BY:

Rasika Abeysinghe
Vicente Checa
Michael Choo
Colleen Dayton
Victor Lima

FACULTY ADVISORS:

Dr. Dan Bauer
Dr. William Hornfeck

LIAISONS:

James Burdine Dr. P.H.
Judy Sabino M.P.H.
EXECUTIVE SUMMARY

• CONDUCTED BY - Lafayette College Technology Clinic, commissioned by the Partnership for Community Health in the Lehigh Valley

• OBJECTIVE - To assess institutional primary health care resources in the Lehigh Valley and to model the Lehigh Valley health care system in order to project results of changes to the system without actually changing system

• PARTICIPANTS - Lehigh Valley institutional primary health care providers (physicians, nurses and administrators)

• FIRST SEMESTER RESULTS - The most acute problems include:
  - inefficient use of health care system (i.e. clinic "jumping", misuse of emergency rooms)
  - rapid increase in number of uninsured/underinsured patients
  - general neglect of health maintenance on the part of Lehigh Valley residents; a correspondingly low level of services devoted to well patient care
  - an uneven distribution of indigent patients among health care providers in the Lehigh Valley due mostly to location of institution
  - difficulty for uninsured/underinsured persons to obtain health care; many do not qualify for medical assistance, are refused from clinics, can not afford to pay private physicians
  - a virtually universal sentiment regarding the inadequacy of the present health care system to meet the needs of future generations of Lehigh Valley residents

• SECOND SEMESTER RESULTS - Built the following computerized models using SimProcess:
  - Ideal model, includes on-line database of medical histories, inexpensive treatments, adequate insurance, and fast, effective health care for all
- **Lehigh Valley model**, shows flow of patients through Lehigh Valley health care system according to insurance status; includes hospitals, visiting nurses associations, health bureaus and private physicians.

- **Clinic/emergency room models**, includes an emergency room and ear/nose/throat, general medicine, and pediatric clinics; shows results of reallocating resources between clinics and emergency rooms.

- **Neonatal model**, shows decrease in cases of newborn deaths resulting from outreach programs and prenatal care.

- These models are portable; each institution can make the model simulate its own operation by inserting appropriate data.

- Models can be used to view effects of administrative changes and/or system use changes, without having to risk consequences of making actual physical changes.
# TABLE OF CONTENTS

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Introduction</td>
<td>1</td>
</tr>
<tr>
<td>Semester One</td>
<td></td>
</tr>
<tr>
<td>Semester One Activities</td>
<td>4</td>
</tr>
<tr>
<td>Semester One Conclusions.</td>
<td>6</td>
</tr>
<tr>
<td>Semester Two</td>
<td></td>
</tr>
<tr>
<td>Semester Two Activities</td>
<td>9</td>
</tr>
<tr>
<td>Introduction to SimProcess</td>
<td>10</td>
</tr>
<tr>
<td>Methodology</td>
<td>13</td>
</tr>
<tr>
<td>Models</td>
<td></td>
</tr>
<tr>
<td>Ideal Model</td>
<td>18</td>
</tr>
<tr>
<td>Lehigh Valley Model</td>
<td>22</td>
</tr>
<tr>
<td>Clinic/Emergency Room Model</td>
<td>28</td>
</tr>
<tr>
<td>Neonatal Model.</td>
<td>32</td>
</tr>
<tr>
<td>Conclusions</td>
<td>34</td>
</tr>
<tr>
<td>Appendices</td>
<td></td>
</tr>
<tr>
<td>Lehigh Valley Health Care Providers Interviewed</td>
<td>37</td>
</tr>
<tr>
<td>Interview Worksheet</td>
<td>39</td>
</tr>
<tr>
<td>Data Sheet.</td>
<td>41</td>
</tr>
</tbody>
</table>
INTRODUCTION

Steve and Betty are a recently married, Lehigh Valley couple who work long hours, do not have insurance, and do not qualify for medical assistance. Steve and Betty are expecting their first child. Since Betty works long hours and believes health care is unaffordable, she does not seek medical attention until she suffers complications with her pregnancy. The baby is born prematurely and requires intensive medical care during the first weeks.

The estimated average cost of intensive care for premature babies is 65,000 dollars\(^1\). It costs about 25,000 dollars to increase a premature baby's weight by one pound\(^2\). If Steve and Betty's baby spends two months in intensive care and gains four pounds, the hospital will have to spend 165,000 dollars. This amount is sufficient to pay for twelve persons' annual tuition at Lafayette College. The spending and suffering, however, probably could have been avoided if Betty had received pre-natal care.

Problems such as this are not atypical of the underinsured persons in the Lehigh Valley. Without preventative care, underinsured persons with acute illnesses are flooding the hospitals. The hospitals are, therefore, absorbing the costs of treating very expensive acute illnesses, many of which could have been prevented with relatively inexpensive care. This problem is not only typical of the Lehigh Valley health care system, but also of the national health care system. The problems people of the Lehigh Valley are experiencing are much like the problems people are experiencing nationally.

Most citizens in the valley live in one of three moderately sized cities. The hospitals serving

\(^1\)Vicky Lysek, Director, A Better Start, Lehigh Valley Hospital

\(^2\)Deanna Seagraves, Nurse Manager of St. Luke's Clinic
the valley do not deal with the health problems of a large metropolis, nor do they battle with extreme transportation difficulties of rural areas. The most acute problems in the Lehigh Valley are the rapid increase of uninsured/underinsured patients, inefficient use of the health care system, general neglect of health maintenance, difficulty in obtaining health care and an uneven distribution of indigent patients among health care providers. At a time when the National Health Care Task Force is scrutinizing the nation’s health care system, the Partnership for Community Health in the Lehigh Valley is collaborating to address the problems of the valley’s health care system.

The Partnership’s purpose is to "collaboratively plan how the health status of the region’s population can be enhanced while decreasing the costs for delivery of health services and simultaneously improving access to care for those with the greatest needs." The Partnership is a consortium of the seven hospitals in the Lehigh Valley, the Lehigh and Northampton county medical societies, and the Trustees of the Dorothy Rider Pool Health Care Trust. The Lafayette College Technology Clinic acted as consultants to the Partnership in their study.

