A project undertaken as part of the BSc (Hons) Business Information Systems Degree, Westminster International University in Tashkent.

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Acknowledgements

“There is no such thing as a "self-made man". We are made up of thousands of others. Everyone who has ever done a kind deed for us, or spoken one word of encouragement to us, has entered into the makeup of our character and of our thoughts, as well as our success.”

— George Matthew Adams

I’d like to take this opportunity to quickly thank: my family, for their unconditional belief in me and my potential; my friends, for their unwavering support through thick and thin; and *all* of my lecturers at WIUT, both for the knowledge that they imparted on me and the effort they put in to do so.

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Glossary

Outpatient care - any healthcare consultation, procedure, treatment, or other service that is administered without an overnight stay in a hospital or medical facility. Routine physical examinations with a primary care provider are one common type of outpatient care.

EMR - An electronic (digital) collection of medical information about a person that is stored on a computer.

OECD – The Organization for Economic Co-operation and Development is an intergovernmental economic organization with 38 member countries, founded in 1961 to stimulate economic progress and world trade.

Abstract

The healthcare sector in Uzbekistan is a rapidly developing industry, both in terms of size and technological advancement. Certain economic factors, however, continue to hinder progress and pose a significant challenge for the infrastructure upgrades that are required to improve the medical system of the country. The proposed solution, AppointMed, an online appointment booking system, attempts to improve one piece of the puzzle by streamlining and expediting a routine process in the healthcare industry. The design choices and methodology take into consideration the fundamental challenges faced by the industry, and attempt to create a solution which is economically viable. The development process was conducted over the course of this past academic year, and aimed to reach all of the objectives set in the beginning of the project. The mobile application that was developed did manage to meet the targeted scope and feature set, although it's important to note that certain modifications had to be made to the initial plans. Specifically, due to delays in the development process, the initial scope of the application had to be scaled back, and certain features had to be backlogged. All in all, the project proved to be an insightful experience into the areas of idea creation, market research and analysis, and the software development lifecycle.

1 Introduction

The technological revolution of the past few decades has fundamentally changed healthcare as we know it. Breakthroughs in the fields of biomedicine and medical technology have saved countless lives and founds cures and treatments to ailments once thought to be untreatable. These developments, as well as their application, however, often overshadow the developments within a different, much more mundane and routine part of healthcare: a visit to the doctor. A 2019 study (Michas, F.) found that the average number of annual doctor's visits among OECD countries can vary from 2.3 to over 17 times per person. The start of the digital age promised one of the first overhauls of the healthcare industry: the computerization of medical records. Even in as far back as 1988, researchers such as McDonald et. al. (1988) predicted that "over the next few years, computer stored medical records will become technically and economically feasible on a broad scale." While the full computerization of medical records would not start until the 2000's (even in highly economically and technologically advanced countries such as the United States) it shows the potential application of new technology that was seen from the very beginning. Nowadays, widespread adoption of the internet and the low barriers to entry to smartphones have created new possibilities for convenience within every aspect of life, including healthcare. The project undertaken in this report aims to utilize one such convenience made possible by technology: managing doctor appointments online, and searching for a reputable healthcare provider based on a patient's own needs.

2 Background

2.1 Problem Overview

An Uzbekistan Healthcare Sector Report conducted by RB Asia in 2019 found that the government of Uzbekistan allocated $1.27bn of the national budget towards the healthcare sector. At the time, that figure was expected to increase to nearly $3.5bn by the year 2022, with their 10-year forecast predicting that the budget allocation towards healthcare would reach $7.19bn by the year 2029. While this does show that the sector is growing at a rapid pace, the country still has a long way to go in terms of utilizing technology to assist the day-to-day processes of outpatient care. In fact, a study conducted by Asadov and Aripov (2009) concluded that the Uzbek healthcare system, among a number of post-soviet countries, had poorly equipped

medical facilities, and that local Quality Improvement projects often fail to address factors that directly support the quality of healthcare. As an example, we can observe this in the country's failure to adopt a nationwide electronic medical record system, despite the fact that numerous studies, including one conducted by Wang et. al. (2002) concluded that the implementation of an EMR system can result in a positive financial return on investment to healthcare providers. Such a counter-intuitive approach often results in a diminished quality of care for patients, and an unnecessarily difficult workload for healthcare providers and doctors alike.

2.1.1 Root Cause(s)

The aforementioned problems are not, however, without cause. While the overall scope of the challenges facing the Uzbek healthcare system is too big to encompass within this report, we will be taking a look at arguably the biggest factor that is hindering the technological development and adoption within the industry: economic and financial limitations.

A study conducted by the World Health Organization (Ahmedov et. al., 2014) analyzed the healthcare sector of Uzbekistan, it's transition to a post-soviet system, and the challenges currently facing the sector. They concluded that "some of the greatest challenges relate to health financing", and the fact that the government allocates a small portion of its comparatively low GDP results in substantial private expenditure for patients. When government funding is not sufficient, and patients are required to pay out of pocket for their care, it becomes evident why adopting even the most basic modern infrastructure developments, such as an EMR, for example, are massive hurdles for healthcare providers.

Furthermore, this issue can also be attributed to the relatively low purchasing power of the general population. While Uzbekistan's Purchasing Power Parity measurement is not available as of writing this report, a GDP per Capita of $6,880, only 40% of the world average, combined with a Gini Coefficient (an index measuring wealth inequality, ranging from 0 to 1, from least to most inequal, respectively) of 0.35 can paint a clear picture of the situation at hand. When the local population does not have the financial power or motive to sustain an increase in the price of healthcare, and when healthcare providers are not adequately funded, it is difficult to achieve substantial growth in terms of infrastructure development and technological adoption.

2.1.2 Economic and Social Detriment of the Current System

Referring back to the study conducted by the WHO, Ahmedov and colleagues (2014) argued that there was a strong business case for improving the user experience of the healthcare system. They pointed out that many medical providers in the country lacked the frameworks for appointment scheduling, and that the system was characterized by long wait times and multiple return visits. While concrete data on the user experience of patients of public medical providers in the country are non-existent, a survey collected in 2010 conducted in 9 post-soviet countries found that on average, 60% of users were not satisfied with their respective healthcare system (Footman et. al., 2013).

In addition, long appointment wait-times have been shown to result in substantial economic losses in the form of wages and productivity. A study conducted by the Frasier Institute (2021), for example, found that Canadian patients as a whole, over the course of their entire treatment, lost between an estimated $2.8bn and $8.4bn in wages. This is compounded when we consider the loss of productivity as a result of having to take more time off of work.

2.2 Aims and Objectives

Having defined the problem at hand, analyzed the root causes, and outlined the disadvantages of the current system, we can specify the objectives of the project that will directly address the issues mentioned above.

2.2.1 General Intent/Guidelines (Macro-Economic and Social Scale)

Note, that the points mentioned below are general guidelines aimed at reflecting the *ethos* of the project, and are meant to be interpreted as a reflection of some of the wider potential implications and benefits of developing and utilizing such an application. They *are not* metrics with which the success of the project will be measured by (those are listed further below under Business, Technical, and Personal Objectives).

- Develop an appointment booking framework which will *partially* address the current inefficiency of the healthcare system in Uzbekistan
- Improve the user experience of outpatient care for the general population
- Mitigate *some* of the economic detriment caused by the shortcomings of the current system

- Present the benefits of, and promote the widespread use and adoption of technology within the healthcare sector
- Reduce some of the "hassle" of visiting the doctor in an effort to promote and increase the number of regular visits

2.2.2 Business Objectives (Micro-Economic Scale)

- Develop a financially sustainable and viable appointment booking framework which can be integrated into the current systems of medical providers with ease
- Analyze different monetization options and select one that results in the lowest costs for both patients and medical providers alike
- Analyze the different platforms available for development (mobile, web, etc.), and select one that results in the largest reach to customers
- Define the target user demographic

2.2.3 Academic Objectives

- Analyze the general state of the current healthcare system of Uzbekistan
- Outline the shortcomings, inefficiencies, and issues facing the healthcare system
- Identify the root causes of said issues
- Develop a potential solution supported by the research that has been conducted
- Analyze the results of the solution and come to a conclusion on its potential viability in a real-world environment

2.2.4 Technical Objectives

Develop a mobile application that allows users to:

- View a list of nearby medical providers
- Search for a medical provider based on their specific requirement
- Select a medical provider, a doctor, and book an appointment based around the schedule of the selected doctor
- Check into an appointment, notifying the doctor
- Cancel an appointment, if the need arises
- View a list of previous appointments

In addition, a back-end REST API server must be created, which can:

- Securely store user authentication and appointment scheduling data
- Securely retrieve and send user data to the mobile application
- Implement authentication
- Implement authorization to ensure proper data access rules
- Be able to perform with a high number of users
- Implement a scalable software architecture to ensure easier long-term development

2.2.5 Personal Objectives

- Develop an application that can be used within a portfolio to showcase my experience and skills with modern OOP languages
- Follow industry standard ‘best practices’ during the development phase
- Learn how to plan a project and manage time effectively
- Learn a new programming language and mobile application development framework, in the form of Flutter and Dart
- Challenge myself to create an application of a size and scale on which I have not worked on before

2.3 Project Scope

It is important to define the limits of both what the application is supposed to do, and what it is capable of evolving into in the future.

The appointment booking system, consisting of a front-end mobile application, and a back-end REST API will consist of the following functionality:

Patient-side:

1. View a list of local clinics based on the type of medical specialization required.
2. Select a clinic and view details (including a location on a map), as well as a list of doctors within the selected department.
3. Select a doctor, view their details, and view a list of available appointment times for that doctor.
4. Select an appropriate date and time and schedule the appointment.

5. Check in to the appointment after reaching the clinic.
6. View a list of both scheduled appointments as well as previously completed appointments.
7. Cancel an upcoming appointment.
8. Create and update an individual User Profile.

Doctor-side:

1. View both a list of upcoming appointments and previous appointment history.
2. Be notified of upcoming appointments, and once users have checked in to their appointment.
3. Change the status of appointments to “Complete”.
4. Cancel appointments.
5. Create and update an individual User Profile.

Backend server is responsible for:

1. User authentication in the form of Json Web Tokens
2. User authorization and restricted endpoints
3. Registration of both user types
4. Persistence of user profiles, clinic details, appointment details on a database
5. Retrieval of patients, doctors, clinics, appointments from the database

Features which can be implemented in the future (but outside the scope of the current project):

- Messaging feature between doctors and patients
- Test result collection
- Review system for medical providers and doctors
- Payment system

3 Business Methodology

3.1 Identifying the Target Audience

In 'Target Market Identification and Data Collection Methods', Curtis and Allen (2018) argue that the first step in defining a target audience is "identifying its key characteristics, such as demographics, psychographics, and products/services the target market wants and values".

Note, that in this instance, the psychographics of the target audience does not play a significant role. The service being offered is utilitarian, and the underlying product behind it, a visit to the doctor, is a necessity for everyone regardless of their individual or collective psychographics.

We can identify our market demographics for patients using the following criteria:

Age: 18-65. Limiting age is important, as an audience younger than 18 is under the provision of their parents (who are older than 18), and an audience over 65 is less likely to own a smartphone (O' Dea, 2021), or possess the technical skills to be able to take full advantage of the application.

Geographic Location: Uzbekistan.

Race, Religion, Gender, Income Level, Family Size, Occupation, Education Level, Marital Status: Any.

The target demographics for corporate users, in this case Medical Providers, will be more nuanced:

Industry: Healthcare.

Sector: Both Public and Private

Company Type: Medical Provider.

Company Size: Any.

Yearly Revenue: Any.

Geographic Location: Uzbekistan.

