A Database Design and Development Case: Elk County Pediatric Medical Center

Robert M. Ballenger
Department of Management
Williams School of Commerce, Economics, and Politics
Washington and Lee University
Lexington, VA 24450
ballengerb@wlu.edu

ABSTRACT

This case provides a real-world end-of-semester project-oriented case study for students enrolled in an introductory database management course. The case consists of a business scenario to provide background information on the need for the application and some of the unique operating characteristics of the Elk County Pediatric Medical Center. In addition, narrative information regarding the functional requirements of the medical center is included along with sample data: parents, patients, services performed, diagnosis codes, insurance carriers, and patient history. The case provides sufficient information to design a moderately complex database for the medical clinic. The functional requirements will force students to resolve numerous many-to-many relationships. In addition, several entities have compound unique identifiers resulting in tables with composite primary and foreign keys. The case provides sufficient real-world data to operationalize the database design into a physical database, populate it with data, and then write a series of queries that satisfy the stated reporting requirements of the medical center. The queries vary considerably in terms of complexity, from simple straightforward queries to others that are quite complex and require multiple sub-queries. Several queries are dependent upon parameters entered at runtime. Some queries all students should be able to answer, while others require critical thinking skills to solve. The case was written so that creation of the physical database and queries were not dependent on the student's database management software. Teaching notes containing suggested instructions, a possible entity-relationship model, the resulting physical database, and the solution to the queries are also provided.

Keywords: Database design, database modeling, database development, systems analysis and design, systems development, case

1. CASE SUMMARY

ELK County Maine has been awarded a federal grant to build a modest pediatric medical center. The grant also paid for the medical education of a pediatrician that will practice at the medical center for at least five years. The grant included purchasing a medical information system to assist the doctor and the county in managing the medical center. The county's Director of Information Systems assigned a business analyst to explore and report on the hardware and software requirements of the new medical system. After the business analyst completed her report, she conducted an extensive investigation to see if an off-the-self software package would meet the functional requirements of the medical center's stakeholders. It was determined that no such software package was available. Due to a near term software development backlog in the county's Information Systems Department, the county decided to hire a consultant to design and implement the relational database for the new medical information system.

2. ORGANIZATIONAL BACKGROUND

Elkhorn is the county seat of Elk County and is located in north central Maine. Elk County is the largest county in Maine in terms of geographic size but at the same time is the least populated. Elkhorn has a population of approximately 9,500 and the county's total is about 35,000. With the exception of Elkhorn, the county's population is highly geographically dispersed. The main industries in Elk County are lumber, tourism, with several well known year round resort lodges, and paper products. For the past decade, like many other rural areas in the United States, Elk County has been experiencing a shortage of medical personnel and facilities. Several years ago the county received a grant from the Federal Government to fund a new but modest pediatric medical facility and the medical education of a pediatrician. The County Manager is responsible for the management of the federal grant. In return for the paid medical education, the pediatrician signed a contract to practice for a minimum of five years at the new pediatric medical facility, the Pediatric Medical

Center (PMC), located in Elkhorn. The doctor, having just recently completed medical training, arrived in Elkhorn a little over a month ago and has started to fulfill her contractual obligation.

3. DETERMINING THE REQUIREMENTS

The initial budget for the medical center included the purchase of a small client/server based medical information system to assist in patient billing and medical record keeping. After consulting with the county's Director of Information Systems, the County Manager decided to wait until the doctor arrived before purchasing the system. The Director of Information Systems was unsure of the requirements in terms of hardware and software and wanted the doctor's input into the decision. He was uncertain about the physician's desired location of individual personal computers (PCs) in the new medical center and, consequently, the quantity of PCs that needed to be purchased. But even more troubling for the manager, was his strong belief that he was highly unqualified to determine or evaluate the software requirements for a pediatric medical system.