A Lafayette College Technology Clinic is typically a team of five or six students aided by two faculty facilitators. The facilitators, as well as client liaisons, work closely with the students to provide direction and advice. In the past, Technology Clinics have been sponsored by agencies such as Olin Hunt, Merck, Ingersoll Rand, and the Lehigh Valley Hospital. The Technology Clinic program strives to solve real world problems over a full academic year utilizing the unique perspective students possess.

Dr. Dan Bauer and Dr. William Hornfeck are the facilitators of the Technology Clinic team working for the Partnership. Dr. Dan Bauer is associate professor and head of the Anthropology and Sociology department. Dr. William Hornfeck is professor and head of the Electrical
Engineering department. The students working on the team represent various academic areas of the college. Michael Choo '93 is an Electrical Engineering major from Kuala Lumpur, Malaysia; Vicente Checa '93 is a Chemical Engineering major from Lima, Peru; Rasika Abeysinghe '93 is a Mechanical Engineering and English double major from Colombo, Sri Lanka; Colleen Dayton '94, from Hillsborough, New Jersey, is a Computer Science major and an Anthropology and Sociology minor; finally, Victor Lima '93 is an Economics and Mathematics double major from Santiago, Chile.

For the first half of the project, our Technology Clinic completed an assessment of institutional primary health care resources available in the Lehigh Valley. James Burdine Dr. P.H. and Judy Sabino M.P.H., of the Community Health Status Assessment Task Force (CHSATF) provided us with the information and guidance necessary to expedite our investigation.

For the second half of the project, we created computer models of the Lehigh Valley health care system, using information we acquired through interviews first and second semester. We developed the models in order to identify areas in which resources are underutilized and in which resources are stretched beyond their limits and to explore the probable outcomes of alternatives. These models are described in detail in later sections.
SEMESTER ONE ACTIVITIES

During the first semester the Hospital Technology Clinic was asked to focus on institutional primary health care providers. To establish a common point of reference, we defined primary health care as the point of entry into the health care system. It consists of the most general level of care, including preventive, diagnostic, and curative services; general internal medicine, pediatrics, family practice, and obstetrics and gynecology. As a result, the relevant categories of institutional providers are health bureau clinics, hospital clinics and emergency rooms, visiting nurses associations (VNA), and women, infant, and children clinics (WIC).

We developed a general approach to obtain qualitative information on the primary health care resources of the area. The team designed a series of interview questions to cover several facets of institutional primary health care. These questions dealt with appointments, patient profiles, clinic logistics, and individual and institutional perceptions of primary health care. We then discussed the questionnaire's content with the Community Health Status Assessment Task Force (CHSATF). At each interview, interviewees were assured of the confidentiality of the information they would provide.

In addition to the interview, we developed a data sheet to leave behind with each interviewee. We requested that the two-page data sheet was completed and forwarded to us. This was designed to get quantitative data from the institutions.

To obtain the broadest perspective of accessibility to care in the Lehigh Valley, we set up
interviews with people from various institutions. The CHSATF suggested an initial list of people with different degrees of involvement in the provision of health care and notified them of the study's purpose. Also, the CHSATF told them that a member of our team would contact them to set up a meeting. From this list, we selected people representative of the greatest variety of occupations and covering all the institutional providers in the Lehigh Valley. The administrators, physicians, and nurses we interviewed, worked in areas ranging from dentistry to emergency care.

To analyze the capacity of the health care system in the Lehigh Valley, we considered aspects such as waiting time for appointments, waiting time in the office, no-show tendencies, and over-booking rates. We sought insight regarding the constraints institutions face, the level of resource utilization, and latent expansion plans, since ultimately these insights provide many of the pieces to the Lehigh Valley health care capacity puzzle.
SEMESTER ONE CONCLUSIONS

We concluded that the institutional primary health care resources in the Lehigh Valley were insufficient to meet the current needs of the population, especially of the indigent. The population is expected to increase very significantly in future years, but there are only modest plans to increase the capacity of health care providers. As a result, the gap between the demand for primary care services by indigent patients will increasingly exceed the capacity of providers. Some interviewees even go as far as to predict an apocalyptic shortage of health care resources in the near future.

Another observation is the apparent paradox involving the existence of idle time at institutions which also report full bookings for months ahead. These institutions prefer not to over-book appointments in order to reduce waiting time in the office. This is done to increase patient satisfaction and to encourage patients to seek care at the same institutions thereby ensuring continuity of care and preventing inappropriate use of the emergency room facilities. The existence of a trade-off between improving efficiency, which would involve heavy over-booking, and improving patient satisfaction, which would involve inefficient use of staff and facilities, restricts the domain of possible improvements.

We found that the emergency room was inappropriately used as a primary health care facility. This practice leads to inefficient use of resources since it costs more to treat patients in emergency rooms (lack of medical records and fear of malpractice suits results in over-prescription of tests and medicine). Emergency room treatment also involves symptomatic treatment and does not consider long term cures for ailments, and this further decreases the efficiency of resource utilization.
Transportation and language barriers were pinpointed as significant problems to access to health care. One hospital administrator noted that although there are institutional staff who can act as translators, they are often too busy to assist in translation efforts. Providers also pointed out that although most patients could understand some English, some had difficulty understanding the medical terminology used by physicians and nurses. Transportation was also seen as a barrier to access to health care since many indigent patients are not able or willing to afford the transportation costs. This problem was not spread throughout all the institutions.

Maintaining an acceptable staffing level was a problem. Insufficient incentives for physicians and nurses to work in public health care institutions, low reimbursement, potential legal risk, and lack of appreciation from patients were some of the key reasons why people choose not to work in the public health sector. A notable exception was the dental clinic at Muhlenberg Hospital. Dr. Jonathan Tenzer, director of the clinic, pointed out that there was a great deal of camaraderie among the 60 dentists who volunteer their services at the clinic. The presence of dental residents also provided the physicians the opportunity to be involved in ongoing professional education by teaching and learning from the residents.

The patterns of population growth also present problems. Senior citizen and indigent populations are increasing and this results in an increasing demand for health care services. Women are also becoming pregnant at younger ages, resulting in increased health care needs for young women. These factors further contribute to the increasing gap between health care resources and needs.