3.2 Industry Analysis

3.2.1 PESTLE

Political	Since its independence from the Soviet Union, the government of Uzbekistan has introduced a number of political reforms aimed at improving the healthcare systems of the country, although the implications of these reforms on healthcare quality have been called into question (Asadov and Aripov, 2009). Nevertheless, the government has approved and undertaken multiple initiatives aimed at improving healthcare access and quality (Ahmedov et. al., 2014): • 1998–2004: Project Health, funded by the World Bank • 2005–2012: Project Health II, funded by the World Bank • 2005–2012: Project on Woman and Child Health Development, funded by the Asian Development Bank • 2012–2018: Project Health III, funded by the World Bank In addition, a number of presidential decrees aimed at outlining the direction of the health reforms have been signed: • 2007: Presidential Decree No. 3923 • 2007: Presidential Edict No. 700 • 2011: Presidential Decree No. 1652 Overall, the political landscape is one that is supportive of decentralizing and partially privatizing the industry. Projects such as this one, which are aimed at improving the quality and user experience of healthcare would likely avoid political pushback.

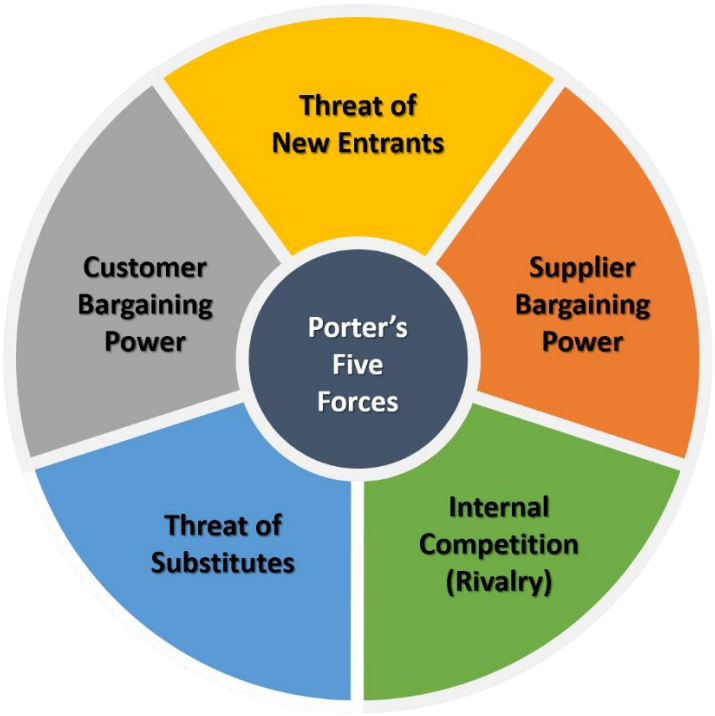
Economic	The economic situation in this context is somewhat complicated. As mentioned above, while the government is increasing the budget allocation towards the sector, it falls short by the standards of more developed countries, and is insufficient in funding even the most essential operations on a nationwide scale. In addition, it has also been identified that, in general, the local population is likely incapable of driving technological innovation and growth through sheer demand. In addition, financial access to medical care has been impeded through the rise of informal charges in the country. According to a World Health Organization estimate, in 2021, out of pocket informal payments accounted for almost half of the total health expenditures (WHO Regional Office for Europe, 2021). Health Expenditure per Capita was also below the average for Central Asia (WHO Regional Office for Europe, 2021). This largely leaves the technological development of the sector at the hands of private medical providers, and government projects and initiatives specifically targeted at making the necessary infrastructure upgrades.
Social	As with any product, there are a number of factors that can affect the choice of a patient when choosing a medical provider. A review on these factors conducted by Kolstad and Chernew (2009) have suggested that patients look for “convenient, generally well-qualified, and responsive primary care physicians”. Based on this finding, we can infer that convenience and responsiveness, two important factors of the user experience, play a crucial role in determining patient satisfaction, and subsequently affecting their choice of healthcare provider. The average user experience of public medical providers in Uzbekistan is categorized as one with long queue times, and multiple return visits (Ahmedov et. al., 2014). While there is little empirical data surrounding the general population’s perception of the healthcare system, we can infer, based on previous findings, that it is inadequate in terms of efficiency and quality.

Technological	The technology used both in specialized care and general visits are limited both in terms of quality and volume. According to the aforementioned WHO study (Ahmedov et. al., 2014) health systems in Uzbekistan have been slow to adopt and utilize the benefits of information technologies. In fact, the use of IT in state owned and operated facilities is constricted to basic electronic data entry and collection. While certain private medical providers, such as “Shox International Hospital” and “Horev Medical Center” advertise the proliferation of IT within their operations, and offer services such as online test result collection, these providers are limited to urban areas and patients who are both willing and capable of paying for higher-than-average medical costs.
Legal	Companies operating in Uzbekistan and handling the personal data of Uzbek citizens must store their data on servers located within the country, according to Article 27-1 of the law. In addition, highly sensitive data, including medical records, must be stored securely to avoid potential liability in the event of a data breach.

3.2.2 SWOT Analysis

	Positive	Negative
	Strengths	**Weaknesses**
Internal	• Streamlines a process that everyone routinely partakes in • Saves time for doctors, lowers wait times for patients • Eliminates the need for doctors to use their own system of remembering and tracking appointments • Can provide insightful and accurate analytics for medical providers • Low cost of entry for medical providers •	• Limited feature set. • Business model fundamentally relies on reaching critical mass before widespread adoption. Medical providers may hesitate to implement a system with a small userbase, userbase will not expand unless there is a variety of medical providers. • Requires re-training of doctors and administrative staff
	Opportunities	**Threats**
External	• Concept has been proven to work in other countries • Lack of competitors offering an identical service • Growing national healthcare sector • Growing technological adoption and digitalization of medical services • Government incentives for "ensuring sustainable improvement of health indicators of the country's population and level of satisfaction with the national health system determined in accordance with universally recognized international practices." (RP-3894, 2018)	• Limited reach due to low smartphone penetration • User resistance to accept product • Reluctance on the part of medical providers to store patient information and analytical data, on external systems • Potential legal liability when working with sensitive data on this scale

3.2.3 Porter's Five Forces



Competition in the Industry

There are several competitors within the healthcare industry of Uzbekistan offering a somewhat similar product:

1. Private Medical Providers: "Horev Medical Center" offers users the ability to sign up for an appointment on their website. This functionality, however, is limited to only providing the center with the user's contact information. Once provided, the medical center's staff call the user to get more details on the type of appointment needed, and the date and time of the appointment. While the system does partially use an online component, the majority of the work is done manually over the phone, meaning they offer a completely different value proposition with this service. The website does not allow the user to choose a specific type of doctor, nor a date and time for the appointment.
2. Certain Individual Public Medical Providers: The Republican Specialized Scientific Practical Medical Center of Hematology offers users the ability to choose a specific doctor, date, and time, for an appointment on their website. The core functionality of this service is extremely similar to the application being developed. However, there are a number of limitations which this product faces: the service is limited to only this specific

medical center, and the fact that the Center of Hematology is an extremely specialized facility limits users in terms of the type of care they can receive.

3. Ministry of Health's website: In late 2020, it was reported by Sputnik News that the Uzbekistan Ministry of Health launched a website for an online queuing system for the family polyclinics of Tashkent. As of writing this report in 2022, 2 years after the launch, their website at https://reg.ssv.uz/ still returns an error message to the user. Evaluation of the service and its potential threat as a competitor could not be conducted due to the fact that the service does not work.

To summarize, while several different parties have attempted to launch similar and competing products, their offerings are either fundamentally limited in scope and functionality, or do not work as intended. A service offering the exact or close to exactly the same functionality does not yet exist. Therefore, competition within this industry in Uzbekistan is low.

Threat of New Entrants

As previously discussed, the government is actively encouraging the development of the IT sphere in the healthcare sector. While this is beneficial for developing an appointment scheduling system, it also increases the risk of other competitors entering the industry. As an example, in a recent project called "100 Ideas for Uzbekistan" sponsored by the Ministry of Innovation Development (among other sponsors), 12 of the 100 winning proposals were in the sphere of healthcare (2021). One specific project called "E-Med", proposed by a WIUT student, was concerned with digitizing medical records into a nationwide system. While this concept is not directly in competition with the project being developed in this report, it can still highlight how active encouragement of development within this sphere leads to a high threat of new entrants. This, in combination with the fact that appointment booking systems are "tried and true" frameworks, means that there is a possibility that certain businesses may have already explored and planned an entrance, and are simply waiting for the right market conditions to do so.

Power of Suppliers

In the case of a mobile application, where a physical good is not sourced or sold, the role of the supplier would be the tools and frameworks used in the development process, and any services used to maintain the application. Throughout the entire *development* process, no paid products

were used. In fact, the only cost associated with the project would be the hosting platform used to host the back-end API server. Given the large number of hosting providers, and the option to purchase dedicated server equipment to self-host the application, the power of suppliers in this instance would be low.

Power of Customers

According to Porter (1979), a buyer group is powerful if:

- It's concentrated
- It purchases in large volumes
- The product it purchases is undifferentiated
- The product does not save the buyer money

With these criteria, we can determine that our customer groups, patients and medical providers, both hold low to moderate power as customers for the following reasons:

- They are not concentrated. There are 1263 medical providers listed on GoldenPages.uz (2022), which is the largest online business directory in Uzbekistan. In addition, not every medical provider is registered with GoldenPages, driving down the concentration even further. Patients are even less concentrated, as virtually every resident of Uzbekistan will visit a doctor at some point in the future.
- While monetization has not yet been discussed, in any case, each and every patient will only use the application individually. In contrast, medical providers, specifically those run by the state, will have considerable leverage given that individual state-owned clinics would not pay for the product; rather, the Ministry of Health, or another government body would negotiate terms or make a purchase for all of their clinics, if not at least a significant portion.
- The product in question is differentiated. In our analysis of competitors within the industry, we determined that a functionally identical product offering was currently non-existent.
- The product would save the buyer money. In terms of patients, time spent waiting in a queue is money lost in the form of wages and productivity. In terms of medical providers,

more efficient use of staff time would result in lower expenditures in the form of salaries paid to doctors and specialists.

We can conclude that the power of customers is low to moderate.

Threat of Substitutes

The appointment booking system has a couple of alternatives, both of which are practiced:

1. Booking an appointment over the phone: As of today, this is one of two major options when visiting a doctor in Uzbekistan. This method in particular poses the biggest threat because it is currently standard practice in the industry. It's a fairly reliable, straightforward, and easy way to book an appointment, and the only pre-requisite is access to a mobile or landline phone on the patient's part. While medical providers and doctors would benefit from an online booking system, there is effectively nothing preventing them from continuing to operate over the phone.
2. Live queue/walk-in: The other option is to forego an appointment and make a visit without one. While we've discussed the drawbacks and costs of waiting in line and potentially having to make a return visit, it would be illogical to assume that demand across different types of specialists, different providers, different cities, and even different doctors within the same field and provider is the same. We can suppose that patients who regularly visit the same doctor have a general idea of how busy they usually are, and in the case of those patients who wouldn't have to wait in a queue either way, the extra hassle of scheduling an appointment (online or otherwise) is simply not worth it.

In this instance, the threat posed by substitutes are high.

