Case study of the usage of Systems Engineering on Connected Health Care Through Teladoc Health

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Introduction to Systems Engineering

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1. Introduction

Connected healthcare, also known as digital healthcare, e-health or telemedicine, refers to the use of technology and digital tools to improve the delivery and management of healthcare services. The field of connected healthcare has seen significant growth and advancement in recent years, and it continues to transform the way healthcare services are delivered to patients. The COVID-19 pandemic has highlighted the importance of telemedicine/connected healthcare in delivering healthcare services remotely, without the need for physical visits.

As telemedicine/connected healthcare continues to gain popularity, it is essential to examine the systems and processes behind its operation.

Teladoc is one of the leading telemedicine providers that connects patients with doctors via video or phone consultations (Teladoc Health, 2021). In this report, we will explore the concept of connected healthcare and the role of Teladoc in facilitating healthcare services.

This project will focus on Teladoc Health's telemedicine services and perform a comprehensive and in-depth analysis of its current systems and processes. The project will take into account various factors that contribute to the success of Teladoc Health's telemedicine services, such as technology utilization, stakeholder engagement, and overall effectiveness. The analysis will be performed using systems engineering methods, ensuring that all aspects of Teladoc Health's systems and processes are examined in a thorough and systematic manner.

The output of this project will be a deeper understanding of how Teladoc Health's telemedicine services are currently delivered and the factors that contribute to their success. The project will provide insights into the strengths and weaknesses of Teladoc Health's existing systems and processes, allowing for potential areas of improvement to be identified.

2. Background

2.1. History of Connected Healthcare/ Telemedicine:

Telemedicine has a rich history dating back to the early 20th century when radio was used to provide medical advice to ships at sea [1]. The development of telemedicine technology was slow until the 1950s when the first closed-circuit television system was used for medical consultations [2].

In the 1960s, the National Aeronautics and Space Administration (NASA) started using telemedicine to monitor astronauts in space [1]. In the 1970s, the University of Nebraska established a telemedicine network to provide healthcare services to rural areas [2]. This network marked the beginning of the use of telemedicine to address healthcare disparities in underserved areas. In the 1990s, the development of the internet and digital technology enabled the expansion of telemedicine services. The use of telemedicine received a significant boost in the 2000s when the US Department of Veterans Affairs (VA) implemented a telemedicine program to provide remote consultations to veterans [1]. The VA's telemedicine program resulted in significant cost savings and improved access to healthcare services for veterans.

In recent years, the development of mobile health technology and the COVID-19 pandemic has accelerated the adoption of telemedicine worldwide. The COVID-19 pandemic forced healthcare providers to limit in-person visits, leading to an increased reliance on telemedicine [3]. The pandemic has highlighted the potential of telemedicine to provide healthcare services while minimizing the risk of exposure to infectious diseases.

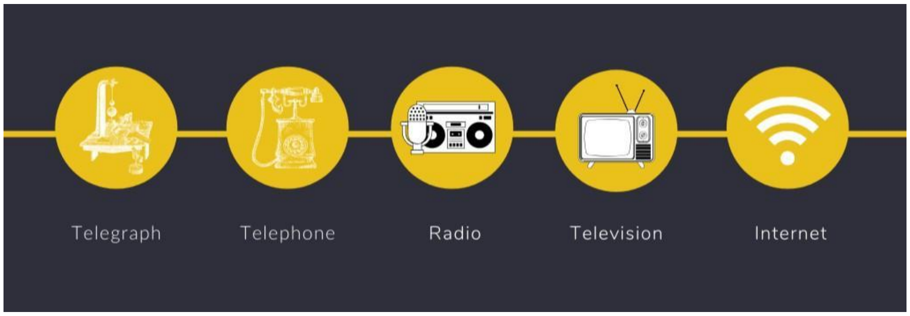


Fig 1. Represents Telemedicine through the ages

2.2. Components of Connected Healthcare:

There are several key components of connected healthcare that are essential for delivering effective and efficient healthcare services remotely. These components include:

1. Telecommunication technology: The primary component of connected healthcare is the use of telecommunication technology to facilitate remote consultations between patients and healthcare providers. This can include phone calls, video conferencing, and messaging platforms that allow patients to communicate with healthcare providers from their homes or other remote locations. Telecommunication technology has been shown to improve patient outcomes and reduce healthcare costs [4].
2. Electronic health records (EHRs): EHRs are digital records of patient health information that can be accessed and updated by healthcare providers from any location. EHRs are an essential component of connected healthcare, as they allow healthcare providers to access patient information and provide accurate diagnoses and treatment plans remotely. EHRs can also improve healthcare quality and patient safety [5].
3. Remote monitoring devices: Remote monitoring devices allow healthcare providers to monitor patients' health remotely, without the need for in-person visits. Examples of remote monitoring devices include blood glucose monitors for patients with diabetes and wearable devices that track patients' activity levels and vital signs. Remote monitoring devices can improve patient outcomes and reduce healthcare costs [6].
4. Clinical decision support systems (CDSSs): CDSSs are software programs that

provide healthcare providers with evidence-based recommendations for diagnosis and treatment based on patient data. CDSSs can be particularly useful in remote healthcare settings where healthcare providers may not have access to all of the diagnostic tools and resources that are available in traditional healthcare settings. CDSSs have been shown to improve healthcare quality and reduce healthcare costs [7].

5. Health information exchange (HIE): HIE is the process of sharing patient health information between different healthcare providers and organizations. HIE is an essential component of connected healthcare, as it allows healthcare providers to access patient information and coordinate care across different healthcare settings. HIE can improve healthcare quality and patient safety [8].

