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# APPLYING TOGAF-BASED ENTERPRISE ARCHITECTURE IN THE HEALTHCARE SECTOR: A CASE STUDY OF THE NATIONAL CENTER FOR DIABETES IN JORDAN

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## *ABSTRACT*

*Technology implementation can significantly benefit organizations, but ensuring that it aligns with their business needs and goals is crucial. Adopting an enterprise-architecture approach can aid healthcare enterprises in overcoming challenges during the transformation process. In particular, this study examines how The Open Group Architecture Framework (TOGAF) can facilitate digital transformation while ensuring alignment with business needs. Using the Architecture Development Method (ADM) of TOGAF, the study analyzes the current architecture of the National Center for Diabetes, Endocrinology and Genetics (NCDEG) in Jordan, intending to develop a target architecture that helps NCDEG effectively achieve its goals by aligning technology implementations with business objectives. Utilizing TOGAF's ADM, the study navigates the complexities of technological advancements while ensuring seamless integration and effective utilization of resources. Furthermore, the findings highlight the critical role of enterprise architecture in facilitating organizational evolution, emphasizing the need for continuous evaluation and refinement to adapt to changing business landscapes and technological advancements for NCDEG and similar organizations. The proposed changes were validated through simulation using Rockwell Arena Simulation Software. Results showed significant improvements in patient handling, process efficiency, waiting times and resource utilization by implementing virtual clinics and digital solutions*.



## *KEYWORDS*

*Digital transformation, Enterprise architecture, Healthcare informatics, TOGAF, Diabetes.*


## 1. INTRODUCTION

Enterprise Architecture (EA) is a practical approach to strategically managing an organization's technology landscape. By aligning technology with business goals, EA ensures that suitable applications and technologies support business processes. As organizations grow and evolve through mergers and acquisitions, EA must govern and guide new projects, systems and processes added to the technology ecosystem. This practice helps control costs by eliminating duplication and ensuring standardization across processes and technologies [1]-[2].

Several factors have recently influenced the healthcare industry, making embracing digital transformation in services and operations imperative. These factors include restrictions, social distancing and the immense strain on the healthcare sector due to the COVID-19 pandemic. Additionally, emerging technologies, such as the Internet of Medical Things (IoMT), mobile health apps, artificial intelligence (AI) and big data have played a crucial role [3].

To keep pace with the digital era, healthcare providers must incorporate modern technologies into their existing systems or transition traditional practices to digital ones. To do this, a thorough assessment of their current status is required, as well as the development of a comprehensive digital transformation plan that aligns with their objectives and purpose.

Organizations can adopt EA through different approaches or frameworks. The most popular frameworks are TOGAF, The US Federal EA Framework (FEAF), the US Department of Defence Architecture Framework (DODAF), Zachman and the UK Ministry of Defence Architecture Framework (MODAF), which was withdrawn in 2021 and replaced by the NATO Architecture Framework (NAF) [1]. Healthcare institutions may benefit from implementing an EA to facilitate and oversee their transformation efforts.

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This study explores the adoption of TOGAF in the healthcare sector, specifically in the case study of the National Centre of Diabetes, Endocrinology and Genetics (NCDEG) in Jordan [4]. In addition, it serves as a milestone to motivate healthcare providers in Jordan to consider EA a valuable tool for guiding and governing their digital-transformation initiatives.

The following sections introduce the significance of technology implementation in healthcare organizations and the challenges that they face in aligning technology with business objectives. We also discuss the rationale behind selecting The Open Group Architecture Framework (TOGAF) as the methodology for this study in the Background and Related Work sections. Collecting the required data and applying the framework are detailed in the Research Methodology section. The simulation's setup and running are discussed in the Results and Analysis section and finally, the Conclusion section summarizes the study.

## 2. BACKGROUND

### 2.1 The Open Group Architecture Framework (TOGAF) Standard

The TOGAF Standard, initially released in 1995, is an EA framework widely used to assist organizations in developing EA for their entire organization or specific parts of it based on their needs [4]. This framework can be used in its entirety or tailored to suit the objectives of the EA. According to the TOGAF Standard, EA's primary goal is to help organizations enhance and integrate their processes, allowing them to better respond to change and support their business strategy. Additionally, it can be advantageous for organizations seeking to establish a seamless data flow within or among multiple organizations. The TOGAF Standard can be accessed online for free or organizations can obtain a licensed copy for downloading and storage purposes [5].

The diagram presented in Figure 1 depicts the central component of the TOGAF Standard 9.2 ADM [6]. The preliminary phase is responsible for preparing and adjusting the ADM and is continuously repeated [6]. It identifies the relevant units impacted by EA and the stakeholders and governance involved. This phase also establishes the architecture-governance framework and any additional support frameworks necessary for managing the architectural materials and the relationship between governance processes and ownership of architectural artifacts. Moreover, it defines the architecture principles, such as business, data, application and technology principles, that are crucial for effective architecture governance. The remaining ADM phases include the following:

A. Architecture Vision phase: develops the vision of the capabilities and business value that the proposed architecture would achieve. In addition, it approves the work plan required to build and deploy the proposed architecture.
B. Business Architecture phase: describes how the business operates or needs to operate to achieve the business goals.
C. Information-system Architecture phase: describes how the information-system architectures (data architecture and application architecture) enable the achievement of architecture vision and business architecture.
D. Technology Architecture phase: describes the target-technology architecture that enables the achievement of architecture vision, target business and information-system architectures.
E. Opportunities and Solutions phase: sets the foundation for delivering the architectures, including the migration and implementation plan, which provides the timeline for the projects required to produce the target architectures.
F. Migration Planning phase: finalizes the migration and implementation plan required to deliver the target architectures.
G. Implementation Governance phase: ensures that the implementation or any ongoing projects within the enterprise conforms with the target architectures.
H. Architecture Change Management phase: describes managing any changes to the new architectures.

The core of the ADM diagram, the Requirements Management phase, is a crucial part of ADM, as it identifies and stores the EA requirements fed into other phases. Throughout each phase, enterprise architects should pinpoint functional and non-functional requirements. These requirements dictate what the architecture should meet. The Architecture Requirements Repository contains all approved

architecture requirements, new-architecture requirements, out-of-scope architecture requirements and any changes to these requirements.

### 2.2 The National Center for Diabetes, Endocrinology and Genetics

The National Center for Diabetes, Endocrinology and Genetics (NCDEG) was established in 1996 as one of the centers affiliated with the Higher Council for Science and Technology [9]. Diabetes Mellitus (DM) is a chronic disease of inadequate control of blood levels of glucose; it has many subclassifications, including type 1 and type 2 [7]. Type 2 is considered the most common type and is regarded as an epidemic in many countries. The Middle East and North Africa Region (MENA) recorded the highest level of DM worldwide in 2019, with 12.2% of its population [8]. DM can lead to severe health conditions if left unmanaged; heart and blood vessel disease, kidney failure and retinal diseases are among the consequences of DM [9].