Patients, especially the indigent, tend to visit health care institutions only when they are acutely ill. This clearly exacerbates the health care problem in the Lehigh Valley. According to
Mary Alexander of the Lehigh Valley Hospital, the health care system is really an "illness" care system. Many people, within the indigent category, have a perception that health care is beyond their means and will not seek care for minor illnesses. Often, these illnesses become major problems, and the patient ends up seeking care at the hospital emergency room. This practice results in the inefficient use of resources as it is generally cheaper to keep people well than to treat seriously ill patients. Although many of the providers agreed that well visits are desirable and benefit both the patients and health care institutions, they also noted that the current capacity of health care resources may not be sufficient to accept many well visits. Most institutions are already operating at full capacity treating mainly patients who are ill. One hospital even reported that it will not care for healthy patients.

As is evident from our first semester field work, many problems beset the Lehigh Valley institutional primary health care system. Knowing where these pockets of inefficiencies occur is, however, the first step towards eliminating them. The experience we acquired during the first semester proved crucial to the development of our second semester models.
SEMESTER TWO

SEMESTER TWO ACTIVITIES

The primary objective of the spring semester's activities was to develop several computer-based models of actual and hypothetical health care systems at various levels of complexity. The models were developed using the SimProcess/SimFactory simulation software package marketed by CACI products, and which runs on MSDOS personal computers. By simulating these models in real time, we are able to gain further insights into the functional characteristics of health care systems with at various levels of detail. In addition, real time simulation, the SimProcess package can also generate cost and resource allocation analysis, as well as the level of activity at each "node," which may be a clinic, nurse, specialist, or other parts of the health care system.

These models do not replicate real systems in every detail but are designed to provide an overview of a process workflow. The level of detail incorporated in each model is selected in order to optimize its usefulness while minimizing unnecessary computations. Excessive complexity and detail also interferes with the intelligibility of the models. The following sections will describe six different models developed during the semester.
INTRODUCTION TO SIMPROCESS

This section is aimed at providing readers with a general understanding of the SimProcess/SimFactory simulation software package and modelling terminology, and assumes no prior experience with simulation techniques.

The three basic node types in a model are the receivers, queues, and stations. Receivers accept raw material from the outside world, which may arrive periodically (repeating arrivals) or at specific times during the simulation (scheduled arrivals) up to a specified receiver capacity limit. Queues store elements-in-progress, which in our models are patients, up to a specified capacity limit and are primarily used to transfer patients between stations with different processing times. Stations process incoming elements and produce one or more products (in our models, products and elements represent patients in various stages of diagnosis, treatment, and recovery). Processing times may be a constant, a function, a range, a Gaussian distribution, or one of several other types of statistical distributions. Products are filtered through the system according to specified percentages, which in our case translates to the percentage of patients requiring intensive care treatment, specialist treatment, emergency treatment, etc. Nodes in a model are linked together via workflows which specify the flow of various products (patients) within the model. Resources represent health care personnel working at specific stations. All icons/nodes in the model take on different colors during simulation to indicate its status:

Yellow: Idle (for stations) or empty (for queues)
Green: Operating (stations) or partially full (queues)
Red:Blocked (stations) or full to capacity (queues)

The following is a very basic model which shows the fundamental nodes and operations. It is a model of an aspirin repacking room where aspirin in large boxes arrives and is repacked into small containers, and then shipped to buyers. Figure A shows the layout of the model and Figure B shows the workflow path of products. Boxes of aspirin arrive at the Receiving Clerk and are passed on to Queue-1. The Unpack station takes a box from the Queue-1 and unpacks it. The unpacked aspirin is sent to Queue-2 where it awaits repacking by Repack station. After repacking, the aspirin in small containers is sent to Queue-3 where it awaits shipping by the Shipping Clerk.

Figures C and D show the layout at two stages of simulation. In Figure C, all boxes of aspirin have been passed on to Queue-1 from the Receiving Clerk. This is indicated by the yellow color of the Receiving Clerk, i.e., empty, and the green color of Queue-1, i.e., partially occupied. The numbers above the Receiving Clerk icon indicate that 10 boxes of aspirin had passed through and none were waiting to be passed on. Similarly, the numbers above Queue-1 indicate that 1 box had been passed on to the Unpack station while 87 are waiting to be passed on. The Unpack station is currently green, which indicates that it is busy processing, i.e., unpacking a box taken from Queue-1. The number above the icon indicates that 1 box has been processed and the second box is currently being processed. In Figure D, the Receiving Clerk is green which indicates that it is partially filled. Its associated numbers show that 34 boxes had been passed on while one box waits to be passed on. Queue-1 is red which indicates that it is filled to capacity (specified to be 100 units) and cannot accept any more boxes from Receiving Clerk. Both Queue-2 and Repack Station are yellow, which indicates that they are awaiting unpacked boxes from the Unpack Station.
FIGURE A
EXAMPLE MODEL

Receiving Clerk

Queue-1  Unpack

Queue-2  Repack

Queue-3  Shipping Clerk
FIGURE B
EXAMPLE MODEL FLOW

Receiving Clerk

Queue-1  Unpack  Queue-2  Repack

Queue-3  Shipping Clerk
FIGURE C
SIMULATION IN PROGRESS

0/10

Receiving Clerk

Queue-1  1  Unpack

Queue-2  1  Repack

Queue-3  1  Shipping Clerk
FIGURE D
SIMULATION IN PROGRESS

Receiving Clerk

1/3

100/3
Queue-1

3
Unpack

8/3
Queue-2
Repack

1/2
Queue-3
Shipping Clerk
Figures E through G are pie charts showing the final operational status of three nodes. These are indicators of the level of activity at each of these nodes throughout the duration of the simulation. Figure E shows that the Receiving Clerk partially filled for 29.0% of the time, and empty for the remaining 71.0% of the simulation time. Figures F and G show the level of activity of Queue-1 and the Shipping Clerk respectively.
METHODOLOGY

To explain the mechanics of health care in the Lehigh Valley, we chose to use a modelling approach. The reasons will be apparent after two central aspects are explained: the models and the methods used to create them. We will begin by examining the models and their purpose.