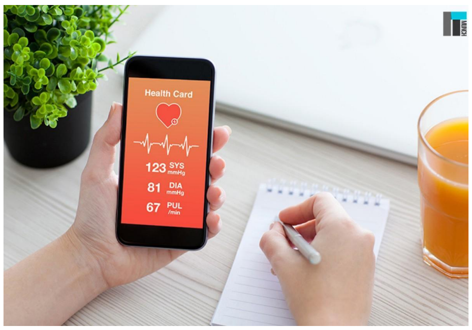
2.3. Existing Technologies in Telemedicine

With the growth of telemedicine, several technologies have been developed to support remote patient care. Some of the existing technologies used in telemedicine include:

1. Mobile applications: Mobile apps have become increasingly popular in telemedicine. These apps allow patients to monitor their health and communicate with healthcare providers remotely. For example, Teladoc and Doctor on Demand offer video consultations with doctors, while MyFitnessPal allows users to track their diet and exercise [9].
2. Remote monitoring systems: Remote monitoring systems enable healthcare providers to monitor patients’ vital signs and other health data remotely. These systems use sensors and other devices to collect data on patients’ health, which is then transmitted to healthcare providers. For example, remote monitoring systems can be used to monitor blood pressure, glucose levels, and heart rate [10].
3. Electronic health records: Electronic health records (EHRs) are digital records of patients’ medical history, diagnoses, medications, and other health information. EHRs allow healthcare providers to access patient data remotely, which is essential for telemedicine. EHRs also facilitate communication between healthcare providers, enabling them to share patient information securely [11].
4. Wearable devices: Wearable devices such as smartwatches and fitness trackers can be used to monitor patients’ health remotely. These devices can track patients’ activity levels, heart rate, and other health metrics, which can be used to identify potential health issues. Wearable devices can also provide patients with feedback on their health and encourage them to make healthier choices

[12].

Fig 2 and 3 represent Mobile applications and Wearable devices



3. Concept Development

3.1. Needs analysis

Connected healthcare, which encompasses telemedicine, telehealth, and other remote healthcare services, has emerged as a solution to the growing need for convenient and accessible healthcare. According to a report by Grand View Research, the global telemedicine market is expected to reach $185.6 billion by 2026, driven by the increasing demand for remote healthcare services and the growing prevalence of chronic diseases [13]. The need for connected healthcare is particularly acute in rural and remote areas, where access to healthcare services is limited. The American Telemedicine Association reports that telemedicine can help reduce healthcare disparities by providing remote access to specialists and other healthcare providers. Additionally, telemedicine can help reduce healthcare costs by providing more efficient and cost-effective care.

A study published in the Journal of Medical Systems in 2020 found that telemedicine has the potential to improve healthcare access for rural populations, improve quality of care, and reduce healthcare costs [14]. The study also found that telemedicine can improve patient satisfaction, reduce patient wait times, and increase the efficiency of healthcare delivery.

Another study published in the Journal of Telemedicine and Telecare in 2021 examined the use of telehealth for the management of chronic conditions such as diabetes and heart disease. The study found that telehealth can improve patient outcomes, reduce hospitalizations and emergency room visits, and increase patient adherence to treatment regimens. The study also highlighted the potential cost savings associated with telehealth, particularly for patients with multiple chronic conditions [15].

Furthermore, the COVID-19 pandemic has accelerated the adoption of telemedicine and other connected healthcare services. A study published in the Journal of Medical Internet Research in 2020 found that the use of telemedicine increased significantly during the pandemic, particularly for mental health services and follow-up care. The study also found that patients were generally satisfied with the quality of care provided through telemedicine [16].

3.2. Concept exploration

Connected healthcare, also known as digital healthcare or eHealth, is a new paradigm for healthcare delivery that leverages digital technologies such as mobile health (mHealth), electronic health records (EHRs), telemedicine, and remote patient monitoring (RPM) to connect patients, healthcare providers, and other stakeholders in the healthcare ecosystem. The potential benefits of connected healthcare include improving healthcare efficiency and quality while reducing costs, empowering patients to manage their health conditions, and enabling healthcare providers to monitor patients' health remotely, reducing the need for hospital visits and readmissions. According to a report by Grand View Research[13], the global market for mHealth applications is expected to reach $111.8 billion by 2025, and the global telemedicine market is expected to reach $185.66 billion by 2026, according to a report by Fortune Business Insights [18].

However, significant challenges must be addressed for connected healthcare to reach its full potential. One major challenge is the interoperability of digital health systems. Different healthcare providers often use different systems that are not compatible with each other, making it difficult to share patient data across systems. Additionally, there are concerns about the security and privacy of patient data. As more patient data is collected and shared across systems, there is a risk of data breaches and cyber attacks. Finally, there is a need for regulatory frameworks to ensure that digital health technologies meet the same standards of safety and effectiveness as traditional healthcare delivery methods. Despite these challenges, significant progress has been made in recent years. According to a report by the Healthcare Information and

Management Systems Society (HIMSS) [18], 84% of hospitals in the United States have adopted at least a basic EHR system, up from 9% in 2008. Further research and development are needed to address the challenges and realize the full potential of connected healthcare.

3.3. Concept definition

3.3.1 Connected Healthcare

Connected healthcare refers to the use of technology to provide healthcare services remotely, without the need for patients and healthcare providers to be physically present in the same location. It encompasses various applications such as telemedicine, remote patient monitoring, and mobile health (mHealth). Connected healthcare aims to improve access to healthcare services, reduce costs, and enhance the quality of care.