Shortly after the doctor arrived, the Director of Information Systems assigned one of the county's assistant business analysts to determine the software requirements for the new medical information system. He brought the analyst up to speed on the situation at the Pediatric Medical Center and requested that she find a suitable "off-the-shelf" software package that will satisfy the processing and reporting requirements of the doctor, the county, the federal grant, the state's Medical Assistance (MA) program and the primary local health maintenance organization (HMO), Healthy in America. Medical Assistance is a statewide program run by Maine's Department of Public Welfare for low-income families that cannot afford medical insurance. Medical Assistance works very much like an insurance company where the doctors that agree to participate in the program accept the state's published fee schedule for services provided to Medical Assistance patients.

The business analyst knew the first task was to determine the functional requirements of the new patient billing and medical records system. This was accomplished by conducting multiple interviews with the doctor, and personnel from the county, the state's Medical Assistance Office and Healthy in America. After the interviews were complete and she felt she understood the requirements of the various parties, the analyst prepared a functional requirements report. The report was submitted for approval by all the parties she interviewed. A few minor changes were suggested and incorporated into the report and then a final version of the PMC Functional Requirements Report was distributed to all concerned parties.

4. FUNCTIONAL REQUIREMENTS

Below are the specifications contained the *Data and Information Requirements* section of the PMC Functional Requirements Report.

4.1 Family Information

The PMC medical system needs to track information on the parents whose children are registered with Pediatric Medical Center and eligible to receive health care services. The new application must be able to determine the financially responsible head of the household's name, address, telephone number, and the name of their insurance carrier (if any). See Table 1 for sample data. The doctor would like to assign each family a unique alphanumeric identifier so that they may identify a specific family that is registered with the Pediatric Medical Center. The identifier will consist of the first 4 letters of the family's last name with a unique two digit number added at the end. For example, if there were three families registered with the last name Smith, the 3 family numbers would be SMIT01, SMIT02, and SMIT03.

4.2 Patients

The new system must contain static information on all the patients that are registered with the Pediatric Medical Center. The doctor needs to know the patient's name (last name may be different from the parent responsible for the child). Each patient is assigned a unique medical record number (MRN). A simple algorithm is used to create this number, which consists of three parts; 1) the first three characters of the patient's last name, 2) the first character of the patient's first name, and 3) two digits that are assigned sequentially so that the first two components when combined with the third insure the MRN is unique. For example, the boxer George Forman has five children named George. Their MRNs would be assigned as follows: FORG20, FORG21, FORG22, FORG23, and FORG24. This assumes that MRN FORG19 already existed in the database. A sample set of patient data is presented in Table 2. If the parent's have any type of medical insurance, including Medical Assistance, then the parent's social security number must be tracked. The insurance companies require that this field be 12 characters long. The first 9 characters are the parent's specific social security number with no dashes. A unique 2 digit number is then assigned to each dependent child and appended to the end of the parent's social security number, i.e., 999999999-99, to form a unique identifier that can be used by the insurance companies to identity each child.

4.3 Services Performed

The billing application must contain information on all of the medical services available from the Pediatric Medical Center. This information consists of an industry standard medical services code, a description of the service performed, the standard fee charged by Pediatric Medical Center for this specific service (this is the fee charged to parents with no insurance), the fee that will be accepted for this service by Maine's Medical Assistance program (MA),

and the fee that will be accepted by all of the other insurance carriers. See Table 3 for a sample fee schedule of the medical services provided by PMC.

4.4 Diagnosis Codes - DRG Codes

The new application needs to support the use of industry standard DRG (Diagnostic Related Group) codes. These are predefined unique codes where each code corresponds to a specific medical diagnosis that a physician may make. These codes and their corresponding descriptions may be purchased on a CD-ROM, where they are stored in tab delimited text file. Some of the most commonly used DRG codes by PMC are listed in Table 4.

4.5 Insurance Carriers

The new application requires the capability to track insurance carriers that have contracts with PMC including Medical Assistance provided by Maine's Department of Public Welfare. Elk County has contracted with the state for PMC to accept Medical Assistance patients. See Table 5 for a listing of all current contracted insurance companies. Each insurance company has been assigned a two character insurance code. Parents that do not have medical insurance with a firm that has a contract with PMC are considered to be self-insured.