The Lehigh Valley is a complex community of 600,000 people. It is, therefore, necessary to look at the health system on four different levels. By breaking the whole into parts, it is possible to take three simplifying steps at once:

- a complicated health system is converted into three simpler, seemingly independent blocks;
- the end-user is able to interpret final models and results in a clear and precise way;
- it is possible to target different health professionals and provide them with a useful tool that will satisfy their specific needs.

The most detailed level of health service examined in this study is that of a specific service provided by an institution. We have chosen to model perinatal care, but the same modelling techniques are useful in modelling any health related process.

At this level, it is possible to look at the impact that instituting well care has on cost and life expectancy. It is possible to get an estimate of the trade-off between lives saved and dollars spent, and if we assume that perinatal care improves the infants' quality of life, then we can also determine "how far a dollar goes" in that respect.

A second level models the flow of people through one institution. As an example, we have used Easton Hospital data to describe our institution. The characteristics of SimProcess allow simple pinpointing of inefficiencies, waiting time for care, unexpected benefits of the triage system, and improper use of the facilities. By altering parameters, it is possible to explore how the Hospital
would perform under extreme conditions. And, by changing its structure, it is possible to make the institution's operation smoother.

A third level is an aggregate of all the types of health providers available in the Lehigh Valley. The theme can, thus, be summarized as patient flow through the entire Lehigh Valley health system. This consists of health bureaus, visiting nurse associations (VNA), Hospitals, and private physicians. This particular model shows how people move through the valley (depending on their insurance category), and whether this flow is appropriate. Perhaps the most notable feature is the provision of a framework for experimenting with possible corrective measures. This is analogous to the process used by hospital executives to correct inadequate procedures in their institution.

Finally, a prototype system was constructed. This is a normative model: it models how the health system could ideally work, not how it actually works. In a sense its purpose is to highlight the importance of intangible variables such as communication and education. It models the process that a person with perfect knowledge of the system would follow in order to receive health care. It also includes several technological advances that target the issue of health care costs and how through careful planning and innovation these could be reduced (and efficiency improved.)

To understand the relationship of each model to reality, it suffices to state that the model of level one resembles reality as it would look through a high power microscope. Models of levels two and three use eyepieces with less magnification, whereas the model of level 4 is like using a telescope to peer out of our system and into the realm of the ideal.

Taken individually, each of the models serves its own purpose; they also complement each other perfectly. The interrelatedness is apparent. If used together these models emphasize the
relevance of policy coordination. Since it is possible to assess the impact of each level of care on the quality of health care in the Lehigh Valley, then it is possible to take a cooperative stand so as to attain a common goal, rather than to pursue individual policies that may actually be detrimental to the final goal.

Sensitivity analysis, or the art of discovering the impact of changes on the status quo, becomes a feasible alternative for policy decisions. Statistical analysis is carried out by the simulations, so rather than working with numbers and hinting at possible effects, it is possible to see the numbers at work and take them to extremes thereby discovering subtle consequences.

In constructing our models, we observed three important rules:

- The model had to be simple; any person with an interest in the topic should be able to use it;
- The models needed to be dynamic rather than static;
- The models needed a solid base, rooted in the true behavior of the systems analyzed.

We chose to make a dynamic model, rather than a static one because the type of problem lends itself to the addition of a time dimension. Since we are attempting to analyze the efficiency of a flow, the best way to do so is to model the little glitches so we know where the flow is stymied. Then we can correct the problems and smooth out the flow. In fact, the time variable is the key to the analysis of the problem.

Since the gathering of accurate data is beyond the scope of our clinic, we focused on acquiring a thorough understanding of the diverse processes involved in each model. In other words, the accuracy of the institutional model rests on the fact that the existing possible pathways are considered. The parameters used, however, do not reflect the true likelihood of each pathway's use. The results of the simulations, therefore, are not concrete. The refinement of the data would result
in an accurate simulation.
MODELS
IDEAL HEALTH CARE SYSTEM MODEL

This model is based on the ideal health care objectives of long healthy lives and efficient care for all. A wide variety of ideal models are possible given this broad definition, and the following model is one of the possibilities. The following key elements are necessary for this ideal model:

1. Educated population

A pre-requisite for this ideal health care system is a literate and well-informed population. The population must know how to use computerized automated databases and interactive communication systems. They must know where and how to access health care providers. They must feel confident that treatment will be satisfactory and efficient. Everyone will undergo periodic comprehensive medical examinations, with the period between examinations based on risk factors such as occupation, medical history, lifestyle, etc.

2. Efficient Database and Communication Systems

Databases will contain information on illnesses and cures, preventive medicines, medical histories of every individual (restricted access), etc. Each individual, as well as health care providers, will have access to the individual’s medical history. This simplifies monitoring the health status of each individual.

Communication systems will enable patients to obtain on-line care and advice, which may be provided by an automated doctor or human professional.
3. Automated Pharmacy

There will be two types of pharmacies--Automated Pharmaceutical Machines (APM) and the traditional Human Pharmacist. The APM is a combination of a vending machine and an Automated Teller Machine used by banks. After consultation with a health care professional or an automated doctor, the patient is informed of the medication necessary. This information will be entered into the patient's medical records and will enable the patient to purchase those medications from APMs. For patients who need further advice, or for dangerous drugs, the Human Pharmacist will be responsible for dispensing medication.

4. Health Care Providers

There are various levels of health care providers in this model. These are created to automate as much of the health care process as possible, thus bringing down costs and increasing efficiency. When a patient calls into the health care system, he/she will access the national Database described above. Based on medical records and patient preferences, the request for care may be processed by an automated physician, nurse, or doctor. If the automated physician determines that this is beyond its scope, it will pass the request to a Nurse Practitioner. Otherwise, advice and medication will be prescribed to the patient by the automated doctor. The Nurse may either send the patient to a doctor as in the case of serious illnesses or prescribe medication and advice to the patient. The human doctor may send the patient on to a specialist, advise hospitalization, or prescribe medication. The specialist may either prescribe medication or request that the patient be hospitalized.
This system is perhaps best described in the form of a flowchart, shown in Figure 1.1. The flowchart is translated into a SimProcess model as shown in Figure 1.2. Figure 1.3 shows the workflow path for patients. The portion of the workflow from Calls to Healthline through Specialist have already been described above. The "output" of each stage is determined through percentages (specified in the model). Since this is an ideal model, the percentages are selected arbitrarily. For patients who are prescribed medication, there are two possibilities to obtain medication—from APMs or Human Pharmacists. In this model, 90% of patients are assumed to choose the APM since it is far cheaper and faster. For those patients who do not need medication, the next stage in the process is the home, where some rest period occurs. After obtaining medication, patients also return home for a rest and recovery period.