3.3 Monetization

In 2021, global consumer spending on mobile applications reached $170bn (Ceci, 2022a). To ensure the sustainability and long-term development of an application, monetization is a crucial aspect. In order to choose a monetization model which is appropriate for our application, it is important to categorize and identify the value it offers customers. In a study conducted by Tang (2016), mobile applications were categorized into two categories based on what users expected to get out of it: utilitarian and hedonic. A utilitarian perspective focuses on ease of use and

aesthetic appeal, while a hedonic perspective includes a personal emotional attachment or achievement component, such as those commonly found in mobile games. In addition, the study further categorizes apps based on the type of benefits sought by the user:

1. Convenience: Apps that simplify daily life, enhance efficiency and/or reduce search and decision costs.
2. Communication: Instant messaging apps
3. Social Networking: Apps that offer users a sense of belonging and acceptance among social groups
4. Entertainment: Games, media, music, etc.
5. Value sharing: Apps that allow users to share their values and earn social recognition

Based on these categories, we can deduce that AppointMed is a utilitarian application offering users convenience, by simplifying a routine process.

With this in mind, several key monetization models can be analyzed to find the optimal choice:

Freemium

"Freemium" (from the words "free" and "premium") monetization is a business model in which a mobile application can be downloaded for free, and which generates revenue solely from In App Purchases (Tang, 2016). These purchases can vary in terms of what they offer, depending on the type of application. For example, a mobile game might sell in-game currency as an In App Purchase, whereas a fitness tracker with In App Advertisements may offer users the option to permanently remove adverts for a one-time payment.

Paid

"Paid" monetization is a business model in which revenue is generated solely from purchasing the application. In certain cases, a "trial" version may be offered to showcase the application's features, but it is usually the exception rather than the norm. This type of monetization model is the least popular both in the United States and globally, with 8% of apps in the United States and 3% of apps globally choosing to monetize in this manner (Ceci, 2022b). Note, that statistics on the distribution of monetization methods in Uzbekistan were not available.

In App Advertising

In App Advertising is a monetization method in which a mobile application is offered for free, and revenue is generated by displaying advertisements across the user interface. These advertisements may come in one of many, or a combination of multiple forms (Tasyurek, 2021):

1. Banner ads: Small rectangular images typically placed across the top or bottom of the screen. Minimally intrusive and easy to implement.
2. Interstitial ads: Fully immersive ads which occupy the whole screen. May or may not be restrictive in terms of when the user is allowed to close the ad. Typically the most intrusive form of advertisement, usually to the annoyance of users.
3. Rewarded ads: Advertisements, often in video format, which incentivize playback by offering an in-app reward. Offers a good balance between intrusiveness and minimizing user frustration, since it is usually optional to open.
4. Native ads: Advertisements, which are designed to fit in with the general aesthetic of the application. Usually employed in applications where there is a "feed" of content within which the adverts can be seamlessly integrated. Ex. Facebook, Instagram ads, etc.

Subscription

Subscription-based monetization is a business model in which revenue is generated on a continual basis through weekly/monthly/yearly subscription fees. Felix Krohn (2018), Vice President of Wolters Kluwer argues that market conditions are shifting towards a customer-centric environment, and that the increase in popularity of subscription-based models are a reflection of that shift. He also argues that the business objective of creating a "hit" product is changing towards increasing the customer lifetime value, and subscription-based products are ones which evolve with the customer over time.

In App Promotions

In App Promotions are a form of monetization whereby suppliers (in this case medical providers) pay to increase their exposure on the application. Usually, this is achieved by modifying content algorithms to promote certain results over others. For example, olx.uz, a local consumer-to-consumer shopping website gives users the options to display their listings at the top of search results for a duration of their choosing if they are willing to pay.

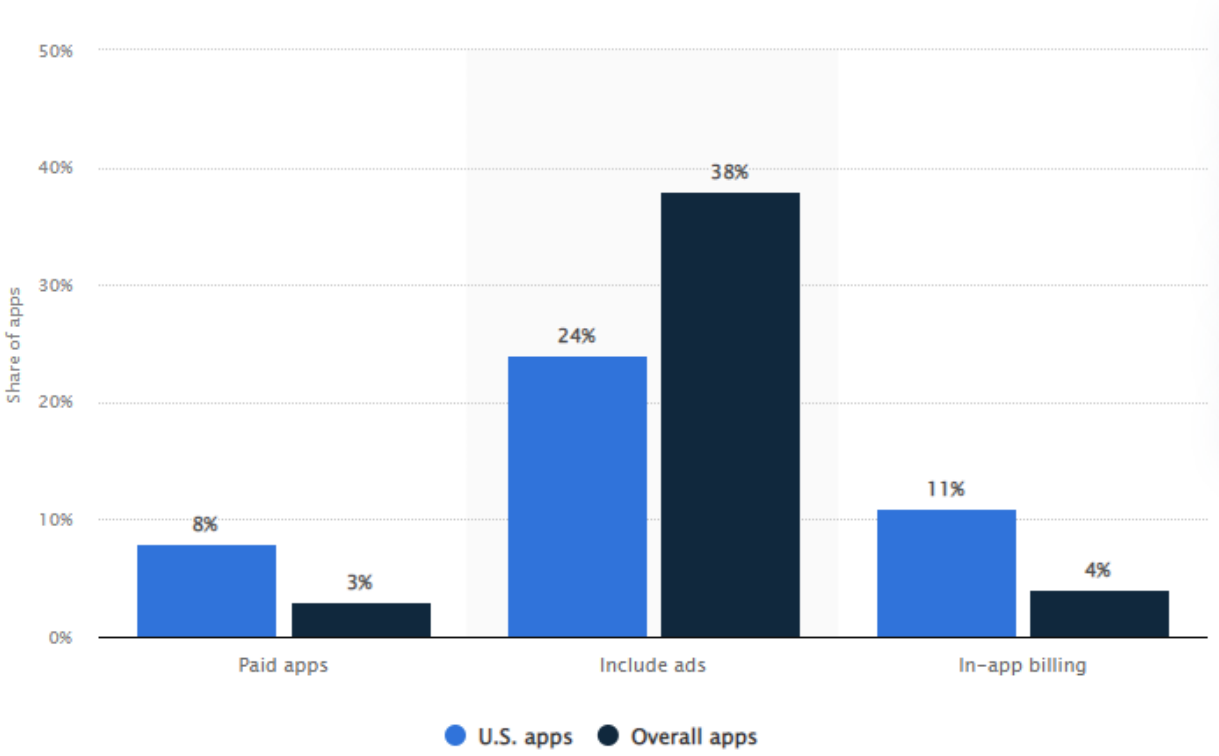


Fig. 3.3(a). Most popular monetization strategies, in the US and Globally, 2021.

3.3.1 Choosing the Correct Model

When choosing the monetization model for the patient-side, it is important to account for the financial constrictions of the population discussed in the 'Background' section of the report. Thus, paid, subscription-based, and freemium models would not be ideal for this purpose. Instead, in-app-advertisements in the form of banner ads and native ads would strike the ideal balance between financial accessibility for consumers, and minimizing the harm advertisements bring to the user experience.

The corporate-side paints a similar picture. As discussed, many public healthcare providers in the country run under an insufficient budget, which would rule out paid or subscription-based access. Therefore, launching with an in-app-promotion model would allow all providers to use and take advantage of the application, while providers that have the budget to promote their establishments can do so freely.

While the aforementioned is the optimal model based on the current economic and market conditions, they may change over time. It is important to note that monetization strategies can and often do change in response to shifts in market conditions.

4 Computing Methodology

4.1 Justification of Hardware/Software Used

4.1.1 User Platform

A mobile application was determined to be the ideal choice of platform for the project.

It is no secret that maximizing consumer reach plays an important role in determining the success of a product. This means that the platform of choice would have to be one which is accessible by the highest number of people in our target audience. According to the World Bank Education Statistics Database, the number of personal computers per 100 people was 3.1 in 2006 (the latest year such data was available). In contrast, mobile phone penetration in Uzbekistan was over 20% in 2007, and as of 2020, it has reached a staggering 99.8% (Helgi Analytics, 2022). Based on this data, we can infer that access to a personal computer is significantly lower among the general population compared to a mobile phone.

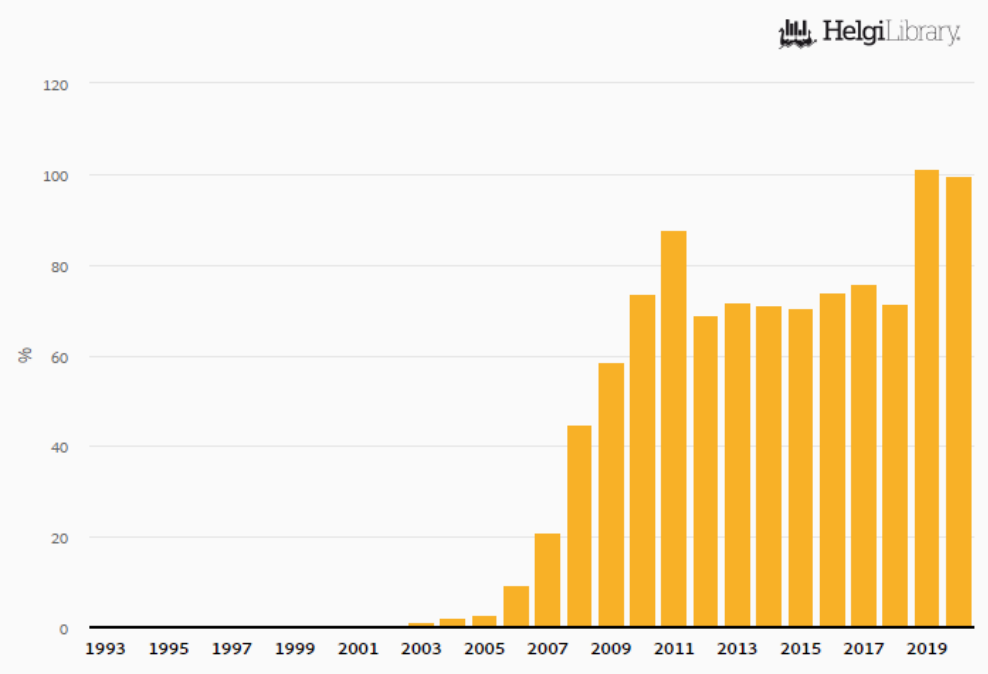


Fig 4.1.1(a). Mobile phone penetration in Uzbekistan, 2003-2020.

In addition, mobile phones have a number of benefits over a traditional responsive web-app, some of which were vital to the functionality of AppointMed:

1. Native access to hardware such as the camera, microphone, etc.
2. Background processing. Mobile applications have the option to run in the background, while web-apps are suspended as soon as the browser window is closed.
3. Notifications. Web-apps currently have no way to send push notifications to the user, whereas mobile apps do.

4.1.2 Hosting Platform

For the server-side, we will be using a cloud computing provider, as it requires zero upfront cost, and in most cases, is a cheaper option than buying custom hardware. Cloud providers can take advantage of economies of scale, have built-in hardware security and redundancy, and offer their own technical support, which is why it is cheaper to rent a server rather than build and maintain an identical one. According to Drake and Turner (2022), Amazon Web Services is in the top three cloud computing platforms by features, and has a free 12-month trial so that we can test our application. Additionally, it has a wide variety of server tiers for vertical scaling (which may prove useful in the future). Furthermore, I have prior experience using AWS from the Distributed Systems and Cloud Computing module.

4.1.3 Backend Server Programming Language/Framework

For the backend server, the .NET 6 framework (which is coded in C#) was chosen for development. First, .NET is an extremely performant framework. ASP.NET is ranked number 1 on the TechEmpower 2021 Plaintext Response Benchmark, beating out other popular alternatives such as Node.js and Django. In addition, C# has a large support community on StackOverflow, with over 1.5 million questions asked. Having the option to refer to an experienced community of developers can greatly assist the development process. Furthermore, the framework is guaranteed long-term support from Microsoft. .NET and C# both receive major yearly updates, and .NET 6 is promised to receive 3 years of long-term support. Moreover, .NET is fully cross-platform, giving developers the option to host on Windows, Linux, and MacOS. Lastly, and most importantly, I have a substantial amount of experience developing applications with C# and .NET, both from

previous course works and personal projects.

