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Development of Data Model for Computerized Information System at a Clinic

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ABSTRACT

databases are integral part of all computerized information systems (CIS). Well-designed database is an important requirement for having a useful and effective CIS. Database analysis and design are essential phases of database development process that would lead to the database creation. This project looks at developing a conceptual data model that can represent a prospective database for supporting a selected healthcare processes at Al-Keesh clinic in Benghazi. Enacting such development process defines the targeted processes and their challenges as well as their data requirements.Methods: requirement analysis is one task of the database development process where data is collected from the field then analysed to produce a conceptual data model for the database. Data are collected via various technique including interviews, document analysis, and work observations which all were used on this project.Results: requirement analysis defined process descriptions for three targeted healthcare processes at the clinic. These descriptions provide an understanding about the database system context and identified a number of challenges that would be resolved by the prospective database. Data redundancy, lack of clear data structure, and fragmented data documentation were some of the findings revealed about the targeted processes. The requirements analysis also defined the conceptual data model which represented the specification of the data content of the database. The produced ERD illustrates 16 entities specific to the targeted processes along their complete attributes as well as the relationship among these entities Conclusions: database analysis and design activities provide the guidelines for establishing the database specifications including the conceptual data model. A conceptual data model that represents local data requirements is essential for developing a CIS that is relevant and useful to the users. These activities also revealed the targeted processes issues and challenges which allow the system analyst to contemplate the adequate technical solution to address them.

Keywords: database design, database model, conceptual model, medical database, data modeling.

تطوير نموذج بيانات لنظام المعلومات المحوسب في العيادة

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ملخـــــص البحـــــث

تُعد قواعد البيانات جزءًا جوهريًا من جميع أنظمة المعلومات المحوسبة**(CIS)** ، حيث إن تصميم قاعدة بيانات محكمة يُعتبر شرطًا أساسيًا لامتلاك نظام معلومات فعّال ومفيد. ويُشكل كل من تحليل وتصميم قواعد البيانات مراحل أساسية في عملية تطويرها، إذ تؤدي هذه المراحل في النهاية إلى إنشاء قاعدة البيانات. يهدف هذا المشروع إلى تطوير نموذج بيانات مفاهيمي يمكن أن يمثل قاعدة بيانات مستقبلية لدعم بعض العمليات الصحية في عيادة الكيش ببنغازي .ويُسهم مثل هذا التطوير في تحديد العمليات المستهدفة وتوضيح التحديات المرتبطة بها إلى

جانب متطلباتها من البيانات؛ يُعد تحليل المتطلبات إحدى المهام الرئيسة في عملية تطوير قواعد البيانات، حيث يتم جمع البيانات من الميدان ثم تحليلها لبناء نموذج بيانات مفاهيمي للقاعدة. وقد استُخدمت في هذا المشروع عدة تقنيات لجمع البيانات، شملت المقابلات، وتحليل الوثائق، وملاحظات سير العمل؛ أسفر تحليل المتطلبات عن توصيف ثلاث عمليات صحية مستهدفة داخل العيادة. وقد وفرت هذه التوصيفات فهمًا أفضل لسياق نظام قاعدة البيانات، كما كشفت عددًا من التحديات التي يمكن معالجتها من خلال القاعدة المقترحة. ومن أبرز هذه التحديات: التكرار في البيانات، غياب هيكلية واضحة لها، وتجزؤ عملية توثيقها. كما حدد تحليل المتطلبات النموذج المفاهيمي للبيانات، الذي مثّل المواصفات الخاصة بمحتوى القاعدة. وقد أُنتج مخطط الكيانات والعلاقات **(ERD)** ليعكس 16 كيانًا رئيسيًا خاصًا بالعمليات المستهدفة متضمّنة جميع خصائصها والعلاقات فيما بينها واهم النتائج بينت أن أنشطة تحليل وتصميم قواعد البيانات تُعد بمثابة الإرشادات الأساسية لتحديد مواصفات قاعدة البيانات، بما في ذلك النموذج المفاهيمي. ويُعتبر النموذج المفاهيمي الذي يُجسّد المتطلبات المحلية للبيانات ضروريًا لتطوير نظام معلومات محوسب يتسم بالملاءمة والفائدة للمستخدمين. كما أن هذه الأنشطة ساعدت على كشف القضايا والتحديات الخاصة بالعمليات المستهدفة، مما يمكّن محلل النظم من وضع الحلول التقنية المناسبة لمعالجتها.