From here two possibilities can occur—either the patient recovers or does not. If the patient recovers, then he/she becomes a happy person and resumes normal activity. If the patient is not cured, then he/she calls the healthline again and is screen by the nurse on duty once again, and proceeds through the system. The healthline can also be designed to check on patients periodically to ensure that the proper medications have been purchased and to remind patients of upcoming medical appointments.

If the patient is hospitalized, two possibilities can occur—the patient either recovers, or dies. If the patient dies, then he/she is sent to the morgue and later to the cemetery. Otherwise, he/she becomes a happy person and resumes normal activity.

The processing times associated with each stage of the model is also arbitrary. Specialists were assumed to require long processing times, while automated physicians have the shortest. APM take less time than Human Pharmacists. Home Treatment i.e. rest, takes shorter time than
Figure 1.1: Ideal Health Care Model Flowchart
FIGURE 1.2
IDEAL MODEL LAYOUT

Database

Nurse

Human Doctor

Specialist

Seeking Medication

procrastinate

Hospitalized

Calls to Healthline

Automated Pharmaceutical Machine

Human Pharmacist

Home Treatment

Happy Person

Morgue
FIGURE 1.3
IDEAL MODEL FLOW

Calls to Healthline

Database

Nurse

Human Doctor

Specialist

Seeking Medication

procrastinate

Automated Pharmaceutical Machine

Human Pharmacist

Hospitalized

Home Treatment

Happy Person

Morgue
hospitalization.

The database which contains medical histories is also an efficient and convenient way for medical professionals to access patient medical histories prior to treatment. Patients can also use the database to keep track of doctor appointments and periodic examinations.

This is only a model of an ideal health care system. There are many other proposals for future health care systems and this is but one of them. However, most proposals will contain one or more elements contained in this model.
MODEL OF THE LEHIGH VALLEY PRIMARY HEALTH CARE SYSTEM

The valley-wide model of the Lehigh Valley primary health care system seeks to demonstrate the movement of people through the system while observing the levels of activity occurring at the major institutions providing health care. To this end we have included in the model what we found to be the most significant primary health care resources. These are:

- Hospital out-patient departments
- Hospital clinics
- Emergency rooms
- In-patient wards
- Health bureaus
- VNA clinics
- Private physicians

Figure 2.1 shows a generic model including these elements. Each station in this model represents the sum of all such elements in the Lehigh Valley; for example the station marked 'Health Bureau' represents all the health bureaus in the Lehigh Valley.

The first four units are located in single type of institution: the hospital. We observed that these units operate with considerable autonomy and decided that it would be beneficial to maintain their activities separately. The private physician base is a single unit. Since the focus of the model is to be on the institutions in the valley we thought that this grouping was justified. We thought that it is important to include private physicians since a large number of residents seek primary care from individual physicians; the family doctor is an integral part of most residents' health care.
FIGURE 2.1
Generic Model of Lehigh Valley Health Care System

Lehigh Valley Population

out-pats

Emergency Rooms

Clinics

In-patient

private physicians

HOSPITALS

Health Bureau

VNA

send home
Visiting Nurse Association clinics and Health Bureaus also cater to a significant portion of the Lehigh Valley primary health care seekers.

Almost all the primary health care providing institutions Technology Clinic members visited during the fall are represented in the valley model (Fig 2.2). These institutions are:

1. Lehigh Valley Hospital - 17th and Chew site
2. Lehigh Valley Hospital - Cedar Crest and I-78 site
3. Allentown Osteopathic Medical Center
4. Easton Hospital
5. St Luke’s Hospital
6. Sacred Heart Hospital
7. Allentown Health Bureau
8. Bethlehem Health Bureau
9. VNA of Easton
10. VNA of Lehigh County

This is not an exhaustive list. Notable omissions are the Muhlenberg Dental Clinics and the Lehigh Valley WIC. Both these institutions have considerable influence on the health of Lehigh Valley residents -- compared to difference in services provided; however, their impact is not readily quantifiable.

These elements are essentially replications of the elements in the generic model (Fig 2.1). They are distinguished from each other by their capacities. Capacities are determined by data specific to the institution.
FIGURE 2.2
Lehigh Valley Primary Health Care System

private physicians
out-patient clinics ER In-patient

LVH - 17 & Chew Health Bureau
LVH Cedar Crest VNA
AOMC VNA
Easton VNA
St. Lukes $ Bethleham Health Bureau
Sacred Heart $ VNA Lehigh County
Lehigh Valley Population $ VNA Easton

send home
funeral
Three categories of people move through the model of the Lehigh Valley primary health care system. The categories of well-insured, under-insured and un-insured people were chosen to represent the Lehigh Valley population because of the relevance of insurance status to obtainable health care and the cost thereof. These categories are easily identified. Data pertaining to each can be culled from most hospital records without difficulty.

As people go through their various paths seeking health care they are assigned one of three states: Healthy, sick or dead. These assignments are made at each of the stations. Essentially the objective of each institution is to cure. If a cure is not effected at that particular stage the patient is sent to another station. The final station in the health care route is in-patient care, and patients there either become well again or die. In reality there is considerable attrition at each stage. Many people do not get cured in the health care system but remain at home, occasionally obtaining treatment from VNAs.

The processes carried out at the institutions -- treatment or referral -- are based on probability. The probability attributes can be assigned based on historical data for a particular institution.

The choices that people make when looking to obtain health care depend on many factors. One of the main factors is insurance status which dictates what choices are affordable. This has been taken into account when constructing the model. Different paths have been specified for each of the categories of people based on typical behavior. For example it is most likely that a person with adequate insurance would consult a private physician for a primary health type ailment. A person with no health insurance would not ordinarily have that option. That person would go to a VNA or health bureau clinic, or would visit the nearest emergency room. These varying paths
make the model quite complex as can be seen from the schematic of the patient flow (Fig 2.3).

