Mobile applications and the digital transformation of healthcare.

1. Introduction

The healthcare industry plays a vital role and is integral to every human being's life. According to the World Health Organization (WHO), the global strategy relies on the further development of different technology applications for the health domain to support or to improve health behaviors, quality of life, and people's well-being and contribute to the overall performance of digital health (WHO, 2021). The pandemic has brought a lot of inconvenient situations, such as social isolation, anxiety, online education, etc. What is more, it further complicated arranging hospital appointments and accessing them. Recent years have seen increased integration of smartphones among healthcare professionals as well as the public. Therefore, an increasing number of healthcare centers are digitalizing their approach and implementing their mobile health apps to enable easier access to care for their patients and an organized work environment for the staff (Imran et al. 2020).

2. Paper-Based Appointment System

Waiting for a service is one of the most unpleasant events in everyday life. According to, World Health Organization, every year, an inadmissible number of patients suffer injuries or die because of unsafe and inadequate quality health care, although most of these injuries are avoidable (Patient Safety 2022). Undoubtedly, every patient deserves timely help and treatment (Zhang, X 2017). However, this may only be partially satisfied using the traditional medical scheduling approach. In this globalized world, hospitals still use the old-fashioned way of booking appointments or registering for a doctor over the telephone or in person (Nikolova –2019). Using the traditional method, clinics utilize a system in which patients are automatically allocated to an appointment time and a specialist based on the free slot. Without proper queue management, the consequences might be harmful to both sides. For example, long waiting times contributes to a wide range of health issues, including impaired access to care or patient dissatisfaction, which may also directly affect the financial viability of the institution, and its reputation, and impose great stress over the clinic (Xie, Z 2017). In addition, this type of system has a wide range of constraints. For example, there needs to be a mechanism to cancel an appointment or get a reminder. Patients must fill out a registration form when arriving at the hospital, expanding the overall time spent at the clinic. Moreover, the patient information on the papers must be corrected when changes need to be made, and the risk of misplacing a record is transparent (SoftClinic 2021).

2.1. The popularity of appointment scheduling

Waiting times have been a subject of discussion since 1984, when Lindsay and Feigenbaum introduced the queuing model, proving that considerable delays in patient booking impose costs (Lindsay et al. 1984). Thirty-eight years later, enhancing patient care experience is still a topic of conversation. As seen in Figure 1, appointment scheduling has been discussed in many literature review topics (Ali Ala & Feng Chen 2022). There has been a substantial increase in the number of papers. In 2012 the total number of manuscripts was 40, whereas, in 2020, the number of articles doubled. Consequently, the public healthcare sector realizes the benefit of reforming the healthcare system.

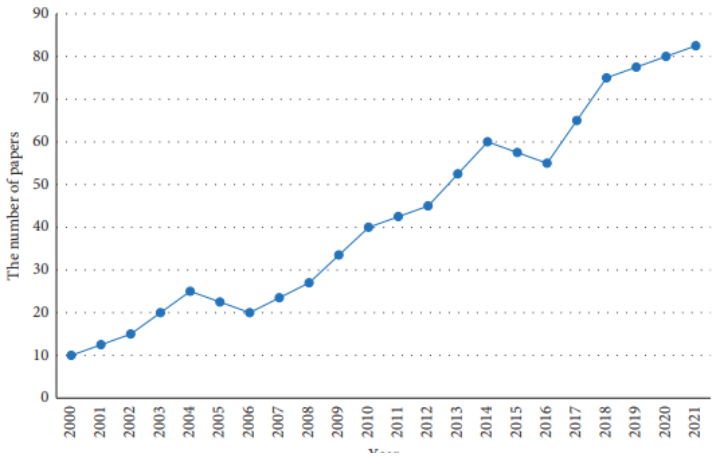

Figure 1. *The trend of the published articles in appointment scheduling 2000–2021*

With the rapid development of the Internet, verbal and paper-based scheduling appointments are getting replaced by web-based appointment systems. More countries worldwide realize the need to change their service approach by adapting technologies to maximize their services' effectiveness and efficiency, offer a positive working environment for the medics, and deliver a better patient experience (Morris, R.H.J. 2022).