Authentication and Authorization Management

For authentication and authorization, it was decided to use the ASP.NET Identity extension, which is developed by Microsoft. ASP.NET Identity seamlessly integrates into .NET applications, and has an extremely wide variety of customization options, including but not limited to Claims based authentication, Role based authentication, and Social Login Providers such as Google, Meta, etc. It must be noted that using ASP.NET Identity requires additional time and effort to set up and manage, increasing the complexity of the application. There are several reasons it was used, as opposed to a simpler and easier to manage solution such as Firebase:

1. Allows us to manage the hosting and persistence of user data, rather than being locked in to Google's proprietary platform.
2. Offers better fine tuning of options for authentication and authorization.
3. Can be integrated into the application as a separate set of endpoints.
4. Is a free extension, as opposed to Firebase, which starts charging as the number of requests scales up.

4.1.4 Database Server

For the database server, MS SQL was determined to be the optimal choice. For starters, MS SQL is a relational database, which is the type typically used to store structured data such as ours. In addition, SQL servers ensure more reliability and data integrity compared to NoSQL counterparts (Sahatqija et. al., 2018). Moreover, relational databases have very secure mechanisms which ensure the security of the services (Mohamed et. al., 2018). Furthermore, prior experience using MS SQL for course works also played a key role in choosing this specific database management system. However, relational databases do have some disadvantages over their non-relational counterparts which must be addressed. Relational databases are not dynamic in their schema, meaning that as the structure of the data changes, it is more difficult to manage compared to non-relational databases. In addition, SQL requires a schema upfront, which forces developers to map out the data structure before starting to code. In our project, both of these issues have been solved using Entity Framework Core, an object relational mapping framework which utilizes a code-first approach to development. With EF

Core, entities and their relationships can be defined in code, relieving developers of the hassle of defining a schema. Furthermore, any changes in the data structure can be reflected in the database using the built-in migration functionality.

4.1.5 Frontend Mobile Application Programming Language/Framework

For the mobile application development, the Flutter Framework, using the Dart programming language, was chosen. As previously discussed, maximizing consumer reach was a priority for this project, so it was necessary to choose a cross-platform development framework which could deploy to both Android and iOS with a single codebase. Flutter is one of just a handful of cross-platform development frameworks, which also include React Native, Xamarin, and Ionic. In terms of performance, Flutter is the closest to native applications, due to the fact that it compiles directly to native code, as opposed to React Native, for example, which uses a JavaScript engine as a bridge. Flutter and Dart are both supported by Google, who has continued to rapidly develop and update both the language and framework since their inception. Lastly, one of the personal objectives set for this project was to learn a new programming language and framework. As the popularity of Flutter and Dart continue to rise rapidly, and with the addition of support for both web and cross-platform desktop application development, it was a clear choice.

4.2 Software Architecture

Deployment

For the server-side application, a monolithic architecture was chosen for deployment. Monolithic applications have a number of benefits and drawbacks (Kharenko, 2015), outlined below:

Benefits:

- Faster initial development and testing phase
- Easier to package and deploy
- Scales both horizontally and vertically
- Does not require the development of a communication mechanism to send data between services

- Easier to implement systemwide changes

Drawbacks:

- Fundamentally limited in size and complexity
- Larger complexity leads to difficulty understanding and maintaining code
- Harder to develop and maintain in a team environment as opposed to microservices
- Partial failure brings down the entire system
- Difficult to implement new technologies and frameworks down the line

The limited scale of the application, the tight schedule, and the restriction to a single developer meant that a monolithic application was the optimal choice, despite its drawbacks.

Code Architecture

For the logical architecture of the code, clean architecture was chosen for its numerous benefits. First, structuring the application around the domain and its core entities allows developers to change frameworks and dependencies with minimal work to transition. Next, decoupling different sections of the application means that changes are easier to implement without breaking the entirety of the codebase. Furthermore, this approach is highly maintainable regardless of the scale of the application.

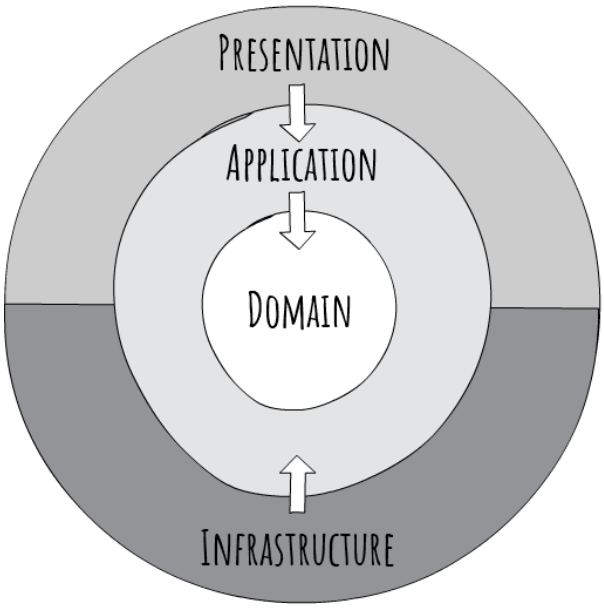


Fig. 4.2(a). Typical Clean Architecture model

In our server-side application, we can see this pattern in the dependency graph:

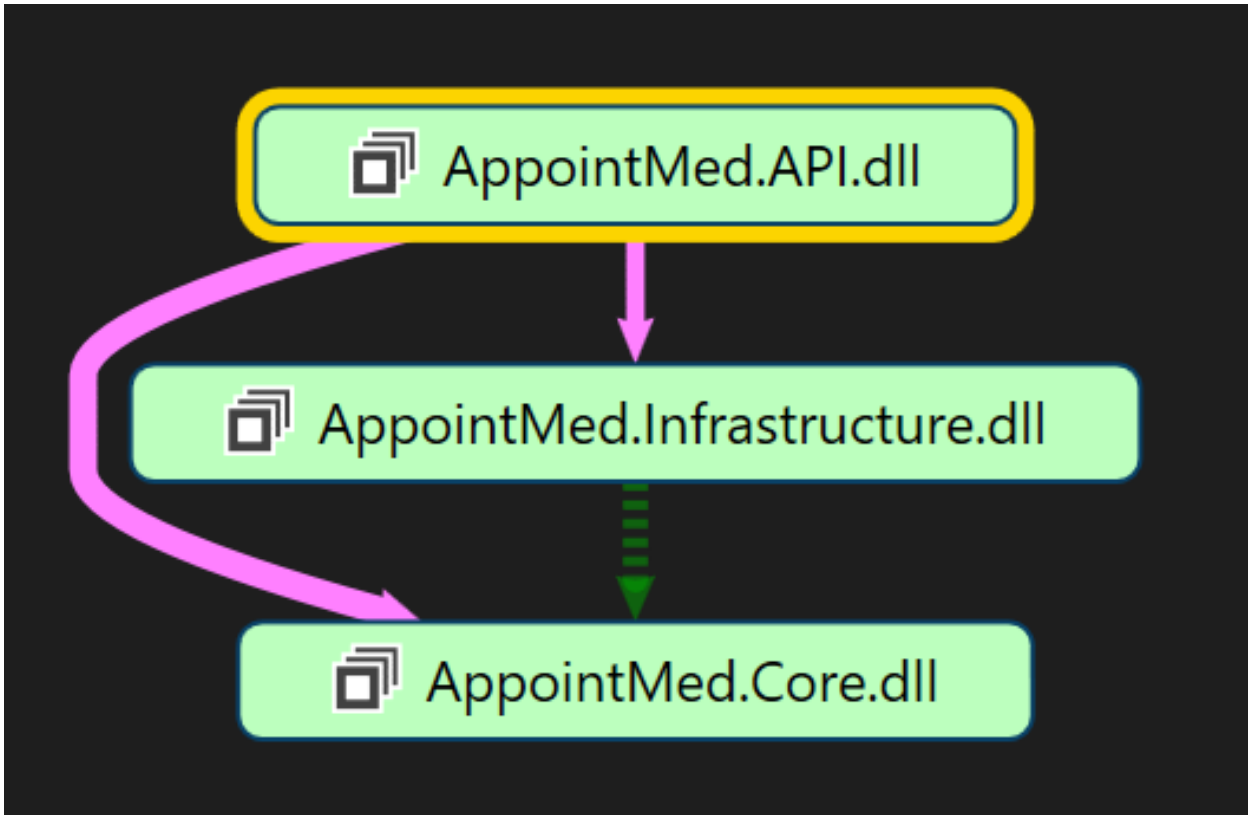


Fig. 4.2(b). Dependency graph of the server-side application project.

4.3 Data Structure

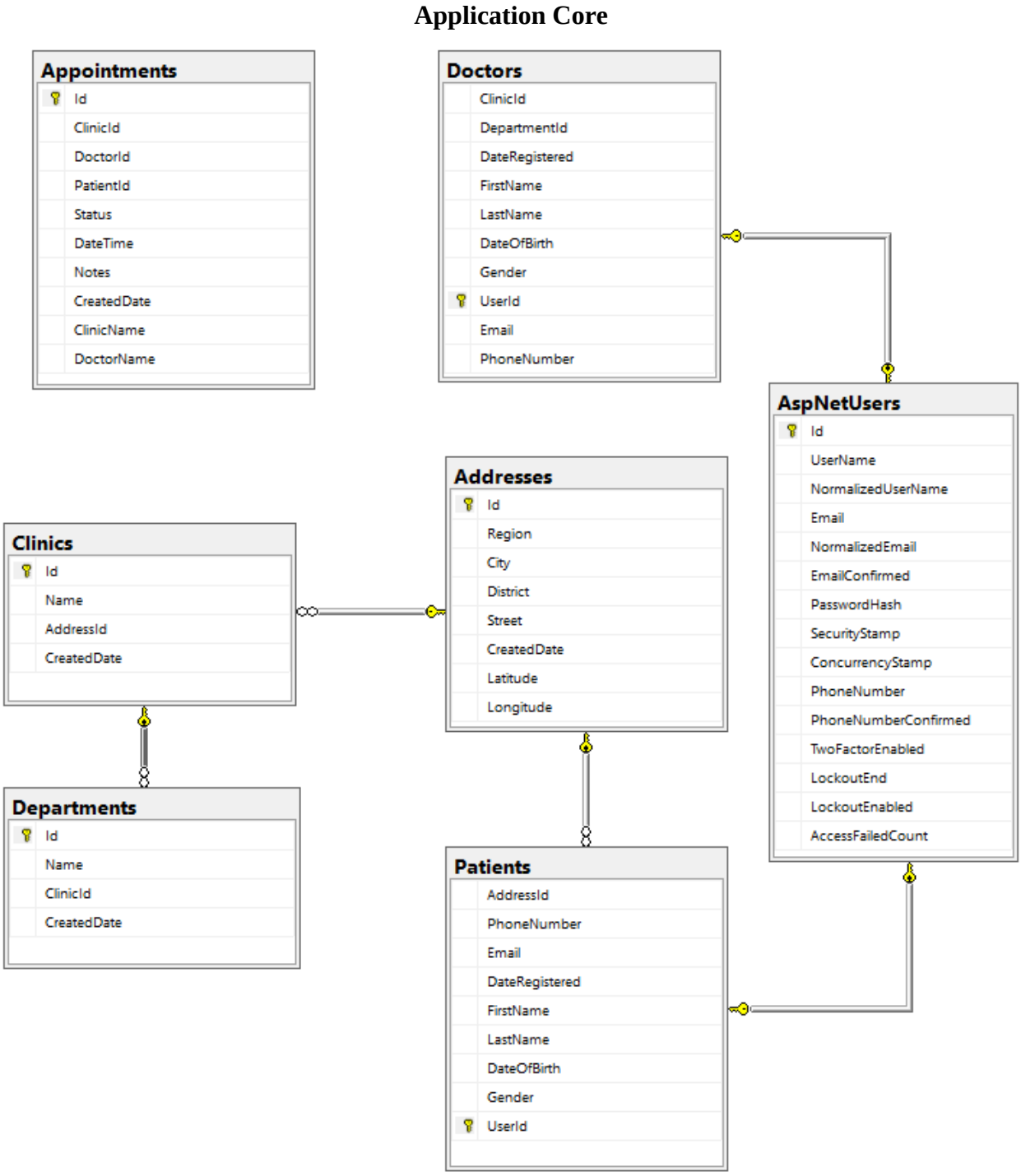


Fig. 4.3(a). Table diagram of the database schema, domain layer only.

