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ENHANCING SIMULATION ANALYSES OF HEALTH CARE DELIVERY POLICIES USING SDL™ DATABASE CAPABILITIES

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ABSTRACT

This paper discusses the effect of the use of SDL™ database management capabilities on the modeling and analysis procedures employed in studying two health care delivery systems: the use of capitation reimbursement in the Iowa Medicaid drug program and the availability of primary care in Indiana. Emphasis is placed on the construction and organization of databases from data produced by running simulation models. This data can then be used to compute measures of performance independently of the running of models. Furthermore, the decomposition of a large, complex model into a set of smaller, less complex component models is discussed. In addition, the assessment of alternatives and the iterative definition and computation of performance measures are described.

1. INTRODUCTION

Health care delivery systems are often characterized by complex relationships between their components and a significant volume of detail within each component. Simulation models which attempt to take these relationships and details into account often become quite large and complex themselves. Further, a significant data management problem is frequently encountered because such models have many parameters whose values must be specified. Furthermore, these models produce observations concerning many variables which need to be synthesized into meaningful system performance measures. The Simulation Data Language (SDL™) [Standridge] has been developed to assist simulators in data management activities involving model inputs and outputs. In this paper, the use of SDL in simulation analyses of two health care delivery systems will be presented. Emphasis will be placed on the unique contribution of SDL to the specification and implementation of the models and the analysis of model generated data. For each case, an overview of the problem will be given, the organization of the SDL database of model outputs and analyses of these outputs will be presented, and manipulations performed on the data stored in the database will be discussed. Preceding this discussion, an overview of SDL will be given.

2. SDL OVERVIEW

2.1 SDL Data Organization

SDL provides a simulation-specific framework for organizing both data gathered from the real world by observation and data generated by executing simulation programs. The data organization framework is based on the relational data organization [Codd], that is a matrix of rows and columns. However, special structures for organizing, in the same database, outputs from different runs of the same model or from runs of different models are provided. Furthermore, special structures for organizing all observations of variables which are generated by a model, statistics and histograms are supplied.

2.2 SDL Commands

SDL consists of over 120 commands organized into 12 categories. These commands provide for the storage and retrieval of data in the database from simulation models and include special commands for storing individual observations of model-generated data as well as model generated statistics and

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histograms; for computing statistics and building histograms concerning data stored in an SDL database and storing the results of the computations in the database; for reporting data stored in the database, either in a format pre-determined by SDL or in a user specified format; and for defining the desired data organization, loading into the database, editing data, deleting data, generating SDL formatted or user formatted plots, creating sequential data files containing data stored in the database; performing needed "housekeeping" functions; estimating variances of sample means; aggregating data; and recovering from errors.

2.3 SDL Applications

To date, eight applications of SDL have been performed. (Two will be discussed in detail in the following sections.) These applications include the assessment of operational policies and rates used by a capitation reimbursement system; the assessment of a hospital clinic and related laboratory operation; the projection of the availability of primary care physicians in Indiana; the assessment of the ability of a maintenance facility to meet scheduled maintenance requirements for a fleet of aircraft; the assessment of the ability of a discrete parts manufacturing operation to meet its production requirements; the development of a network simulation language for modeling river systems; the development of a simulation language tailored for modeling steel operations; and the development of a transition path analysis language for economic, technological and societal problem assessment. These applications have shown SDL to be useful in (1) constructing a model generated database and performing analyses by querying that database; (2) storing and analyzing data collected from the system under study and using this data within a simulation program; (3) linking models of different system components; (4) storing and manipulating data concerning individual entities occurring in a simulation model; and (5) implementing modeling languages to provide automatic, user-transparent data collection and analysis. These applications are described by Standridge.