3. Web-based Application System

In 2013 Xiuju Zhan and Xiufeng Liu developed an interactive clinic appointment registration system consisting of several data operation functions, including appointment booking and data management, for example, addition, deletion, and searching, which is one of the most significant disadvantages in the past. (Xiuju Zhan, Xiufeng Liu 2013). According to Zhan and Lui, the system can be divided into two user categories. The first category is for those who want to make an appointment, while the second is for the hospital staff. Compared to the old-fashioned queuing methods, the web-based appointment system could significantly increase patients` satisfaction, reduce total waiting time spent in the clinic, and effectively help the staff to manage their time. Figure 2 shows the system function structure. Regarding patient functionalities, it is evident that patients do not have the option to cancel, defer or get a notification about an appointment.

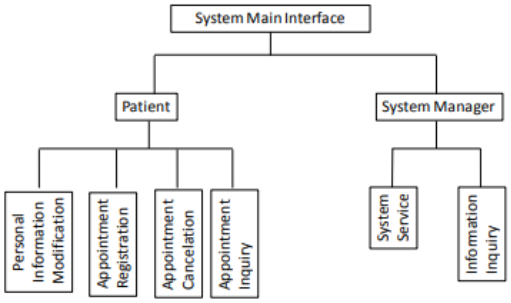

Figure 2. *System function structure (Xiuju Zhan, Xiufeng Liu, 2013).*

Due to the lack of these functions missed appointments are a common occurrence. Non-attendance is a persistent problem in the medical industry. During 2014 and 2015, around 5.6 million NHS outpatient appointments were in England, according to Quarterly Hospital Activity Data (Nhs.uk 2015). Research regarding adult patients missing an appointment shows that "the mean rate of missed appointments was 15.2%" (Parsons et al. 2021). It should be highlighted that patients with long-term mental health conditions who missed more than two appointments had a greater chance of deteriorating the condition (McQueenie, R. et al. 2019). Failing to attend a hospital appointment harms a clinic's workflow and wastes NHS resources. The problems mentioned above lead to the improvement of the web-based approach.

In 2014 the research work by Idowu proposed a user-friendly, dependable medical appointment system for a Nigerian Teaching Hospital (Idowu et al. 2014). The proposed website empowers the patient to book and manage their appointments, shortening the unnecessary waiting time for consultation and notifying them via email or SMS 2 hours before the actual session. The administrator interface allows the staff to easily edit, insert, delete and check the overall report of registered patients. Undoubtedly, a responsive website can compensate for the distance between doctors and patients and provide fast and adequate medical services. However, web apps need an active internet connection, while mobile apps may work offline. In addition, VWO - the world's leading web testing and conversion optimization platform, reported that users prefer mobile apps rather than mobile websites (Deshdeep N. 2015)

Based on the discussion above the aim of the current project will be the implementation of a mobile application which gives the user a chance not only to book an appointment but also to manage it with the help of different features such as editing an appointment, cancelling it and getting a remainder.

3.1 The improvement of Telemedicine

After SARS-CoV-2 has hampered every aspect of our life, but most of all, the healthcare system, some countries have found new opportunities and methods to combat it. To the American Medical Association, 74% of the population did not have access to or were unaware of telemedicine before the pandemic (Truex, G. 2022). Nevertheless, in 2020, a survey showed that nearly 45% of Americans used telemedicine during the pandemic (DrFirst 2020). The pandemic has rapidly accelerated the use of telemedicine, which imposes the need to implement new features in healthcare software development such as smoothly moving towards the mobile development.

4. Mobile Application System

The current section will focus on reviewing the literature around different mobile applications. It will discuss their limitations and strengths that this project needs to be aware of.