4.6 Patient History

The new system must retain a complete patient history. This includes services performed and fees charged for those services. The doctor wants the capability to over-ride the standard fee schedule. Also, some fees are subject to frequent change, especially those associated with injections and lab work. Consequently, the doctor needs to know the fee charged at the time the service was provided. In addition to tracking historical services, the system must maintain a complete history of the diagnoses made by the doctor on each patient visit. If a doctor sees a patient multiple times in a single day it will be recorded in the system as a single visit. The pediatrician may perform multiple services and make multiple diagnoses on individual patient in a single day. Also a doctor may perform a service without making a diagnosis, for example: allergy injections given on a bi-weekly basis or a scheduled immunization.

4.7 Reporting & Query Requirements

The Pediatric Medical Center's new medical information system must support the following reporting and query requirements:

1. What are all the possible services a doctor may perform? Display the service code and description. Sort by service code.
2. Same report as above but only for laboratory services.
3. What PMC patients of live in Elkhorn, Maine? Display the family number, the parent's last and first names in separate columns, city, state, and phone number.
4. Patient List Report. Display the family number, parent's last and first name separated by a comma, patient's first name, and patient's last name. Sort by family number and patient's first name. Do not repeat the family number or the parent's last and first name.
5. Patient Insurance Report. Display the insurance carrier, family number, parent's last and first name separated by a comma, patient's first and last name, and insurance assigned social security number. Sort by insurance carrier, family number and social security number. Do not repeat the insurance company, family number, or the parent's first and last name.
6. Daily Non-Insurance Billings Report (parents that are self-insured). Display the date of service (formatted as mm/dd/yy), family number, parent's last and first names separated by a comma, the patients first and last name, insurance carrier, service code, description of service and the service fee. The report is to total the service fee by family and a grand total is to appear at the end of the report. The service fee is to be formatted as currency. This report is to contain appropriate descriptive column headings (no abbreviations), Report Title, and Report Footer. The report is to be sorted by family number. The report is to prompt the user to enter the date the services were performed.
7. Same report as above but this time for all insurance carriers (parents that have medical insurance). Do not include Medical Assistance patients.
8. Patient Medical History Report. Display the date of diagnosis (formatted as Mmm dd, yyyy), family number, parent's last and first names separated by a comma, the patients first and last name, DRG code, and diagnosis description. The output is to be sorted by date. This report is to contain appropriate descriptive column headings (no abbreviations), Report Title, and Report Footer. The report is to be for a single patient and the user is to be prompted to enter the patient's MRN.
9. What patients have had the same services performed on them as another patient? Display family number, patients first and last names, service code, and service description. This query is to be completely data driven, which means the only information available to the user running this query is the comparison patient's MRN. Include the comparison patient in the output.
10. In order to satisfy the federal grant reporting requirements, PMC needs to identify the families that have fewer patients in their family then the average number of PMC patients per family for the city in which they reside. Display the family number, parent's first and last name, the number of patients in the family, city, and the average number patients per family in a city. Sort the output by city and number of patients in the family.

5. CURRENT CHALLENGES FACING THE ORGANIZATION

The business analyst began to match PMC's functional requirements with the features and capabilities of various "off-the-shelf" software packages. However, no standard software package was able to satisfy all of the critical requirements. There were lots of standard packages that handled patient billing and medical histories. A few of the packages even had very good HMO billing and tracking capabilities. But the real issue was that no package could handle the integration of state's requirements for Medical Assistance billing into a single comprehensive package. This is a significant issue as the county and state have estimated that approximately 25-30% of the medical center patients will be on Medical Assistance.

The business analyst reviewed her findings with the County Manager and the Director of Information Systems. They understood the situation and asked the analyst to make a recommendation. She stated that the only real alternative was for the county to internally develop the software for PMC's medical information system. The Director of Information Systems said that his department already had a backlog of work and it would probably take months to get the software written. Frustrated, the County Manager exclaimed that the Pediatric Medical Center needed the software yesterday and that the staff was currently doing everything by hand! The business analyst then stated the project could easily be done utilizing a standard relational data base management system (RDBMS). The Director of Information Systems agreed. In order to speed up delivery of the system, the county decided to contract with a consultant to design and implement the database. In addition, the consultant was to develop the procedures to populate the database, as well as, write many of the required queries. After the consultant completed the work, the county's Information Systems group would then use the tools that came with the RDBMS to construct the user interface, build the input and query forms, and develop reports based on the consultant's queries.