3. OPERATIONAL POLICIES AND RATES USED BY A CAPITATION REIMBURSEMENT SYSTEM

3.1 The Problem

Recently an experiment was begun in 32 counties of Iowa in which the Medicaid drug program reimburses pharmacies for providing prescription drug services to Medicaid eligibles on a capitation basis. That is, pharmacies are prepaid a fixed amount per person per month. The amount of payment varies with the sex, age and institutional status (whether residing at an institution or not) of eligibles. The Medicaid payments are intended to provide for all of the prescription drug needs of an eligible. Eligibles must receive all of their prescription drugs from one pharmacy of their choosing for one month but may choose different pharmacies from month to month. A complete description of capitation is given in Norwood and Yesalis. This application of SDL is discussed in Standridge and Standridge and Wortman. The fundamental reimbursement principle of capitation, the payment of a fixed amount per person per period in exchange for all services received, is very simple. However, the experience of researchers involved in the development and evaluation of the experimental capitation reimbursement system has shown that the exact configuration of such a system may be quite complex. For example, pharmacies serving different numbers and/or different case mixes of eligibles must be considered. Furthermore, since it was decided that pharmacies should not be placed at financial risk under capitation, the effect of providing supplemental payments to pharmacies for costs incurred that were more than capitation payments received must be considered. Most basically, the acceptability of a given set of capitation the experience of researchers involved in the development and evaluation of the experimental capitation reimbursement system has shown that the exact configuration of such a system may be quite complex. For example, pharmacies serving different numbers and/or different case mixes of eligibles must be considered. Furthermore, since it was decided that pharmacies should not be placed at financial risk under capitation, the effect of providing supplemental payments to pharmacies for costs incurred that were more than capitation payments received must be considered. Most basically, the acceptability of a given set of capitation rates to provide reimbursement for costs varying around these amounts must be addressed.

Thus, the operational policies and reimbursement rates of the Iowa capitation reimbursement system for pharmacy services were of interest to program administrators, program evaluators, pharmacists and Medicaid eligibles. It was recognized that the reimbursement policies of the particular system to be used for capitation reimbursement were as important as the fundamental principles of capitation. Furthermore, incorrect capitation rates could lead to the demise of capitation. Thus, an assessment of the adequacy of these policies and capitation rates prior to the beginning of capitation reimbursement was deemed necessary. Such an assessment was made for the capitation experiment which began April 1, 1981.

3.2 The SDL Database Organization

Figure 1 gives the organization of the SDL database, with respect to the models and analysis procedures employed, used in assessing the capitation policies and rates. Notice that the specification and implementation of the simulation model as well as the analysis and reporting of model generated data has been broken down into three independent steps:

1. a model generating a list of the eligibles choosing one pharmacy (eligible list generation model);
2. a model generating the prescription drug costs for one pharmacy given a list of eligibles choosing that pharmacy (cost generation model); and
3. procedures for the computation and reporting of performance measures.

Thus, the use of SDL provides an alternative to the normal procedure of including all of the components of a model in one program along with the computation and reporting of performance measures. The linkage between the components is provided by SDL. For example, a list of eligibles needed as input by the cost generation program can be retrieved from the database where it was stored by the eligible list generation program. In addition, the database contains data supplied by the Medicaid drug program concerning historical drug costs and histograms which summarize this data.

Especially important is the separation of the computation and reporting of system performance measures from the two models. In this study it was known that the performance measures would be functions of the capitation rates, which were determined externally to this study, and the costs generated by the cost generation model. However, the exact definitions of the performance measures were not known when the study was begun. Thus, the cost generation model was designed to store the simulated costs incurred by pharmacies in the database. Since capitation rates were also stored in the database, performance measures could be defined, computed and reported whenever desired without modifying and rerunning model programs. Furthermore, the output values of all runs of the eligible list generation program and the cost generation program for each of ten pharmacies considered are stored in the database. Thus, analyses across runs for a particular pharmacy to estimate the variance of a sample mean or across runs for different pharmacies for comparison purposes are facilitated.

3.3 Component Interfaces with the Database

In this section, the relationship to the SDL database of each of the four components of the modeling and analysis procedure will be discussed.