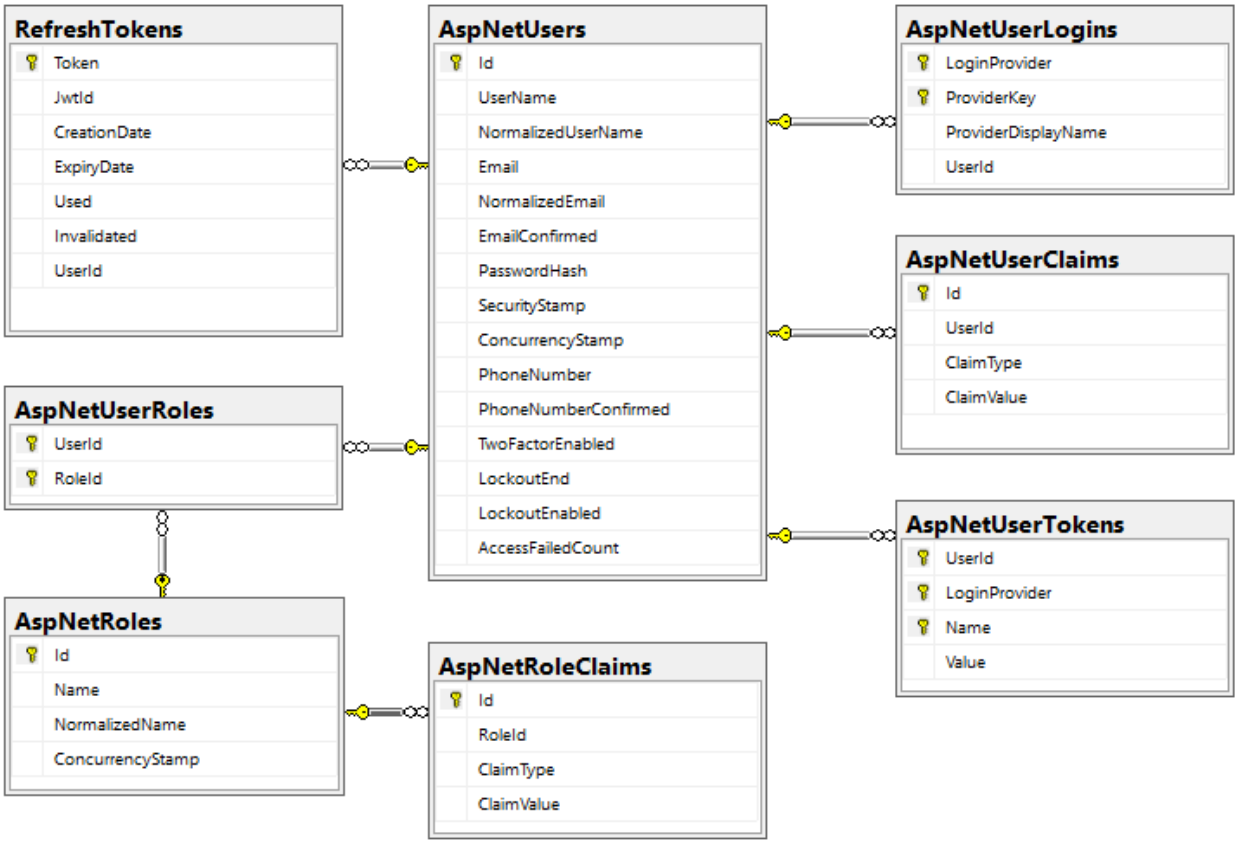


Fig. 4.3(b). Table diagram of the database schema, identity models only.

4.4 Activity Flow

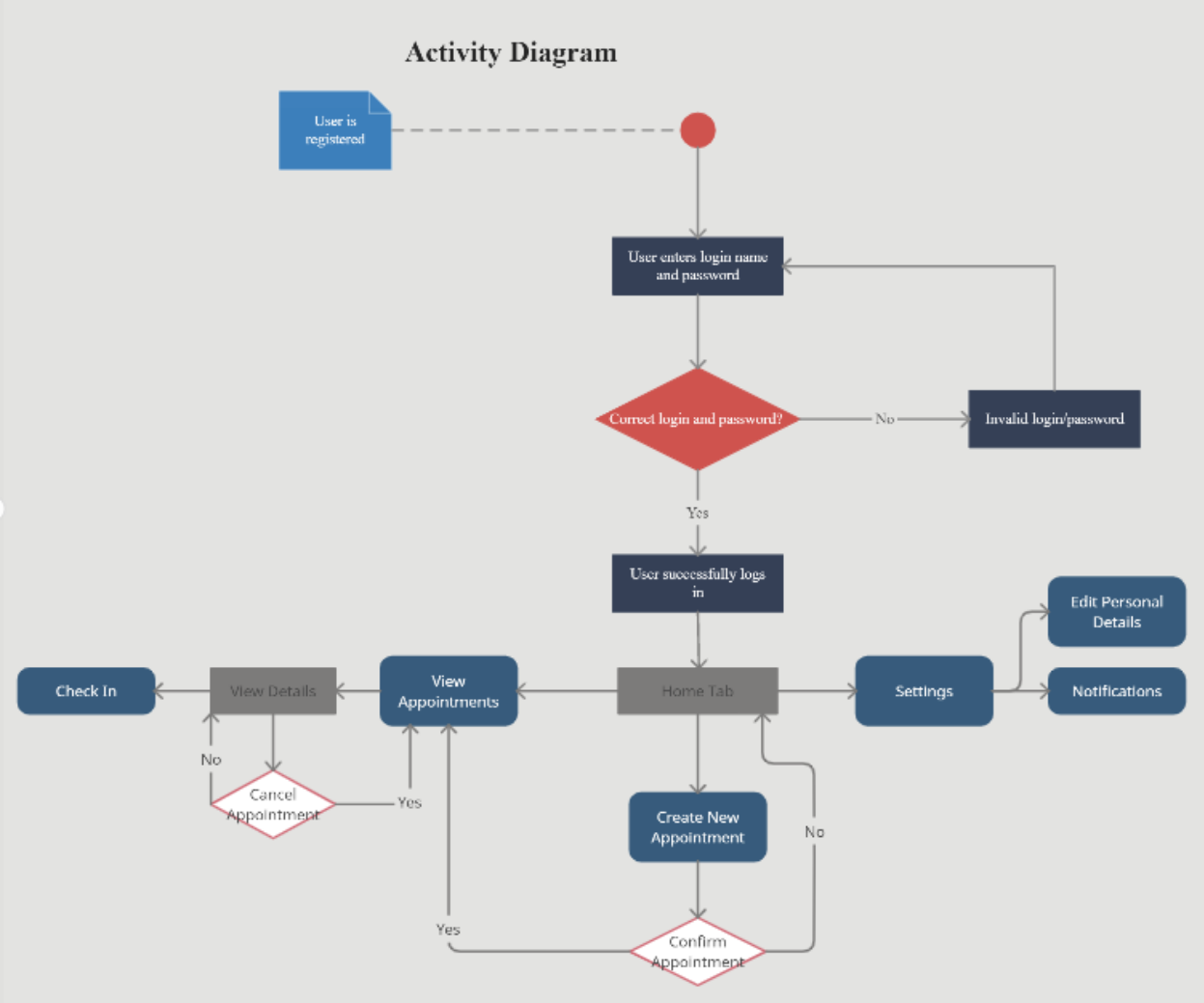


Fig. 4.4(a). Activity flow for the client-side mobile application.

4.5 Development Lifecycle

For the software development lifecycle, an agile methodology, specifically Kanban was chosen to manage the workflow of the project. Initially, the plan was to implement the Scrum methodology, but several drawbacks of the approach were identified during the process. First, while Scrum has found success in many team environments, its efficiency within a project with only one developer is questionable. Assigning the roles of product owner, scrum master, and team member is rather pointless when there is only one person to assign it to. In addition, the scrum methodology calls for daily scrum meetings. While this is a great way for members to communicate their progress and any issues they may be facing, and for the scrum master to

ensure that the process is going smoothly, it is unnecessary when both parties consist of the same person. Furthermore, scrum requires segmenting the workflow into ‘sprints’ with a fixed length of time, and assigning ‘stories’ to each member. This, in turn, requires splitting larger, more abstract tasks into smaller tasks, and assigning ‘points’ based on the difficulty of the task. Again, while this is an effective way to track progress, it can consume substantial amounts of time which could otherwise be spent on actual development rather than planning.

In contrast, Kanban proved to be a better fit, because of its less restrictive guidelines and emphasis on keeping the workflow tracking simple:

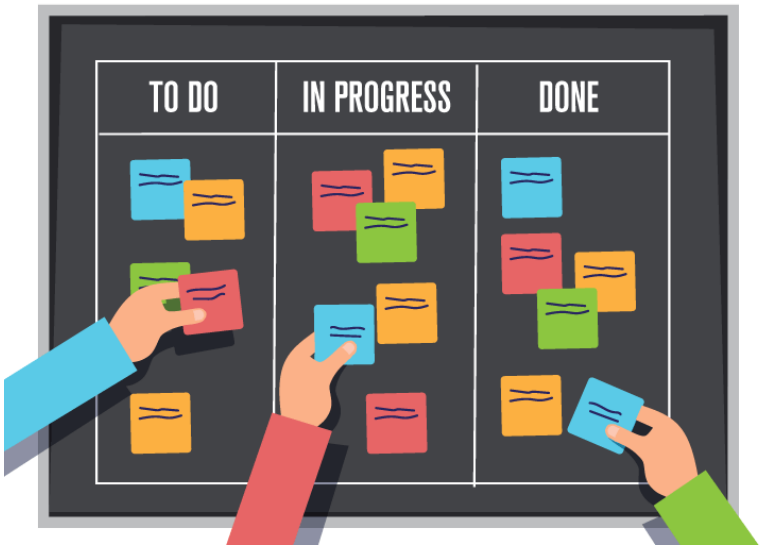


Fig. 4.5(a). Typical Kanban board used to monitor workflow.

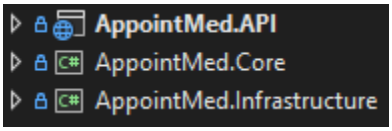
What’s more, it was a better fit for the project due to the way planning was set up in the initial phases, with larger, more abstract tasks, and varying durations assigned to each task.