4.1. Popular App Categories

Looking back at 2017, the most popular app store categories among Android users were Games, Dating, Shopping, Communication, etc. The statistic in Figure 5 shows that Android consumers are not interested in Health apps. A few years later, after the global impact of the pandemic the health category moved further up in the statistics. The outcomes of the illness, such as lockdown, including not being able to see Health and social staff, could be considered as a reason, according to the Organisation for the Review of Care and Health App (ORCHA) research. ORCHA expected that digital Health would move forward and be

entirely integrated into care pathways to achieve a better patient experience and an improved working environment for the physicians (ORCHA 2021).

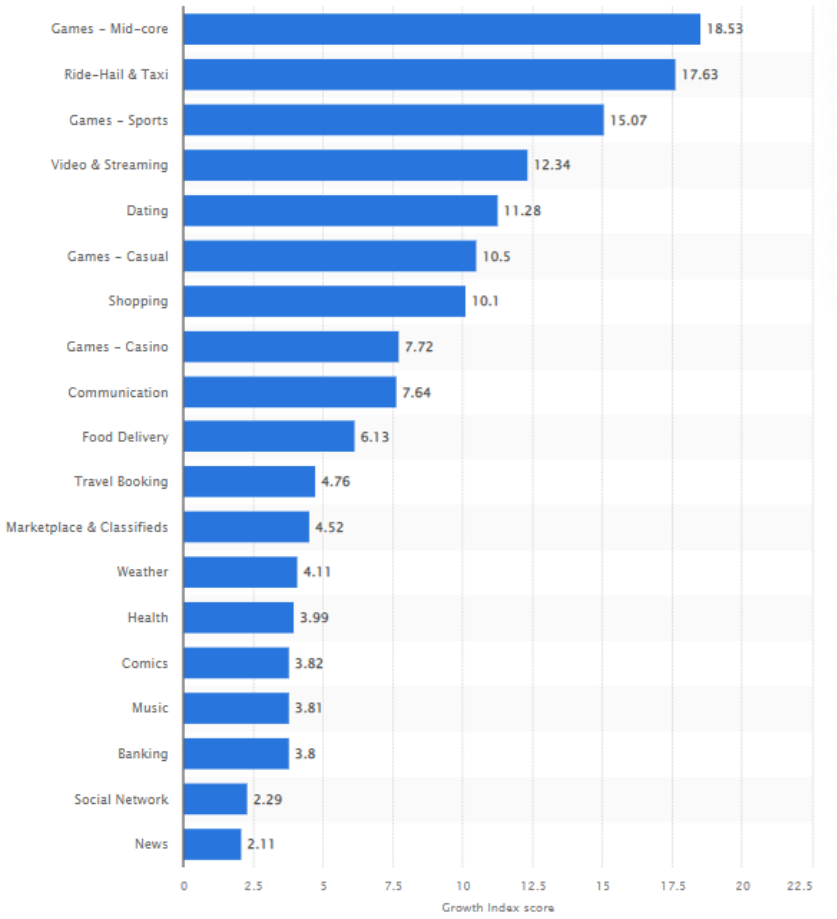

Figure 3. *Leading Android app categories in the UK 2017,(Statista, 2022)*

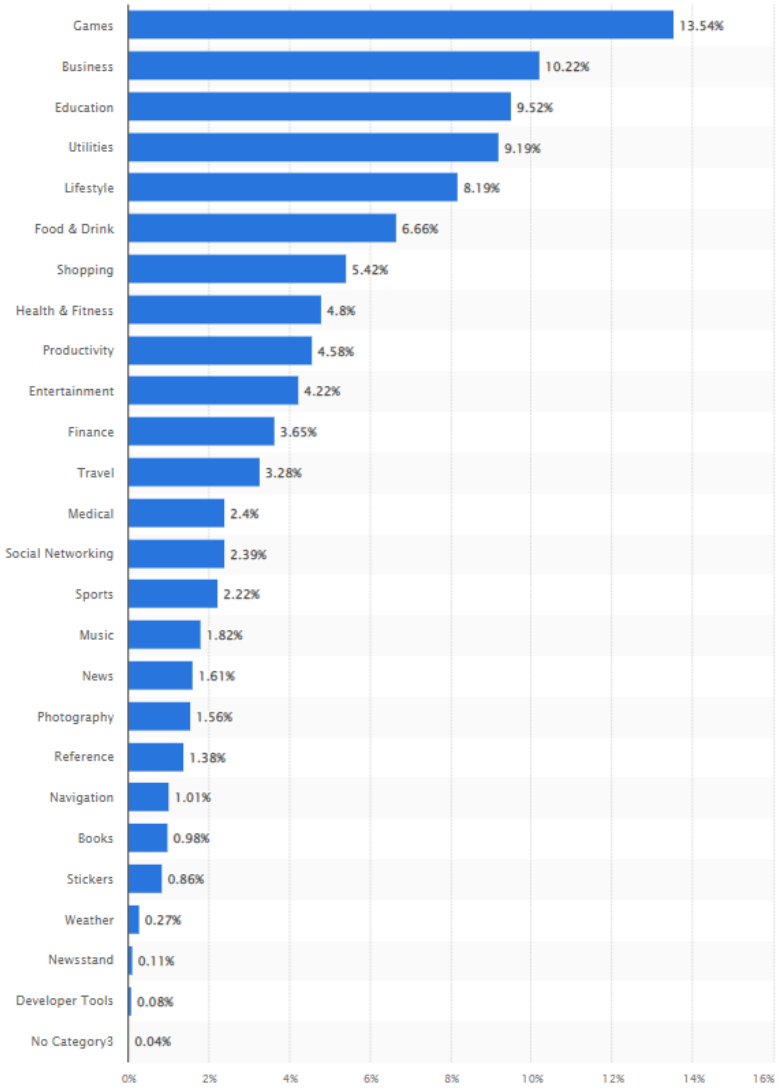

Figure 4. *Most popular app categories in 2022 (Statista 2022)*

According to Malaysian Family Physician website establishing effective communication between a doctor and a patient can result in better patient care, might decrease stress, improve emotional health, and prevent other communication challenges (Kabir, M.J. et al. 2022). Consequently, the integration of a In-App Chat widget feature is getting widely popular in many health apps.

4.2. Comparison between existing mobile apps on the market

An example is Medici which is a simple mobile app for patients to see their doctor virtually. As the coronavirus took hold, more GP (General Practitioner) surgeries closed for in-patient appointments and began offering only video consultations through mobile application. The health-tech company Visionable surveyed around 3000 people in 2020 and the responders are agreeing that “you do not always need to see a doctor in person to receive appropriate care (Highland Marketing 2020). The appetite for virtual appointments is getting higher in recent years and made it a preferable option among the population.

Using Medici consumers can search for and connect with their doctors or healthcare providers. From a doctor`s perspective, they can easily set up their accounts and begin connecting with patients. Regarding functionality, the app is limited only to virtual conversations. The examination of ratings and reviews shows that consumers exhibit contradictory opinions.

