needed to write numbers, which is doable even for people with low literacy skills. Indeed, from the context analysis, it was gathered that they know numbers usually, especially to use with new money. Once the user has entered a correct amount, they can confirm or abandon the interaction and restart from the product selection. If they confirm, the quantity of the relevant product is modified in the database. If the user is done with changing quantities, an audio message is sent which corresponds to a communiqué. This message contains the names of the cooperative, what products they offer if a member has some in stock and the number at which to contact them if someone wishes to make an order.

The state transition diagram of the bot is shown in the Appendix. Every time the user enters an incorrect input, or if an error occurs internally, the bot notifies them, as shown in the diagram.

6.4.3 Use of AI

Artificial intelligence (AI) is currently undergoing a huge developing phase worldwide. Large language models are yielding better and better results and companies are racing to surpass themselves. However, in order to be trained, models need enormous amounts of written or audio data in a language to become proficient in it. For very common languages such as English or French, the data is easy to find online. However for languages spoken in countries of rural West Africa, recorded resources of languages for Mooré for example are more difficult to come by. AI could be enormously successful in helping build systems accessible to communities with low literacy skills.

In 2023, Meta came out with Massively Multilingual Speech project (MMS) which aimed at extending AI models for speech processing to languages that are often forgotten from mainstream models. They successfully scaled models on more than a thousand languages, using recordings and transcriptions of religious texts. Notably, for Mooré, they created

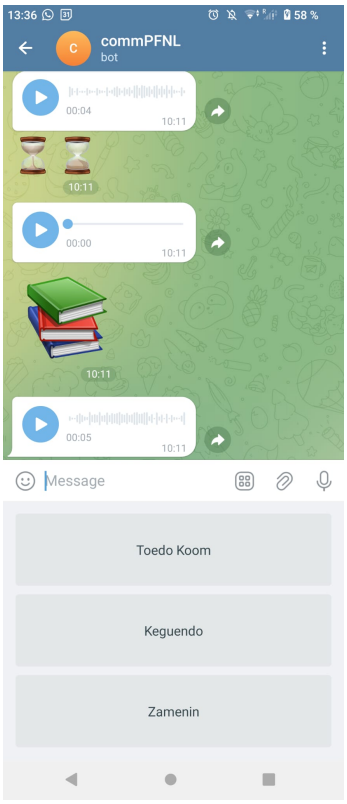

Figure 6.4: Screenshot from bot interaction on Telegram

Text To Speech (TTS) and Automatic Speech Recognition (ASR) models. These could be very useful for the use case, as its aim is to fully implement voice functionalities to facilitate navigating the system for users with low literacy.

In this research, the author proposes to introduce TTS functionalities to the bot. Future users are not used to artificial voices and they might be surprised by its use. This also aims at testing the accuracy of the model with different input. This research is a great opportunity to try a newly developed model and test its usefulness, while maybe finding some of its limitations. ASR functionalities are deemed too error-prone to implement in a system developed a short time span without the possibility to really test it in real conditions.

For the use case at hand, it was decided that some outputs from the system will be recorded by a native Mooré speaker, to cultivate familiarity in the system, especially for the first voice messages heard by the user. It has been found very important to use familiar voices to boost usage of voice application (1)(15). A few key outputs were selected to be spoken through TTS and this includes outputs with variable text. For example, the list of products and their respective quantities will be produced by the AI model. All fixed output, for example asking the user to click on the relevant button or error messages are pre-recorded audios.

The only exception made is for the communiqué, which is technically variable output; it depends on the cooperative and its current products available. However, because it is destined to other people, especially to be broadcasted on the radio, the artificial voice is not deemed authentic enough. Therefore, recordings of key sentences of the communiqué, names of cooperatives, NTFP names and numbers (for advertising phone numbers) have been made in Mooré in order to assemble a custom communiqué.

The MMS models of Meta does not include numerals. Therefore, an important part of pre-processing text for the TTS model is to write out numbers. For common languages, Python libraries exist for that purpose, however it is not the case for Mooré. A contribution of this thesis is a class method which takes as input an integer and returns the written out number in Mooré.

Regarding the Artemisia use case, Meta's MMS project does not include the Bambara language unfortunately. No other TTS model was found which performed reasonnable accuracy. Therefore, the implementation in Bambara will not include AI. This can be seen as the control subject, compared to the Mooré implementation. It would be useful to compare users' reactions towards a bot that uses AI and one which does not.