4.6 Tasks

Data Structure Modelling. 11/10/21 – 11/30/21

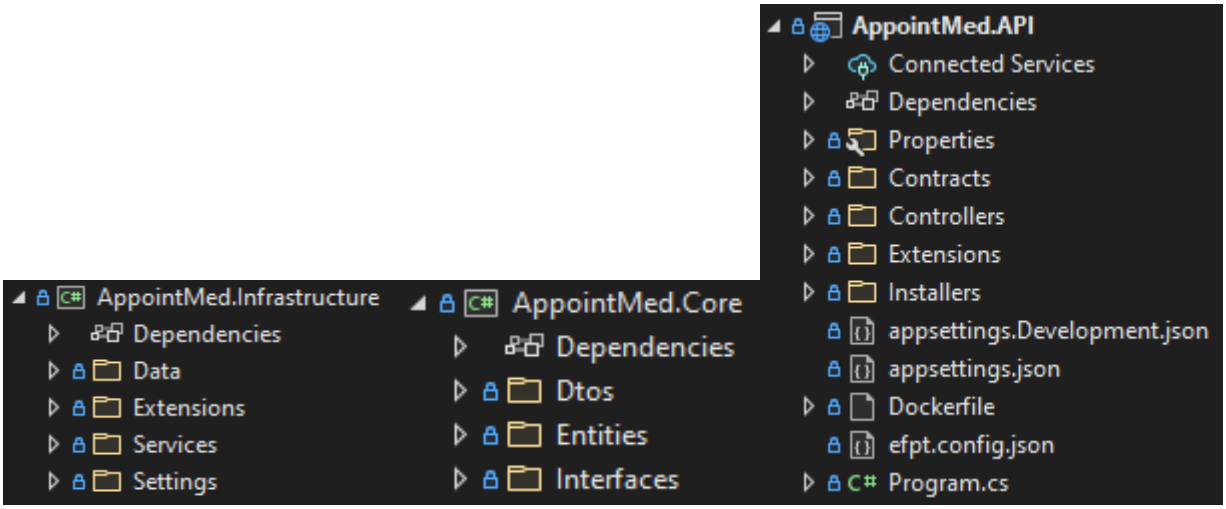
This task consisted of planning out the core domain of the project and deciding on how the objects would be structured and interact with each other. Please refer to Figures 4.3(a) and 4.3(b) for the completed version of the schema. Note, that these are the final versions of the schema; the model changed over the course of the project, and the database went through multiple migrations.

System Architecture Modelling. 12/3/21 – 12/29/21



To stay consistent with clean architecture guidelines, the application was split into three separate projects: Core, containing all of the models, dtos, and interfaces; Infrastructure, containing the data access layer, both for the appointment system and authentication; API, containing the exposed endpoints for our client-side mobile application to communicate with the server-side application.

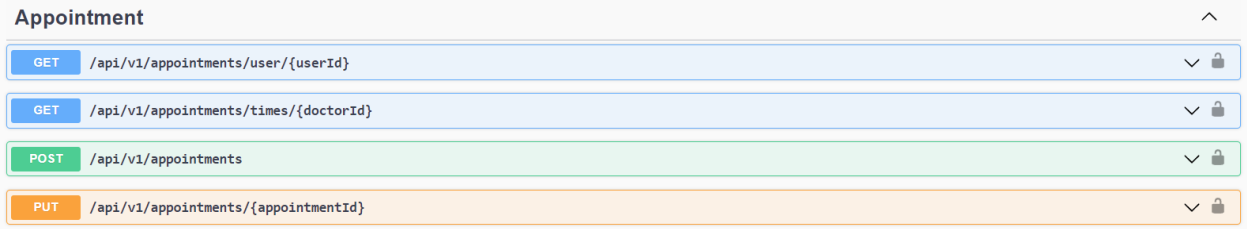
In addition, dependencies were compliant with clean architecture guidelines as well. Referring to Figure 4.2(b), we can observe that dependencies flow only inwards towards the application core layer. This approach ensures that our core domain is not dependent on any external frameworks, packages, etc., and that any changes in the implementation (such as the data access, endpoints, mapping, etc.) will not affect the domain layer.

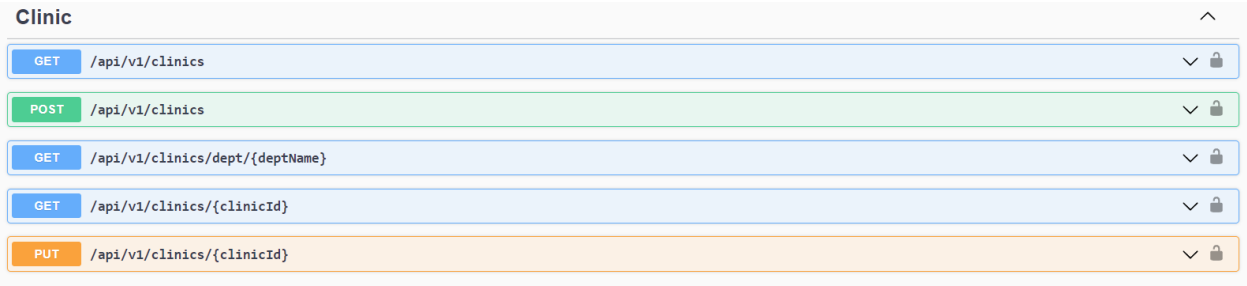


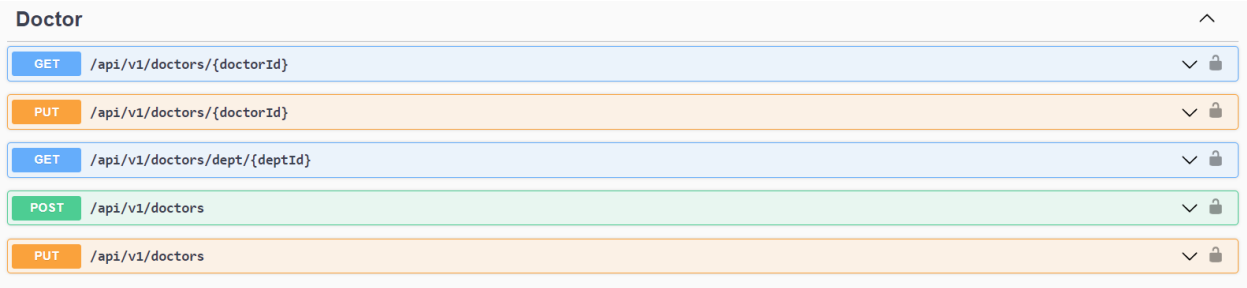
Backend logic and API Development. 1/5/22 – 2/12/22

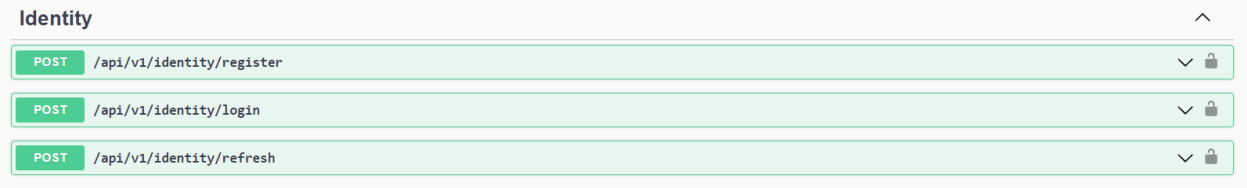
As previously mentioned, Entity Framework Core was used to map our objects and create the database scheme. Entity Framework Core also allows us to utilize its built-in methods to access and modify our database tables. Our data access/service classes were initialized in the API using dependency injection. The ASP.NET web API handles all of the middleware and routing. ASP.NET Identity is used to handle authentication and authorization. Most controllers are locked

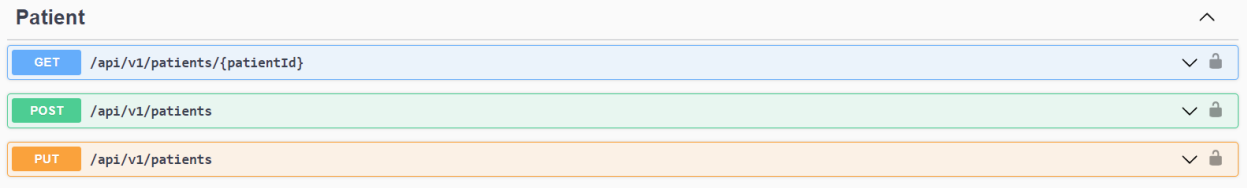
using Role based authorization. All controllers are locked using the provided authentication scheme. The following endpoints are exposed to the user:









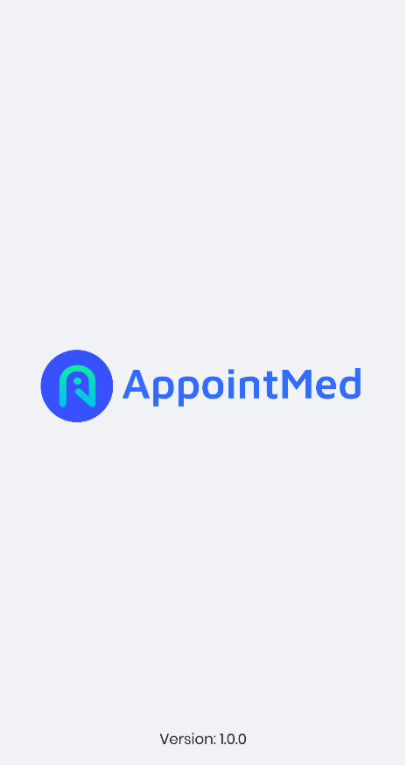


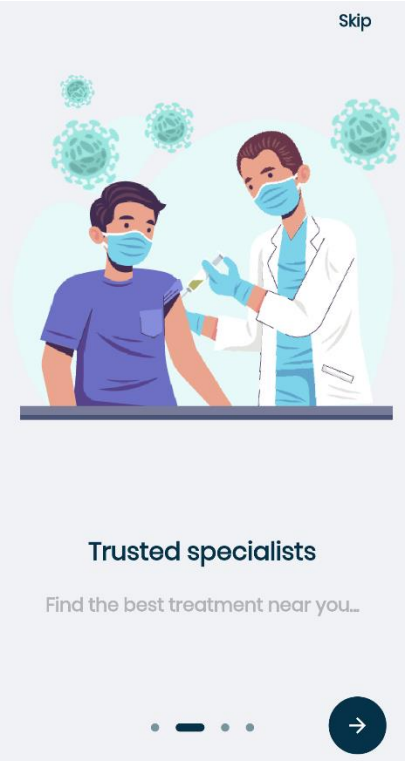
Backend Quality Assurance. 2/13/22 – 2/17/22

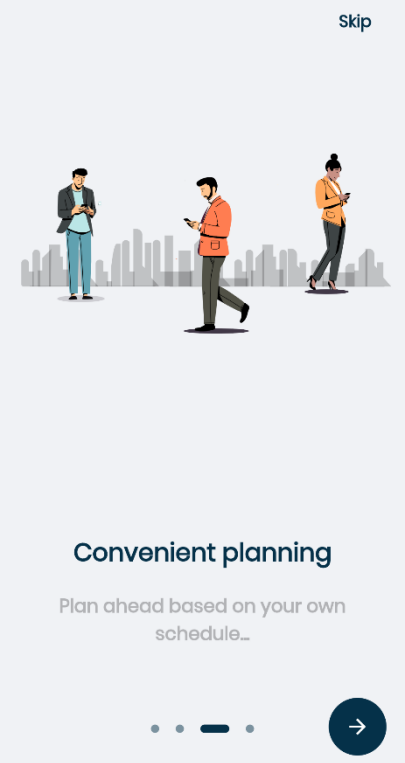
All endpoints are tested, both for functionality, and for authentication/authorization. More extensive testing details can be found in the results section.