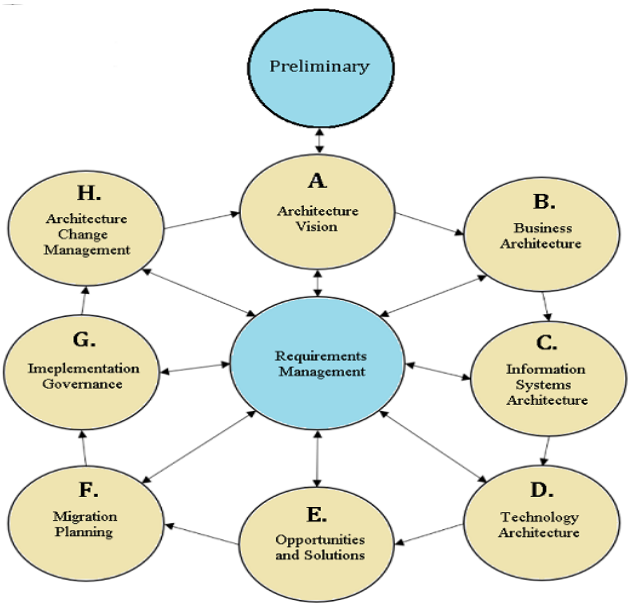


Figure 1. TOGAF Standard ADM [10].

In Jordan, 15% of the Jordanian population (aged 20-79) have been diagnosed with diabetes [11]. The prevalence of DM in the country has steadily increased; for example, it reached 32.4 % of males over 25, representing 125% of its prevalence among the same population in 1994 [12]. It is also projected that a fifth of Jordanian people will have type-2 DM by 2050 [13].

NCDEG is the only specialized healthcare provider in Jordan that provides comprehensive treatment services for DM, its complications, endocrine diseases and genetic disorders. These services include DM-specialized clinics, Endocrinology clinics, Genetics clinics, Diabetic Foot Care Clinics and other specialized clinics. In addition, NCDEG has a Radiology, Imaging and Nuclear Medicine department, four labs and a specialized pharmacy dedicated to providing medications for DM and its complications, endocrine disease and genetic disorders.

Given the substantial demands placed on the services offered by NCDEG, the findings of this study are anticipated to contribute significantly to developing an EA that effectively enhances NCDEG's service delivery and outcomes.

## 3. RELATED WORK

Numerous research studies have delved into EA's various applications and roles in healthcare organizations. In our work, we have come across a few such studies. One such comprehensive systematic review was conducted by [14], which analyzed 46 studies in 19 countries between 2015 and 2019. These studies explored the practical applications of EA in various healthcare settings, including hospitals, public and private health systems, e-health, health-information systems (HIS), public-health systems, pharmaceutical corporations and health companies. According to the review results, TOGAF, Adaptive Integrated Digital Architecture Framework (AIDAF), Weil and Ross and Zachman are the four most

commonly implemented EA frameworks in the healthcare sector, accounting for 43% of the studies included in the review. TOGAF was the most widely adopted, featured in 22% of the total studies, followed by AIDAF in 11%, Weil and Ross in 6% and Zachman in 4%. The review also highlighted that several studies employed a combination of multiple frameworks.

A Dharmais Cancer Hospital case study in Indonesia identified the need for an effective information technology solution [15]. However, this proved challenging due to the need for an EA to guide the implementation and execution of technology solutions and evaluate their effectiveness. The study's authors found that TOGAF was the ideal framework for creating an EA, focusing on processes and their alignment with business strategy. Using TOGAF's ADM, the authors identified 36 gaps between the baseline and target architecture needing improvement.

A recent study discussed the Queensland State in Australia model to create a digital health vision enabling all stakeholders to access health and medical information in a consumer-centric system. However, to achieve this vision, adopting an EA framework was necessary. The study noted that in addition to realizing the vision, the framework would need to address several challenges, including inefficient data sharing, difficulty in integrating diverse systems and databases across Queensland, insecure data access, lack of adequate IT governance and a need to increase digital literacy among medical professionals and staff to adapt to new technologies. After conducting a literature review of common EA frameworks, such as TOGAF, Zachman and FEAF, the study concluded that TOGAF was the most suitable framework for the case of Queensland and explained how it would address the identified challenges.

A conceptual EA framework, the Hospital EA Framework (HEAF), was created and specifically designed for hospitals in Iran [16]. This framework is based on the well-established TOGAF framework, but was adapted to meet the unique needs of Iranian hospitals. Through a rigorous methodology for selecting criteria, the authors could justify their reliance on TOGAF and determine the architectural elements involved in each phase. Their study found that this new EA framework could be implemented in hospitals throughout Iran.

Another recent case study was conducted at the Setiabudi District Public Health Center in South Jakarta, Indonesia. The study employed the TOGAF-ADM method, analyzing business, application and technology architecture. Primary and secondary data was gathered through observational studies and interviews at the Public Health Center. Gap analysis is used to compare the target architecture with the current-state architecture. The primary outcome of the research is the presentation of an EA design for the Setiabudi District Public Health Center, aiming to enhance the effectiveness and efficiency of its services [17].

This study contributes to the field of healthcare enterprise architecture by examining the digital transformation process within NCDEG in Jordan. The primary contribution lies in applying The Open Group Architecture Framework (TOGAF) as a methodology to facilitate this transformation while ensuring alignment with the organization's business goals. This approach offers a systematic and comprehensive framework for analyzing the current architecture of NCDEG, identifying areas for improvement and developing a target architecture to address the organization's needs effectively. The simulation provides a strong indication of how this model can assist the center in achieving its goals with better performance measurements. The novelty of this paper lies in its focus on leveraging TOGAF for healthcare enterprise architecture, particularly in the context of a specialized medical center like NCDEG. By employing TOGAF's Architecture Development Method (ADM), our study provides a structured and rigorous methodology tailored to the unique requirements of healthcare organizations, thus filling a gap in the existing literature. This research contributes to advancing the understanding of digital transformation in healthcare settings and provides valuable insights for practitioners and researchers seeking to implement similar initiatives.

The comprehensive nature of TOGAF, along with its flexibility and the ability to align with business goals, are the main reasons for selecting it as an EA framework that could address the complexity of the technological landscape and operational concerns at NCDEG.

## 4. RESEARCH METHODOLOGY

This qualitative exploratory study utilized specific research steps to construct the NCDEG's EA. The

following steps were implemented:

**Phase 1:** Obtaining primary data from NCDEG through observations and semi-structured interviews with officials from NCDEG's IT and quality departments. The first phase aimed to comprehend NCDEG's IT structure, direct medical services and role in providing them. Additionally, necessary data was obtained to establish a baseline and target for the EA.

**Phase 2:** The NCDEG's EA was built by implementing TOGAF ADM (refer to Figure 1) on its direct medical services. The second phase was accomplished through a sequence of steps.

**S1:** In the preliminary phase and phase A of the TOGAF Standard ADM, we define NCDEG's business goals based on its mission and vision. We also determine the scope of the EA and establish the EA's principles and governance requirements.

**S2:** Developing the baseline EA is crucial to understanding NCDEG's current architecture. It involves creating the baseline core architectures of TOGAF Standard ADM: Phase B-Baseline (business architecture), Phase C-Baseline (information-system architecture) and Phase D-Baseline (technology architecture).

**S3:** To identify areas for improvement and build the target EA, we conduct a gap analysis of the baseline architectures following NCDEG's primary business drivers and goals.

**S4:** Developing the target EA involves addressing the shortcomings identified in the baseline EA analysis to enhance NCDEG's performance and achieve its business goals. We develop the target core architectures of TOGAF Standard ADM: Phase B-Target (business architecture), Phase C-Target (information-system architecture) and Phase D-Target (technology architecture).

**Phase 3:** Validating the results by utilizing the Rockwell Arena Simulation Software. This study aims to create an EA for NCDEG's direct medical services, which includes the elements, units, stakeholders, processes and technologies specific to this scope. We will follow the TOGAF ADM phases pertinent to EA development, but not those related to its implementation and governance.

### 4.1 Research Limitations

This study applies the TOGAF Standard 9.2 ADM phases to the NCDEG case, specifically focusing on the development phases ranging from preliminary to phase D for current/baseline and target architectures. It is worth noting that we have excluded the implementation and governance phases at this study stage.