AUTHOR BIOGRAPHY

Robert M. Ballenger, Ph.D. is an Associate Professor of Information Systems in the Williams School of Commerce, Economics, and Politics at Washington and Lee University. Prior to earning his doctorate in Management Information Systems from Lehigh University, Dr. Ballenger worked for Unisys Corporation for more than eleven years in a variety of information technology related positions. Professor Ballenger has taught at Babson College, University of Alabama in Huntsville where he received the Undergraduate Outstanding Teaching Award, and Wake Forest University before returning to his alma mater. Dr. Ballenger's teaching, and research interests are in the areas of electronic commerce, database management systems, object-oriented technologies, and online learning environments.

Table 1
Parent Information

Name	Address	Insurance	Phone
Tyler Alterio	727 Willow Bank St. Hamilton, ME 06823	Healthy in America	(207) 355-0795
Timothy B Ballenger	2830 Linden St # 3F Boalsburg, ME 08017		(207) 974-9022
Richard W Bishop	1279 Zion Rd Hamilton, ME 06823		(207) 355-1358
Wilson Decker	RD #2 Box 410-D Hamilton, ME 06823		(207) 692-8178
Wilma Flagstone	65 Quarry Rd Elkhorn, ME 06001	Blue Capital HMO	(207) 355-9279
Gene McCray	911 Green Ave Hamilton, ME 06823	Healthy in America	(207) 355-0020
Jenny Smith	45 West End Rd Elkhorn, ME 06001	Medical Assistance	(207) 692-9278
Betty Richardson	67 Quarry Rd Elkhorn, ME 06001	Healthy in America	(207) 355-8565
Boris Roberson	1316 Charles St Maryville, ME 06801	Medical Assistance	(207) 237-0519
Jane Watson	777 Fox Blvd Apt 445 Maryville, ME 06801		(207) 237-0555
Franklin T Wellard	350 West Hunter Ave Boalsburg, ME 08017		(207) 777-7777
Prescott Wilson	222 Ocean View Dr Elkhorn, ME 06001	Healthy in America	(207) 777-7780

Table 2
Patients

Patient Name	SS Number	Parents
Thomas Ballenger		Timothy B. Ballenger
Chad Decker		Wilson Decker
Justin Smith		Wilson Decker
Megan Smith		Wilson Decker
Newborn Decker		Wilson Decker
Angela McCray	111223333-02	Gene McCray
Taylor McCray	111223333-01	Gene McCray
Donald Ballenger		Timothy B Ballenger
Natalie Wellard		Franklin T Wellard
Alison Bishop		Richard W Bishop
Dennis Roberson	111334444-01	Boris Roberson
Carol Roberson	111334444-02	Boris Roberson
Scotty Alterio	222113333-01	Tyler Alterio
George Alterio	222113333-02	Tyler Alterio
Mary Ann Bishop		Richard W Bishop
Mary Roberson	111334444-03	Boris Roberson
John Roberson	111334444-04	Boris Roberson
Patrick Roberson	111334444-05	Boris Roberson
Bert Wellard		Franklin T Wellard
David Wilson	333221111-01	Prescott Wilson
Newborn Smith	111332222-01	Jenny Smith
Pebbles Flagstone	333552222-01	Wilma Flagstone
Ben Richardson	444113333-01	Betty Richardson
Judy Watson		Jane Watson
Leroy Watson		Jane Watson

Table 3
Services Performed[1]