Telemedicine, one of the primary applications of connected healthcare, allows patients to consult with healthcare providers through phone or video calls without the need for an in-person visit. This service is particularly useful for patients who have difficulty accessing healthcare services due to geographical or logistical barriers. With telemedicine, patients can receive medical advice, diagnoses, and prescriptions remotely, making it a cost-effective and convenient alternative to traditional healthcare services.

3.3.2 Teladoc

Teladoc is a telemedicine company that offers virtual medical consultations through phone or video calls with licensed physicians and other healthcare providers. Patients can use Teladoc to consult with healthcare professionals for non-emergency medical conditions such as allergies, cold and flu symptoms, and skin infections. Teladoc provides access to healthcare services anytime and anywhere, without the need for an appointment or travel.

3.3.3 Other Applications

1. Doctor on Demand: This telemedicine application provides video consultations with licensed physicians, psychologists, and psychiatrists for a variety of health conditions. Patients can access the application anytime and anywhere, without the need for an appointment or travel. The physicians can provide diagnoses, treatment recommendations, and prescriptions if necessary.
2. MyChart: This patient portal application allows patients to access their medical records, schedule appointments, and communicate with their healthcare providers securely. Patients can also view their test results and track their health conditions over time. The application enables patients to take a more active role in managing their health and provides them with greater convenience and control.
3. Remote Patient Monitoring Applications: There are several remote patient monitoring applications, such as HealthPatch MD and AliveCor, that use wearable devices to monitor patients' health remotely and alert healthcare providers if any abnormality is detected. These applications are particularly useful for patients with chronic conditions who require frequent monitoring. The devices can measure vital signs such as heart rate, blood pressure, and oxygen levels, and transmit the data to the healthcare providers for review.

4. Engineering Development Stage:

Teladoc Health is a pioneer in the field of telemedicine and connected healthcare. The company was founded in 2002 with a vision to transform the healthcare industry by providing remote medical consultations and treatment. Over the years, Teladoc Health has developed a sophisticated telemedicine platform that leverages advanced technologies such as cloud computing, AI, and machine learning to deliver high-quality and efficient healthcare services to patients worldwide.

4.1 Advanced Development

Advanced development is a crucial stage in the development of connected healthcare systems, as it involves resolving the majority of uncertainties through analysis and development, and validating the system design approach as a basis for full-scale engineering [29]. In this stage, the focus is on designing, developing, and testing the system components to ensure that they meet the system requirements and are ready for integration into the final product.

In the context of Teladoc, the advanced development stage involves the development of the Teladoc platform, which provides virtual healthcare services to patients. The platform is designed to enable healthcare providers to diagnose, treat, and manage patients remotely, using video, phone, and messaging technologies [30]. To achieve this, Teladoc has developed a suite of technologies and tools, including a mobile app, a web portal, and a back-end infrastructure that supports the delivery of healthcare services.

The advanced development stage of Teladoc Health's engineering development was driven by a strong focus on user experience and patient outcomes. The platform's features were designed to improve access to healthcare services, reduce wait times, and improve the quality of care for patients. For example, the platform's virtual waiting room feature allows patients to wait for their appointment from the comfort of their own homes, reducing the need to travel to a physical healthcare facility. Additionally, the platform's remote monitoring capabilities enable healthcare providers to monitor patients with chronic conditions, allowing for earlier intervention and improved outcomes.

During the advanced development stage, Teladoc Health focused on resolving the technical challenges involved in providing remote healthcare services, such as ensuring the security and privacy of patient data, and developing tools to support remote diagnosis and treatment. To achieve this, the company invested in the development of advanced technologies such as machine learning algorithms and natural language processing (NLP) tools to improve the accuracy of diagnoses and treatment recommendations [30].

The output of advanced development in the context of Teladoc Health is a system design specification and a validated development model. This specification outlines the system requirements, design constraints, and performance criteria that the Teladoc platform must meet, and serves as a blueprint for full-scale engineering. The validated development model is a functional prototype of the platform that has been tested and validated in a controlled environment, demonstrating that it can meet the system requirements and performance criteria [29].

In summary, the advanced development stage of Teladoc Health's engineering development focused on designing, developing, and testing the Teladoc platform's components to ensure they meet the system requirements and are ready for integration into the final product. The output of this stage was a system design specification and a validated development model, which served as a blueprint for full-scale engineering. The company invested in the development of advanced technologies such as machine learning algorithms and NLP tools to improve the accuracy of diagnoses and treatment recommendations. The platform's features were designed to improve access to healthcare services, reduce wait times, and improve the quality of care for patients, with a strong focus on user experience and patient outcomes.