Moreover, TOGAF recommends several artifacts that architects may develop in each phase of the TOGAF ADM. These artifacts are a collection of catalogs, matrices and diagrams that can address different stakeholders' concerns and requirements within the organization. In this research, the authors decided to use a limited number of diagrams that fit this research.

## 5. RESULTS AND ANALYSIS

This section presents the NCDEG's baseline EAs, the gap analysis to identify areas for improvement and the target EA that resulted from following the research methodology's phases.

### 5.1 The Preliminary Phase

The preliminary phase encompasses four main steps: (1) understanding the organizational context, (2) identifying the EA's key business drivers and objectives, (3) identifying and defining the fundamental units, organizations and stakeholders impacted by EA and (4) defining the EA principles. The following sub-phases will cover the preliminary phase of TOGAF ADM.

***Organizational Context, Business Drivers and EA Objectives:*** By interviewing NCDEG officials, we could determine the following business objectives:

1. Providing a comprehensive, safe, high-quality treatment facility as a one-stop destination for patients with diabetes, endocrinology and genetic disorders.
2. Ensuring that all provided medical services and treatments adhere to national and international quality standards.

3. Addressing the prevalence of diabetes, endocrinology and genetic disorders in Jordan, seeking to limit their impact on the population.
4. Integrating medical services with scientific research, training and education and establishing a cohesive synergy between healthcare provision and advancing knowledge in the field.

In addition to the abovementioned objectives, essential business drivers pose challenges, yet offer potential opportunities. These business drivers are the core reasons for dedicating time, resources and effort toward developing and implementing an EA for NCDEG. Figure 2 depicts the EA's objectives derived from NCDEG's business drivers and objectives:

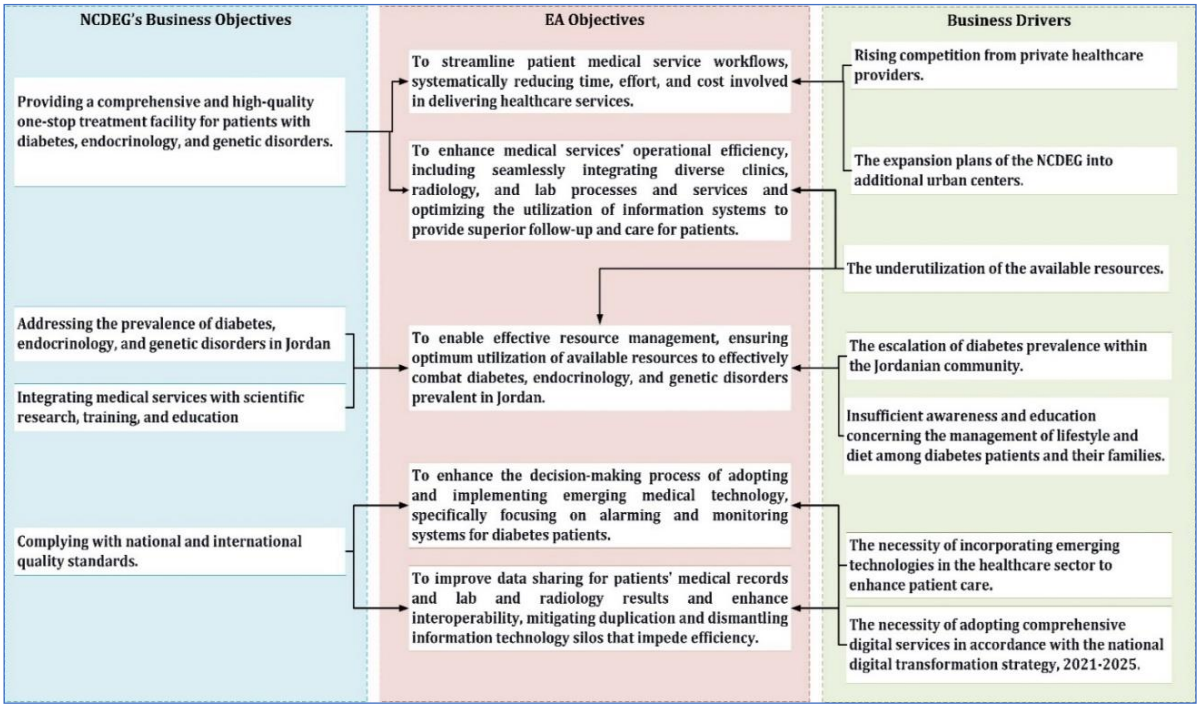


Figure 2. NCDEG's EA objectives.

***Identifying and Defining the Fundamental Units, Organizations and Stakeholders Impacted by EA:*** To maximize the benefits of implementing EA in the NCDEG's medical services, the study has identified the core units that will be significantly impacted. These include the Diabetes Clinics and their labs (including regular and consultation clinics), as well as other specialized clinics, such as Ophthalmology, Cardiology, Pulmonology, Gynaecology, Nephrology, Urology, Dermatology, Neurology and Diabetic Foot Clinic. The Central Lab, imaging department, Pharmacy and Appointment department are also expected to derive maximum value from implementing EA.

***Defining the EA Principles:*** During this phase, the governance mechanism and architecture principles are established to oversee the ADM cycle and the creation, upkeep and utilization of EA and IT resources. These principles guide decision-makers, as the TOGAF Standard outlines. The architecture principles themselves can be categorized into various groups, including business principles (e.g. the importance of principles in all NCDEG divisions), data principles (e.g., treating data as a strategic asset and implementing data governance) and application and technology principles (e.g. prioritizing ease of use and technology independence).

***Architecture Vision (Phase A):*** In this TOGAF ADM phase, we identify the business scenario and stakeholders involved. Specifically, we focus on the NCDEG, the only center for diabetes in Jordan and the challenges that the medical staff and patients face. The busy schedules of physicians and consultants make it challenging to schedule appointments flexibly or quickly, while patients must undergo a lengthy, manual process to access medical services and prescriptions. Stakeholders include NCDEG's administrative and medical staff, management and patients. Figure 3 outlines NCDEG's primary and support activities, which aim to increase efficiency and resource utilization while improving patient service quality. The EA's vision is to achieve these goals.

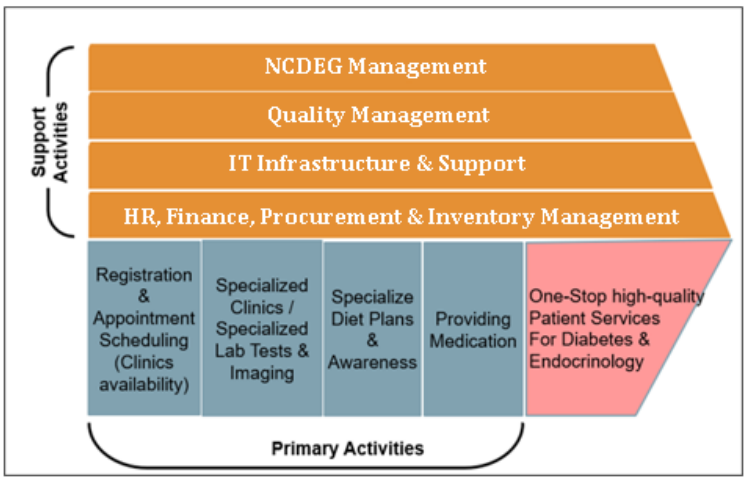


Figure 3. Value chain of NCDEG.