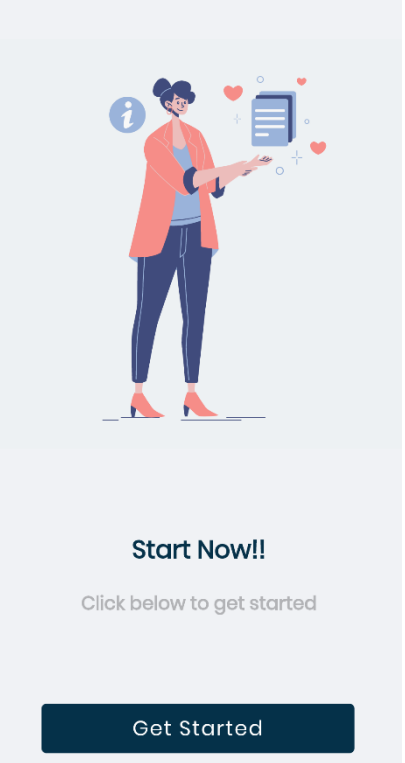
UX Prototype. 2/18/22 – 2/19/22

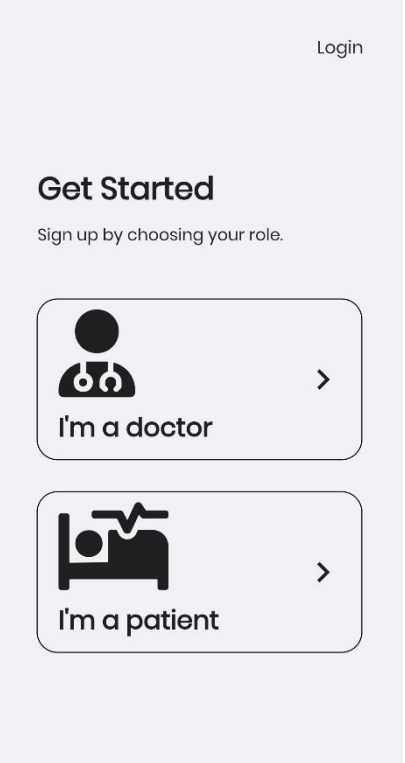
Splash Screen and Onboarding



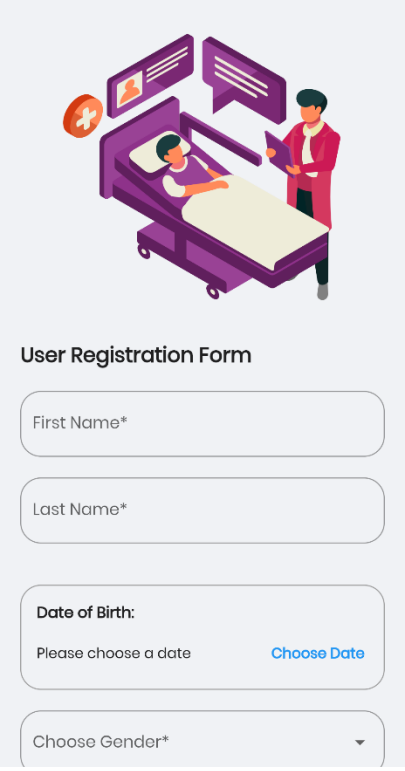


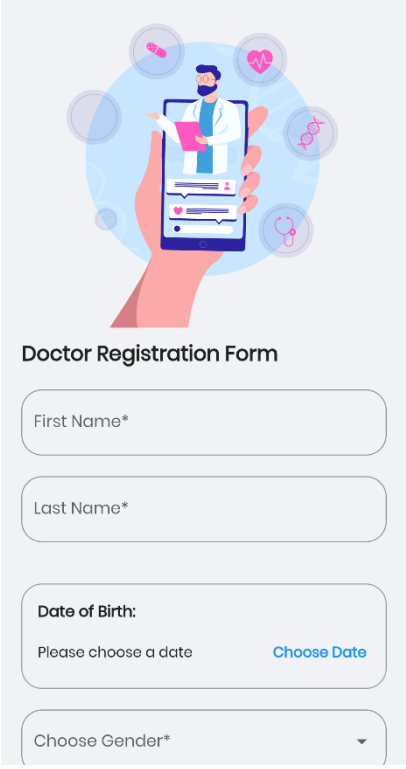


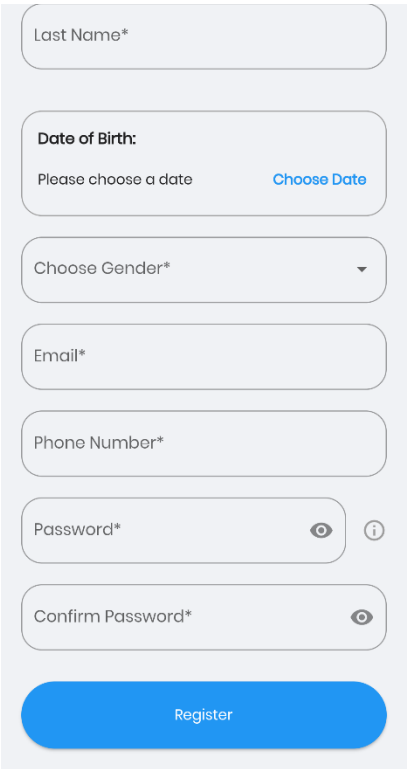




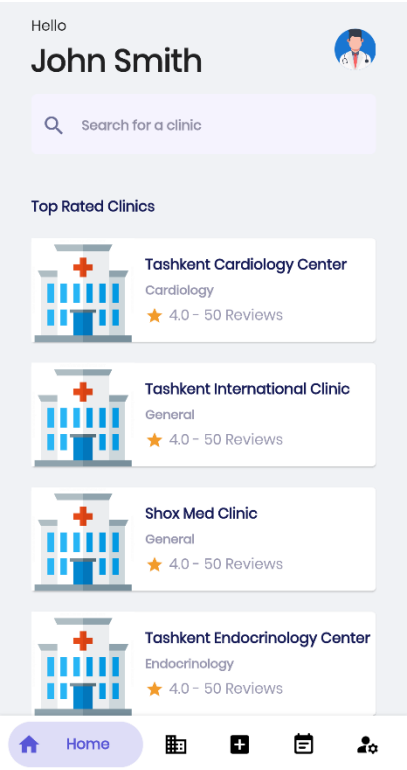
Registration Forms

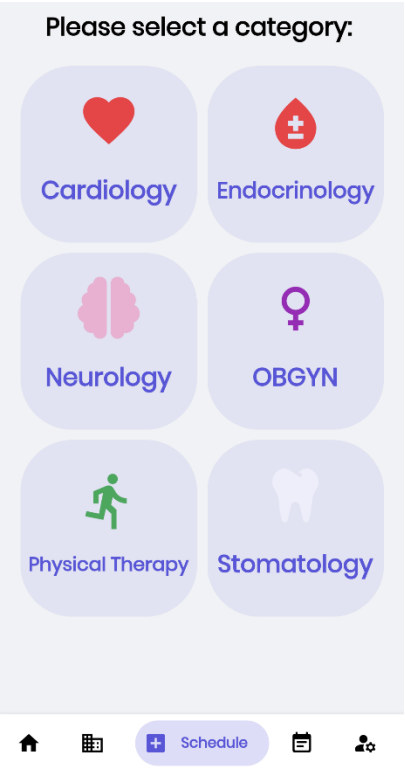


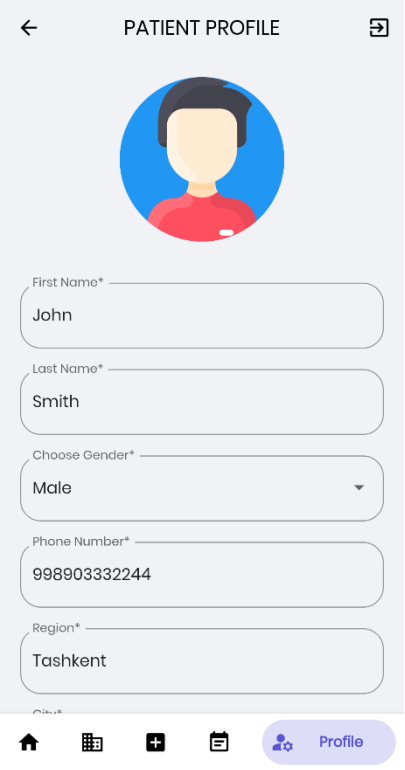




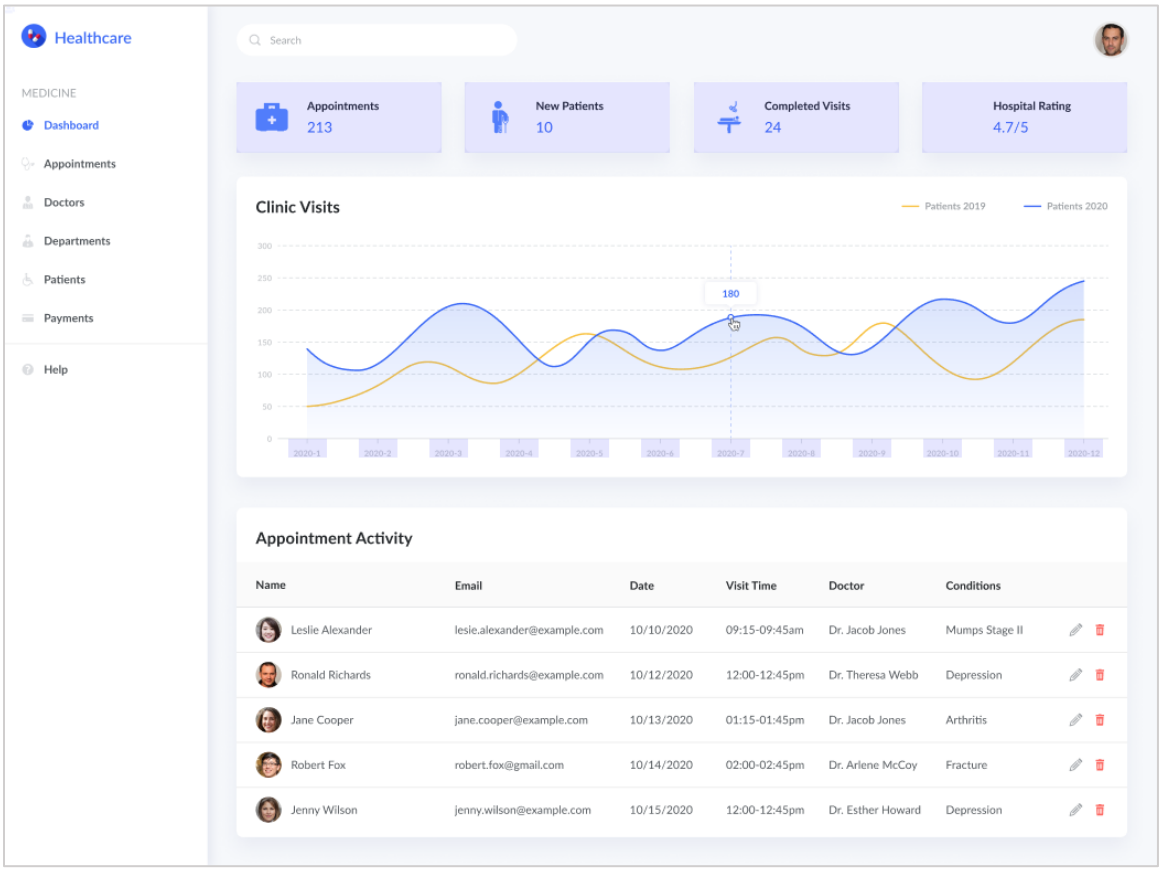
Main Screens

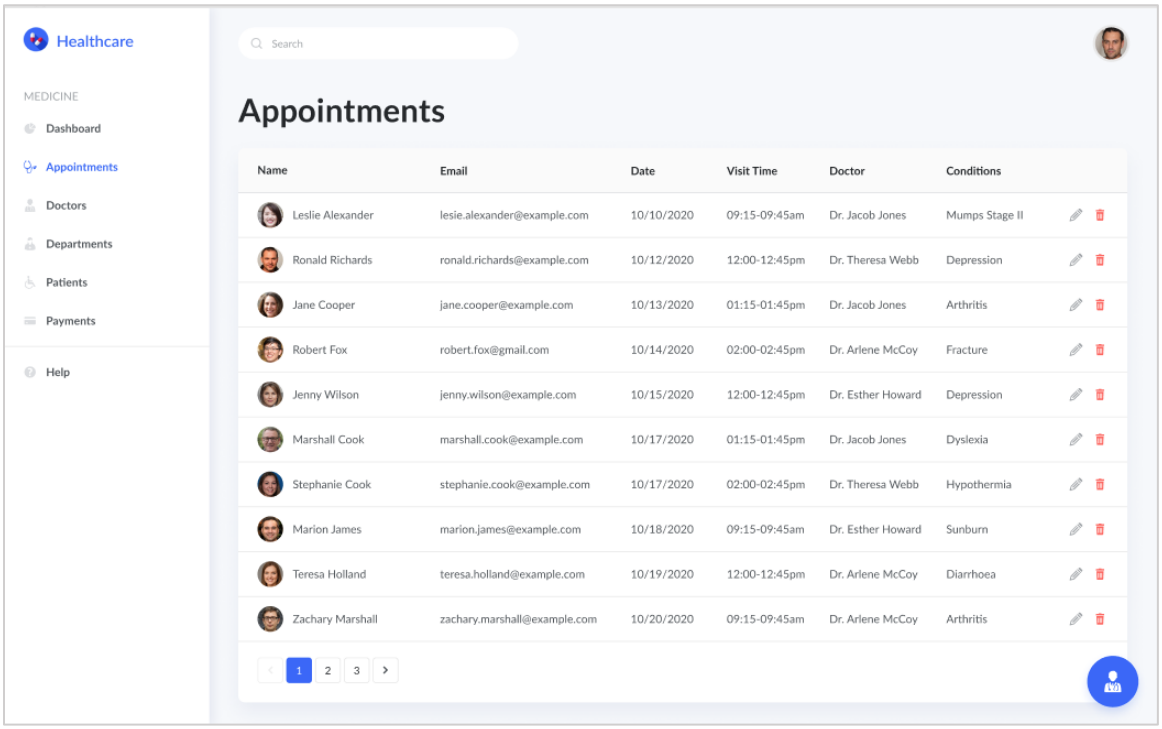






Admin Panel Prototypes (Backlogged)





Mobile UI Development. 2/20/22 – 3/7/22

Due to various delays, the client-side mobile application was developed under a very limited time frame. As a result, research into various architecture models and their implementation could not be accomplished. Nevertheless, the code *is* structured, albeit not to the greatest extent. Widgets have been refactored to meet certain standards and best practices. Duplication of code is present to a limited extent, but time constraints did not allow for refactoring.

Mobile Application prototype. 3/10/22 – 3/12/22

A prototype with a fully working feature set was developed, but certain bugs still needed to be corrected.

Mobile UI Quality Assurance. 3/13/22 – 3/15/22

All features were tested, bugs were corrected for the most part. More extensive testing details can be found in the results section.

5 Results

All in all, we managed to meet all of the objectives we set at the beginning of the project:

Business Objectives:

- ✓ Develop a financially sustainable and viable appointment booking framework which can be integrated into the current systems of medical providers with ease
- ✓ Analyze different monetization options and select one that results in the lowest costs for both patients and medical providers alike
- ✓ Analyze the different platforms available for development (mobile, web, etc.), and select one that results in the largest reach to customers
- ✓ Define the target user demographic

Academic Objectives

- ✓ Analyze the general state of the current healthcare system of Uzbekistan
- ✓ Outline the shortcomings, inefficiencies, and issues facing the healthcare system
- ✓ Identify the root causes of said issues
- ✓ Develop a potential solution supported by the research that has been conducted

- ✓ Analyze the results of the solution and come to a conclusion on its potential viability in a real-world environment

Personal Objectives

- ✓ Develop an application that can be used within a portfolio to showcase my experience and skills with modern OOP languages
- ✓ Follow industry standard ‘best practices’ during the development phase
- ✓ Learn how to plan a project and manage time effectively
- ✓ Learn a new programming language and mobile application development framework, in the form of Flutter and Dart
- ✓ Challenge myself to create an application of a size and scale on which I have not worked on before

As for the technical objectives and plan we laid out, all of our tasks were completed by the deadline. While certain changes had to be made, both to the scope of the project and the Gantt chart, these changes were planned and implemented to be able to deliver a working product by the end of the timeline.

TASK NAME	START DATE	END DATE	START ON DAY*	DURATION* (WORK DAYS)	PERCENT COMPLETE
Business Idea	10/1	10/15	0	15	100%
Background Research	10/15	10/21	14	7	100%
Project Scope and Limitations	10/26	10/31	25	6	100%
Timeline Planning	11/1	11/2	31	2	100%
Project Initiation Document	11/3	11/9	33	7	100%
Data Structure Modelling	11/10	11/30	40	21	100%
System Architecture Modelling	12/3	12/29	63	27	100%
Backend logic and API Development	1/5	2/12	96	39	100%
Backend Quality Assurance	2/13	2/17	135	5	100%
UX Prototype	2/18	2/19	140	1	100%

Mobile UI Development	2/20	3/7	141	17	100%
Mobile Application prototype	3/10	3/12	160	3	100%
Mobile UI Quality Assurance	3/13	3/15	163	3	100%
Deploying a Working Prototype	3/23	3/28	173	6	100%
					100%
Deploying Production Version	4/1	4/2	182	2	100%
Analyzing Outcomes and Conclusion	4/3	4/8	184	6	100%
Finalizing Report	4/9	4/13	190	5	100%

5.1 Testing

Black-box testing was conducted to ensure the functionality of both the server and client-side applications:

Test Case	Expected Result	Actual Result
Try to access app without an internet connection	App displays an error screen asking to try again with internet access.	As expected.
Register a new patient/doctor.	Successfully register a new patient/doctor.	As expected.
Register a new patient/doctor with invalid email and password.	Error message is returned.	As expected.
Login using correct credentials.	Successful login.	As expected.
Login using incorrect credentials.	Error message is returned.	As expected.
Update user profile.	Successfully updated user profile.	As expected.
Schedule Appointment.	Successfully scheduled appointment.	As expected.
View List of Appointments.	List of Appointments is presented.	As expected.
Check into Appointment.	Patient checks in and appointment status is updated.	As expected.
Complete Appointment.	Doctor completes appointment and status is updated.	As expected.
Cancel Appointment.	Patient cancels appointment and status is updated.	As expected.

6 Conclusion

The appointment booking solution, AppointMed, provides users with an easy and intuitive way to book appointments with the doctor. Over the course of the project, the business, academic, and personal objectives that were laid out have been met. In response to certain delays, the scope and feature set of the application was scaled back. This planned change allowed for the delivery of a functioning system by the deadline. It is worth pointing out that the feature set and overall purpose of the application is founded based on the market analysis conducted earlier in the process. The application is designed to fulfill a demand within the market that has not yet been fulfilled. With these factors in mind, it can be concluded that with further developments and improvements, the solution has potential long-term viability.

7 Final Chapter

7.1 Self-Assessment

Planning