الكلمات الدالة: تصميم قاعدة البيانات، نموذج قاعدة البيانات، النموذج المفاهيمي، قاعدة البيانات الطبية، نمذجة البيانات.

1. INTRODUCTION

Healthcare systems rely on effective data management and databases to collect, analyze, and improve patient outcomes. A database is a large, organized data repository that facilitates retrieval, modification, and updating. A database management system (DBMS) is computer software designed to create, manage, and process databases, allowing multiple users to access and benefit from them simultaneously. DBMS manages data, database schema, and database engine, facilitating access, storage, retrieval, and processing of information. Databases are essential in the health sector as they ensure data preservation, enable backups, and provide accurate information for patients. A properly designed database provides access to accurate, up-to-date information. The database design life cycle includes requirements analysis, logical design, and implementing the database and creating tables. The data model describes the structure of the database, which can be conceptual, physical, or representation models.

1.1-The problem:

Databases in computerized information systems are designed based on real-world healthcare processes, a complex and interesting problem that involves defining data models to address shortcomings.

Importance of the proposed work:

•Investigate and analyze real world healthcare delivery processes to understand issues and recommend solution,

1.2-Project objectives:

The main objective is to create a conceptual data model for a database at Al-Keesh clinic to build a database in the future. The sub-objectives include:

- Identify and define the targeted healthcare processes.
- Define the data requirements for the targeted processes.
- Develop the ER diagram that conceptually represent the data requirements of the targeted processes,
- Understand and appreciate challenges facing database designers performing this process

1.3- Literature review

A. Database definition

A database is an organized collection of data for its intended function, allowing for easy display, printing, and creation of new data for various purposes. (5).

Database refers to a large collection of computer-organized data, organized for easy expansion, updating, and retrieval for various uses. (1).

HIM professionals need a basic understanding of database technology to collaborate with IT staff and contractors as it transitions from supporting paper systems to centrally digitized health information systems. (8).

Modern societies rely heavily on databases and database systems and most of us engage in multiple daily tasks that require interacting with databases (17).

Mastering conceptual modelling is crucial for success in computer science and software engineering, but learners face complex tasks & challenges in this common practice. (18)

B. Database components

Databases store data in data structures, managed by a Database Management System (DBMS) and user interface. It includes a data dictionary, manipulation language, and definition language. (4).

In another perspective database components include:

- Users: end users who use and update (entry, delete, change) database and application programmers,
- Software: DBMS which is a set of programmes that enable users to create and maintain Database.
- Data a set of facts associated with each other in an arranged way,
- Hardware which include secondary storage for storing data (13).

Distributed database, which is another type of database architecture, helped distribute tasks to more than one location, which led to faster work completion, concealed processing burden, and achieved data privacy (9).

C. Database applications in healthcare

Effective databases require accurate data entry, consistent terminology use, rapid information exchange, efficient storage, and authorized personnel access for efficient performance. (10). Databases are crucial for quality clinical research, requiring strict data management, validation rules, and well-structured case report forms for data collection and simplifying database design. (16).

1.4 -Advantages of healthcare database

Healthcare databases enhance efficiency, information exchange, quality evaluation, and monitoring, supporting emergency departments and individual medical organizations, enabling informed decision-making and improved operational management. (12).Quick access to records enhances efficiency, ensures patient safety, aids in diagnosis and prescription, reduces errors, aids in documentation and billing, and reduces medical facility costs.(2)

1.5-HealthCare Database Limitations

Database systems have limitations such as increasing user workload, posing technical issues during storage, and posing privacy and security concerns due to potential hacking. (7)

1.6-Creation of database systems

The database design process can consist of four steps: establish the goal, design the data structure, specify the relationship, then define and execute business rules in order of importance (6). Designers must plan databases in advance, understand data representation, data acquisition, operating volume, and storage to optimize efficiency and prevent data redundancy, inconsistency, and corruption. (11).

The database design lifecycle involves requirements analysis, logical design, entity identification, key attribute identification, data constraints, normalization, and data visualization. It focuses on creating a high-level architecture, determining storage types, and identifying key attributes. (14).
The database life cycle involves requirements analysis, conceptual design, data structure, user interaction, and system representation, analyzing organizational work and labor laws to understand system structure. (15).