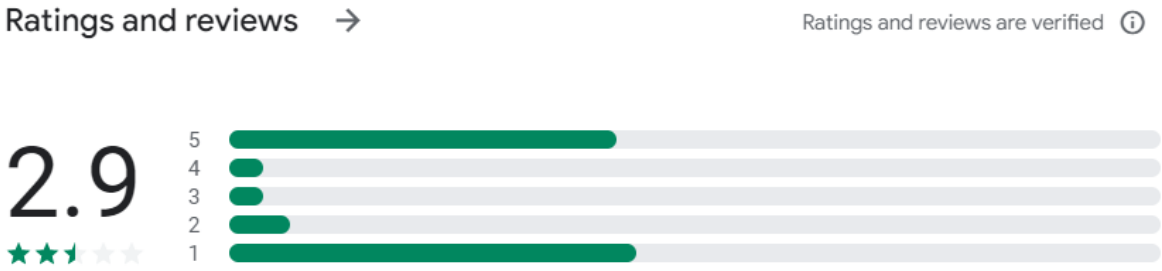

Figure 5. *Ratings and reviews of Medici for Patients (Google Play 2022)*

On the contrary, the MFine health app also offers online connecting or chatting with a doctor like Medici. The reason that it implements more features is set to be more preferred to Medici. MFine is a step further compared because it has added features like AI (Artificial Intelligence) bots, booking appointments not only for a health check but also for a lab test, Heart Rate Monitor, BMI Calculator and reminders. That is the reason it has a 4.4 Rating and 5M+ downloads compared with Medici. Nevertheless, MFine has a pricing list for some of its premium features. Setting the right price for a product is a balancing act. A premium mobile app needs to be significantly better than free alternatives to monetize from it. The market continues to grow and boom and free apps always appeal to new customers (MFine 2022).

The technology that involves mobile phones is taking speed. According to Cisco Annual Internet Report, global mobile data traffic has doubled for the fourth year in a row and looking towards the future over 70% of the global population will have mobile connectivity by 2023.
In 2019, Freaktemplate organisation released a Doctor Finder App. It is an end-to-end medical solution to find doctors, pharmacies, and hospitals near you. Undoubtedly, the geolocation implemented in the application is of utmost benefit because it supplies driving locations and shows the nearest health department in case of an emergency. However, a major downside of the inability to book an appointment or order any medications online which is a drawback in case of need. According to UNECE persons aged 65 years and older are almost 17% of the population in 2020. The proportion of the population aged over 80 is expected to double over the next thirty years. Consequently, this population trend might affect challenges in emergencies, since older people tend to be more affected (Springer International Publishing 2021).

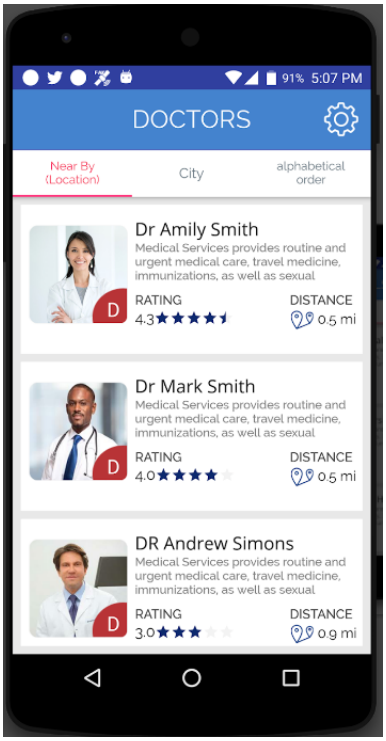

Figure 6. *List of the doctors near the user (Doctor Finder – complete medic, 2022)*

With a rating of 4.6 out of 5, ZocDoc is a two-sided popular online appointment scheduling system which widely used all over the healthcare industry. (ZocDoc 2022) It gives the patient a convenient way to book appointments on-the-go while taking into consideration the location. Also, the appointment system enables patients to reschedule appointments, receive confirmation messages, and get push notifications before the arrangement. Doctors, in turn, can choose to be listed on ZocDoc and allow the platform to access and integrate their timetables so the patient can view available slots. The award-winning app is also further preferred because it gives the user a chance to choose between an online visit or attending a hospital. A different comparison between DoctorFinder and ZocDoc shows that ZocDoc is undoubtedly more convenient, interactive, and beneficial for both patients and doctors. Furthermore, the geo-location implemented in the application is an effective way for elderly or their carers to book an appointment and find the closest hospital in case of an emergency. Consequently, one of the main goals of the current project is going to be the implementation of that feature.

Despite Zocdoc's aesthetic design and very tech approach, it does come with a few disadvantages. It is not an accurate scheduling software because it does not sync with most doctors' practice management software and does not read or write into the system (David Chen et al. 2022). Here comes the double-booking problem. It is a term when multiple patients are accidentally scheduled to see a health provider at the same time slot (Bano, R. 2022). Being double-booked might be a nightmare for everyone, especially if the patient has a surgery appointment or their life is at risk. Undoubtedly, one of the aims of the current project will be focused on valuable and correct time management to avoid duplicating appointments and causing a commotion between patients and doctors.