Histogramming Program The purpose of the histogramming program is to produce one histogram for each of the 20 classes of Medicaid eligibles concerning the quarterly dollar amount of prescription drugs consumed. Input to the program is data provided by the Iowa Medicaid drug program. The 20 histograms are generated and automatically stored in the database using one SDL histogramming command. A second SDL command is used to print a report of the histograms. These commands are involved in a program written in the SDL high level programming language, known as OIL. The OIL program used is shown in Figure 2.

Eligible List Generation Model The eligible list generation model interfaces with the database by storing a list of eligibles, corresponding to one pharmacy, each time the model is run. As was previously discussed, the SDL data organization is relational, that is it consists of a matrix of rows and columns. As is shown in Figure 3, a single relation was used to hold all outputs of the eligible list generation model. A row corresponds to one eligible. Columns correspond to eligible characteristics (age, sex, institutionalized or not, Medicaid class). Rows of the relation are partitioned into subsets, tables in SDL terms, each of which corresponds to one pharmacy.

The eligible list generation model was implemented as a FORTRAN program. One subroutine in the program was written to store data in the database as is shown in Figure 4.

Cost Generation Model The cost generation model retrieves from the database one eligible list, the list for the pharmacy being simulated, and the 20 histograms produced by the histogramming program. As shown in Figure 5, the model stores in the database one relation for each pharmacy simulated. Each relation is composed of tables corresponding to each replication of the model for one pharmacy, rows corresponding to eligibles and columns corresponding to model output variables. These values are stored in the database in the same manner illustrated in Figure 4.

Analyses of Outputs As shown in Figure 1, all data relevant to this study is stored in one SDL database and thus is readily available for use in the computation of performance measures. In addition, computed performance measures can be stored in the database for later reporting or use in making comparisons between pharmacies or between alternative reimbursement procedures.

To illustrate, one performance measure and its value for each of two alternative reimbursement policies will be considered. If, in any one time period, the actual cost incurred by a pharmacy exceeded the capitation payment then the Medicaid program would make a supplemental payment to the pharmacy in the amount of the difference between the actual cost incurred and the capitation payment received. At issue was the length of the time period, either one quarter or one year. (Each replication of the cost generation model was one year in length). The desired comparison was obtained by performing several steps for each alternative, one quarter and one year:

1. Use SDL statistics commands in an OIL program to compute the sum of the capitation payments and the sum of the simulated costs for the desired time period from the outputs of the cost generation model, for each replication in each pharmacy, storing the results in the database;
2. Write a FORTRAN program (about 30 lines) to retrieve the sums computed in step 1 from the database and compute the difference between the capitation payments received and the simulated cost for each time period for each replication of each pharmacy, (in the year case prorate the difference to quarterly by dividing by four); store in the database the amount of the supplemental payment required or zero if none is required.
3. Compute statistics concerning the supplemental payment amount by pharmacy over all replications and time periods using an OIL program.

The final result of these three steps is the subsection of the database shown in Figure 6. From this data, the desired comparison can be made. For example, a report showing the average supplemental payment for each pharmacy for each of the two time periods being considered can be generated using a single SDL command.

4. PROJECTING THE AVAILABILITY OF PRIMARY CARE IN INDIANA

A project to project the availability of primary health care in Indiana from 1971-2000 was performed from 1975-1977 and has been reported by Standridge and others. A simulation model was constructed to project the number of primary care physicians (physicians such as family practioners who provide initial, first contact care) and the number of patient visits they supply. In addition, the model received projections of the population of Indiana as input and estimated the number of visits demanded by the population. Thus, the projected availability of primary care in Indiana could be estimated by comparing the projected number of visits supplied to the projected number demanded. This relationship between the components of the model is shown in Figure 7.