2. MATERIALS AND METHODS

2.1 Information systems Methodology

Developing a database is an organized, systematic process to create a database that meets specific needs, with the following stages:
The process of requirements definition involves consulting stakeholders to agree on data and processes. This is expressed in a requirements statement. The database designer gathers data from users to understand the proposed system and obtain functional requirements. A data requirements document confirms user understanding. Data analysis starts with a statement of data requirements and produces a conceptual diagram of a database using a high-level conceptual data model. Database design begins with a conceptual data model and a logical schema specification, determining the specific type of database system (network, relational, object-oriented). Implementation involves creating a database according to the logical schema specifications. Maintenance involves dealing with variables or errors. (19)

Designing an effective clinic database is critical to ensuring smooth workflow and improving the quality of patient care. This research used methods for fact-finding, data collection and analysis, and the design of a database model that meets the needs of the Keesh Clinic, Primary Care Department (17). It is worth noting here that there are several methods for fact-finding:

- Sampling existing documents, forms and databases.
- Research and field visits.
- Observation of the work environment.
- Interviews.
- Questionnaires.
- Prototyping.
- Joint requirements planning.

Information systems development employs techniques like interviews, document analysis, and work observations to gather facts and information about a system, aiming to provide a detailed description of requirements. (20)

2.2-Research plan

This research project started with conducting a brief literature review to further understand database technology and identify guidelines for database design. Then the project went through three phases:

A. The search phase where a host site for the project was sought then identify the project scope by determining the healthcare processes that the database design will target for solving real world problems,

B. The data collection phase where data about the targeted processes were collected to identify the users' requirements,

C. Data analysis phase where the outcomes from the previous were group analyzed to define the ER diagram.

The team conducted preliminary interviews with senior management and department heads at AL-Keesh clinical to identify healthcare processes for database design. Primary healthcare department was the focus due to senior management's recommendation and department head's encouragement. The primary healthcare department provides several services that include:

- Motherhood follow-up primary care which follows the pregnancy development of women from the start until the delivery date.
- Childhood follow-up primary care which follows the development of children from infancy until the age of 15.
- The third is the vaccination services to provide scheduled vaccines to children up to the school age.
- Phase 3 data collection involved 23 unstructured interviews with 15 participants from March to July 2024. The archive contained old records, such as register books for newborns, vaccinations, and follow-up forms. A sample of previous years' books and forms was selected for analysis, spanning from 2015 to 2022.

The interviews were guided by set of questions, which included asking about the participant's routine duties, data type, storage, management, flow, problems, and opinion on a database for supporting their work are all discussed. Two team members conducted interviews, documented results, and analyzed healthcare processes and data requirements using Dia drawing software, deciding next interviews and preparing for meetings.

size 10 normal, 1.0 line spacing, and page margins 0.97" on each side. The pages must be a minimum of (5) pages and not more than (15) pages as a maximum, including figures, references and tables.

3. RESULTS

The manager of Al-Keesh clinic suggested the primary healthcare department needs an information system for better organization and a database for BCG vaccines. The clinic offers free IT training courses for employees and has a new statistics department, but the old manual database is illogical. The organization chart shows various departments and services, including internal medicine, diabetes follow-up, blood pressure, neurology, insurance, devices, endoscopy, heart and catheterization, neurosurgery, rheumatology, diseases, and urology.

Processes description

The interviews helped us understand the users' work processes and data requirements for the prospective database, specifically targeting three healthcare services: pregnant woman follow-up, child follow-up, and vaccination healthcare services.

3.1-Pregnant woman follow-up

Pregnant women visit reception, provide information, and undergo examinations. Doctors request tests, dentists refer, and nutritionists assist. Frequent visitors' data is collected through records and prenatal information cards, with the receptionist filling out form A.

- Family registration number
- date of registration with clinic
- the pregnant number
- the name
- the husband’s name
- the husband profession
- medical history
- the age of the pregnant woman
- age at marriage

- menstrual condition
- date of last menstruation
- date of the first day of pregnancy
- probable date of delivery
- Family medical history

3.2-Child follow-up

A monthly neonatal screening at a clinic records a child's name, age, previous examinations, diagnosis, treatment prescription, and medication duration. If necessary, they are transferred to an outpatient clinic. A children's health file is created from birth to age 15.

The document provides a comprehensive health and vital information section for a child, covering medical history, nutrition, growth monitoring, natural follow-up, chronic case diagnosis, examination results, and examination duration.

3.3-Vaccination

Newborns undergo pediatrician examinations and vaccinations, recorded in a registry book by the National Center of Disease Control, which reminds parents, provides search options, and generates reports. Process challenges and issues The data records are plagued by issues such as inaccurate recording, limited structure, insufficient writing space, illegible handwriting, ambiguous data, inadequate IT training, repeated recording, and paper-based methods.