The model has been created using a view of the primary health care system that the Technology Clinic obtained during the fall semester. At that time we identified the important elements of the Lehigh Valley health care system. We also documented the typical paths taken by under-insured and un-insured persons. Data obtained previously was used in establishing the capacity of the model. Some of the other numbers used, such as cost, were arbitrarily chosen. Processing times were obtained from the data gathered last semester.

RESULTS

The most evident result that can be gleaned from the operating model is the status of any station. It is possible to determine when capacity is exceeded due to the influx of people. It is easy to observe the effect of one unit on another. If the hospitals are too full and unable to admit more patients to in-patient care, then the clinics will have to treat the backlog of patients who will return for more treatment.

Costs can be obtained for each operation of each station. The cost of treating a patient at an institution varies; one source of variation is insurance status. Different rates have been given for the treatment of people from the three categories. These are important where people are treated regardless of their insurance level. The cost incurred over a period of time can be broken down according to the people treated. One can also obtain the amount of time a particular group of persons were present at a station.

The groups can be tracked through the system, and during the simulation the different icons
can be observed. After the simulation is complete, the reports generated will provide information on the processes performed on the people and on their movement through their various workflow paths.

Future possibilities

It is possible to categorize the people in greater detail tagging an individual with his or her insurance status and city of residence. It is possible to assign sex, age, and even disease. The disadvantage is the complexity the model will assume. The model will run slower and it will become increasingly difficult to extract the required results. The best solution would be to have only those people with one to three categorizations each moving through the model. Having one group — e.g. women — going through the model at a time would be the most efficient and will be sufficient if the purpose is to obtain costs. Such a simulation, however, will not give meaningful results regarding the efficiency of the overall system.

Modifications can be made to more parameters such that the results are connected to changes. Possible changes to the Lehigh Valley health care system that can be modelled are increasing the capacity of clinics, introducing clinics to take care of low priority primary care patients, where the load is handled by nurses thus reducing costs, or increasing community outreach and thereby reducing the number of people entering the system.

The locations of institutions can be linked to the performance of the system. The effect of transport services can be modelled using conveyors.

The effect of using a central automated database, or a database operated by a nurse to
efficiently route patients as they seek appropriate care would be interesting to observe. A result would be the avoidance of blockage by patients in places in which they need not be. The use of a nurse, or bank of nurses by telephones, would reduce the number of people entering the system, thus alleviating some of the capacity problems. The possible effect can be quantified by adding such a station in the simulation.

The use of feedback can be tested by changing the inventory control rules. A centralized station can be set up where a person can get information on the current clinic conditions and then, assuming that transportation is not a factor, could go to the least busy clinic.

It is important to note that, while SimProcess is flexible and offers many possibilities, the results are only as meaningful as the data used to specify attributes of the system. Careful consideration should be given to the data required and appropriate methods should be developed to obtain this data.

Conclusion

A model of the Lehigh Valley health care system, even though simplified to facilitate simulation, can be used effectively to observe the system as a whole and to speculate on changes before they are implemented. The fairly global perspective afforded will be especially useful for a group such as the Partnership for Community Health which is taking a valley-wide approach to health care.
CLINIC/EMERGENCY ROOM MODELS

In this scenario, our first task was to choose a hospital on which to base our model. We wanted a hospital with a typical emergency room (i.e. not a trauma center, such as Lehigh Valley Hospital, Cedar Crest). We also wanted a hospital with a clinic system typical of the Lehigh Valley. These prerequisites left us still with many options. We chose, however, to model Easton Hospital because it is close to our campus and because we had excellent contacts at the hospital from our first semester interviews.

Upon discovering the detail needed to perform accurate simulations with SimProcess we narrowed the scope of our project to two parts of the hospital structure: the emergency room operation and the operation of the general medicine, pediatric, and ear/nose/throat clinics. We chose these three clinics because the primary care patients utilizing the emergency room usually have these kind of problems\(^3\). We created separate models for the emergency room and for the clinics. Figures 3.1 and 3.2 show the layout of the emergency room model and figures 3.3 and 3.4 show the layout of the clinic model.

Even after narrowing the scope of our project, we found ourselves with a cumbersome task to complete. The first difficulty we encountered was in collecting the information necessary to model the hospital accurately. The exact number of patients visiting the clinics and the emergency room each year and the cost to the hospital for treating these patients was unavailable to us. However, we obtained the information for our models by interviewing Lois Altemose, RN, Nurse Manager of Easton Hospital Emergency Room and Shirley Schwarzbach, RN, Easton Hospital.

\(^3\)Lois Altemose, RN, Nurse Manager of Easton Hospital Emergency Room
FIGURE 3.1
EMERGENCY ROOM LAYOUT
FIGURE 3.2
EMERGENCY ROOM PATIENT FLOW
FIGURE 3.4
CLINIC PATIENT FLOW
Clinic Coordinator.

Much of the information in the model is based on educated estimations by Lois Altemose, Shirley Schwarzbach, and ourselves. This, however, does not affect the goal of our model, because it was not built for the express analysis of Easton Hospital. We intend for our models to be portable, allowing other institutions to plug in their values in order to simulate potential outcomes resulting from changes to their existing emergency room and clinic systems.

The information a person would need to accurately model hospital and clinic systems includes the following:

- salaries and schedules of nurses, clerks, and doctors
- percent efficiency of each employee
- # of patients entering the ER and the clinics
- rate at which patients arrive
- time the patients spend with nurses, doctors, and clerks
- cost to keep each waiting room, ER room, and clinic room in working order
- time and cost to admit a clinic patient and ER patient to the hospital
- time and cost to process a death

SimProcess is a very intricate software package and given our time limitations we were unable to explore all the functions of the software. There are, however, many more ways to use SimProcess that hospitals could benefit from. Using SimProcess with accurate data, hospitals could predict the outcomes of changes to their current system. With this information, they could discover
unique ways to minimize their expenses, while maximizing the quality of care given to their patients. SimProcess could provide hospitals with a relatively inexpensive mechanism to discover how to revolutionize health care delivery.

In order to show an example of what can be accomplished with the models, we modelled how a 'perfect' clinic system would affect the emergency room. Our 'perfect' clinic system would take care of all primary care patients in a timely fashion and would decrease the number of primary care patients visiting the emergency room.