4.1 Database Structure

In the original study, the single simulation program made all of the needed projections (except for population projections which were obtained from an independent source) as well as computing and reporting the desired performance measures. A reimplementation of this model using SDL concepts has been performed. The structure of the SDL database of component model outputs is shown in Figure 8. As in the previous example, the use of SDL allowed the single large simulation program to be broken into simulation programs of each component of the system. These component models are linked together by the database. This decomposition capability is especially important in this case because the system is large and complex. The development and modification over time of a set of simpler, component models and their computer implementations should prove easier than that of a single, large complex model. Furthermore, implementation of alternative models of particular components is simplified.

The model developed in this case was deterministic. Thus, only one replication of each component model for a particular set of parameter values was required. All model outputs for each component for each set of parameter values are stored in one database. Thus, comparisons between the same measures of availability for different scenarios, that is different sets of parameter values, or between outputs of the same component for different sets of parameter values are facilitated. These comparisons will be discussed in the next section.

4.2 Component Interfaces with the Database

In this section, the outputs of each component model will be described.

Physician Projection Model The physician model is complex, taking into account physician education, retirement and migration of physicians in 5 specialties (general/family practice, internal medicine, general surgery, pediatrics, and obstetrics/gynecology), two regions of Indiana (urban and rural), and 9 age classes. The output of this model, shown in Figure 9, is one relation containing numbers of physicians. The relation has two tables, one for each region of Indiana. Rows correspond to years, 1971-2000. There are 46 columns one for each combination of physician age class and specialty and one for the year. Each run of the physician projection model with different input parameter values produces one such relation.

Supply Model The supply model produces one relation each time it is run similar in structure to the relation shown in Figure 9. Values in the relation give the number of visits provided. The supply model uses the data in one relation output by the physician projection model as input to the computation of the number of visits provided.

Population Projection Model The population projection model is also complex, taking into account population birth, death and migration in five age groups, two sexes, and two places of residence (urban and rural). The output of this model, shown in Figure 10, is one relation similar in structure to the output relation of the physician projection model. Again, each run of the model using different input parameter values produces one such relation.

Demand Model The demand model produces one relation each time it is run similar in structure to the relation shown in Figure 10. Values stored in the relation give the number of visits demanded. The demand model uses the data in one relation output by the population projection model as input to the computation of the number of visits provided.

Estimation of and Reporting of Availability Three classes of measures of availability were considered:

1. comparisons of visits supplied to visits demanded;
2. comparisons of numbers of physicians to numbers of people; and
3. comparisons of outputs of the same component model for different scenarios, values of model input parameters.

The SDL database of model generated data provided all data needed to compute measures of availability belonging to each class. For example, a FORTRAN program was written to compute (1) the percentage of the demand in each region which was being satisfied by the supply year by year and (2) the number of visits demanded not being supplied. This program produced one relation as output as shown in Figure 11. As with the other relations, previously described in this application, there was one row for each year and one table for each region. The three columns corresponded to the year and each of the two measures of availability. Program inputs were retrieved from the database and consisted of one of the relations produced as output by the supply model and one of the relations produced as output by the demand model. Each execution of the program could be used to generate the measures of availability, stored in a different relation, for a different scenario, that is a different combination of supply and demand model output relations. SDL report generation commands can be used to generate reports showing the measures of availability from a single scenario or across as many scenarios as required.

During the course of this study there was significant interaction between modelers and physicians. Part of the result of this interaction was the definition of measures of availability on an iterative basis. That is, the modelers would present measures such as those previously discussed. Then the modelers and physicians working together would define additional measures. One such measure is the ratio of physicians to 10,000 people. A FORTRAN program was written to compute these measures. Program inputs consisted of one output relation of the physician projection model and one output relation produced by the population projection model. The program produced a relation similar in structure to the relation shown in Figure 11. SDL report generation commands were used to generate reports showing both the original measures of availability and the measure just computed.