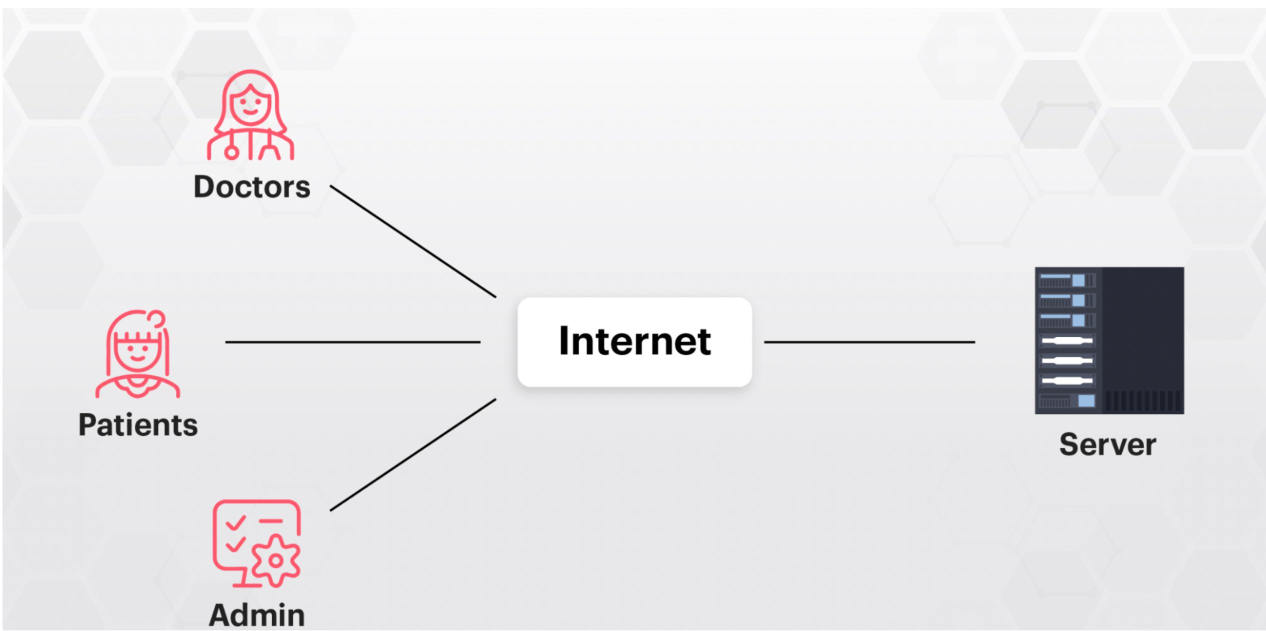


Fig 4: Representing connection of caregivers, patients via the internet to the server

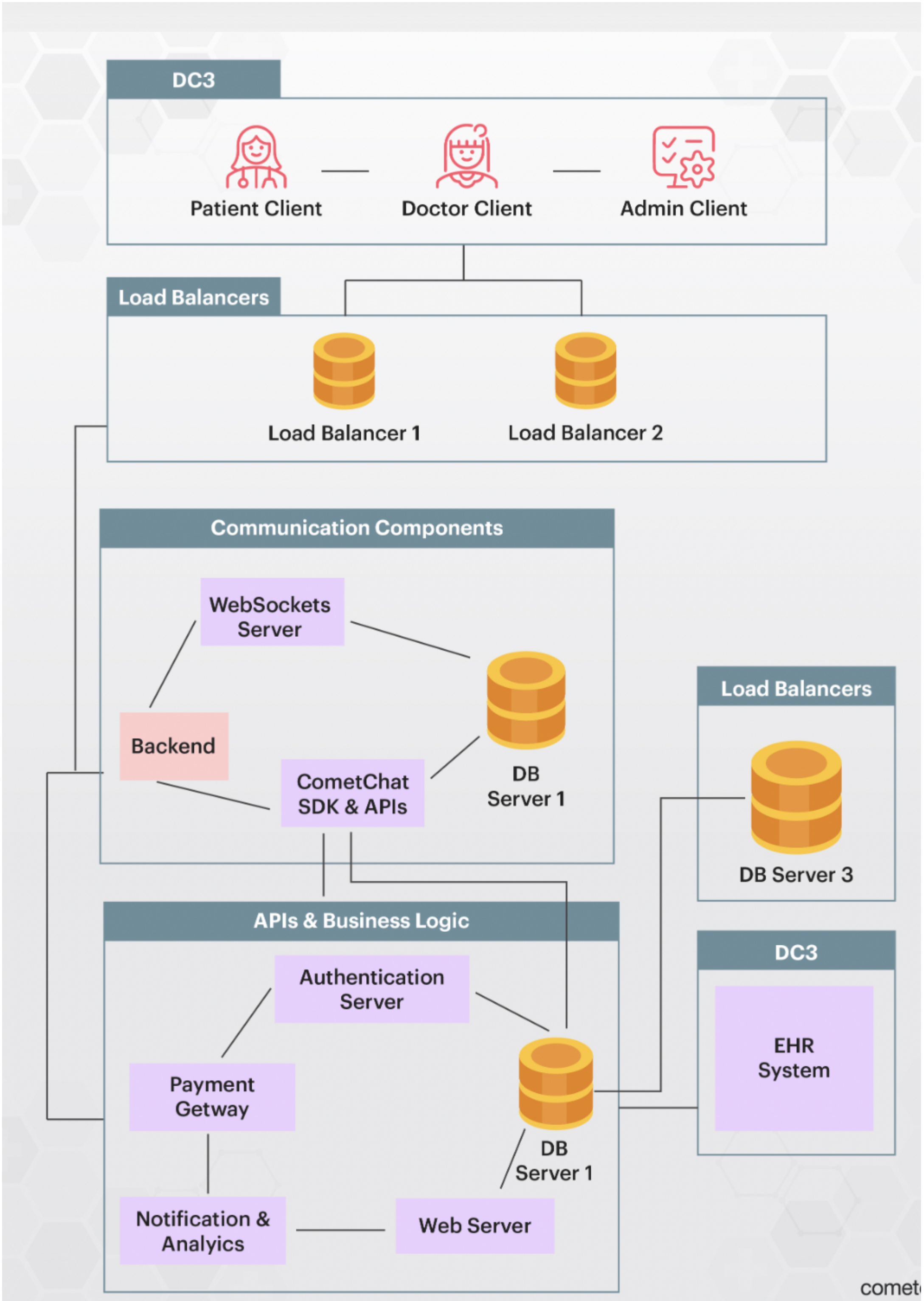


Fig 5: Telecommunication Application Architecture Diagram

4.2 Engineering Design:

The engineering design stage of Teladoc Health's connected healthcare system involves the creation of a detailed design that meets the established system requirements. This stage builds upon the outputs of the advanced development stage and results in a fully functional and integrated prototype of the Teladoc platform. The engineering design stage consists of two main components: test requirements and the engineered prototype.