## 5.2 Developing the Baseline Enterprise Architecture

This step is crucial in comprehending the present state of NCDEG architecture. It involves the development of the current or baseline core architectures of NCDEG by the TOGAF Standard, comprising business, information system and technology architectures.

***Baseline-Business Architecture:*** A detailed baseline process diagram (Figure 4) has been created to gain a comprehensive understanding of the processes in line with this study's scope. It represents the primary activities necessary to achieve NCDEG's goals.

***Baseline-Information System Architecture:*** The information-system architecture entails understanding the data and application architectures. Based on the information gathered from NCDEG, the current NCDEG Health Information System (HIS) comprises the components depicted in Figure 5. In this phase, the baseline data and application architectures were not presented thoroughly due to data access restrictions; however, the gathered data to create the HIS functional decomposition diagram was provided and validated by the NCDEG.

***Baseline-Technology Architecture:*** The NCEDG's IT management must provide adequate details to construct the current technology architecture. However, they have mentioned that users connect to servers *via* wired or wireless connections. Oracle DBMS and the backup appliance are utilized to manage data on database servers. Additionally, NCDEG must employ cloud services to safeguard patient privacy and information security.

## 5.3 Baseline EA Gap Analysis

After analyzing the baseline EA, we have identified several gaps and areas for improvement. One significant issue is the improper follow-up process for patients referred for laboratory tests or imaging procedures. Currently, patients only receive updates on their results from the referring physician when their next appointment is scheduled, which can take up to three months in diabetes clinics and 4-5 months in specialized clinics, like cardiology and neurology clinics, due to limited available appointments. This inadequate follow-up process can lead to severe health complications for affected patients, making it crucial to address this issue.

***The Lengthy Prescription Renewal Process:*** Patients requiring only a renewal of their medical prescriptions must undergo an extensive procedure to obtain their medications, much like any other patient. This process worsens the problem of appointment unavailability in heavily crowded clinics and it also costs patients considerable time, effort and financial resources. It is essential to streamline this process and make it more efficient to improve patient outcomes and reduce the burden on the healthcare system.

***Inefficient Monitoring of Glucose Levels:*** For diabetes patients, especially those who rely on insulin therapy, monitoring blood sugar levels is crucial to assess and adjust their therapy and diet plans continuously. During a visit to the NCDEG, it was noted that patients are given booklets to record their daily glucose readings, known as self-monitoring blood glucose (SMBG). However, some patients

overlook this step and resort to the accumulative sugar blood test HbA1c, which alone cannot offer a comprehensive analysis of the patient's condition to establish an effective diet plan or support the doctor's assessment of the current treatment plan, particularly for insulin therapy, as SMBG can.

Nevertheless, providing doctors and dieticians with a booklet containing three months of daily readings is impractical. It would be challenging for doctors to allocate sufficient time to review and analyze all these readings effectively.

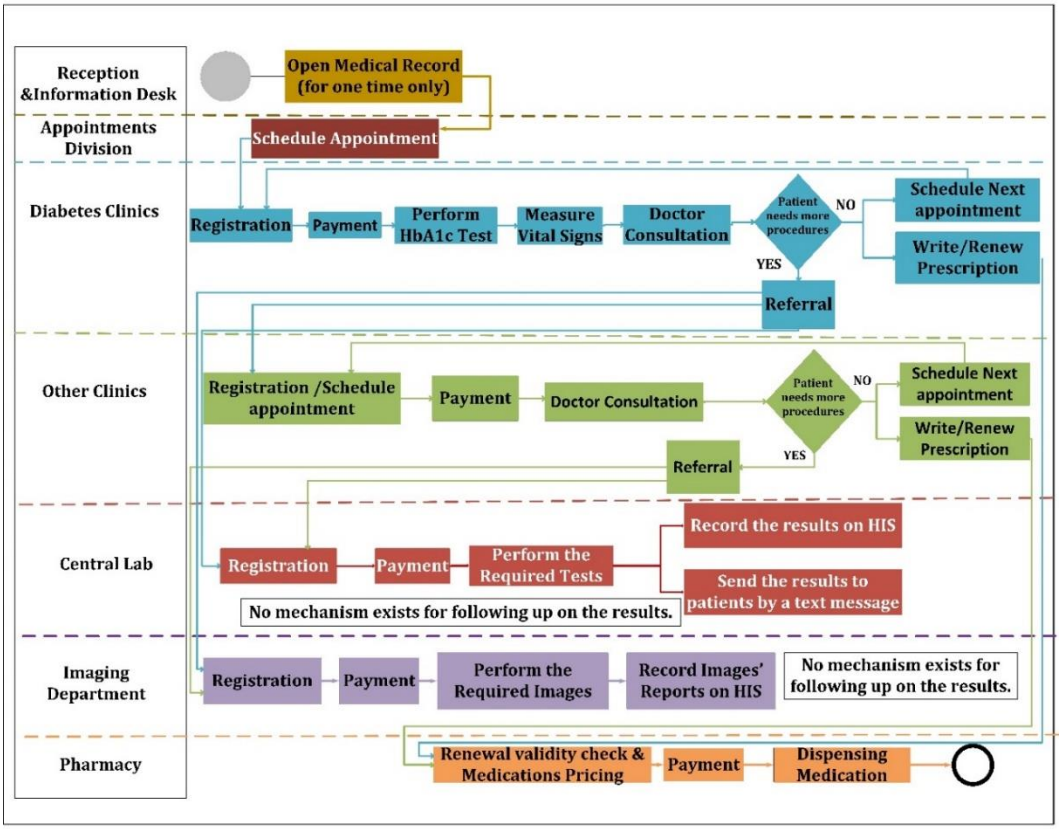


Figure 4. Baseline business architecture.

***Appointment Availability:*** Securing a timely consultation with NCDEG physicians is problematic. In specific clinics, the next available appointment could be months away. This task poses a significant challenge to patients' treatment plans and could worsen their health. Furthermore, the unavailability of appointments may put an added financial strain on insured patients with NCDEG. In such situations, patients may be compelled to seek treatment from private healthcare providers, which could result in a loss of revenue for NCDEG.

***Incomplete Process Automation and Modules Integration:*** The existing process lacks full automation, requiring patients to complete specific paperwork at various stations during their visit, such as the clinic registration desk and pharmacy. This could lead to increased time that patients spend on a particular service.

***Resources Underutilization (Utilization of Education and Dietician Services):*** Research has highlighted the significance of managing one's diet and weight and engaging in physical activities to mitigate diabetes complications and enhance the patient's quality of life. The NCDEG offers a dietetics clinic and a diabetes-education clinic to provide patients with the necessary resources for self-management. However, a visit to the NCDEG reveals that both clinics suffer from low attendance rates, which could jeopardize patients' well-being and health. Furthermore, this underutilization of services undermines the NCDEG's mission to disseminate diabetes education and raise awareness of self-management requirements [9].