We ran simulations of the system with primary care patients using the emergency room as they do now and also with the majority of primary care patients using the 'perfect' clinic (Figures 3.5 and 3.6) instead of the emergency room. With our fictitious data, the cost to run the emergency room with primary care patients averaged 5.43 million dollars per year. The cost to run it with the 'perfect' clinic averaged 4.61 million dollars per year. This accounts for a $820,000 savings per year. To run the three clinics alone costs $4,000 per year, admittedly not a realistic figure. To run the 'perfect' clinic in which a doctor is available twelve hours a day for any primary care patient in conjunction with the original three clinics costs $36,000 per year. This is a $32,000 per year increase in the cost of running the clinics.

Since we obtained these numbers by using imaginary data, they have no real significance. The best way to analyze the model output is to calculate a percent savings when the 'perfect' clinic is used. This is calculated at 14.5%. This value tells us that, with the data that was used to create the models, it is possible to save a great amount of money by establishing a twelve hour clinic.

If more accurate data were used or if the model had been applied to a different institution, the results could have been different. There are many factors that could affect the outcome. Maybe
Figure 3.5
Perfect Clinic Layout

Clinic Entrance
Clinic Waiting Room
Pediatric Clinic
Medical Clinic
Ear, nose, throat Clinic
Clinic Discharge
Clinic Inpatient
All-Purpose Clinic
FIGURE 3.6
PERFECT CLINIC PATIENT FLOW

Clinic Entrance → Clinic waiting room → Ear, nose, throat Clinic

Clinic Entrance → Clinic waiting room → Medical Clinic

Clinic Entrance → Clinic waiting room → Pediatric Clinic

Clinic Entrance → Clinic waiting room → All-Purpose Clinic

Clinic Entrance → Clinic discharge

Clinic Entrance → Clinic inpatient
in another part of the country it would be too expensive to run the twelve hour clinic because of the increased cost of hiring doctors. It is important to note that the models are very flexible and applicable to a variety of situations. Our results are not real and should not be used by Easton Hospital.
NEONATAL CARE MODEL

To better illustrate the usefulness of modelling, we modeled a simple health care system. One that could be easily understood was the Perinatal Model. It traces a person from the DNA base through gestation and birth to help us understand the costs involved in an average person’s birth.

Since the simulation is most effective when a very simple model is created first, the initial model represents a birth with no outreach program or prenatal care. The process will start as DNA, go on to the womb where conception and gestation occur, and then be born. A newborn baby might have a low birth weight and therefore be more likely to go through a newborn intensive care unit. This person could then become healthy and go home or s/he might die.

The probability of all these events happening are estimated values which only approximate the actual numbers. An effort was made to be as accurate as possible, but it must be realized that the value of our models lies in the representation and not in the exact values provided by the model.

We then added an outreach program and prenatal care to the model to determine their effect on the cost for the community and on the number of deaths. These factors acted on the womb to reduce the risk of low birth-weight babies. This, in turn, reduced the number of deaths relative to the original model. The model can be seen in Figure 4.1. The path for the process is shown in Figure 4.2.

The probabilities used here were also estimates. These could be changed to their actual values to determine if the cost incurred by running the additions to the model are really lower.

With the stated probabilities, there was a relative cost of $583,000 for the original model and a relative cost of $352,000 for the modified model. This cost could vary greatly if the effectiveness
FIGURE 4.2
NEONATAL COSTS WITH AND WITHOUT OUTREACH

DNA → WOMB → NO PERINATAL CARE → DELIVERY ROOM → NICU → HOME

DNA → WOMB → OUTREACH AND PERINATAL → DELIVERY ROOM → NICU → DEATH
of the outreach programs or of the prenatal care were modified.

With the original model, an average of 2.5% of the people died. This is compared to the average 1.6% deaths in the modified model. The probabilities estimates will also affect these numbers.

The reported results are for the duration of the simulation and have no real meaning except for comparison purposes. The model shows how portions of the overall primary health care system can be examined separately with a modelling program to determine the effects of changes made to the system.
CONCLUSIONS

The primary health care resource assessment completed in the fall semester shows that overall, the Lehigh Valley primary health care system adequately serves the majority of the population. However, the demography of the Valley is changing and the number of underinsured people is rapidly increasing. The health care needs of this section of the population is not sufficiently met by the existing system. The care that they receive is often costly to the system and not entirely effective in maintaining and improving their health status.

In the spring semester, we attempted to model health care systems at the ideal, valley, and institutional levels, as well as the perinatal outreach programs. The SimProcess software package enabled us to model health care in terms of process workflows, resource allocation and utilization, and cost-benefit analyses.

The ideal model describes our proposal for a possible health care system of the future. Our model was built to accommodate the patient’s need for personalized health care and the providers’ requirement of efficiency.

Our model of an institution allows us to observe the monetary effects of the different routes taken by people in the health care system. It also allows to reallocate personnel from clinics which are underutilized to those which are over subscribed. We can play hospital administrator in a way that an actual administrator cannot afford to. We can take steps towards making the institution ideal, without knocking down too many walls. As an example, underutilized clinics may be converted to treat more than one illness. We can even idealize our system by assuming patients with perfect literacy of health care.
Our model of neonatal care serves to illustrate the importance of education and community outreach programs. Sometimes simple common sense can go a long way, and health care is no exception. If little issues such as timely child vaccinations, considerable resources could be saved. The key word that comes to mind is awareness. It is imperative that the population at large is made aware of basic and efficient health care practices.

Cures thus effected on the 'little' level reach out like relief from a toothache which brings comfort to the larger body. The larger body in our case would be the primary health care system of the Lehigh Valley. The global view afforded by the models has given us an appreciation of the value of holistic care to the system at large. Efficient services lead to efficient institutions which contribute to an improved health care system.

We don't see a total reconstruction of the health care system. All the elements present in the system are of irreplaceable utility. However, a little remodelling for health's sake may be in order.