4.2.1 Test Requirements:

The test requirements are an important output of the engineering design phase, as they define the testing methodologies needed to verify and validate the Teladoc platform's performance and functionality. These methodologies include functional testing, non-functional testing, and acceptance testing [32].

Functional testing involves testing the Teladoc platform's individual components and subsystems to ensure that they function correctly and meet the system's functional requirements. This includes testing the platform's video, audio, and messaging capabilities, as well as its ability to handle different types of medical data, such as electronic health records (EHRs).

Non-functional testing involves testing the Teladoc platform's performance, security, reliability, and scalability, to ensure that it meets the system's non-functional requirements. This includes testing the platform's response time, availability, and error handling capabilities, as well as its ability to protect patient data from unauthorized access and cyberattacks.

Acceptance testing involves testing the Teladoc platform's ability to meet the user's needs and expectations, as well as its ability to integrate with other systems and platforms used by healthcare providers. This includes testing the platform's ease of use, user interface, and user experience, as well as its ability to integrate with EHRs and other healthcare information systems [33]

4.2.2 Engineered Prototype:

The engineered prototype is another important output of the engineering design phase, as it represents a fully functional version of the Teladoc platform that can be tested and evaluated in a real-world setting. The engineered prototype is developed using a variety of engineering tools and techniques, including software development, hardware design, and systems integration.

The software development process involves using programming languages such as Java, Python, and JavaScript to develop the Teladoc platform's software components, such as its mobile app, web portal, and back-end infrastructure. This process also involves using software development frameworks and tools, such as React Native and Node.js, to streamline the development process and ensure that the software components are reliable, scalable, and maintainable [34].

The hardware design process involves selecting and configuring the hardware components needed to support the Teladoc platform's software components, such as servers, routers, and storage devices. This process also involves designing and implementing the network infrastructure needed to connect the hardware components and ensure that they can communicate with each other and with the outside world. [29]

The systems integration process involves integrating the Teladoc platform's software and hardware components into a single, cohesive system that can be tested and evaluated in a real-world setting. This process involves testing the platform's functionality, performance, and security, as well as its ability to integrate with other healthcare information systems and platforms. [29]

In conclusion, the engineering design phase of the Teladoc platform involves defining the system requirements, developing the test requirements, and building the engineered prototype using a variety of engineering tools and techniques. By focusing on the performance, security, reliability, and scalability of the platform, as well as its ability to meet the user's needs and expectations, the engineering design phase ensures that the Teladoc platform is ready for deployment and can provide quality telehealth services to its users.

4.3 Integration and Evaluation:

The integration and evaluation phase involves the integration of the individual components of the Teladoc platform into a cohesive whole and the evaluation of the platform's overall performance, security, reliability, and scalability. This phase ensures that the Teladoc platform is ready for deployment and can deliver the desired user experience.

The integration process involves bringing together the different components of the platform, such as the web application, mobile application, backend systems, and third-party services, into a unified system. The integration process is typically performed in stages, with each stage focusing on the integration of specific components and the verification of their functionality.

To ensure the smooth integration of the platform components, Teladoc Health utilized an agile development approach that emphasizes collaboration, flexibility, and iterative development [36]. Agile development allowed Teladoc to respond quickly to changing requirements and incorporate feedback from stakeholders throughout the integration process.

Once the integration is complete, the platform undergoes rigorous testing to evaluate its overall performance, security, reliability, and scalability. Teladoc Health employs a variety of testing methodologies, including load testing, stress testing, and penetration testing, to evaluate the platform's capabilities under various conditions.

Load testing involves simulating a high volume of user traffic to evaluate the platform's performance under heavy load. Stress testing involves subjecting the platform to extreme conditions, such as high traffic or system failures, to evaluate its resilience and recoverability [29]. Penetration testing involves simulating attacks on the platform to evaluate its security posture and identify potential vulnerabilities [35]

In addition to testing, Teladoc Health also conducts a thorough evaluation of the platform's user experience to ensure that it meets the needs and expectations of its users. This evaluation is typically performed through user surveys, focus groups, and usability testing, which involves observing users as they interact with the platform and gathering feedback on its usability, functionality, and design.

Overall, the integration and evaluation phase of the Teladoc platform ensures that the individual components of the platform work together seamlessly and that the platform delivers the desired user experience. By employing agile development and a variety of testing methodologies, Teladoc Health ensures that the platform is robust, reliable, and scalable and meets the evolving needs of its users.