Teledoc looked at the possibility of pulling data from HealthKit in their application. They have spent 20 years perfecting their services and-what makes them most unique compared with the applications above is the HealthKit feature they offer (Teledoc 2022). Teledoc imports the most recent details on blood

pressure, temperature, heart rate, and average sleeping time right into the user profile. The stored information is visible to the medic during the visit. A study in 2020 reported that by directly reviewing the strip generated by the Apple Watch that visually shows a user's heart rate, doctors were able to flag more cases of abnormal heart rhythms (Seshadri et al. 2020). Therefore, Physicians, especially cardiologists, can make more meaningful evaluations with the collected data.

5. Mobile User Interface

5.1. Colour blindness

An estimated 300 million people worldwide have colour vision deficiency (ClintonEye no date). On average, one out of 12 men and 1 out of 200 women see the colour differently than everyone else (ClintonEye no date). Although many tools and concepts in the modern world support online user accessibility sometimes, the coverage of colour blindness or vision deficiency is inefficient or simply not enough. A few colour palettes are available to handle various colour vision deficiencies. For example, Trello, a web-based application, allows users to organize their tasks and activate a colour-blind mode. Briefly, it adds a simple textured overlay to the colour labels everywhere they are shown. While being a simple and lightweight feature, it is remarkably effective without changing the overall interface and feel of the final product.

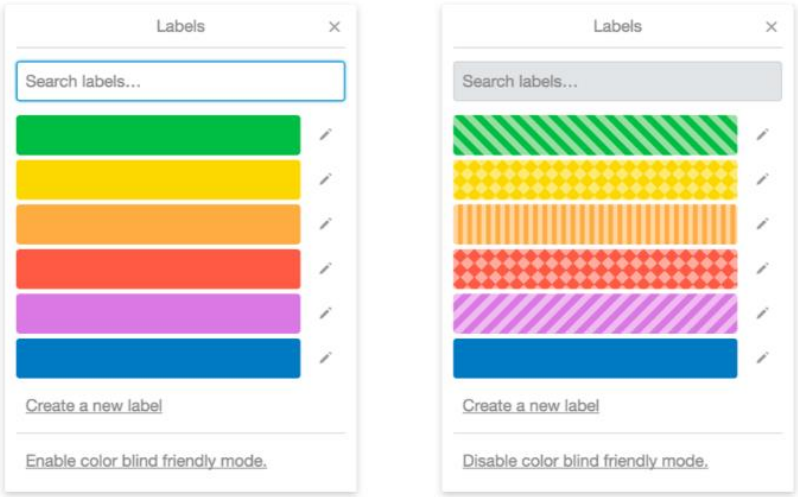

Figure 7. *The Trello interface with the Colourblind Friendly mode on/ off (Trello 2022)*

Some colour combinations to avoid for people with colour blindness include Red and Green, Green and Blue (Collinge, R. 2017). In contrast to Trello, the aforementioned Doctor Finder App has a lower level of accessibility and could be further developed. Since the app uses a red-green-blue colour combination and does not offer colour-blind mode, it could pose a difficulty for colour blind users.

Figure 8.*Doctor Finder App Login Screen (Doctor Finder 2022)*

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Regarding interface, the aim of the current project is to make a use of a modern and minimalistic design which will keep the user at ease with the product. It will be combined with colour blind friendly palettes.

6. Technology Stacks for Mobile App Development

There is a wide range of modern-day mobile app development frameworks. They supply built-in benefits like speed, effectiveness, and a bug-free atmosphere. One of the biggest debates that are continually going on among mobile developers is Flutter Vs. React Native and which one is better. React Native is a JavaScript-based open-source mobile application framework released by Facebook in 2015 (Maciej Budziński 2021). It is used to build some of the world`s most popular mobile apps, including Instagram, Pinterest, and Skype. Developer communities widely prefer it as it gives a clean, fluid, and responsive user experience.