Code	Description	Standard Fee	MA Fee	BC Fee	HA Fee	MH Fee
OFFICE VISITS						
99211	Minimal	$ 20.00	$ 15.00	$ 18.00	$ 20.00	$ 20.00
99212	Brief	30.00	25.00	20.00	20.00	20.00
99213	Limited	40.00	30.00	35.00	32.50	35.00
99215	Extended	55.00	39.50	42.50	42.50	42.50
HOSPITAL VISITS						
99223	Comprehensive	150.00	100.00	115.00	105.00	125.00
99232	Limited	95.00	65.00	90.00	88.00	88.00
99431	Newborn Administrative	225.00	175.00	195.00	175.00	200.00
99433	Newborn Subsequent	30.00	35.00	30.00	30.00	30.00
99251	Initial Consultation Limited	75.00	50.00	55.00	55.00	55.00
PROCEDURES						
92551	Audiometry	30.00	30.00	30.00	30.00	30.00
69210	Ear Irrigation	35.00	30.00	33.00	32.00	32.00
92499	Vision Screen	40.00	25.00	37.00	37.00	37.00
LABORATORY						
85014	Hematocrit	25.00	20.00	25.00	25.00	25.00
85018	Hemoglobin	30.00	25.00	30.00	30.00	27.00
86317	Rapid Strep	30.00	22.00	27.00	27.00	27.00
87060	Throat Culture	25.00	20.00	24.00	23.00	23.00
81002	Urinalysis	25.00	21.00	24.00	24.00	24.00
87086	Urine Culture	30.00	24.00	27.00	27.00	27.00
INJECTIONS						
95115	Allergy	20.00	15.00	20.00	20.00	20.00
90701	DPT	150.00	135.00	150.00	150.00	150.00
90731	Hepatitis	65.00	50.00	60.00	65.00	65.00
90724	Influenza	40.00	40.00	40.00	40.00	40.00
90705	Measles	50.00	35.00	40.00	45.00	45.00
90704	Mumps	40.00	30.00	39.00	39.00	39.00
90706	Rubella	45.00	30.00	40.00	37.00	40.00
90703	Tetanus	40.00	27.00	35.00	35.00	35.00

[1] MA – Medical Assistance
BC – Blue Capital HMO
HA – Healthy in America
MH – Maine Health Care

Table 4
Diagnosis Codes - DRG *Codes*

DRG Code	Description	DRG Code	Description
789.0	Abdominal Pain	464.4	Croup
682.9	Abscess	692.0	Dermatitis
706.1	Acne	250.01	Diabetes Type I
477.9	Allergic Rhinitis	691.0	Diaper Rash
285.89	Anemia	558.9	Diarrhea
V70.0	Annual Exam General	380.4	Ear Wax Impacted
493.9	Asthma	703.0	Ingrown Nail
919.4	Insect Bite	998.2	Laceration
320.9	Meningitis Bacterial	047.9	Meningitis Viral
075	Mononucleosis	V20.2	Well-baby/Child Care
373.111	Stye	520.7	Teething
728.85	Muscle Spasm	278.0	Obesity
034.1	Scarlet Fever	684	Impetigo
008.8	Gastroenteritis	789.1	Colic
780.3	Seizure	473.9	Sinusitis

Table 5
Insurance Carriers

Code	Insurance Carrier
BC	Blue Capital HMO
HA	Healthy in America
MA	Medical Assistance
MH	Maine Health Care
SI	Self-Insured

Table 6
Patient History

Parents	Patient Name	Date	DRG Code	Service
Franklin T Wellard	Natalie	04/02/03	789.0	99212
Gene McCray	Angela	04/02/03	706.1	99211
Boris Roberson	Dennis	04/02/03	464.4	99213
Boris Roberson	Dennis	04/02/03		86317
Timothy B Ballenger	Donald	04/02/03	V20.2	99215
Timothy B Ballenger	Donald	04/02/03		99433
Prescott Wilson	David	04/02/03	008.8	99212
Prescott Wilson	David	04/02/03		85018
Franklin T Wellard	Natalie	04/03/03	789.0	99211
Jane Watson	Leroy	04/03/03	V20.2	99213
Jane Watson	Leroy	04/03/03		90701
Jane Watson	Leroy	04/03/03		85014
Richard W Bishop	Alison	04/03/03	380.4	99213
Richard W Bishop	Alison	04/03/03	919.4	
William Decker	Newborn	04/03/03	V20.2	99431
Timothy B Ballenger	Thomas	03/29/03	998.2	99213
Timothy B Ballenger	Thomas	03/29/03	780.3	

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