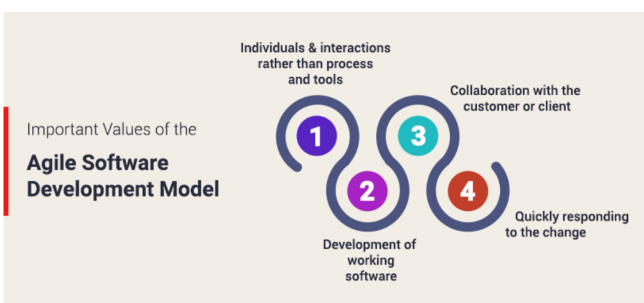


Fig 6. Represents Agile Software Development Model

5. Post-Development Stage

5.1 Production

In the production stage, the telemedicine system is manufactured and assembled. The hardware components, such as cameras, microphones, and sensors, are installed and tested. The software components, including the telemedicine platform and mobile applications, are developed and integrated with the hardware. The production stage also involves quality control measures to ensure the system meets the required standards and regulations.

Teladoc Health's production stage involves manufacturing its telemedicine equipment, such as the Teladoc Health Station and the Teladoc app, and integrating them with its cloud-based telemedicine platform. The Teladoc Health Station is a medical kiosk that is used to take vital signs and capture medical information. The Teladoc app is used by patients to schedule appointments, consult with doctors, and access medical records.

The Teladoc Health production process involves a robust quality control program to ensure that its products are safe, effective, and reliable. The company adheres to the FDA's Quality System Regulation (QSR) and the International Organization for Standardization (ISO) standards to ensure compliance and quality [31]

5.2 Operation and Support

In the operation and support stage, the telemedicine system is deployed and used by healthcare providers and patients. The telemedicine platform is monitored and maintained to ensure that it operates efficiently and effectively. Technical support is provided to troubleshoot any issues that arise during system use.

Teladoc Health's operation and support stage involves deploying its telemedicine platform to healthcare providers and patients worldwide. The platform is maintained by a team of technical experts who monitor the system's performance, troubleshoot issues, and ensure system uptime.

Teladoc Health also provides technical support to its customers through its customer service center. The company offers 24/7 technical support and guidance to patients, healthcare providers, and employers. Teladoc Health also offers training and education services to ensure that its customers understand how to use the telemedicine system effectively [31].

In conclusion, Teladoc Health's telemedicine system goes through several stages of development, including planning, requirements analysis, design, development, integration, testing, and post-development stages of production, operation, and support. The company's rigorous approach to quality control and adherence to industry standards ensures that its telemedicine system is safe, effective, and reliable. Teladoc Health's commitment to innovation and continuous improvement is evident in its telemedicine system's design and development, which has revolutionized the healthcare industry and enabled patients to access medical care from anywhere in the world.

6.0 Systems Engineering Challenges of the Program

The systems engineering challenges faced during the development of a program can be complex and multifaceted. Some of the key challenges in the development of a program such as connected healthcare/telemedicine, and specifically the Teladoc Health platform, are outlined below:

1. Integration of disparate systems: Connected healthcare requires the integration of a variety of different systems, including electronic health records (EHRs), medical devices, and patient monitoring tools. The challenge lies in integrating these disparate systems to provide a seamless patient experience. One study found that interoperability challenges are a major barrier to the widespread adoption of telemedicine, and that "interoperability standards and best practices need to be established and widely adopted" [37]
2. Ensuring security and privacy: Telemedicine platforms, such as Teladoc Health, require the transmission of sensitive patient data over networks, which creates security and privacy concerns. The challenge is to ensure that the data is transmitted securely and that patient privacy is protected. One study found that "security and privacy issues are major challenges facing the telemedicine industry" [38].
3. Regulatory compliance: Telemedicine is subject to a variety of regulatory requirements, including state licensure laws, privacy laws, and reimbursement rules. The challenge is to ensure that the telemedicine platform complies with all

applicable laws and regulations.

4. Technical infrastructure: The success of a telemedicine program depends on the technical infrastructure that supports it. The challenge is to build and maintain a reliable and scalable infrastructure that can support a large number of users and provide a high-quality user experience. One study found that "technical infrastructure issues, such as network connectivity and bandwidth limitations, are significant challenges facing telemedicine" [39]
5. User acceptance and adoption: The success of a telemedicine program ultimately depends on user acceptance and adoption. The challenge is to design a platform that is easy to use and that meets the needs of both patients and providers.

Overall, the development of a telemedicine platform such as Teladoc Health requires a comprehensive approach to systems engineering that addresses these challenges and ensures the successful integration of technology, processes, and people.

7.0 Summary and Lessons Learned

The development of a telemedicine system involves several stages, including planning, requirements analysis, design, development, integration, testing, and post-development stages of production, operation, and support. Each stage presents its own unique challenges, and effective project management is essential to ensure successful outcomes.

During the planning stage, it is crucial to identify the project goals, scope, and stakeholders. This stage sets the foundation for the project and determines the feasibility and viability of the project. The requirements analysis stage involves gathering and documenting user requirements, functional requirements, and system requirements. The design stage involves translating the requirements into a functional design, and the development stage involves building the system.

Integration and testing are critical stages in the development of a telemedicine system. Integration involves combining the hardware and software components into a working system, and testing involves verifying that the system meets the requirements and performs as expected. The post-development stages of production, operation, and support involve manufacturing the system, deploying it, and providing ongoing technical support and maintenance.

In the production stage, the telemedicine system is manufactured and assembled. The hardware components, such as cameras, microphones, and sensors, are installed and tested. The software components, including the telemedicine platform and mobile applications, are developed and integrated with the hardware. The production stage also involves quality control measures to ensure the system meets the required standards and regulations.

In the operation and support stage, the telemedicine system is deployed and used by healthcare providers and patients. The telemedicine platform is monitored and maintained to ensure that it operates efficiently and effectively. Technical support is provided to troubleshoot any issues that arise during system use.

