Vol. 16 No. 01 (2025):81-90
DOI: https://doi.org/10.61841/turcomat.v16i1.15212

DESIGN AND IMPLEMENTATION OF A COST-EFFECTIVE, NETWORK-BASED CLINIC MANAGEMENT SYSTEM FOR SMALL HEALTHCARE FACILITIES IN IRAQ

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ABSTRACT

Managing clinics efficiently requires a cost-effective and user-friendly system that simplifies daily operations while maintaining data security and accessibility. This paper proposes a clinic management system that does not require a dedicated server in order to minimize costs and ease the process of setup. The system is developed using SQLite, a lightweight database management system that enables easy data management on local machines and supports networked terminals. For the best performance, we divide the data into two SQLite files; the first for the basic activities of the clinic and the second for prescriptions and other attachments to enhance the processing and use of the system. The system is developed using C# and has a friendly graphical user interface for doctors and secretaries. It has role-based access control that provides secure user authentication and database is encryption to ensure that patient's information is well protected. The system is deployed via Windows network sharing, which makes it very easy to connect multiple terminals simultaneously through LAN or Wi-Fi without the need of professional IT personnel. This system has been used in more than 50 clinics and has proven to be reliable, efficient and easy to use and is therefore suitable for small to medium size healthcare institutions. It improves the management of the patient's records, the flow of work, and provides a cost-effective alternative to traditional clinic management solutions.

1. INTRODUCTION

In recent years, there has been a significant positive change in the healthcare field which is due to development in technology [1]. Among the most important aspects of change there is the use of digital solutions to manage clinic operations. Small clinics which are the source of primary health care in most areas face certain challenges because of resource limitations [2]. Large hospitals are different from clinics in Iraq which generally use paper work or outdated systems for scheduling patients, managing appointments, billing and storing prescription [3]. The use of traditional

methods of running the operations is slow and often results in mistakes that affect the quality-of-service delivery to the patient.

The need for an affordable and effective clinic management system is becoming increasingly important with the increase in patient expectations and the increasing complexity of regulatory requirements. The global movement toward digital health is supported by WHO's strategy which emphasizes cost-effective, scalable, and secure systems especially in underserved regions [4]. Small clinics are now expected to maintain correct electronic health records (EHRs), secure data, and provide a smooth patient experience, all while operating within a constrained budget. Research indicates that digital health tool adoption sped up dramatically throughout the COVID-19 pandemic specifically in primary care settings and small clinics [5]. However, most commercially available clinic management systems are designed for large healthcare facilities and are therefore expensive and complex for small-scale operations. This gap shows that there is a need for a cost effective, network-based solution that is tailored to the requirements of small clinics.

Network based systems have several advantages like centralized data storage, real time access to information and enhanced collaboration among clinic staff. Small clinics can streamline their operations without incurring significant infrastructure costs by leveraging local area networks (LAN) or cloud-based platforms. The use of open source technologies and lightweight databases can also be used to keep development and maintenance costs low, thus extending the availability of such systems to clinics with few financial resources.

This paper aims to address these challenges by introducing cost-effective, network-based clinic management system designed specifically for small healthcare facilities. In combination with user friendly design, the proposed system is expected to fill the gap between the need for digital transformation and the financial constraints of small clinics. The main goal is to provide these clinics with the means to provide quality care and improve operational performance.

2. LITERATURE REVIEW

The development and implementation of clinic management systems have been investigated widely in the context of healthcare technology. Existing research shows the revolutionary impact of digital solutions on healthcare operations and performance, including lower costs, less errors, and better patient outcomes such as Epic Systems, Cerner [6] [7]). However, these systems are meant for large healthcare organizations and the present review reveals a gap in the literature regarding solutions tailored for small clinics with limited resources. Also, user resistance, lack of training, and system complexity remain common barriers in small-scale settings [8]. Other systems are proposed as clinic solutions, such as in [9] , the authors proposed a tiered architecture for the performance analysis of web-based healthcare systems, where the prototypes were consolidated onto a single homepage and linked through a hyperlink recommendation approach. The tiered

Submission Date: February 10, 2025 | **Acceptance Date:** March 14, 2025 | **Publication Date**: 16 April 2025

architectures—single, two, and three-tier—play a vital role in Web-Based Healthcare (WBH) systems, each tier playing a different role in hospitals or clinics.