Contrary to React, Flutter was developed by the tech giant Google and used Dart as a programming language. It is used for cross-platform mobile application development (Flutter no date). In other words, it allows you to create a native mobile project with only one codebase and work seamlessly in Android and iOS. A look at Google Trends results reveals a fierce battle between the two opponents. Figure 9 shows that Flutter became a more often searched query globally and continues to be so in 2022.

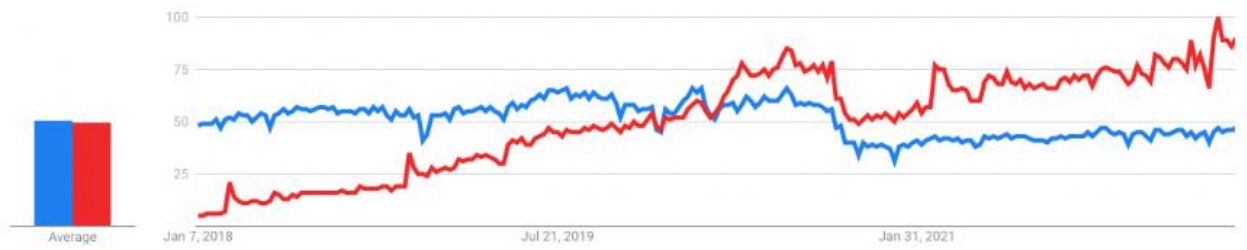

Figure 9.*Worldwide Flutter (red) and React Native (blue) popularity trend (2018–2022) (Google Trends 2022)*

The latest research from Statista proves that the new leader among cross-platform mobile development frameworks is Flutter. In 2021 Flutter surpasses React Native by 4%.

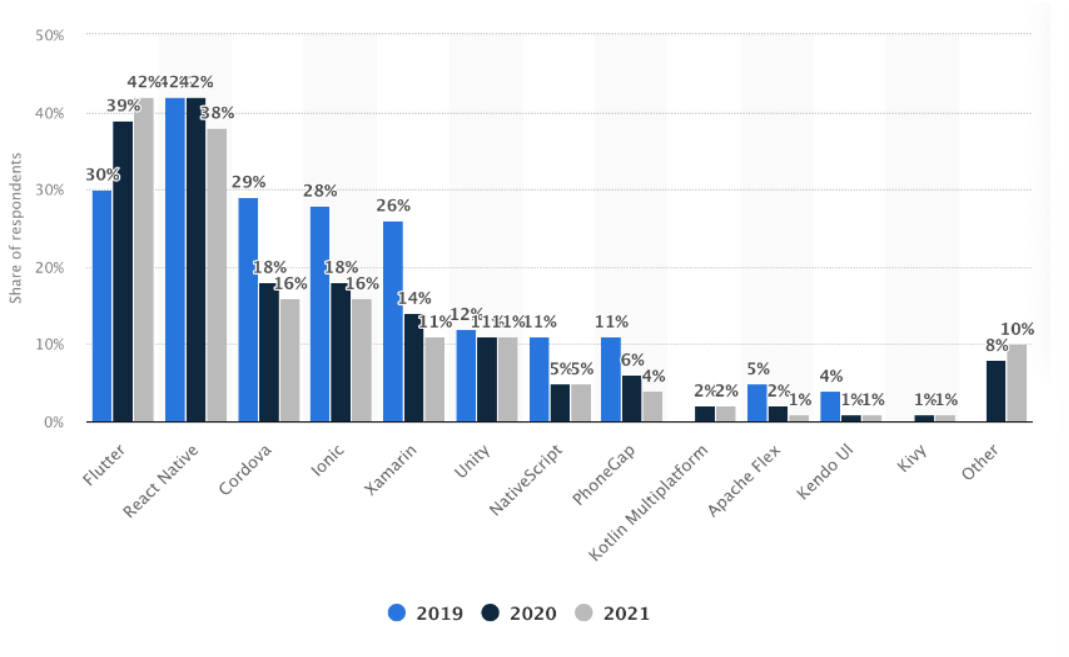

Figure 10. *Cross-platform mobile frameworks used by global developers 2019-2022*(Statista 2021)

In conclusion, the current project will make use of Flutter. It allows you to develop native iOS and Android platforms simultaneously, thus eliminating the need to write different code. Consequently, this cuts development time significantly and removes costs.