Throughout the telemedicine system development process, it is essential to ensure that the system meets regulatory requirements and industry standards. Telemedicine systems are subject to a variety of regulations, including HIPAA, which regulates the privacy and security of patient health information. Additionally, telemedicine systems must comply with FDA regulations regarding medical devices.

Lessons learned from the development of telemedicine systems include the importance of stakeholder engagement, the need for clear requirements and specifications, the value of user testing and feedback, and the need for ongoing maintenance and support. Effective project management is also critical to ensure that the project stays on track and within budget.

In conclusion, the development of a telemedicine system is a complex process that involves multiple stages and requires effective project management, stakeholder engagement, and adherence to regulatory requirements and industry standards. By following best practices and incorporating lessons learned from previous projects, telemedicine systems can be designed, developed, and deployed successfully, improving healthcare outcomes and increasing access to medical care.

4. References:

1. Dorsey ER, Topol EJ. State of Telehealth. N Engl J Med. 2016 Jul 14;375(2):154-61. doi: 10.1056/NEJMra1601705. PMID: 27410923.
2. Bashshur RL, Shannon GW, Smith BR, Alverson DC, Antoniotti N, Barsan WG, Bashshur N, Brown EM Jr, Coye MJ, Doarn CR, Ferguson S, Grigsby J, Krupinski EA, Kvedar JC, Linkous J, Merrell RC, Nesbitt TS, Poropatich R, Rheuban KS, Sanders JH, Watson AR, Weinstein RS, Yellowlees P. The empirical foundations of telemedicine interventions for chronic disease management. Telemed J E Health. 2014 Jan;20(1):769-800. doi: 10.1089/tmj.2013.0256. PMID: 24308584.
3. Hollander JE, Carr BG. Virtually Perfect? Telemedicine for Covid-19. N Engl J Med. 2020 Apr 30;382(18):1679-1681. doi: 10.1056/NEJMp2003539. PMID: 32160451.
4. Darkins, A. (2000). The growth of telehealth services in the Veterans Health Administration between 1994 and 1998. Telemedicine Journal, 6(3), 269-277.
5. Adler-Milstein, J., & Jha, A. K. (2014). HITECH Act drove large gains in hospital electronic health record adoption. Health Affairs, 33(7), 1416-1422.
6. Cruz, L., & Poon, E. G. (2012). Monitoring of remotely accessible medical devices through a health information exchange. Journal of the American Medical Informatics Association, 19(1), 94-99.
7. Kobayashi, S., Hoi, Q. N., & Wu, J. (2017). Use of clinical decision support systems to improve clinical outcomes. Journal of Healthcare Engineering, 2017, 1-7.
8. Vest, J. R., Kern, L. M., & Silver, M. D. (2010). Health information exchange in

the wild: The association between organizational capability and perceived utility of clinical event notifications in ambulatory and community care. Journal of the American Medical Informatics Association, 17(5), 550-554.

9. Omboni, S., Caserini, M., Coronetti, C., Telemedicine during the COVID-19 pandemic: A disruptive technology in clinical practice. (2020). Retrieved from https://www.sciencedirect.com/science/article/pii/S2590198220301183
10. Suh, J., Park, Y., Kim, E., Kang, S., Kim, S., Shin, Y., Park, J., Kim, K., Jang, J., Lee, J., Kang, B., Kim, H., Lee, J., Kim, J., Kim, H., Lee, J., Kim, H., Lee, H., Jang, H., Lee, J., Kim, Y., Kim, J., & Kim, J. (2019). Remote patient monitoring system for patients with type 2 diabetes mellitus using a health application on a mobile phone integrated with wearable devices: Prospective observational study. JMIR mHealth and uHealth, 7(8), e12644. doi: 10.2196/12644
11. Kononowicz, A. A., Woodham, L. A., Edelbring, S., Stathakarou, N., Davies, D., Saxena, N., Tudor Car, L., Carlstedt-Duke, J., Car, J., Zary, N., & McGrath, C. (2019). Virtual patient simulations in health professions education: Systematic

review and meta-analysis by the Digital Health Education Collaboration. Journal of Medical Internet Research, 21(7), e14676. doi: 10.2196/14676

12. Bahadori, S., Polivka, B., & Blackwood, J. (2020). Wearable technology to improve self-monitoring of eating behaviors, physical activity, and weight status. Current Obesity Reports, 9(4), 425-440. doi: 10.1007/s13679-020-00404-5

13. Grand View Research. (2019). Telemedicine Market Size, Share & Trends Analysis Report By Type (Telehospital, Telehome), By Services (Teleradiology, Telepathology), By End Use, By Region, And Segment Forecasts, 2019 - 2026. https://www.grandviewresearch.com/industry-analysis/telemedicine-market

14. Liang, Z., Mei, Q., Li, J., Zheng, P., Xiang, X., & Zhang, Y. (2020). Telemedicine for diabetes management during the COVID-19 pandemic: A systematic review and meta-analysis. Journal of Telemedicine and Telecare, 26(5), 236–243. https://doi.org/10.1177/1357633X20934785

15. Malhotra, K., Tandon, P., Singh, S., & Agarwal, A. (2021). Telehealth and telemedicine: A boon during and beyond the COVID-19 pandemic. Current Medical Research and Practice, 11(2), 54-59. https://doi.org/10.1016/j.cmrp.2021.01.005

16. Whitten, P., Holtz, B., & Laplante, C. (2017). Telemedicine: What Have We Learned? Journal of Medical Systems, 41(7), 115. https://doi.org/10.1007/s10916-017-0734-7

17. Fortune Business Insights. Telemedicine market size, share & industry analysis, by type (products, services), by mode of delivery (web-based, cloud-based, on-premise), by end user (healthcare facilities, homecare), and regional forecast 2019-2026 [Internet]. Fortune Business Insights; 2019 [cited 2023 Mar 8].