5. SUMMARY

This paper has presented SDL simulation analysis procedures for health care delivery issues by discussing two applications. The fundamental SDL analysis concept is to build a database of all data generated by models and data gathered from the system under study. This concept supports the decomposition of a large scale, complex model into relatively smaller, less complex component models. These models are linked together by the database allowing data produced as output by one component model to use as input by another. Furthermore, the definition and computation of system performance measures for each system scenario can be postponed until after model runs have been made. Furthermore, these measures may be defined and computed iteratively over time without incurring the cost of rerunning models. In addition, measures comparing system alternatives may be defined and computed using data stored in the database. While these capabilities have been illustrated in terms of two health care examples, they apply in general to all large scale, complex simulation problems.

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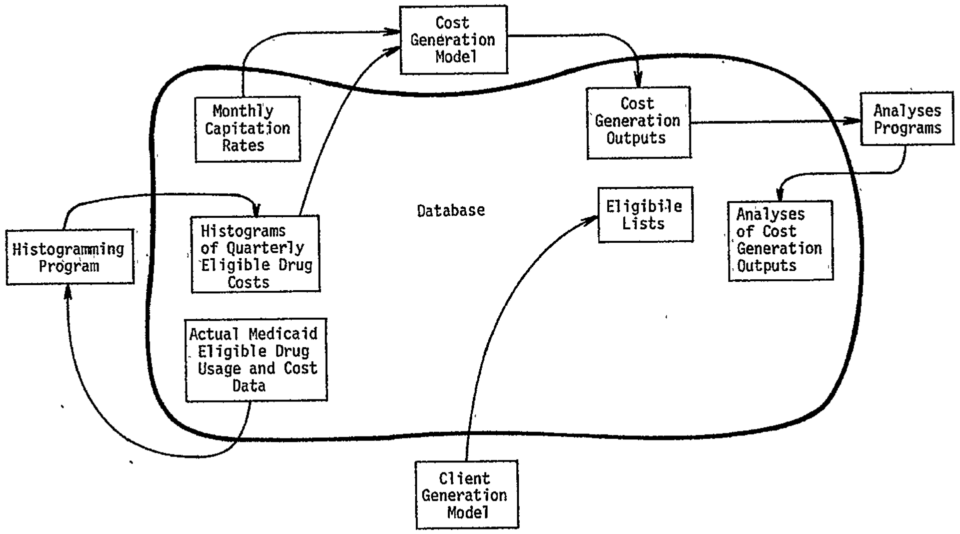

Figure 1. Analysis Components

```
BEGIN;

     COMMENT, PROGRAM TO HISTOGRAM QUARTERLY DOLLAR AMOUNT
          OF PRESCRIPTION DRUGS CONSUMED;

     COMMENT, CREATE AND STORE HISTOGRAMS;
     HISTOGRAM BY COLUMN VALUE,
          DATA (REGULAR, 101,, (1)),
          ID SCENARIO (102,'HISTO DOLLAR DRUGS'),
          COLUMN VALUES (1, (1), (2), (3), (4), (5), (6),
                (7), (8), (9), (10), (11), (12), (13),
                (14), (15), (16), (17), (18), (19), (20);

     COMMENT, PRINT HISTOGRAMS;
     ECHO HISTOGRAM RELATION,
          ID HISTOGRAM (102);
END;
```