Table 1 summarizes the gap analysis, highlighting the current shortcomings in the NCDEG process, their impact on critical patient aspects, like health, cost and time, and their influence on NCDEG's

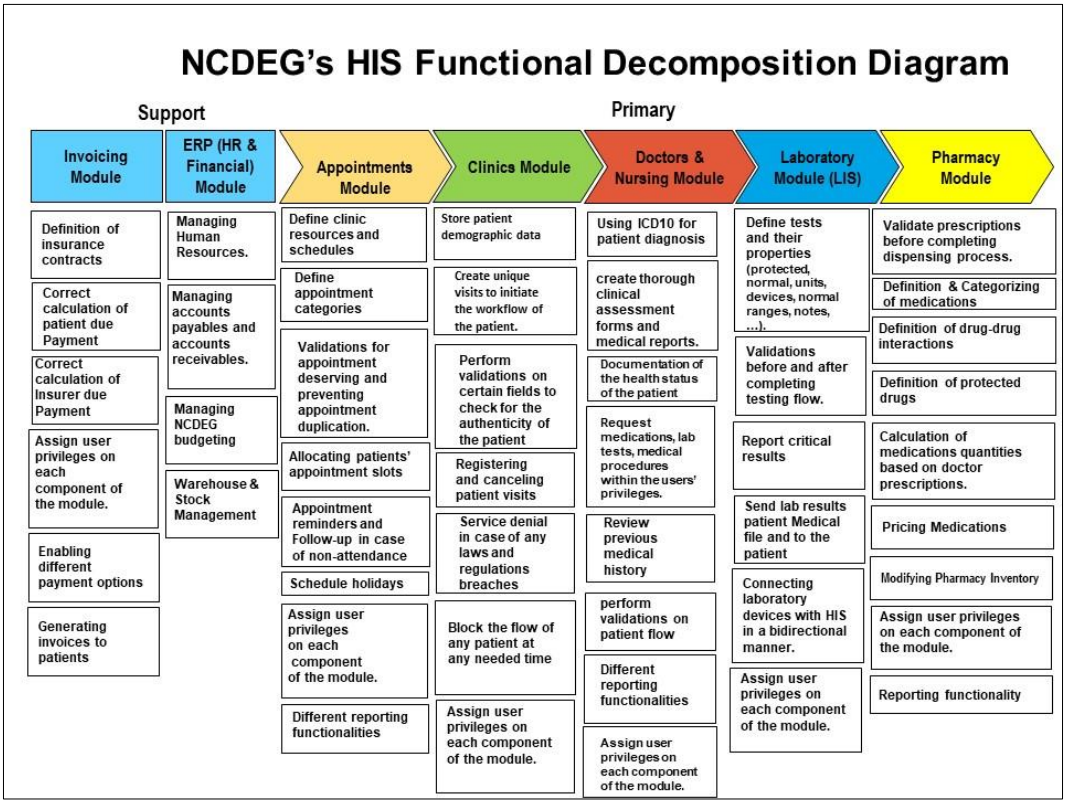

Figure 5. HIS functional decomposition diagram – Baseline information-system architecture.

primary activities. The red cells in Table 1 indicate the impacted aspects out of seven ones. After analyzing the table, it was found that improper follow-up and unmonitored glucose levels are the most critical issues affecting patient well-being and NCDEG's primary activities. These issues represent 71% (5/7) and 57% (4/7) of criticality, respectively, assuming that all aspects have the same weight/importance. Therefore, it is crucial to prioritize resolving these shortfalls.

Furthermore, the analysis highlights the significant effect of current process shortfalls on patient health and NCDEG's overall operations. Process automation, HIS module integration and streamlined prescription renewals are recommended to address prolonged service times and appointment unavailability. These measures would enhance patient care, improve efficiency and resource utilization and reduce waiting times.

In the following part, we will discuss NCDEG's EA, which aims to fill the gaps in the baseline architecture and address these analysis outcomes.

## 5.4 Developing the Target Enterprise Architecture

The targeted EA encompasses business, information-system and technology architecture changes.

***The Target Business Architecture (Phase B):*** The target business process outlined in Figure 6 addresses issues related to medical prescription renewals, appointment availability and underutilization of resources. The process described in Figure 6 focuses on several key areas, including:

1. Advanced technologies, like telemedicine and virtual clinics, save patients' time when renewing prescriptions. Through online sessions with a doctor, patients can have their case assessed and prescription renewal approved through the HIS. Telemedicine and mobile apps can also offer dietician services and awareness programs to improve resource utilization. Integrating AI technologies with wearable devices or mobile apps can provide personalized tools for diabetes prevention and management, including the detection of diabetic complications, such as hypoglycemia, diabetic retinopathy and cardiovascular risks, and the enablement of the artificial pancreas.
2. The process also includes follow-up sessions with patients after receiving test or imaging results to ensure that they are updated on their results and any necessary actions or procedures as soon as possible, rather than waiting until their next visit, which could be up to three months away.

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Table 1. Gaps impact on patients and NCDEG's primary activities (impacted cells are in red color).

| | Impacts on Patient | | | Impacts on NCDEG's Primary Activities | | | |
|---|---|---|---|---|---|---|---|
| Shortfalls | Health Impacts | Financial Impacts | Service Time | Registration & Appointment Scheduling | Specialized Clinics / Lab Tests & Imaging | Specialized Diet Plans & Awareness | Providing Medication |
| Improper Following up 71% ( *5/7* impacted aspects) | | | | | | | |
| Lengthy Prescriptions Renewal Process 42% (*3/7*) | | | | | | | |
| Inefficient GCM 57% (*4/7*) | | | | | | | |
| Appointments Unavailability 42% (*3/7*) | | | | | | | |
| Incomplete Process Automation & Modules Integration 42% (*3/7*) | | | | | | | |
| Resources Underutilization 42% (3/7) | | | | | | | |

Figure 6 depicts the newer technology in daily-basis activity in NCDEG, where the new architecture comprises several interconnected elements to enhance the organization's operational efficiency and patient-care quality. These elements include adopting digital health solutions, including telemedicine and virtual clinics, integrating AI technologies for personalized patient care and optimizing existing processes and workflows to streamline operations.

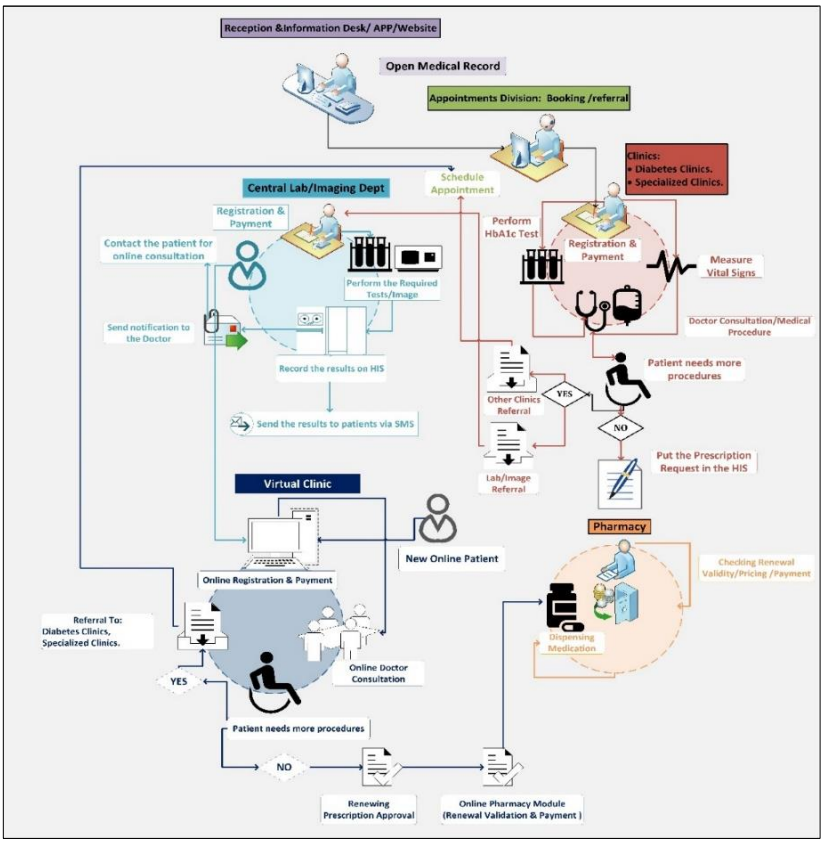


Figure 6. The target business architecture.