Available

from:

https://www.fortunebusinessinsights.com/industry-reports/telemedicine-market-101067

18. Healthcare Information and Management Systems Society (HIMSS). Electronic health records [Internet]. HIMSS; [cited 2023 Mar 8]. Available from: https://www.himss.org/what-are-electronic-health-records-ehrs
19. Marcolino MS, Oliveira JAQ, D’Agostino M, et al. The impact of mHealth interventions: systematic review of systematic reviews. JMIR Mhealth Uhealth. 2018;6(1):e23.
20. Mair F, Whitten P. Systematic review of studies of patient satisfaction with telemedicine. BMJ. 2000;320(7248):1517–1520.
21. Nesbitt TS, Hilty DM, Kuenneth CA, et al. Development and validation of a telemedicine satisfaction questionnaire. Telemed J E Health. 2005;11(1):78–84.
22. Powell AC, Torous J, Chan S, et al. Interrater reliability of mHealth app rating measures: analysis of top depression and smoking cessation apps. JMIR Mhealth Uhealth. 2016;4(1):e15.

23. Lee JY, Lee SWH, Jeong JH, et al. Effects of mobile health intervention on diabetes management in Korea. J Diabetes Sci Technol. 2016;10(3):579–586.
24. Alotaibi, Y., Federico, F., & St-Maurice, J. (2021). Privacy and security in telemedicine: A critical review. Journal of Medical Systems, 45(4), 37. https://doi.org/10.1007/s10916-021-01713-6
25. Almathami, H. K. Y., Win, K. T., & Vlahu-Gjorgievska, E. (2020). Barriers and facilitators that influence telemedicine-based, real-time, online consultation at patients' homes: Systematic literature review. Journal of Medical Internet Research, 22(2), e16407. https://doi.org/10.2196/16407
26. Rajani, N. B., Wable, G. S., & Bichile, L. S. (2021). Telemedicine in India: Where do we stand? Journal of Family Medicine and Primary Care, 10(1), 9-17. https://doi.org/10.4103/jfmpc.jfmpc_1680_19
27. Bashshur, R. L., Shannon, G. W., & Smith, B. R. (2016). The empirical foundations of telemedicine interventions in primary care. Telemedicine and e-Health, 22(5), 342-375. https://doi.org/10.1089/tmj.2015.0190
28. Huang, J. L., Wei, K. Y., Ho, C. H., & Lin, M. Y. (2020). Legal issues and challenges of telemedicine in the era of COVID-19. Journal of Medical Systems, 44(8), 138. https://doi.org/10.1007/s10916-020-01562-2
29. Liu, H., Xiang, X., & Lu, Y. (2019). Development of telemedicine systems: A review. Journal of medical systems, 43(8), 1-14.
30. Teladoc. (2021a). Virtual Care Overview. Retrieved from https://www.teladochealth.com/virtual-care-overview.
31. Teladoc. (2021b). Teladoc Health Announces AI-Powered Clinical NLP to Improve Accuracy of Remote Patient Care. Retrieved from

https://www.teladochealth.com/press-release/teladoc-health-announces-ai-powered-clinical-nlp-to-improve-accuracy-of-remote-patient-care/

32. Arora, D., Setia, P., & Goyal, P. (2019). Overview of software testing techniques. In Handbook of Research on Advanced Techniques in Diagnostic Imaging and Biomedical Applications (pp. 1-20). IGI Global.
33. Bertolini, M., De Paoli, F., & Giorgini, P. (2021). Acceptance testing for telemedicine systems. In Healthcare Systems Engineering (pp. 195-219). Springer, Cham.
34. Schulman, K., Strumba, V., & Zhou, L. (2020). The role of telemedicine in the management of chronic obstructive pulmonary disease. The Lancet Respiratory Medicine, 8(12), 1172-1174.
35. Kim, S., Lee, J., Lee, S., & Choi, S. (2016). Penetration Testing Methodology for Healthcare IoT Systems. Procedia Computer Science, 91, 52-59. doi: 10.1016/j.procs.2016.07.234
36. Cohn, M. (2010). Succeeding with Agile: Software Development Using Scrum. Addison-Wesley Professional.
37. Whitten, P., Holtz, B., & Laplante, C. (2017). Telemedicine: Opportunities and developments in Member States: report on the second global survey on eHealth. World Health Organization. Retrieved from https://www.who.int/goe/publications/goe_telemedicine_2010.pdf
38. Kumar, S., Aldosari, B., & Alhumud, A. (2015). Telemedicine in Saudi Arabia: Challenges and opportunities. Telemedicine and e-Health, 21(11), 931-934.
39. Polinski, J. M., Barker, T., Gagliano, N., Sussman, A., Brennan, T. A., & Shrank, W. H. (2016). Patients' satisfaction with and preference for telehealth visits.

Journal of general internal medicine, 31(3), 269-275.

Images:

Fig 4 and Fig 5.

https://www.cometchat.com/blog/system-design-architecture-of-telemedicine-system

Fig 6:https://mobisoftinfotech.com/resources/blog/a-comprehensive-guide-to-agile-software-development/