All in all, while I did reach the objectives that I had set, I was not entirely content with the manner in which it was reached. The initial scope and planning of the project exposed my lack of experience and knowledge in accurately assessing the amount of work it would take to complete such a project, and the amount of work I could do in that given timeframe. As a result, certain features, such as the admin panel for clinic administrators, had to be backlogged for future development. In addition, the initial planning phase of the project was flawed. By segmenting the project into large, abstract chunks, it was difficult to estimate how much of the project was completed. That led to large spans of time where the project was not being worked on, because I was under the impression that progress was going according to schedule. This approach backfired when I realized that the amount of time allocated towards creating the frontend mobile application would not be enough without “crunch” time. This led to certain corners to be cut, most prominently in UX design and testing. Moreover, in the first version of my Gantt time table, I failed to account for the time it would take to submit course works from the other modules. While I did partially correct it when submitting the progress report, I now realize that the amount of time I dedicated towards course works and exam preparation was not sufficient, leading to even more schedule revisions down the line.

Coding

On the technical side of things, there were no major difficulties, only mistakes stemming from a lack of experience working on a project of this size. Looking back, I now realize that I had spent an excessive amount of time planning and deciding on a system architecture which would be easy to maintain. After deciding to develop the application using the Clean Architecture model, I quickly found out that on a project of this scale, complex architectures such as the one I chose would end up unnecessarily fragmenting the codebase and requiring more time to maintain than a more traditional and simple approach. I also now realize that learning an entirely new language and framework from scratch (while potentially beneficial for my career) was something best done during my own time, and not as a prerequisite to completing my final year project. Initially, I had planned on developing the server-side application with Django (a framework with which I had no experience), but luckily, decided to switch back to .NET very early in the process. If I had to undertake a similar assignment in the future, I would make sure to stick to an area of development I am more familiar with.

Character

Finally, this project was somewhat of a rude awakening that I needed to learn to manage my time effectively. There were many instances over the course of this past year where I knew I needed to be working on the project, but chose to prioritize less urgent tasks. All of the work that was behind schedule did eventually catch up to me in the latter stages of the process, and I had no choice but to put everything else on hold and make up for lost time. Reflecting on this journey, I can see that it was a clear example of why certain people, teams, and companies are able to meet deadlines and achieve the targets they set with ease, and why others reap the consequences of the decisions they have sowed, and are left paying back the metaphorical ‘debt’ they have taken on. I’ve also seen how small choices, whether it be in the planning, designing, or development phase, can drastically alter the direction of a project, and why it’s important to not only monitor the progress of a project, but also make sure that the initial goals, visions, and targets are still aligned with what is being produced.

7.2 Limitations

First and foremost, I'd like to point out that this project was heavily constrained in terms of time, manpower, and experience. While the background research and methodology were completed to the best of my abilities, I am not someone who has experience working in, or extensively studying the healthcare sector, nor am I someone who fully understands the economic or social factors in play. Moreover, the limited literature that *is* available on the subject is often outdated, poorly structured, or contains potentially subjective points which are not backed by concrete, quantitative data. Objective, reliable, and relatively recent studies such as the report by the WHO (Ahmedov et. al., 2014) are few and far between.

Moreover, both the server-side and client-side are limited in features. While the basic functionality is present, developing and deploying an application for real world use would require a more robust feature set, such as a chat system, clinic and doctor review system, test result delivery system, etc. In addition, while the server-side application is built on a performant framework, it has not been tested under extensive loads, such as those which it would experience with a high number of users.

7.3 Future Improvements

Circling back to the scope definition of the project, we mentioned a few key features which could be added in the future:

- Messaging feature between doctors and patients
- Test result collection
- Review system for medical providers and doctors
- Payment system
- Admin Panel

In addition, I believe restructuring the application in a way which makes it easy to integrate within a current EMR would benefit its long-term viability. While most medical providers in the country still operate on paper records, the government has expressed interest in switching to a unified electronic record system, meaning that a large portion of the country's medical providers would be operating with an EMR at some point in the future. Adopting an appointment system

which seamlessly integrates into their current system would be a more enticing option than having to use two separate applications.

Lastly, the project would benefit from a product viability assessment, ideally conducted by someone with experience in the Uzbek market and in the healthcare sector. While the design choices and methodology were justified based on research (where possible), in a developing country such as Uzbekistan, market conditions, social factors, etc. are constantly shifting, and having someone with the knowledge and expertise of designing a product for the local market would be advantageous.

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