***The Target Information-system Architecture - Data (Phase C):*** Regarding the information-system architecture, proposed changes to the business process outlined in Figure 6 necessitate adjustments to the current system. The system consists of data and application architectures that depict the various entities within it and their relationships. Specifically, the data architecture of the system must allow for the electronic capture of patient data and glucose-level readings and integration with the patient's record in HIS. Currently, NCDEG's patients manually record their daily blood-sugar levels, which requires six

inputs daily in a notebook provided by NCDEG. The new system will also enable patients to schedule appointments, update their data and profile and allow NCDEG staff to interact with the system's data per their roles, as illustrated in Figure 7.

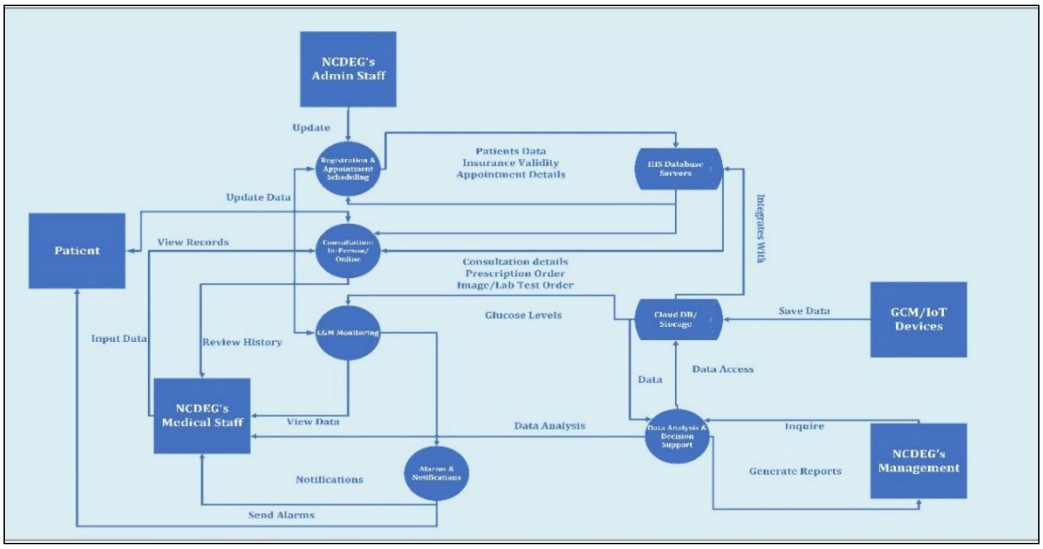


Figure 7. The target information-system architecture (data).

***The Target Information-system Architecture - Application (Phase C):*** The architecture comprises several components that seamlessly provide a comprehensive healthcare experience. These components include a telemedicine module that enables online consultations, with added features, such as online payments and insurance-validity checks, if necessary. Additionally, the system allows for collecting and managing patients' data, including important factors, like sugar levels and blood pressure. The platform includes AI-powered patient-data analysis and visualization for better data interpretation and decision-making. Finally, the system provides follow-up reminders and alarms for patients whose sensed data or test results reveal risky conditions. For a more detailed understanding of the target architecture, please refer to Figure 8. Figure 8 depicts the suggested three platforms (interfaces): web, mobile-phone interfaces and data warehouse for data storage and archiving. The main modules that incorporate AI-powered services are included in the figure.

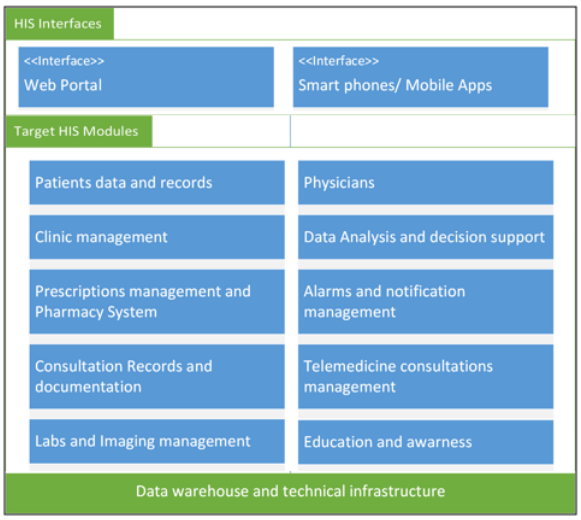


Figure 8. The target information-system architecture (application).

***The Target Technology Architecture (Phase D):*** Figure 9 describes the target information system with the required technological advancements that can be implemented to improve services' quality and performance. The figure shows the sequences of actions that the user and NCDEG staff privileges can take. The HIS modules manage the interaction between the patient and staff views to verify the procedures before the integration process and data analytics. Data management and warehouse store the data for future reference and reporting.

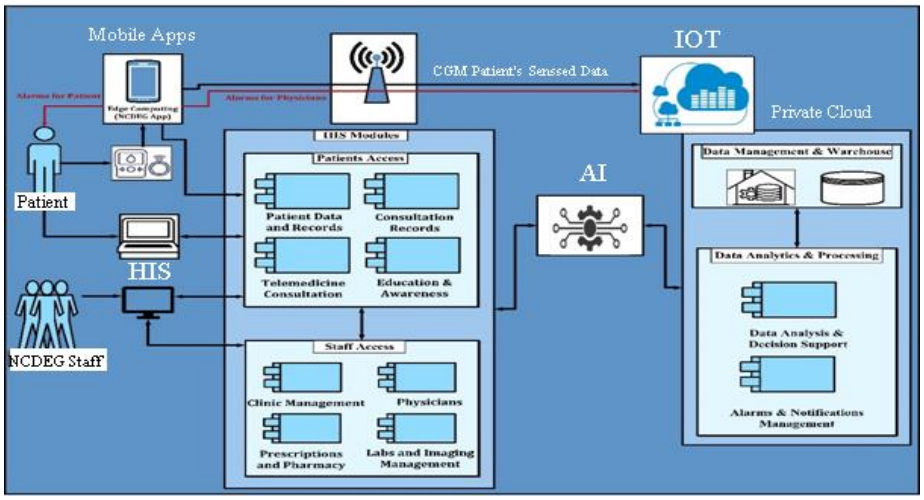


Figure 9. The target technology architecture.

Figure 10 outlines additional improvements and enabling technologies that the NCDEG can leverage to enhance its services. The enablers represent the cutting-edge technologies that can improve the center's services in general to achieve its goals.

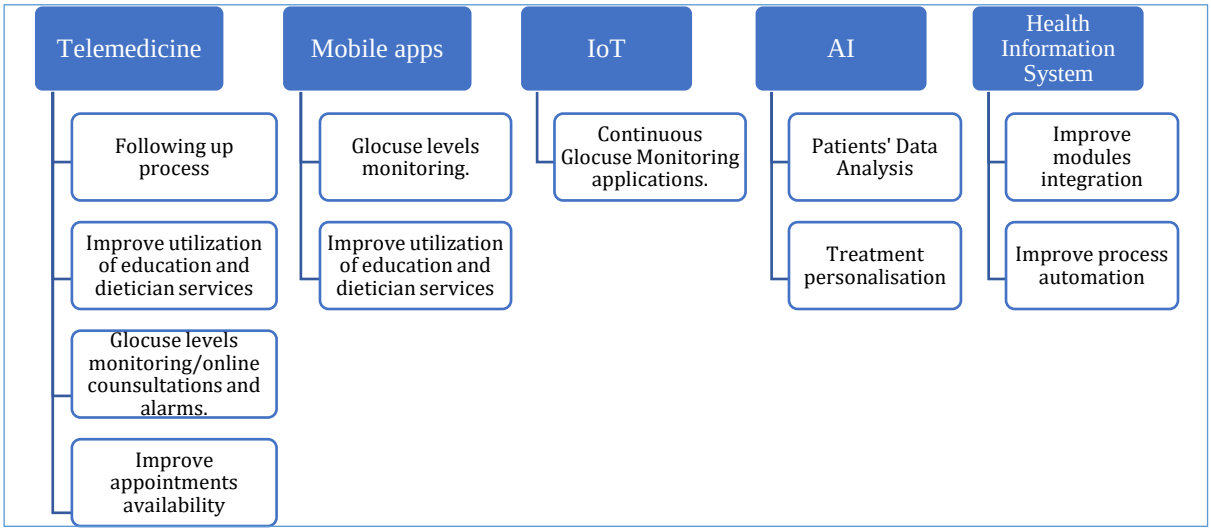


Figure 10. Proposed technologies and improvements.