In their article, Rasha T. Hameed and colleagues suggested an eHealthcare management system design for Iraq clinics. They recommended an adaptable e-healthcare management model based on Cloud Computing and Service-Oriented Architecture (SOA). The study identified the major challenges and weaknesses of the current paper-based systems used in hospitals across Iraq and introduced the proposed system as a possible solution to the challenges [10]. In [11]the system was divided into three major modules: Doctors, Registration and Login. It was developed using a three tier Internet service architecture which has a client tier (web browser), an application tier developed in Apache and PHP and a database tier which is managed by MySQL. Both [12] [13] where the authors suggest an online management system for clinics, however, they require a website hosting with database server and Internet connection which include a monthly fee. Authors of [14], propose a friendly management system design where it requires a computer to act as the server. In addition, the difficulty on preparing the system for work, i.e., installing the server software and hosting the database and setting up the network connection between the server and other terminals. While our proposed system does not need a server or server or a complicated network initiation or hosting of a database.

3. PROPOSED COST-EFFECTIVE CLINIC MANAGEMENT SYSTEM

In order to design a cost-effective clinic management system, we aimed to keep the system as simple as possible and at the same time ensuring it remains effective for managing clinic operations. After identifying the basic system requirements, we identified that using a computer server with licensed software could be costly. Additionally, setting up a server and configuring it for network use can be challenging for individuals without IT knowledge. Web-based systems are hosted online and need an Internet connection which is often unreliable in many areas of Iraq, and at extra cost. In order to overcome these challenges, we designed our system **without a server**, to reduce on the total costs and make the setup process easier. Instead, we employ the use of the **SQLite database engine** to store clinic data. SQLite is a relational, serverless database management system that can be run on any computer and used directly, which is suitable for small clinics. Where SQLite has proven effective in embedded healthcare systems due to its simplicity and performance [15].

The system is designed with **two SQLite database files**:

1. **clinicDB.sqlite**: Stores essential patient information, scheduling, login credentials, exam details, prelisted drugs, clinic information, and financial data (as shown in Figure 1).
2. **DoctorDB.sqlite**: Stores prescription data and attached files.

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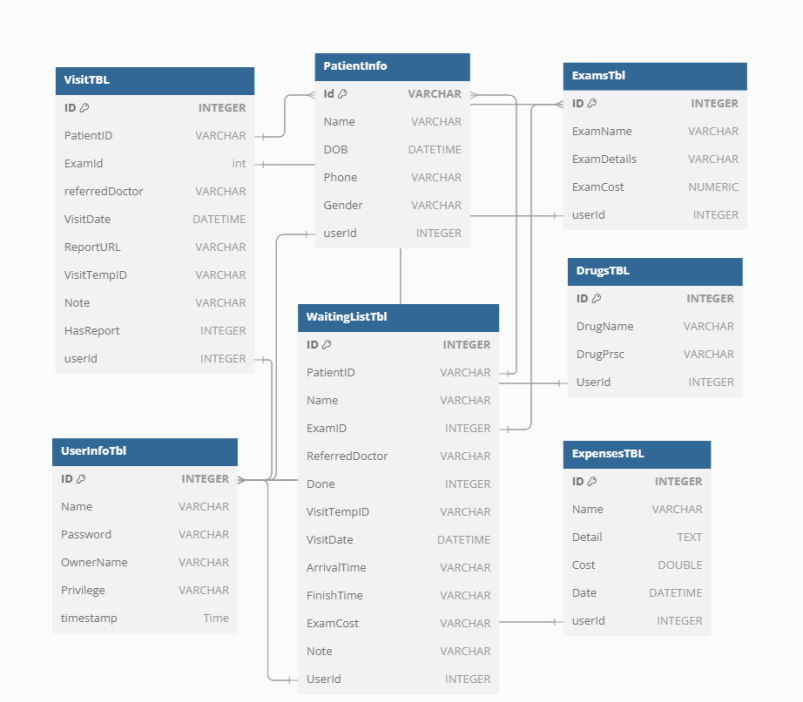

Figure 1

We separated the databases to enhance system performance. The first file contains frequently accessed text-based data, while the second file saves large files (e.g., lab exams) that are only which are use by doctor when needed.