Figure 2. OIL Program

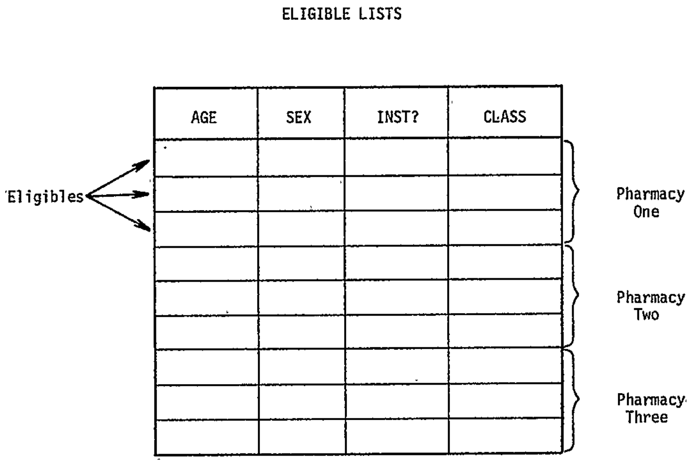

Figure 3. Eligible List Subsection of the Database

```
      SUBROUTINE STRROW (IDREL, IDPHRM, AGE, SEX, INST, CLASS)

C     ROUTINE TO STORE ONE ROW IN THE DATABASE
C     IDREL IS THE RELATION ID NUMBER (READ IN)
C     IDPHRM IS THE PHARMACY ID NUMBER (READ IN)
C     AGE IS THE ELIGIBLE AGE
C     SEX IS THE ELIGIBLE SEX
C     INST IS AN INDICATOR AS TO WHETHER OR NOT THE ELIGIBLE IS
C        INSTITUTIONALIZED
C     CLASS IS THE ELIGIBLE MEDICAID CLASS

      DIMENSION ROW(4)

C     ASSIGN VALUES TO ROW

           ROW(1) = AGE
           ROW(2) = SEX
           ROW(3) = INST
           ROW(4) = CLASS

C     USE THE SDL COMMAND TO STORE DATA IN THE DATABASE

      CALL PTNXT (IDREL, IDPHRM, ROW)
      RETURN
      END
```

Figure 4. Subroutine of Eligible List Generation Program which Stores One Row in the Database