6.5 Deployment

As of now, the bot is deployed on PythonAnywhere [1]. This platform provides a free tier for hosting services and since the database and bot do not use many resources,thus the free tier is sufficient for deployment. The only condition to keep the web application running on PythonAnywhere is to click a button to keep it activated at least every three months. This ensure that they do not have idle applications uselessly consuming their resources.

The bot is accessible on Telegram by looking either for CommPFNL when wanting to access the NTFP bot for cooperatives or VenteArtemisia for the Artemisia version of the bot. For the users to be able to interact fully with the bot, they have to be registered on the admin panel.

[1] `https://www.pythonanywhere.com/`

7

Evaluation & discussion

The chapter presents the findings from elaborating the prototype. Unfortunately, due to the political insecurity in Burkina Faso and Mali, the team of project Sumbala could not travel to meet with its participants and help them set up the bot before the end of the thesis. This would have been an opportunity to learn design flaws of the system and iterate on development to improve them. However, this chapter reflects on the prototype created and its long term sustainability. Moreover, it provides insights on the choices made to build it, the challenges encountered and potential for improvement.

7.1 Evaluation

A prototype can only be validated through users in the field who can show proficiency in using the system and attest to its usefulness for their everyday lives. Because this was not possible at the time of writing this thesis, this section explores the sustainability of the bot and the challenges of its development.

7.1.1 Sustainability analysis

An essential part of the ICT4D3.0 framework is the sustainability analysis. It aims at ensuring that the project can be successful long term. It is important to carry it out in the early stages of a project to verify that it makes sense to implement the project for all parties involved. One way to verify that is to ensure value co-creation (18) which assesses the added value of using the system for each stakeholder.

In the case of NTFP commercialisation, the stakeholders are: cooperative heads and members, réseau MARP, radio stations and potential clients. The cooperative heads and members both stand to gain time and money by using the system. They gain time by having

a streamlined process to enter their quantities and make advertisement. Furthermore, they could increase their sales with said advertisement. Réseau MARP's stake in the system is their goal as an NGO to help local communities take action to improve their business. Radio stations benefit from the system by having advertisement already made, so they gain time and they get paid to broadcast them. At first, project Sumbala has a budget set aside to subsidise adds on the radio, but if the cooperatives notice an increase in sales due to advertisement, they will pay themselves for it eventually. Lastly, potential clients get to hear about NTFPs and in exchange for money to cooperatives, they obtain nutritional or medicinal products.

The system was developed for free during a master's thesis and the smartphones for each cooperatives were purchased through the Sumbala project. Therefore, these costs are not a problem anymore. The bot, administration panel and database are all hosted for free on PythonAnywhere. It will stay hosted there on the condition that the owner of the account (the author of this thesis) clicks on a button every three months to ensure that the web application stays active. The authors plans on keeping it active as long as the system is used. Moreover, the code is open source on Github [1], so the project can be deployed again somewhere else, should Pythonanywhere disappear.

The costs incurred from the system itself would stem from maintaining or scaling it. Maintenance or implementing new features would require a developer. They could be another master student who could do it for free, or a professional who will require payment. This payment could come from the cooperatives if they make enough money from sales of their products. A problem that could happen in the future, if too many users join the system, is scalability. Indeed, the database is a simple SQLite database, so if the number of users grows exponentially, it could become a bottleneck. The same thing goes if too many people use the system at the same times, as the server is also limited by Pythonanywhere free tier. This project so far focused on making a solid proof of concept and scalability was not a concern when developing it.

Developing a bot on Telegram was relatively easy because of the extensive documentation available online, which is also being kept up to date as it is maintained. Moreover, it is simple to deploy and be accessible to everyone with internet due to platforms for low resources projects. Telegram also manages messages sent and received when the device is offline, thus a patchy network connection is not a problem to use the system. This is a real improvement from voice application on a phone line, while keeping a similar flow of interactions on a platform that is familiar to the user.

[1] `https://github.com/mmmld/commPFNL`

Using the AI model trained by Meta was also relatively easy due to the documentation made available by Meta and by HuggingFace [1], the platform on which the model is hosted. It is also extremely convenient to create output on the fly, however, it still requires to have written text in the target language. No translation module is available yet for Mooré, therefore, one has to rely on a native speaker to provide the translations, which can take time, especially since the grammar can differ from region to region. The main downside of using AI is its resource consumption. Compared to the bot, it is more difficult and expensive in resources to host an AI model, so it is important to take into consideration when adding it to one's application, even if it is very useful.