## 5.5 Validation

The proposed changes have been validated by simulating the current and target processes to enable comparison and analysis of each process's key performance indicators (KPIs). Figure 11 illustrates the simulation of the proposed changes (target business process) using Arena Simulation Software.

***The Data Gathering Phase:*** Data gathering consisted of visiting NCDEG for four days to collect observational data (5 cases per day) from diabetes clinics. The data collection focused on gathering data on patients' visits to diabetes clinics, the radiology department, the labs and the pharmacy.

***The Simulation Phase:*** Rockwell Automation's Arena Simulation Software (version 16) was used to conduct five replications based on observational data. Each replication was designed to mimic six days with eight operational hours per day and the Base Time Units were represented in minutes. The simulation of the current process resulted in the following main KPIs shown in Table 2 and Table 3. In contrast, the simulation of the target process, which includes physical and virtual clinics running simultaneously, resulted in the main KPIs shown in Tables 4 and 5.

### *Analysis of the Simulation Results*

1. The analysis of simulation results indicates that establishing a virtual clinic, even with minimal resources, can significantly improve NCDEG's ability to handle an enormous patient load. The

simulations demonstrate a marked increase in the total patient count, representing a 32% rise, from 2322 to 3067. The virtual clinic enables patients who require prescription renewals to consult with doctors online without undergoing the typical clinical process. Such a digital health solution can relieve stress for NCDEG's constrained resources, enhancing the overall availability of medical appointments.

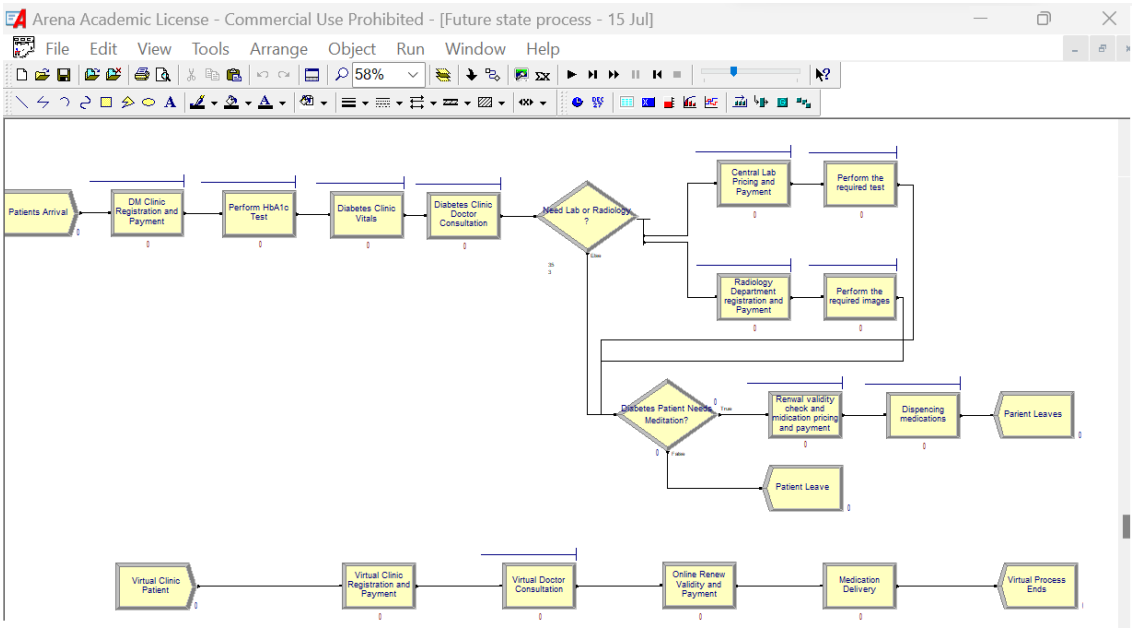


Figure 11. Illustration of the simulation of the proposed changes using the Arena Simulation Software.

Table 2. Entity (patient) KPIs.

| Entity | Average Number |
|---|---|
| Patients' Total Number in | 2380 |
| Patients' Total Number out | 2322 |

Table 3. Time KPIs.

| Waiting Time (Minutes) | Average | Maximum |
|---|---|---|
| Total Process Length | 46.1643 | 83.8235 |
| Total Waiting Time | 12.3707 | 64.5179 |
| Total Time to Service (Process Length+ Waiting Time) | 58.5350 | 142.33 |
| DM Clinics Queuing Time (Registration Queue + Payment Queue + Nursing Vitals Queue+ HbA1c Test Queue) | 0.011499 | 3.5663 |
| DM Clinics Doctors Consultation Waiting Time | 10.0711 | 62.5091 |
| The Central Lab Queuing Time (Central Lab Payment Queue + Central Lab Pricing Queue+ Performing the required Test Queue) | 0.853825 | 7.6104 |
| Pharmacy Queuing Time (Pricing Queue + Payment Queue+ Dispensing Medications Queue) | 2.2335 | 29.2735 |
| Radiology Dept Queuing Time (Registration Queue + Payment Queue + Performing the Required Image Queue) | 2.742817 | 42.0904 |

Table 4. Entity (patient) KPIs.

| Entity | Average Number |
|---|---|
| Inpatient number (in-person clinics) | 2389 |
| Virtual inpatient number | 723 |
| Total inpatient number | 3112 |
| Outpatient number (in-person clinics) | 2350 |
| Virtual outpatient number | 717 |
| **Total outpatient number** | **3067** |

Table 5. Time KPIs.

| Waiting Time (Minutes) | Average | Maximum |
|---|---|---|
| **Traditional In-Person DM Clinic KPIs** | | |
| Total Process Length | 43.7283 | 75.5309 |
| Total Waiting Time | 11.5185 | 72.9616 |
| Total Time to Service (Process Length+ Waiting Time) | 55.2468 | 124.71 |
| DM Clinics Queuing Time (DM Clinic Registration and Payment + Nursing Vitals Queue+ HbA1c Test Queue) | 0.000971 | 1.872 |
| DM Clinics Doctors Consultation Waiting Time | 9.6415 | 61.1566 |
| The Central Lab Queuing Time (Central Lab Pricing and Payment Queue + Performing the Required Test Queue) | 0.018707 | 2.853 |
| Pharmacy Queuing Time (Renewal Validity Check and Medication Pricing and Payment Queue+ Dispensing medications Queue) | 1.9254 | 19.8665 |
| Radiology Dept. Queuing Time (Registration and Payment Queue + Performing the Required Image Queue) | 3.455178 | 37.2402 |
| **Virtual DM Clinic KPIs** | | |
| Total Process length | 12.0500 | 12.0500 |
| Total Waiting Time | 0.00 | 0.00 |
| Total Time to Service (Process Length+ Waiting Time) | 12.0500 | 12.0500 |
| Pharmacy Queuing Time | It is not applicable as the medicine should be delivered to the patient. | |