The ER diagrams ER diagrams were created for each targeted healthcare process, then integrated into a single diagram to illustrate all entities and existing interrelationships.

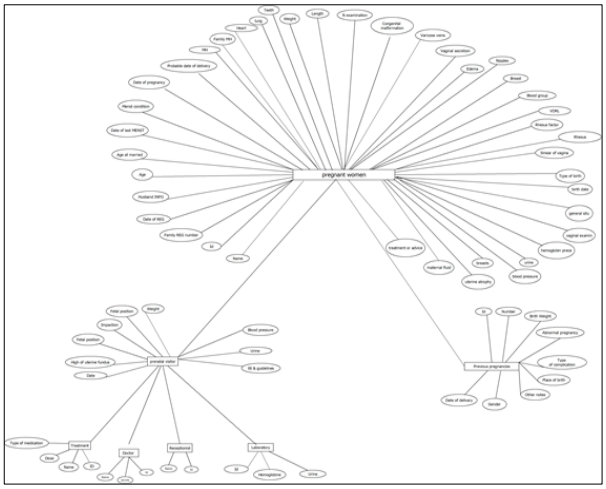

Fig 1: ERD of pregnant follow-up.

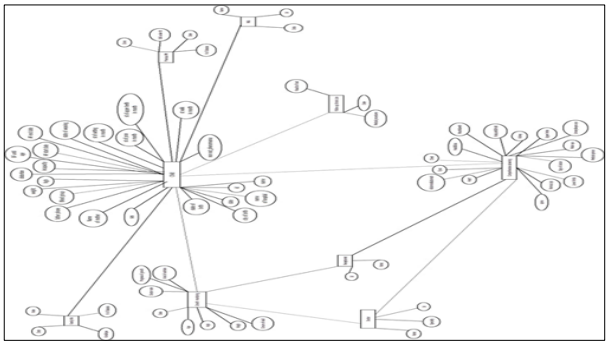

Fig 2. ERD of child follow-up.

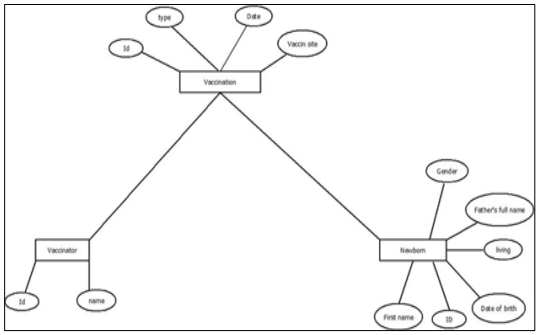

Fig 3. ERD of vaccination.

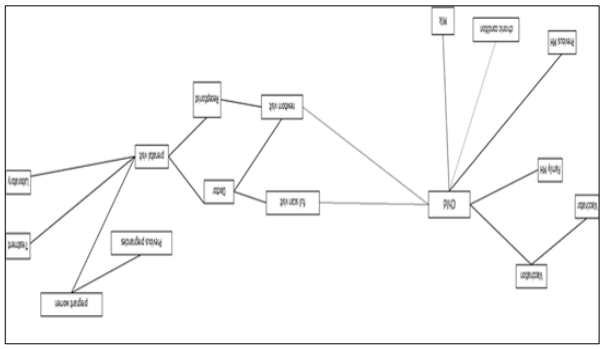

Fig 4. Integrated ERD.

Figure 4 outlines 16 entities for targeted processes such as vaccination, vaccinator, child, family MH, chronic condition, milk, scan visit, doctor, newborn, receptionist, prenatal, pregnant woman, treatment, and laboratory.

4. CONCLUSIONS

Database systems are crucial for healthcare delivery, ensuring data organization, accessibility, and security. This project aimed to develop a conceptual data model through database analysis and design processes. A requirement analysis was conducted to identify data in the database and define the model. Interviews, documents analysis, and field observations were conducted to collect data about targeted processes at Al-Keesh clinic. The data from interviews and fact-finding techniques was analyzed to create an ER diagram of the prospective database. This process helped define the target processes, identify their problems, and identify data requirements for the targeted processes.

5. RECOMMENDATIONS

- In the future, this model could be developed and contain more information related to relation types and cardinalities.
- It can be developed from a conceptual model to a logical model to create a database in the future.

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