7.1.2 Challenges encountered

When developing the prototype, several challenges were encountered. The first as mentioned above, is obtaining translations and audio recordings from native speakers. This sometimes created delays because the next steps of development were based upon those recordings. Patchy internet sometimes meant that the person could not send the recordings when they wanted to. Moreover, writing translations can be a challenging task for a Mooré speaker because they are unsure of the grammar, if they are more used to writing in French for example. Delays were incurred when verifying the specific grammar with other people. There is also a notable lack of resources online on the Mooré language. The author wanted to learn how to count and write numbers, and found online resources with contradictory spellings and sometimes rules. It was complex to create a generic code which could write out an integer.

Another challenge encountered was for handling the second use case for Artmesia. The structure of the bot was essentially the same, with a simpler data scheme. However, translating everything proved to be more difficult because no accurate enough AI model was found, therefore a lot of slot and filler audios had to be made. This needed some understanding of the Bambara language and where words fit. It also required to understand the numbering system, which is admittedly simpler than Mooré. Overall, developing the bot in Bambara required non trivial actions that took time, notably delays in getting audio recordings.

[1] `https://huggingface.co/`

7.2 Discussion

Let us reflect on the usefulness of this research in its current context and how it can be generalised to broader domains. The project carried out in this thesis was just an example use case of how modern technologies can be leveraged in a relevant way for underserved rural communities of developing countries. This section delves into the potential of messaging bots in low resource environment and how it could be improved in the future.

7.2.1 Domain of application

As seen in the developing and deploying phase, bots on messaging applications can be extremely cheap and easy to deploy due to the growing penetration rate of internet. Voice applications have been used for more than 10 years but they can be costly to implement as one needs to have a dedicated hotline. Therefore voice systems for smartphones are a useful way to circumvent those costs and embrace current technologies while adapting it to its future users.

The project exhibited in this thesis is but one example of meaningful application in the domain of providing services to rural communities in West Africa. As seen in Chapter 5.1, from the context analysis, already four different use cases have emerged. And because of time constraint, the use cases were kept fairly simple by the author. They were also designed to help a very specific community of women producing NTFPs and farmers selling Artemisia.

If the project is well validated by its intended users, it would be a good proof of concept for future research in implementing interactive voice systems for rural communities in developing countries. The advantages are many and could improve people's lives in many different contexts. Spreading ICTs to facilitate efficient and effective communication among community members could boost access to income (1), access to information about their profession (14) (19), about their education (20) (9), about their rights (21) (22) or even about their health (23). Those domains were already researched in different countries for voice based applications, as the articles cited show. A more mainstream options of creating and developing bots entirely online could boost the current research for more creative solutions.

AI particularly has shown great potential in helping reach people who speak local languages. More and more initiatives are taken to build models on languages less common (24) and developing models which can be trained on minimal amounts of data (25) (26).

The main downside of using AI is its complexity to run in low resource environments. Indeed, it AI models require considerable computing power that is more expensive and thus less accessible in for rural communities in developing countries. However, with technology advancing, it could be made more accessible in the future.

7.2.2 Future work

To enhance the inclusivity and accessibility of the project, it is essential to support additional local languages spoken in Burkina Faso, such as Dyula, Bissa, and Fula. Incorporating these languages will ensure that the bot can cater to a broader audience, reflecting the linguistic diversity of the region. This extension will involve translating the user interface and voice messages into these languages, enabling more members to use the bot effectively. By doing so, we can promote wider adoption and ensure that language barriers do not hinder the communication and cooperative efforts within rural communities.

Implementing ASR functionalities in multiple languages can also significantly enhance the user experience of the Telegram bot. ASR technology can convert spoken language into text, allowing users to interact with the bot through voice commands, which is particularly useful in areas with low literacy rates. Developing ASR capabilities for languages such as Mooré, Dyula, Bissa, and Fula will require collaboration with linguistic experts and leveraging machine learning models trained on these languages. This advancement will make the bot more intuitive and user-friendly, facilitating smoother and more efficient communication for all users, regardless of their literacy levels.

To further support cooperatives, the bot can be improved with additional functionalities that enable cooperative heads to manage their members more effectively. This could include features that allow cooperative heads to view the stock levels of each member, send automated messages to them requesting to update their current stock, and maintain an accurate, real-time inventory. By integrating these functionalities, cooperative administration can better oversee their operations, ensure timely updates from all members, and make informed decisions based on up-to-date information. These enhancements will streamline communication within the cooperative, reduce manual administrative tasks, and promote greater transparency and efficiency in stock management, ultimately contributing to the productivity and success of the cooperative selling model facilitated by the bot.