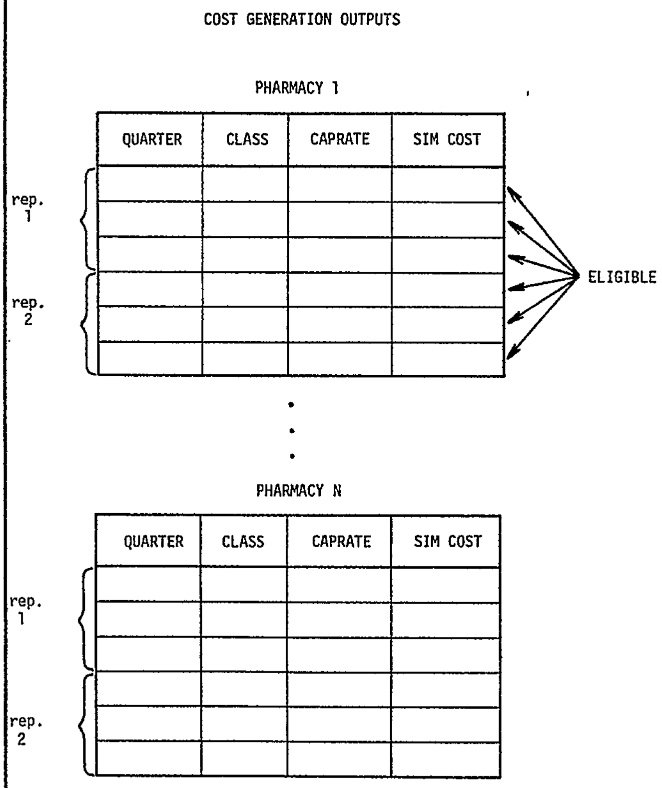

Figure 5. Cost Generation Subsection of the Database

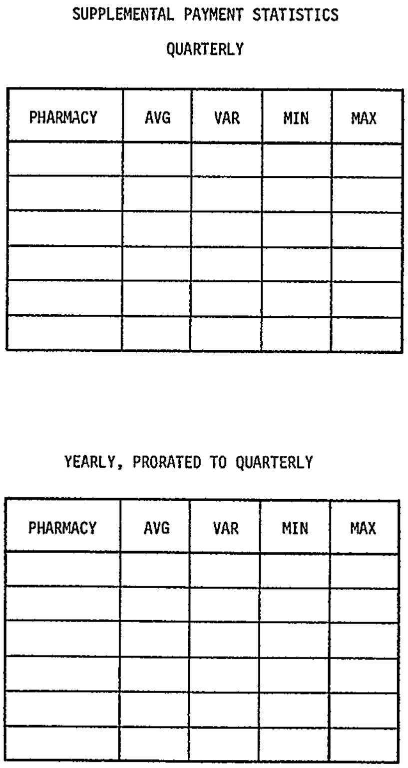

Figure 6. Time Period Comparison Database Subsection

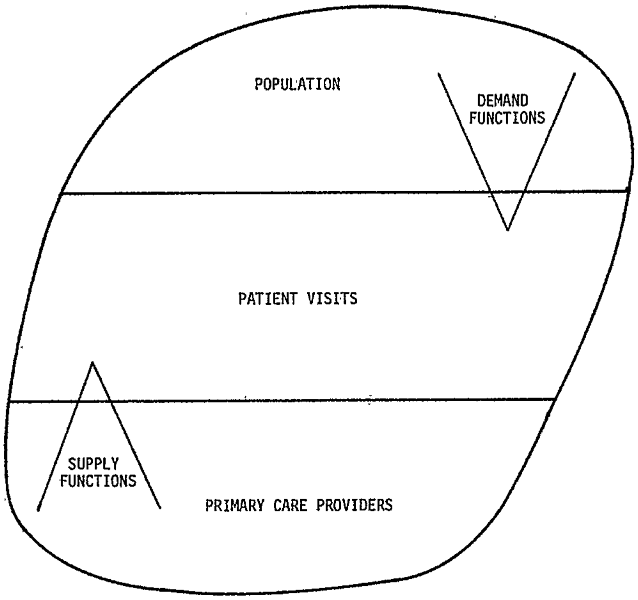

Figure 7. Components of the Primary Health Care Availability Projection Model

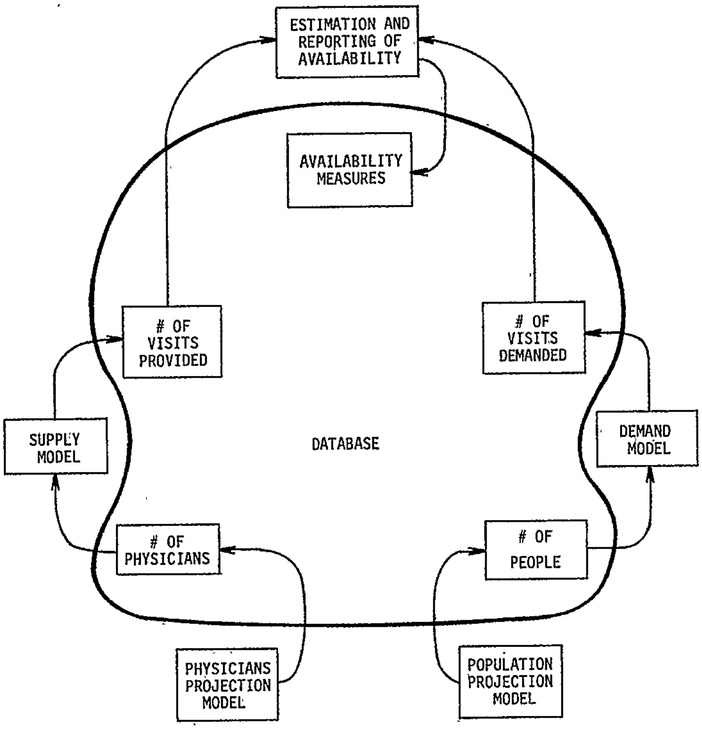

Figure 8. SDL Database Structure for Projecting the Availability of Pharmacy Care