2. The proposed changes can reduce the maximum service time, including process duration and waiting time, by 12%. The current process has too many unnecessary steps, making it long, complicated and wasteful. Merging the clinic registration and payment into one step can save time and simplify the process's complexity. The same idea can work for the central lab, radiology and pharmacy departments by joining the registration/pricing and payment into one more straightforward step.
3. The virtual clinic offers a streamlined process where registration and payment can be completed online. Additionally, medications can be dispensed to these patients *via* a paid delivery service. The virtual clinic also provides a practical and accessible platform for follow-up interactions between patients and doctors. For instance, if lab tests or radiology reports reveal concerning results, the doctor and the patient can swiftly arrange a virtual consultation session, avoiding the necessity for an in-person visit, subject to appointment availability.
4. Digitalization of services can significantly improve existing processes. For instance, a separate step for medicine pricing becomes redundant within the proposed virtual clinic. This action is possible, because the system automatically registers approved medications, enabling their readiness for online payment. This strategy can be effectively applied to in-person clinic visits as well. The electronic health assistant (EA) can improve interoperability and integration among NCDEG's Health Information System (HIS) modules. When a doctor prescribes medications through the system, the integrated clinic and pharmacy modules can autonomously calculate the cost and prepare the prescription for payment, thus eliminating the need for a distinct queue for medication pricing.
5. Moreover, digital transformation has the potential to assist patients visiting the NCDEG in person in bypassing the queue for payments. This action can be achieved by facilitating online payments *via* the NCDEG's app. or website or installing smart kiosks that streamline clinic registration and payment for various services, such as clinics, labs, radiology and pharmacies.
6. The virtual-clinic model can enhance dietary and diabetes awareness services. Although the NCDEG has yet to provide data on the number of patients using these services, several visits at varying intervals suggest a low usage rate. However, transitioning these services to a virtual format could increase their reach and accessibility, benefiting NCDEG patients and the wider Jordanian community. Given the high prevalence of diabetes in Jordan, such a transition could significantly enhance diabetes awareness, understanding and management, aligning well with the business goals of NCDEG.

## 6. DISCUSSION

The integration of the new architecture at NCDEG is justified by its potential to address critical

challenges and capitalize in emerging opportunities within the healthcare landscape. By utilizing digital health solutions and AI technologies, NCDEG can enhance its capacity to deliver comprehensive, safe, high-quality treatment facilities while adhering to Jordanian and international quality standards. Moreover, optimizing existing processes and workflows enables NCDEG to streamline operations, reduce waiting times and improve overall service delivery, ultimately contributing to better patient outcomes and organizational efficiency.

The implementation of EA at the NCDEG in Jordan marks a significant milestone in the organization's digital-transformation journey. Several vital challenges were encountered throughout this process, reflecting the inherent complexities of integrating technological advancements within a healthcare framework. The various elements of the new architecture interact synergistically to support NCDEG's overarching business goals and objectives. For example, integrating telemedicine and virtual clinics enables patients to access medical services remotely, reducing the need for in-person visits and enhancing appointment availability. Additionally, AI technologies facilitate data-driven decision-making and personalized patient interventions, improving clinical outcomes and patient satisfaction.

We should keep in mind all difficulties that may arise during the implementation, including user resistance, the complexity of automating the process and facing procedures that may stop the adoption of the suggested framework. Looking ahead, several opportunities for future enhancements and refinements within NCDEG's EA framework become apparent. Firstly, ongoing monitoring and evaluation of the implemented solutions will be essential to assess their effectiveness and identify areas for further optimization. Additionally, continued collaboration with healthcare practitioners and IT experts will ensure that the EA framework remains adaptive and responsive to evolving patient needs and technological advancements. Moreover, efforts to enhance data security and privacy measures will be paramount, particularly in light of the increasing reliance on digital health solutions and the sensitive nature of patient information.

The successful integration of the new architecture at NCDEG underlines the transformative potential of technology in improving healthcare delivery and patient outcomes. By providing clear explanations of the elements, interactions and justification for the new architecture, NCDEG has taken significant strides toward providing better medical services while reducing the time and cost for the institution and creating a better patient experience.

## 7. CONCLUSION

The National Cenetr for Diabetes, Endocrinology and Genetics (NCDEG) in Jordan underwent a study utilizing the TOGAF Standard framework. Primary data was obtained through interviews with NCDEG officials despite restrictions on data provision. The application of TOGAF Standard ADM revealed areas for improvement in NCDEG's business, information systems and technology architectures and proposed changes to better align their digital-transformation initiatives with their vision, mission and business objectives. To ensure better results, improved interoperability and integration among processes, data and technologies, the study recommends developing EA while ensuring top-management engagement and assessing available resources for successful development. The TOGAF Standard 9.2 ADM phases applied to the NCDEG case include the development phases, from preliminary to phase D for current/baseline and target architectures. Implementation and governance phases were excluded. A baseline and target processes simulation was conducted to validate proposed changes and highlight their impact. It is recommended that the healthcare sector in Jordan can utilize EA as a strategic tool to plan, manage and govern its digital transformation and IT landscape using suitable EA tools or frameworks.

The study relied on available data from NCDEG, which may have limitations in terms of completeness and accuracy. Another limitation is the narrow scope of the evaluating simulation compared to open-scope real-life systems. The future direction is to explore the applicability of the proposed approach to other healthcare organizations and settings. Security, privacy and other confidential measures must be examined in future works.

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**ملخص البحث:**

يُمكن لتطبيق التّكنولوجيا أن يفيد المنظّمات بشكلٍ كبير، ويجب أن تنسجم مع احتياجات المنظّمات وأهدافها. ويُمكن لتطبيق "بنية مشروع" مساعدة مؤسسات الرّعاية الصّحية في التّغلُّب على التّحدّيات في أثناء عملية الانتقال الرّقمي.

هذه الورقة تبيّن كيف يُمكن لتطبيق "بنية مشروع" أن يسهل عملية الانتقال الرّقمي مع ضمان أن يتماشى ذلك مع احتياجات العمل. وباستخدام طريقة تطوير بنية المشروع، تعمل هذه الدّراسة على تحليل البنية الرّاهنة للمركز الوطني للسّكري والغدد الصّمّاء والوراثة في الأردن بهدف تطوير بنية جديدة للمركز من شأنها أن تساعد المركز على تحقيق أهدافه، وذلك من خلال التّناغم بين تطبيق التّكنولوجيا وغايات المركز المراد تحقيقها. وتبحث الدّراسة في التّعقيدات المتعلّقة بالتّطورات التّكنولوجية في الوقت الّذي يُحْرص فيه على دمج التّكنولوجيا ببنية المشروع بسلاسة وفاعلية في استغلال الموارد المتاحة. يُضاف الى ذلك التّركيز على الحاجة الى تقييم بنية المشروع وضبطها باستمرار لمواجهة التّطورات الّتي تحدث في بيئة العمل. وقد تمّت محاكاة التّغيرات الضّرورية في بنية المشروع باستخدام البرمجيات المناسبة، وبيّنت النّتائج تحسُّناً ملحوظاً في التّعامل مع المرضى، وفاعلية العمليات، وأوقات الانتظار، واستغلال الموارد عبر تطبيق العيادات الافتراضية والحلول الرّقمية.