8

Threats To Validity

In this chapter, the potential threats to the validity of the research findings are addressed. Recognizing and mitigating these threats is essential to ensure the robustness and reliability of conclusions. The framework proposed by Wohlin *et al.* serves as a comprehensive guide to systematically identify and address these threats (27). According to this framework, threats to validity can be categorized into four main types: construct validity, internal validity, external validity, and conclusion validity. They are expanded upon in this chapter.

8.1 Internal Validity

Internal validity addresses whether the observed effects are due to the treatment and not some other factors. It is about the causality in the study. In the case of this research, the cooperatives will have help from other people in navigating the system, especially the first they try it out. This means that it could make it more difficult to perceive what parts are usable and what parts are harder to grasp. However, the goal is for as many people as possible to use the system and find its usefulness. Therefore, it is essential to have proper training and teaching in using it so that users can correctly adapt to it.

8.2 External Validity

This concerns the generalisability of the study findings to other contexts, settings, or populations. This study aims at generalising results for rural populations in West Africa. This threat is mitigated by the fact that the bot will not only be used by people from different regions of Burkina Faso and also from rural Mali. Therefore the author feels that the sample popular population will be representative of the general population. In terms

of setting, one can argue that West African countries, especially neighbouring ones can be quite similar. However, it will be harder to generalise conclusions to countries from other continents for example, because the variations in settings might be too different.

8.3 Construct Validity

This pertains to whether the study measures what it claims to be measuring. It focuses on the appropriateness of the operational definitions used in the study. The participants evaluating the project will do so under supervision at first to ensure that they can correctly navigate the systems. This might introduce evaluation apprehension as they will be aware that they are being evaluated. Maybe, they will feel the need to be overly positive about the bot. They might also feel reluctant to share some of its flaws to its creator.

8.4 Conclusion Validity

Conclusion validity focuses on whether the conclusions drawn from the study are statistically sound and reliable. In the case of this study, the threat to conclusion validity resides in low statistical power. This means that not many people will test the application: at least 17. This is still considered sufficient to gauge if the bot can be efficiently used, because those 17 cooperative heads can prompt their respective members to also use the bot and give feedback later on. Because the solution developed during this study is aimed at being implemented for a long time, its conclusion validity will increase with time.

9

Related Work

This chapter discusses the related work of the study. Prior to this thesis, the author conducted a systematic literature review of papers on voice based applications implemented in developing countries. In it, she explores the challenges encountered when developing such applications and used their teachings to develop the prototype described in this thesis. In the following chapter, key papers are mentioned, which are more closely related to this research.

This study is built on the work that Web Alliance for Regreening Africa (W4RA) [1] did in Mali almost 10 years ago. They conducted the VOICES project, which resulted in the system RadioMarché (1) being implemented. This project focused on helping farmers commercialise their products in Mali. They used a mix of voice and web technologies to aggregate seller data and make communiqués that could be broadcasted on the radio. This study uses a similar idea because it proved fruitful, however it is updated with modern solutions. Namely, now smartphones and the internet are more accessible and AI models are becoming mainstream, so this study aims at finding out how well they could be integrated for systems in rural West African countries.

Avaaj Otalo is a key project in voice based interactive systems (14). In 2008, it laid some of the groundwork for implementing successful voice applications in rural areas of developing countries. They also targeted farmers but to help them exchange tips and advice on how to better grow their crops. This proved really successful in fostering a community feeling for people living in remote areas who were isolated in their practices. TWhile Avaaj Otalo implemented a knowledge base for its users to refer back to when

[1] `https://w4ra.org/`

they had questions, this research is focused on improving processes in a business sense, by improving logistics (stock survey) of cooperatives and their advertisement.

An implementation in rural India tried to compare the usage of an interactive voice call with that of an interactive bot on WhatsApp in Indian rural communities (28). They aimed at finding at what was the most effective to reach people and get them to use the system. They focused on delivering training content for farmers. This thesis only considers the impact of an interactive bot of a rural community, and aims at finding out if it can be proficiently used to improve some of its users' life.