Michelangelo once said that the most beautiful sculpture could be found within a piece of wood. It was the artist's job to use his tools and find it, for it was there. Within the Lehigh Valley health care system, we can find a cost-efficient system. To find it, we need to enact appropriate policies and work together toward the common goal of good health care for all.
APPENDICES
Lehigh Valley Health Care Providers Interviewed

1. Allentown Osteopathic Medical Center
   Dr. David Stein, Director of Emergency and Clinic Services

2. Easton Hospital
   Lois Altemose, RN, Nurse Manager of Emergency Room
   Dr. Victor Rodriguez, Clinic Pediatrician
   Faith Jendzeizyk, RN, former Clinic Manager
   Shirley Schwarzbach, RN, Clinic Manager

3. Good Shepherd
   Karen Turner, RN, Head Nurse of Outpatient Clinic

4. Lehigh Valley Hospital
   17th & Chew site
   Sandy Eberwein, RN, Head Nurse of Clinics
   Mary Lou Snyder, RN, NP, Pediatric Clinic
   Vicky Lysek, Coordinator, A Better Start
   Mary Alexander, RN, Head Nurse of Emergency Room

   Cedar Crest & I-78 site
   Dr. Ronald Lutz, Chair of Emergency Medicine

5. Muhlenberg Hospital Center
   Anne Panik, RN, Head Nurse of Emergency Room
   Dr. Jonathan Tenzer, Chief of Dental Services

6. Sacred Heart
   Kenneth Turner, Chief Operating Officer
   Joan Berta, Assistant to President
7. St. Luke's Hospital

   Deanna Seagraves, RN, Nurse Manager of Clinic

8. Allentown Health Bureau

   Anne Adams, RN, MSN, Manager-Clinical Services Program

9. Bethlehem Health Bureau

   Glenn Cooper, Director
   Kim Zsitek, RN, Nursing Director

10. Visiting Nurse Association of Bethlehem and Vicinity

   Jean Fiore, RN, Director

11. Visiting Nurse Association of Easton

   Theresa Onorata, RN, Executive Director

12. Visiting Nurse Association of Lehigh County

   Patricia Frenduto, RN President, CEO
   Kay Edman, RN
   Shirley Green, RN

13. Lehigh Valley WIC Clinic

   Nanette Arnold, Supervisor
Interview Worksheet

Person being interviewed: 

Institution: 

Date: 

Time: 

1. How would you define Primary Care?
   *Our definition: Point of entry into health system; least specialized level of care; Preventive, diagnostic, curative services; General Internal Medicine, Pediatrics, Family Practice, Obstetrics and Gynecology*

2. Services provided: Tick all that apply.
   - General Internal Medicine?
   - Obstetrics and Gynecology?
   - Pediatrics?
   - Family Practice?
   - Nurse Practitioners?
   - Dieticians?
   - Therapists?
   - Others?

   **Note:** We will be leaving behind a sheet for you to indicate the number of staff in each field and the number of hours they work.

3. What areas do most of your patients come from? Range of distance? Typical distance?

4. Many Spanish/other non-English speaking patients? Translators available?

5. How have the patients and services changed over time? Why?

6. What does your institution do particularly well? Compare with other providers.

7. Accept Medical Assistance (Medicaid, Medicare, etc.)? Difficulties?

8. How do patients normally get here? Do you think that patients have difficulty getting here?

9. Waiting time for appointments?

10. Waiting time in office?

11. How many patients miss their appointments (number, %)? Are they reminded? How (phone)?

12. Do you require patients to come in for "well" visits i.e. when they aren’t ill?
13. What is the general attitude of the patients? Do you think they’re satisfied with the treatment?

14. Hours open?

15. How many? Physicians- Full time: -Part time: -Volunteer:

    Nurses- Full time: -Part time: -Volunteer:

    Others?

16. Clinic operating at full capacity? (Every day, every minute?) All resources used to full capacity?

17. Ways to improve clinic? More money? Staff? How many more?

18. Do you see clinic’s capacity increasing in the near future? Any plans? Which areas? Why not other areas?

Partnership for Community Health in the Lehigh Valley
Community Health Resources Assessment

Mail: Dr. Dan Bauer
Technology Clinic Coordinator
Department of Anthropology and Sociology
Lafayette College
Easton, PA 18042
(215) 250-5189
or Fax to (215) 559-7659

1. Person completing form: ____________________________
2. Institution and Department: ____________________________
3. Describe staffing in your clinic:

<table>
<thead>
<tr>
<th>Physicians:</th>
<th>Number</th>
<th>No. of hours/week</th>
</tr>
</thead>
<tbody>
<tr>
<td>General Internal Medicine</td>
<td>_____</td>
<td>_____</td>
</tr>
<tr>
<td>Obstetrics and Gynecology</td>
<td>_____</td>
<td>_____</td>
</tr>
<tr>
<td>Pediatrics</td>
<td>_____</td>
<td>_____</td>
</tr>
<tr>
<td>Family Practice</td>
<td>_____</td>
<td>_____</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Nurses:</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Nurse Practitioners</td>
<td>_____</td>
<td>_____</td>
</tr>
<tr>
<td>Registered Nurses</td>
<td>_____</td>
<td>_____</td>
</tr>
<tr>
<td>Licensed Practical Nurse or Nursing Assistants</td>
<td>_____</td>
<td>_____</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Allied Health Professionals:</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Physician Assistants</td>
<td>_____</td>
<td>_____</td>
</tr>
<tr>
<td>Registered Dieticians</td>
<td>_____</td>
<td>_____</td>
</tr>
<tr>
<td>Respiratory Therapists</td>
<td>_____</td>
<td>_____</td>
</tr>
<tr>
<td>Others: (specify below)</td>
<td>_____</td>
<td>_____</td>
</tr>
</tbody>
</table>
4. Describe patients:

(a) Number of patients per week ______
    year ______

(b) Male/Female ratio ______

(c) Ethnicity (per 100 patients)
    Caucasian ______
    Hispanic ______
    Afro-American ______
    Asian ______
    Other ______

(d) Age in years (per 100 patients)
    Infants: 0 - 2 ______
    Preschool: 2 - 5 ______
    School: 5 - 18 ______
    Young Adult: 18 - 25 ______
    Adult: 25 - 65 ______
    Seniors: 65 & over ______

(e) Family income group in thousands per year (per 100 patients)
    Low Income: < 10 ______
    Lower Middle Income: 10 - 40 ______
    Upper Middle Income: 40 - 100 ______
    High Income: > 100 ______