7. Requirements Analysis

7.1. Functional:

- All Users:
  - Users must be able to create new account in the application.
  - Users must be able to login after they created their account.
  - Every user must be able to delete their account.
  - Every user must be able to log out.
  - Every user must be able to change their credentials.
  - Every user must have only one profile associated with their email.
- Patients:
  - Patients must be able to see doctor`s timetable with latest available timeslots.
  - Patients must be able to book an appointment.
  - Patients must be able to cancel/reschedule an appointment.
  - Patients should be able to access the info page about every doctor.
  - Patients must be able to access the BMI calculator page.
  - Patients must be able to see their upcoming appointments.
  - Patients should be able to see a list with their past appointments.
  - Patients should be able to enable their geo location on the phone and search for the nearest doctor.
  - Patients should be able to see the directions on a map to the doctor`s location.
  - The patient should be able to see a list of all doctors in alphabetical order.
  - Patients should receive a notification if their appointment is cancelled by the doctor.
  - Patients should receive a notification 2h before their appointment
  - Patients should be able to leave feedback using star rating
  - Patients should be able to search doctors based on categories (e.g., Eye-doctor, Aesthetic Doctor, Cardiologist, etc.)
  - When the user is done with the details about the appointment, they should be able to see a summary before proceeding further.
- Application
  - The application must have a navigation menu.
  - App must be free.
- Doctors:
  - Doctors must be able to create a profile page filling information about their background.
  - Doctors must be able to create a personalized timetable based on their working hours and edit it if needed.
  - Doctors must be able to cancel an appointment (e.g. an emergency might occur)
  - Doctors must have access to all upcoming appointments.

7.2 Non-functional

- Interface/ Design:
  - The application must have simple and clean design.
  - The application should be colour-blind friendly.
- Security
  - The application should define a way of confidential access for example using passwords and username.

    - The application should offer security and privacy to the users.
    - Users must be logged in order to interact with the bookings and other features the app offers.
- Maintainability
    - The mobile should use standard accepted design patterns in the construction of the base architecture.
- Data storage
    - A Google Firebase platform should be used.
    - The system must store data effectively.
    - The system should be responsible for taking backups
- Device requirements
    - The mobile application should support Android OS version 4.0(API 14), IOS 14 or later
- Performance
    - The application may be able to provide services to at least 20 users concurrently.
    - When the application is start-up, it should not take more than 3-4 seconds to load home screen.
    - When the application gets interrupted by call, then the information must be saved and return the same page which was there before it got interrupted.
    - The application should be easy to use, efficient, and accessible.
    - The application must be scalable to different screen sizes.
- Support
    - Users should have access to contact us page in case of bug.
    - Users could be helped appropriately to fill in the mandatory fields, in case of invalid input such as identifying the missing requirements.
- Testing
    - The testing should involve analysing the app for functionality, usability, visual appearance, and consistency across multiple mobile devices.
- Availability
    - The system should be available during rush hours. If any maintenance needs to be done it should be outside these times.

8. Conclusion

The purpose of this review is to examine the different types of booking systems in a chronological timeline and highlight their benefits and disadvantages for the community and health staff. In the real world, patients face significant problems related to appointments, registration, searching locations, and long waiting times. The research looked at useful features to prevent users from facing the aforementioned problems. The use of mobile health apps could improve not only patient satisfaction but also the functionality of the health center and its workers. Therefore, adopting a mobile health app in healthcare settings to improve the physician-patient experience is encouraged.

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