The system is a **network-based application** that allows multiple to work at the same time. It is developed using the **C# programming language** and utilize a user-friendly graphical interface for a smooth user experience (as shown in Figure 2). The system consists of several sections, some for doctors and others for secretaries, which we will not detail here for brevity.

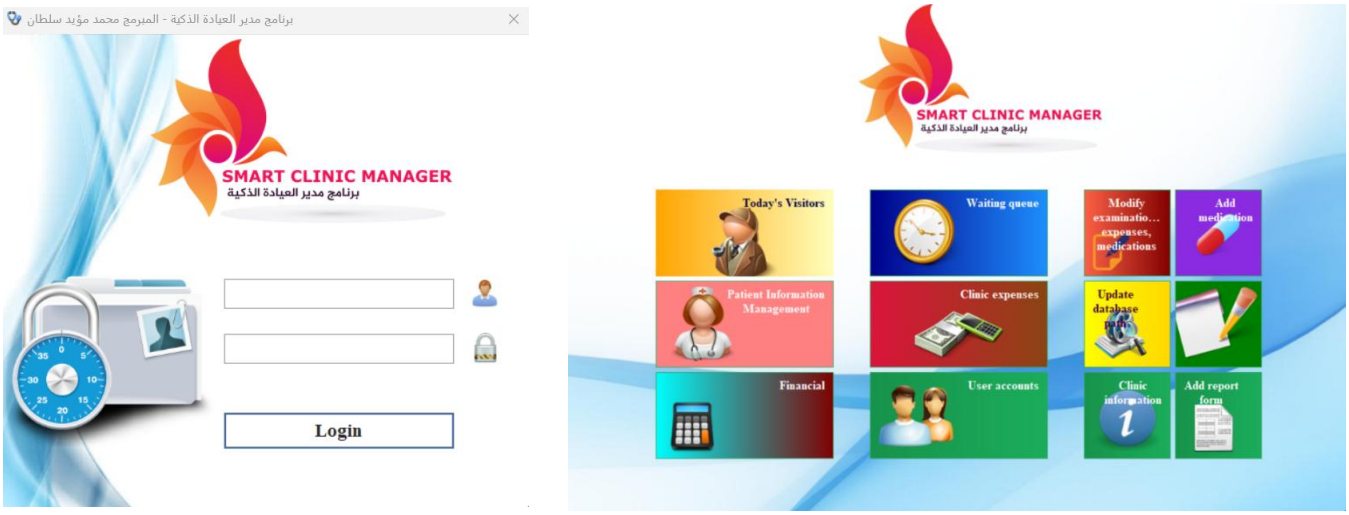

Figure 2

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SECURITY FEATURES

- The system is protected with **username and password authentication**, and each user has specific privileges that constrain his activity in the system which determined by the clinic administrator.
- The database files are **encrypted** using an embedded key to prevent unauthorized access and ensure patient data privacy. Implementing encryption follows with best practices in healthcare systems where patient privacy is paramount [16].

ENCRYPTION METHOD:

```
public string EncryptMethod(string txt)
    {
      string k = "EC";
      byte[] cByte = Encoding.Unicode.GetBytes(txt);
      using (Aes enc = Aes.Create())
      {
        Rfc2898DeriveBytes pdb = new Rfc2898DeriveBytes(k, new byte[] { 0x49, 0x76, 0x61, 0x6e, 0x20, 0x4d,
0x65, 0x64, 0x76, 0x65, 0x64, 0x65, 0x76 });
        enc.Key = pdb.GetBytes(32);
        enc.IV = pdb.GetBytes(16);
        using (MemoryStream mStream = new MemoryStream())
        {
          using (CryptoStream cryptoStm = new CryptoStream(mStream, enc.CreateEncryptor(),
CryptoStreamMode.Write))
          {
            cryptoStm.Write(cByte, 0, cByte.Length);
            cryptoStm.Close();
          }
          txt = Convert.ToBase64String(mStream.ToArray());
        }
      }
      return txt;
    }
```