In (26), Qasim *et al.* propose a solution to provide weather information to communities of rural Pakistan. They faced challenges such as low literacy and digital literacy skills and showed real improvement in usage when adapting to the users' customs. What's more, they build a high accuracy ASR system for regions of Pakistan in multiple languages. They proved that taking users' feedback into account when developing an interactive voice application is highly effective in increasing its usage. This study will focus on implementing an interactive bot on a messaging application and not on implementing ASR.

Meta came out with Massively Multilingual Speech project (MMS) which aimed at extending AI models for speech processing to languages that are often forgotten from mainstream models (24). They scaled models on more than a thousand languages, using recordings and transcriptions of religious texts. This study makes use of some of MMS's models but does not fine-tune them or train their own model.

10

Conclusion

Overall this research successfully implemented a prototype which could facilitate and improve communication in rural communities of West African countries. This prototype still needs to be validated in the field but if it is adopted, it serves as proof of concept for future research on communication in rural communities.

With the increase in internet and smartphone usage everywhere in the world, especially under-served communities, this thesis aimed at finding ways to leverage new technologies for novel purposes. Indeed, voice system can easily be built and answer needs of diverse communities in terms of literacy and digital literacy skills.

Future works should focus on expanding the current prototype to ensure that it is valuable for its intended users. Moreover, the technologies touched upon in this thesis, namely building a bot on a messaging app and integrating AI models for speech processing, could be reused in many different use cases to further help more people. This has the capacity to increase the quality of life and access to information for many communities often forgotten about.

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Appendix

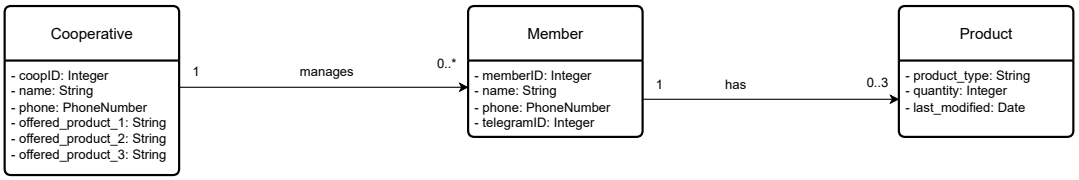
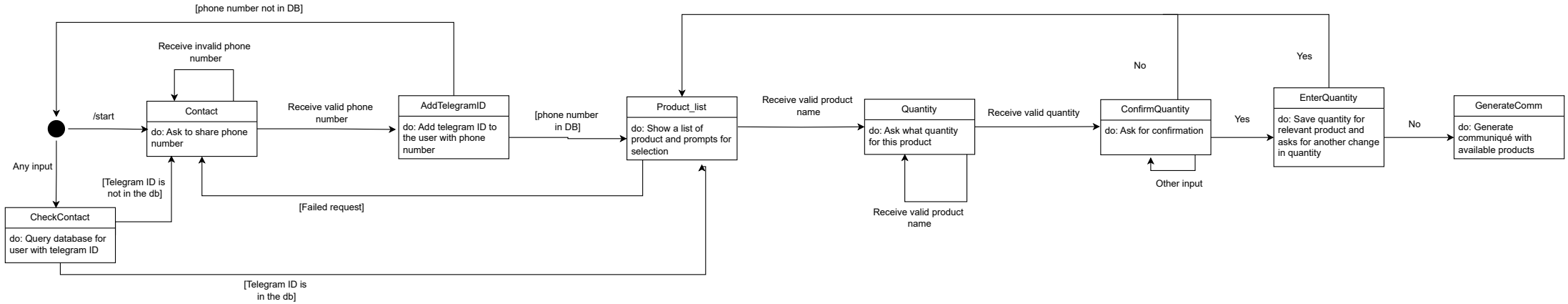


Figure 10.1: Class diagram of the database


[phone number not in DB]
Receive invalid phone number
/start
Contact
do: Ask to share phone number
Receive valid phone number
AddTelegramID
do: Add telegram ID to the user with phone number
[phone number in DB]
Product_list
do: Show a list of product and prompts for selection
Receive valid product name
Quantity
do: Ask what quantity for this product
Receive valid quantity
ConfirmQuantity
do: Ask for confirmation
No
Yes
EnterQuantity
do: Save quantity for relevant product and asks for another change in quantity
Yes
No
GenerateComm
do: Generate communiqué with available products
Other input
Receive valid product name
Any input
[Telegram ID is not in the db]
CheckContact
do: Query database for user with telegram ID
[Failed request]
[Telegram ID is in the db]