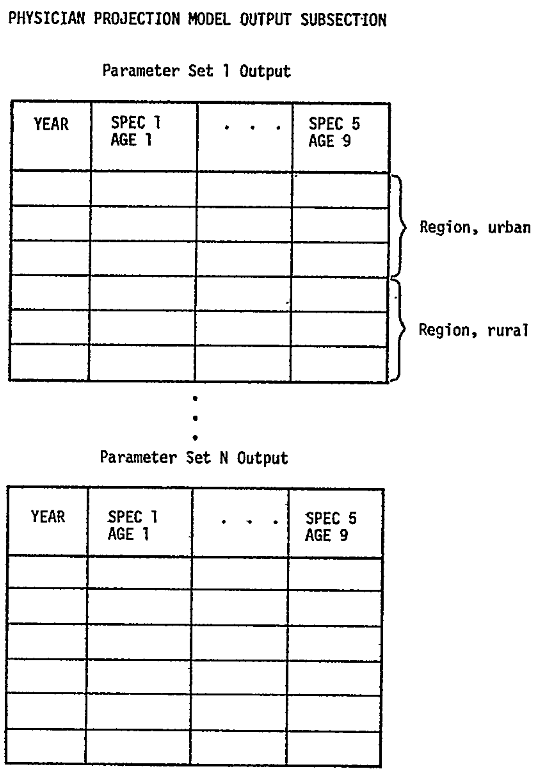

Figure 9. Physician Projection Model Output Subsection of the Database

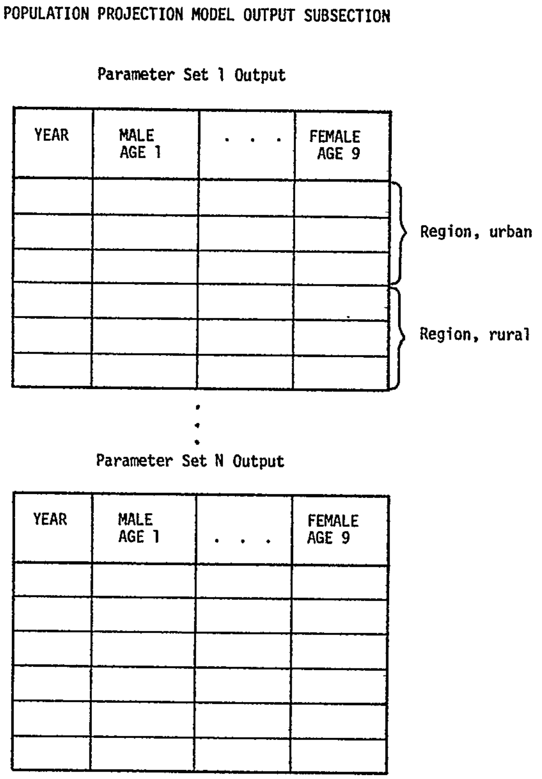

Figure 10. Population Projection Model Output Database Subsection

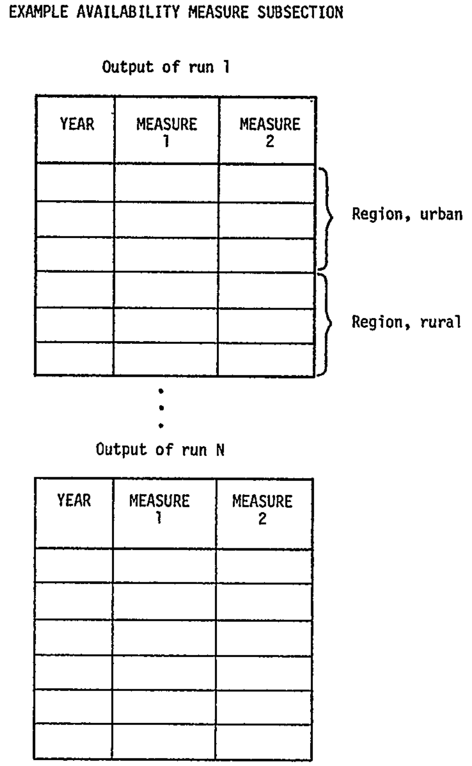

Figure 11. Example Availability Measure Database Subsection