DATABASE CONNECTION STRING:

```
SQLiteConnection connection = new SQLiteConnection("Data Source=" + MyDirectory() + "\\EF.sqlite;
Version=3; Password=" + sv.EncryptMethod(Properties.Settings.Default.E) + ";");
```

USER AUTHENTICATION:

```
public DataTable searchUserByName(string name)
{
  string query = "SELECT * FROM UserInfoTbl WHERE Name='" + name + "'";
  return dbConn.runQuery(query);
}

DataTable dt = DB.searchUserByName(userTxt.Text);

foreach (DataRow row in dt.Rows)
{
```

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```
    if (row["Name"].ToString() == userTxt.Text.Trim() && row["Password"].ToString() ==
passTxt.Text)
    {
        Info.fullName = row["OwnerName"].ToString();
        Info.admin = row["Privilege"].ToString(); // Store user privilege and essential info
        MainForm m = new MainForm();
        m.Show();
        this.Hide();
        break;
    }
}
```

The system utilizes a compression images mechanism to reduce size and maintain reliability before store it in the database to avoid unnecessary over size and as follow:

```
public Bitmap ResizeImage(Image orgImg, int w, int h)
{
    if (orgImg == null)
        throw new ArgumentNullException(nameof(orgImg));
    if (w <= 0 || h <= 0)
        throw new ArgumentException("Width and height must be greater than 0.");


    int orgWidth = orgImg.Width;
    int originalHeight = orgImg.Height;

     double ratioX = (double)w / orgWidth;
    double ratioY = (double)h / orgHeight;

    double ratio = Math.Min(ratioX, ratioY);

    int newH = Convert.ToInt32(orgHeight * ratio);
    int newW = Convert.ToInt32(orgWidth * ratio);

    Bitmap thumbnail = new Bitmap(newW, newH);
    using (Graphics gr = Graphics.FromImage(thumb))
    {
        gr.InterpolationMode = InterpolationMode.HighQualityBicubic;
        gr.SmoothingMode = SmoothingMode.HighQuality;
        gr.PixelOffsetMode = PixelOffsetMode.HighQuality;
        gr.CompositingQuality = CompositingQuality.HighQuality;

        gr.Clear(Color.Transparent);
        gr.DrawImage(orgImg, 0, 0, newW, newH);
```

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```
    }

    return thumb;
}
```

3.1 INITIAL SETUP OF THE PROPOSED SYSTEM

As mentioned earlier, the system does not require a server. Instead, it uses **SQLite databases**, which are typically placed on the doctor's computer to reduce costs. The system mainly operates on two computers (doctor's PC and secretary's PC), but additional terminals can be added if needed.

NETWORK CONFIGURATION

- The connection between computers can be established using either **wireless connection (Wi-Fi)** or a **local area network (LAN)**. For simplicity and cost-effectiveness, we recommend using a **LAN cable**.
- No Internet Protocol(IP) setting is needed.
- To protect the privacy of the doctor's PC (where the database is saved), we utilize **Windows sharing features**. A dedicated Windows account (e.g., "Clinic") is created with password protection, and this account is added to the database folder's network sharing settings (as shown in Figure 3).
- On the doctor's computer, both **Network Discovery** and **Password Protected Sharing** are enabled from the network and sharing settings.

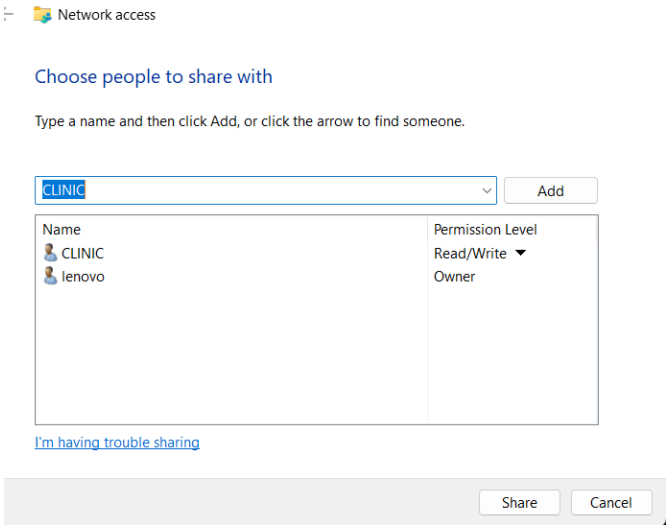

Figure 3

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SYSTEM DEPLOYMENT

The system is delivered to clinics in two parts:

1. **Program Folder**: Contains the application.
2. **Database Folder**: Contains the SQLite database files.

Both folders must be copied to the doctor's computer, and the sharing settings must be configured for the database folder as listed before. When the program run for the first time, it will ask the user to select the database file location (as shown in Figure 4).

For the secretary computer and other terminals, only the program folder is copied. The database location is selected through the network path to the shared folder on the doctor's computer.

System Readiness

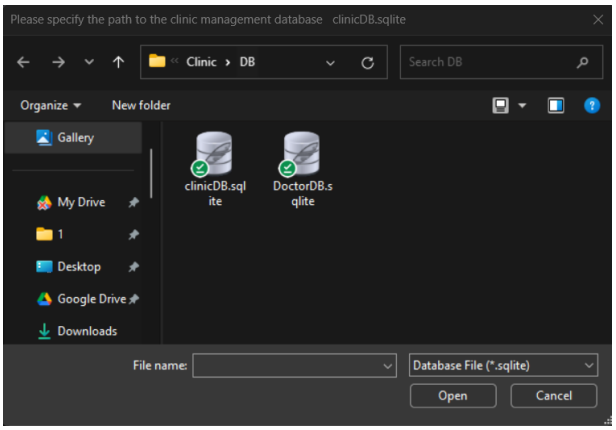

Figure 4

Once the setup is complete, the system is ready for use. The clinic administrator can add initial clinic information, such as clinic details, user accounts, and prelisted drugs … etc.

REAL-WORLD APPLICATION

This system has been successfully implemented in **over 50 clinics in Iraq** and has been operational for more than **20 months**. We found it to be stable and suitable for small clinics to manage patient information efficiently and improve the daily workflow. The system is a fast and reliable way to write and print prescriptions and reports to enhance overall clinic efficiency.

4. CONCLUSION

A cost-effective clinic management system designed for small clinics in Iraq, especially in limited resource settings is proposed. By using the SQLite database engine and not requiring a dedicated server, the system significantly reduces setup and maintenance costs while retaining robust functionality. Simplicity, ease of use, and security were the primary design features of the system

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to ensure that clinics can handle patient information, appointments, prescriptions and financial data without the need of an advanced IT support.

Key features of the system: User authentication, data encryption, and network based operation; address important needs for accessibility, privacy and security of data. The ability to work on multiple terminals simultaneously significantly improving the work flow and making it easier for doctors and administrative staff to collaborate. Furthermore, the separation of essential data and prescription files is optimized in such a way that it improves the performance and thereby reduces the likelihood of slowdown during high usage.

More importantly, the success of this implementation across more than 50 clinics in Iraq for 20 months shows that the system is robust and appropriate for application in small-scale healthcare facilities. Clinics have indicated higher efficiency in the management of patient's records, faster prescription delivery and better workflow. Being cost effective, easy to install and use, and having a friendly interface, the system is suitable for clinics that are upgrading their systems without having to spend a lot.

Future work could include expanding the system's features, such as integrating telemedicine, mobile apps, or more sophisticated analytics of patient data. Furthermore, more testing in various healthcare conditions may help understand the potential for scalability and adaptability to larger clinics or hospitals.

In conclusion, this cost effective clinic management system is a significant step towards the implementation of the technology healthcare gap closure in the underserved regions. Thus, it enables small clinics to enhance the quality of patient care and improve the effectiveness of their operations at an affordable, secure, and efficient cost. This paper shows that the use of lightweight, serverless technologies can be used to solve real-world challenges in healthcare management and that there is a possibility of even better and more accessible solutions in the future.

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